The Computer in the Garbage Can: Air-Defense Systems in the Organization of US Nuclear Command and Control, 1940-1960

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Abstract

During the late 1950s, the United States Air Force initiated development on nearly two-dozen military "command and control systems." What they shared in common was a novel application of digital electronics to the problem of nuclear warfare. Most of these systems descended, in some fashion, from a program called "SAGE," the Semiautomatic Ground Environment, which gathered data from a network of radar stations for processing at large Air Defense Direction Centers, where digital computers assisted human operators in tracking, identifying, and, potentially, intercepting and destroying hostile aircraft.

Although histories of SAGE have been written before, they have tended to stress digital computing as a rationalist response to the threat of mass raids by nuclear-armed Soviet bombers. Nevertheless, organizational sociology suggests that large bureaucratic organizations, such as the United States Air Force, often defy our intuition that decisions, technological or otherwise, must follow a perceived problem to its potential solution. According to the so-called "garbage-can model of organizational choice," problems and solutions may, in certain circumstances, arise independently and join together unpredictably, because the basic social phenomena do not conform to bureaucratic ideals.

This dissertation argues that SAGE, and indeed, the entire Cold War project of nuclear-and-command, can be understood as a sequence of "garbage-can-like" decisions, resulting in a conglomeration of independent systems whose behavior appeared reasonable from the perspective of the using organization, but which nonetheless failed to cohere against the far greater danger of a global thermonuclear exchange. They did, however, succeed at satisfying the government's need to act by projecting uncomfortable questions of political organization onto popular technology programs.

The tradition of all dead generations weighs like a nightmare [*ein Alp*] on the brains of the living.

Karl Marx, *Der achtzehnte Brumaire des Louis Bonaparte,* 1852

Acknowledgments

The longer the list of acknowledgments grows, the greater the risk of unintentionally neglecting someone with as justifiable a claim to acknowledgment as another named herein. Therefore, in the interest of brevity, and in recognition of the fact that no one is likely to ever read this page anyway, the following list has been limited only to those most directly involved in the project. As my primary adviser throughout this ordeal, I should first extend my gratitude to Peter Galison, though Dave Kaiser, it should be mentioned, has also participated generously from beginning to end. While Matt Hersch joined the committee at a later stage, I have found his comments pointed and constructive, helping greatly to fill the void left by Heidi Voskuhl, whose guidance proved indispensable at the outset. For any strengths contained in the final manuscript, and none of its flaws, I credit Suzanne Smith. Gwen is sure to be embarrassed if mentioned last, thereby implying that her contributions exceeded all others, in hours, forms, and capacities, so I will be certain to imply as much now. Hopefully, she does not notice.

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Introduction

Air-Defense Systems in the Organization of Command-and-Control

> The rules of decision making…may be much more preoccupied with the problem of assigning outcomes their legitimate history than with the question of deciding before the actual occasion of choice the conditions under which one, among a set of alternative possible courses of action, will be elected.[1]
>
> Harold Garfinkel, *Studies in Ethnomethodology*, 1967

During the 1960s, America's postwar ambitions for continental air-defense simultaneously reached their fulfillment and lapsed into decrepitude. The decline was evident in the number of projects canceled, outposts shuttered, squadrons deactivated, and officers reassigned, as well as in reduced funding and personnel levels overall.[2] Yet it was the curtailment of the Semiautomatic Ground Environment, or SAGE, that most strongly attested the retrenchment of the continental air-defense program. The technological centerpiece of plans devised only a few years earlier, SAGE achieved the dubious distinction of not only rapidly diminishing in scope prior to its deployment, but actually being withdrawn from service while that deployment was still in progress.

According to the schedule drawn up in December 1955, 46 SAGE "direction centers," each housing two 21,000-square-foot AN/FSQ-7 computers—one active, and the other on standby—

1. Garfinkel, *Studies in Ethnomethodology*, 114.

2. Figures tabulated in *Historical Data of the Aerospace Defense Command, 1946–1973*, ADCHO 73-4-12 (Ent AFB, CO: Office of Command History, Headquarters, Aerospace Defense Command, April 1973), AFHRA (1006100), vols. 1–2, which overlaps somewhat with *History of Strategic Air and Ballistic Missile Defense*, 2 vols. (1972; repr., Washington: US Army Center of Military History, 2009). A narrative overview of much of the following passage was compiled in Richard F. McMullen, *The Aerospace Defense Command and Antibomber Defense, 1946–1972*, Aerospace Defense Command Historical Study No. 39 (Ent AFB, CO: Office of Command History, Headquarters, Aerospace Defense Command, June 1973), redacted copy provided by Command History Office, US Northern Command, Peterson AFB, CO.

were to be constructed between 1955 and 1961; total cost: $1.161 billion.[3] Six months later, the number of anticipated SAGE installations had fallen to 40, of which, 32 would be Direction Centers. The remaining eight consisted of so-called "combat centers" equipped with pairs of cheaper but less capable variants of the AN/FSQ-7, designated AN/FSQ-8. The date on which the first Direction Center was supposed to come online at McGuire Air Force Base in central New Jersey likewise slipped from 1955 to 1957. Quietly, the headquarters of the Air Defense Command—the agent of the United States Air Force charged with guarding the continental United States—expressed serious doubts about even this significantly relaxed deployment schedule. Their apprehensions proved well founded, as by 1957, the order had been again reduced to 28 Direction Centers and 8 Combat Centers, with the final completion date receding to late 1963.[4]

Ultimately, only 22 SAGE installations were ever built: all Direction Centers, three with an adjoining Combat Center, and each on the grounds of a major airbase in the United States, and, in one case, Canada.[5] The roll-out effectively halted, just as it began, in 1958, when Air Force headquarters began deleting lower priority sites from its air-defense plan in order to fund the construction of "super combat centers." This improved type of SAGE facility would be equipped with a miniaturized AN/FSQ-7, its vacuum-tube circuits replaced by transistorized equivalents, and buried hundreds of feet underground in order to mitigate the blast effects of a ballistic-missile strike.[6]

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3. During development, Lincoln Laboratory referred to the AN/FSQ-7 as "Whirlwind II" and labeled its prototype as the XD-1. Generally, the production model was simply called the "Q-7."

4. The initial SAGE implementation schedule from December 1955, the revised schedule adopted in August 1956, and its subsequent revision, Schedule No. 7, issued in November 1957, were summarized in Richard F. McMullen, *The Birth of SAGE, 1951–1958,* ADC Historical Study No. 33, vol. 1, Narrative (Ent AFB, CO: Headquarters, Air Defense Command, December 1965), AFHRA (0500702), 32–34, 58–62, 72–74, respectively.

5. The structure for a fourth Combat Center was built at Minot Air Force Base in North Dakota, but equipment was never installed and the facility never occupied. Of the 22 Direction Centers, ADC reserved one—at Richards–Gebaur Air Force Base in Kansas City—for training and software development, though, to help offset the wave of closures in 1966, it later transitioned into operational use. At the same time, a previously unfinished Direction Center in the San Francisco Bay Area was fitted with a transistorized BUIC II computer (see below) and added to the network as well.

6. Thomas A. Sturm, *Command and Control for North American Air Defense, 1959–1963* (Washington: USAF Historical Division Liaison Office, January 1965), 10–23, https://media.defense.gov/2016/Apr/22/2001521098/

When this program too was suspended late in 1959, digging had begun at only a single bunker in North Bay, Ontario; it was later fitted with AN/FSQ-7 computers still reliant on vacuum tubes and operated as a regular Direction Center. By the time it became operational in 1963, five other facilities had already been shut down. None had been operated for more than four years; the Direction Center in Minot, North Dakota, for instance, was barely two years old, with the empty blockhouse for an uncompleted Combat Center still abutting its structure like a vestigial appendage.[7] Another wave of four closures followed in 1966 and 1967, leaving just six centers trucking on until 1983, after which point, an additional eight were deactivated between 1968 and 1969.[8]

The broad strokes of causality are not difficult to see. In 1953, the SAGE plan had called for 46 installations, all active by 1961, at a total cost of $1 billion. By 1962, when the Secretary of Defense decided to draw down the 22 facilities that had been completed to date, the SAGE program was costing $2 billion *per year*.[9] Meanwhile, the threat of mass raids by nuclear-armed Soviet aircraft, so feared in the early postwar period, had never materialized. Conscious of its geographical disadvantage with respect to forward-basing, and pragmatic about the cost of long-range heavy bombers, the Soviet Union had concentrated its investment in missiles and rockets instead.[10] The same developments that led to Russia's early victories in its "space race" with the United States likewise rendered SAGE doubly irrelevant: a system of soft targets, with few anticipated targets of its own.

As the network collapsed, Hollywood prop-houses began to stock components salvaged from decommissioned AN/FSQ-7 computers, which added futuristic set-dressing to film and television productions as early as 1966 and as recently as 2016—a useful, if perhaps

-1/-1/0/AFD-160422-409-002.pdf .

7. Sturm, *Command and Control for North American Air Defense, 1959–1963*, 40–45.

8. According to the catalog in David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, November 1997), 89 and following.

9. Sturm, *Command and Control for North American Air Defense, 1959–1963*, 31–32.

10. Cf. Pavel Podvig, ed., *Russian Strategic Nuclear Forces* (Cambridge: MIT Press, 2001).

undignified afterlife, though one hardly worth the estimated $11 billion of public wealth consumed by the project.[11] Among the last of the original models to go was housed on the campus of the System Development Corporation in Santa Monica—the "Q-7 building," as it was aptly called—since a single AN/FSQ-7, used for software development and testing, comprised nearly its entirely volume. "Once accounting for $40 million of SDC's annual revenues," the remaining air-defense work "stood at $15 million in 1969 and shrank to a $5 million residue...in 1971," a small retainer to support what remained of the training program, most of it for the BUIC system: SAGE's successor, or its subtraction, depending on the perspective.[12]

"Symbolic of this decline," lamented Claude Baum, author of *The System Builders*, the company's self-chronicle, "SDC's AN/FSQ-7 computer, once a proud forerunner of large modern computers and the nerve center of SAGE, found itself sitting forlornly in SDC's parking lot in September 1970, waiting to be picked up for scrap."[13] It was hot, that September, even for a late summer in Southern California. As the sharp, modernist angles of SDC's machine—among the last of the AN/FSQ-7—quivered in the sultry air rising from the blacktop, its aluminum surfaces as warm as a skillet, it languished as surely as any computer in a garbage can, albeit one that had cost millions.

11. Mike Loewen, "The AN/FSQ-7 on TV and in the Movies," accessed July 17, 2017, http://q7.neurotica.com has been fastidiously recording appearances of the computer's machinery in popular entertainment for many years.

12. The Back-Up Interceptor Control, or BUIC (pronounced "Buick"), program began with a 1962 plan to augment a select number of radar sites with hand-operated command posts intended to assume the functions of the local SAGE center in case it was destroyed or incapacitated by Soviet missiles, prior to the arrival of the main bomber force. During the mid-to-late 1960s, these "backup" stations became highly capable in their own right as they were gradually equipped with transistorized BUIC II, and later, BUIC III computers, the latter of which incorporated more than a decade of advances in computing technology over the AN/FSQ-7. By 1972, a total of 12 BUIC IIIs, plus the six remaining SAGE centers, was considered sufficient to operate the greatly reduced interceptor force still active at that time. Sturm, *Command and Control for North American Air Defense, 1959–1963*, 23–39, *History of Strategic Air and Ballistic Missile Defense*, 73–77; McMullen, *The Aerospace Defense Command and Antibomber Defense*, 277.

13. Claude Baum, *The System Builders: The Story of SDC* (Santa Monica: System Development Corporation, 1981), 144.

1 The computer in the garbage can

What makes a technological object a "success" or a "failure"? As the first real-time, mission-critical, networked system of digital computing devices, SAGE has attracted vigorous debate as to whether it represented a pathbreaking technological achievement, a miscalculated waste of public funds, or both. Given the prevailing, almost self-evident significance attached to its peripheral and subsidiary developments, which ranged from automated machine-tools to the global Internet, retrospective judgments have come down predominantly in favor of success.

Evidence suggestive of failure, most notably the fact that the American public derived little to no benefit directly from the outrageous sums expended on the project, have generally been played down against SAGE's genuine, though indirect benefits of relevance today, including, for instance, the cultivation of the nation's nascent digital-computing industry, or the establishment of important technological precedents for their own sakes. Nevertheless, none of these outcomes could have been stated affirmatively beforehand, and indeed, their proliferation closely tracked the movements of the most prominent storytellers themselves: the scientific-technical professionals who had staked their careers on its construction.

Permutations of the success narrative

As a classic in the field, Paul Edwards' *The Closed World* is the obvious place to begin sampling some retrospective evaluations of the SAGE program. As the culmination of a project commenced during the escalation of Cold War tension, and concomitant arms build-up, under the Reagan Administration, Edwards' monograph was, as a rule, suspicious of the motives underlying the absolutist push for automatic control through digital computing. On air-defense specifically, he wrote skeptically of "the hope of of enclosing the awesome chaos of modern warfare...within the bubble of automatic, rationalized systems," even though "the *military* potential of SAGE was minimal":

> Many, perhaps most, of those who worked on the project knew this...In any case, SAGE would not have worked. It was easily jammed, and tests of the system under actual combat conditions were fudged to avoid revealing its many flaws. By the time SAGE became fully operational in 1961...SAGE control centers would have been among the first targets destroyed in a nuclear war.[14]

While Edwards fumbled some historical facts of variable importance, his general critique still holds.[15] After all, it was, as we shall see, inspired by others made before, and a prototype for those that followed.

Nevertheless, *The Closed World* continued to acknowledge that "in another important sense, SAGE *did* 'work' ":

> It worked as industrial policy, providing government funding for a major new industry. Perhaps most important, SAGE worked as ideology, creating an impression of active defense that assuaged some of the helplessness of nuclear fear. SAGE represented both a contribution and a visionary response to the emergence of a closed world.[16]

The statement elegantly furthered Edwards' ultimate thesis linking computer development with the Cold War imperative of security at any cost, but it is also, fundamentally, a recapitulation of the argument for success through industrial expansion and sheer technical accomplishment.

Meanwhile, in *Rescuing Prometheus*, Thomas Parke Hughes expressed more sympathy for the scientists and engineers who participated in the SAGE program, especially those acting in the capacity of technology managers. Consistent with his career-long, discipline-defining interest in "large technological systems," Hughes viewed SAGE as less of a political object than a managerial one. "Can SAGE be labeled simply a failure?" he asked:

14. Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996), 110, emphasis in original.

15. For instance, Edwards evinced only a vague sense of how a SAGE sector operated, leading to an unfortunate conflation of SAGE with the AN/FSQ-7 computer itself; moreover, his brief characterization of the Strategic Air Command Control System (SACCS) and the Worldwide Military Command and Control System (WWMCCS) was completely inaccurate. Nevertheless, his thesis included not only a forceful repudiation of utilitarian explanations of the military origins of modern computing, but also a persuasive statement that such explanations had been proffered retrospectively—a critical precedent for the argument to be presented here.

16. Edwards, *The Closed World*, 110, emphasis in original.

> At the bar of history, critics will emphasize SAGE's inadequacies as a defense against both bombers and missiles. Supporters, however, will stress that it became a learning experience of surpassing influence...Subsequent to SAGE, the Air Force funded development of similar computerized command, control, and communications systems including those for the Strategic Air Command Control System, the North Atlantic Air Defense Command, the NATO Air Defense Ground Environment, and the World Wide Military Command and Control System.[17]

In light of additional non-military application, which included public infrastructure, such as the FAA's automated Air Route Traffic Control Centers, as well as commercial products like American Airlines' SABRE booking and scheduling system, Hughes identified SAGE as an agent of "technology transfer," a wellspring of methods and experience that would eventually transform the global information economy as a whole.[18]

Once again, the claim for success is an indirect argument-from-utility. "Much like the Erie Canal project early in the nineteenth century became the leading engineering school of its day," Hughes added, "the SAGE project became a center of learning for computer scientists, engineers, and technicians." The condensation of expertise extended from individuals to institutions as well; for instance, the problem of implementing a computerized air-defense network motivated the foundation of Lincoln Laboratory, now among the oldest federally contracted private research-centers; the MITRE Corporation, among the earliest firms dedicated to the integration of large electronic systems; the System Development Corporation, likewise the world's first dedicated software company. It also contributed to the growth of related enterprises, such as MIT's Project MAC, IBM's Federal Systems Division, and the Digital Equipment Corporation.[19]

17. Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects That Changed the World* (1998; repr., New York: Vintage, 2000), 65–66.

18. In addition to the works of Hughes and others mentioned in this passage, publications such as David F. Noble, *Forces of Production: A Social History of Industrial Automation*, 2nd ed. (1984; New Brunswick, NJ: Transaction, 2011); Martin Campbell–Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge: MIT Press, 2003); James W. Cortada, *How Computers Changed the Work of American Public Sector Industries*, vol. 3 of *The Digital Hand* (Oxford: Oxford University Press, 2008); Rebecca Slayton, *Arguments That Count: Physics, Computing, and Missile Defense, 1949–2012* (Cambridge: MIT Press, 2013); and Martin Campbell–Kelly et al., *Computer: A History of the Information Machine*, 3rd ed. (Boulder: Westview Press, 2014) have all cast SAGE in some sort of genetic role, though they do not share a universally positive view of the technological precedent it set.

19. Cf. Atsushi Akera, *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S.*

Though hardly the only source still worthy of comment, there is, at last, *From Whirlwind to MITRE,* the definitive research-and-development history of the AN/FSQ-7, cultivated and refined over a span of decades by Kent C. Redmond and Thomas M. Smith.[20] Redmond had begun chronicling SAGE as early as 1958, when, as a professor at the University of Oklahoma, he prepared a small study of MIT Lincoln Laboratory for inclusion in the annual historical report of the Air Research and Development Command (ARDC), which, though classified, would have likely been read by hundreds security-cleared technology managers across the military-industrial-academic complex.[21]

Some time after moving to Worcester State Teachers College, Redmond contracted with the Air Force again in order to co-author a standalone history of the Air Defense Systems Integration Division (ADSID), the field office that had administered ARDC's stake in the SAGE program at a government-owned campus shared with Lincoln Laboratory at Laurence G. Hanscom Field in Bedford, Massachusetts.[22] Then, in 1967, Redmond partnered with Thomas M. Smith of the University of Wisconsin to draft a history of Project Whirlwind for new patrons at the MITRE Corporation, the nonprofit "systems integration" firm that MIT had spun off from Lincoln in 1958 solely to support the work of ADSID. The latter was quickly superseded by another pair of Air Force agencies—also located at Hanscom—called the Command and Control Development Division and the Electronic Systems Center, which merged in 1961 to form the Electronic Systems Division. MITRE likewise expanded

Cold War Research (Cambridge: MIT Press, 2007); Simson L. Garfinkel, *Architects of the Information Society: 35 Years of the Laboratory for Computer Science at MIT*, ed. Hal Abelson (Cambridge: MIT Press, 1999); Emerson W. Pugh, *Building IBM: Shaping an Industry and Its Technology* (Cambridge: MIT Press, 1995); Edgar H. Schein et al., eds., *DEC Is Dead, Long Live DEC: The Lasting Legacy of Digital Equipment Corporation* (San Francisco: Berrett–Koehler, 2003).

20. Kent C. Redmond and Thomas M. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge: MIT Press, 2000).

21. *History of the Air Research and Development Command, 1 Jan–31 Dec 1958*, vol. 1, Narrative (Baltimore: Headquarters, Air Research and Development Command, n.d. [1959?]), redacted copy provided by staff, AFHRA (0484795), 47–80.

22. Kent C. Redmond and Harry C. Jordan, *Air Defense Management, 1950–1960: The Air Defense Systems Integration Division*, ARDC Historical Publication 61-31-I, vol. 1, Narrative (Bedford, MA: Historical Branch, Office of Information, Air Force Command and Control Development Division, February 1961), AFHRA (0485177).

its business by offering to apply its experience with SAGE to the FAA's air-traffic control system, among other public-sector applications.[23]

Apparently, the Redmond–Smith manuscript circulated informally for nearly a decade before MITRE began printing its own copies as *Project Whirlwind: A Case History in Contemporary Technology* in 1975.[24] "In the beginning," read the foreword, "MIT begat Whirlwind. Whirlwind begat SAGE; SAGE begat Lincoln Laboratory; Lincoln Laboratory begat MITRE." This pseudo-biblical chronology more accurately described that of its author, Robert R. Everett, who had followed the computer from a graduate program at MIT to the presidency of the MITRE Corporation. "Lest our lineage be forgot, we publish the Whirlwind History."[25] Originally intended for the Smithsonian Institution Press, the work of Redmond and Smith was not even professionally typeset until the Digital Equipment Corporation released a revision of the MITRE edition as *Project Whirlwind: The History of a Pioneer Computer* in 1980.[26] When the MIT press finally published the greatly expanded *From Whirlwind to MITRE* in 2000, it fulfilled a nearly decades-long project by its authors, who had produced, very nearly, a first-hand account of their subjects.

Theirs were indeed *subjects*, plural, because the story they told was, more precisely, the story of technologists become managers—most of whom, like Everett, began their careers at MIT's Digital Computing Laboratory, before moving to Division 6 of Lincoln Laboratory in 1952, and thence to the MITRE Corporation in 1958—rather than Whirlwind itself, or of

23. Cf. Howard R. Murphy, *Early History of the MITRE Corporation: Its Background, Inception, and First Five Years*, MITRE Report M72-110 (Bedford, MA: MITRE Corporation, June 30, 1972), Internet Archive, Bitsavers Collection, https://archive.org/details/bitsavers_mitreM7211heMITRECorporationJun72_22060658 ; Robert C. Meisel and John F. Jacobs, eds., *MITRE, the First Twenty Years: A History of the MITRE Corporation, 1958-1978* (Bedford, MA: MITRE Corporation, 1979).

24. Kent C. Redmond and Thomas M. Smith, *Project Whirlwind: A Case Study in Contemporary Technology* (Bedford, MA: MITRE Corporation, November 1975), Internet Archive, Bitsavers Collection, https://archive.org/details/bitsavers_mitwhirlwirlwindACaseHistoryInContemporaryTechnolo_14582082 .

25. Redmond and Smith, *Project Whirlwind*, iii. Pieces of Everett's biography appear scattered in various sources and oral histories; "MITRE Mourns the Passing of Former CEO Robert Everett," August 16, 2018, accessed September 1, 2018, The MITRE Corporation, https://www.mitre.org/news/in-the-news/mitre-mourns-the-passing-of-former-ceo-robert-everett gave a brief summary of his career in memoriam.

26. Kent C. Redmond and Thomas M. Smith, *Project Whirlwind: The History of a Pioneer Computer* (Bedford, MA: Digital Press, 1980).

its successor: designated AN/FSQ-7, for "fixed special equipment," in standard Army–Navy equipment nomenclature.[27] On this point, they did not dissemble: "the men in this story were engineers," they acknowledged in the introduction to the 1967 manuscript.[28] The closeness of the relationship with the subjects is evident, for example, during a roundtable oral-history discussion conducted for a 1982 issue of the *IEEE Annals in the History of Computing*, dedicated entirely to SAGE, in which Redmond and Smith both recalled and interpreted some of the other participants' actions for them.[29]

This is not to suggest that Redmond or Smith were inherently compromised by proximity to their subjects; on their contrary, their practical embeddedness in the "Hanscom complex," as the cluster of facilities became known, produced a good-faith account rich with observational description that will likely never be replicated with the same degree of fidelity. The Redmond–Smith story should thus be appreciated as an authentic rendering of the mentality of the Hanscom community during and, just as critically, after the peak of the SAGE program, though it needs also to be acknowledged as such. It is undeniably optimistic, as narratives evolved from official histories tend to be, emphasizing problems solved and challenges surmounted, yet it is neither outrightly whiggish nor unprincipled in identifying what those problems and challenges were, or dismissive of their severity. In fact, the overall picture that emerges is almost one of a controlled train-wreck followed by a surprisingly successful effort to improvise with parts salvaged from the debris field.

Indeed, the 1967 manuscript appears to have been calculated to rebut a widespread opinion that Whirlwind—and, by extension, SAGE—had, in some crucial respect, *failed*.

27. Although numerous oral history interviews of many of Everett's colleagues exist in various archives and special collections, John F. Jacobs, *The SAGE Air Defense System: A Personal History* (Bedford, MA: MITRE Corporation, 1987) is the only published memoir (though see the roundtable discussion cited below). An exceptional case was the force behind the original Project Whirlwind, Jay W. Forrester, who pursued other topics after leaving Lincoln Laboratory in 1956: Peter Dizikes, "The Many Careers of Jay Forrester," *MIT Technology Review*, June 23, 2015, https://www.technologyreview.com/s/538561/the-many-careers-of-jay-forrester .

28. Redmond and Smith, *Project Whirlwind*, 1.03.

29. "A Perspective on SAGE: Discussion," *IEEE Annals in the History of Computing* 5, no. 4 (July–December 1983): 375–398, doi:10.1109/MAHC.1983.10091.

There is a sense of lingering soreness, for instance, over the unfavorable 1949 assessment of the Institute of Advanced Study, commissioned by the Office of Naval Research—which was, at the time, still funding Project Whirlwind as a simulator for training pilots—even though its negative pronouncement precipitated the events leading to the Air Force's long-suffering patronage in the first place.[30] "In the view of others," reported Redmond and Smith, "the men of Project Whirlwind extravagantly spent some five million dollars of public money in five short years" in order to pursue an "impetuous, risky, and unrealistic research and development practices in peacetime," practices appropriate only "in time of war or extreme crisis":

> According to this view, Project Whirlwind provided not a lesson in how the efficient and and expeditious conduct of research and development might be achieved as a new norm, but a demonstration of its malpractices, of the essential wisdom of traditional procedure.
>
> It succeeded rather than failed, according to this argument, because of unusual and unexpected circumstances beyond its control. The project had become an engineering-development project without a practical mission until these circumstances, involving a potential shift in the very balance of international power in world affairs, had intervened. Not only was the project not a business-as-usual enterprise, but it took nothing less than a looming national military and political crisis to come to its rescue. Had Project Whirlwind been conceived in the beginning or shortly thereafter been modified in anticipation of this crisis, then its importance, its priority rank, and its conduct of its own affairs would have developed naturally. Instead, one could argue, it had been fiscally hell-bent to develop a fantastic machine for which virtually no one except its enthusiastic builders could see any use.[31]

In short, "Project Whirlwind, when all was said and done, had been lucky."

Evidently, the poison injected by the IAS report continued to sting, even two decades after the fact, because the authors dedicated several lengthy passages to pointing out how history had eventually proved them wrong. "Because Project Whirlwind succeeded does not mean that it was inevitably destined to succeed," they argued, adding:

30. Akera, *Calculating a Natural World*, 181–220 gives the best reading of Project Whirlwind's early phase, though it too built upon the basic facts presented in Redmond and Smith, *Project Whirlwind*.

31. Redmond and Smith, *Project Whirlwind*, 1.04–1.06.

> It was, like all challenges, a creature of human endeavor. It did achieve its goal, however, and it did accelerate computer progress both by the concepts it demonstrated and by the talented engineers it developed. As a consequence, hindsight permits one to hail it as a model of R&D.[32]

Like Edwards and Hughes, who both drew on the work of Redmond and Smith, they identified the project as a managerial innovation and singular point of origin for commercially significant technologies and engineering talent. Moreover, they noted that the project had "national historical significance" for introducing the "conceptions of 'Command and Control' which Whirlwind had demonstrated as feasible, and in the development of which Whirlwind had played a vital role." Not only were these ideas "incorporated into the national defense structure as an essential element," they expanded "well beyond military use through application to other governmental needs and to the needs of industry and society in general, as the computer moved in the direction of becoming one day a true public utility which, so proponents argued, would rank with the telephone and the water faucet."[33] Devices, experts, skills, businesses, industries, concepts, even models of scientific research-and-development; this was an argument-from-utility that operated on many levels.

But not every level. The United States Air Force did not involve itself in the project in order to cultivate a workforce, or a discipline, or an industry, to test competing fashions in research and development, develop concepts of "command and control,"—a term that did not even exist yet—or to apply the digital computer to real-time automation of organizational systems merely to prove it could be done. All these were rationalizations *ex post facto*, outcomes impossible to predict in 1950, 1955, or even 1958, when the first SAGE sector became operational. None of them addressed the central question of whether the AN/FSQ-

32. Redmond and Smith, *Project Whirlwind*, 13.18.

33. Redmond and Smith, *Project Whirlwind*, 13.3–13.4. The invocation of public utilities here referenced the then-popular belief in the future of a "computer utility," a concept obsoleted by the unexpected economics of the personal-computer. However, it can be viewed as distorted precedent to modern "cloud computing," where the only substantive difference is that its infrastructure is entirely private and unregulated. See Martin Campbell–Kelly and Daniel D. Garcia–Swartz, "The Rise, Fall, and Resurrection of Software as a Service: Historical Perspectives on the Computer Utility and Software for Lease on a Network," in *The Internet and American Business*, ed. William Aspray and Paul. E. Ceruzzi (Cambridge: MIT Press, 2008), 201–230.

7 itself performed the function for which it had been explicitly intended—at any cost, let alone a reasonable one.

By the time *From Whirlwind to MITRE* was published in 2000, however, Redmond and Smith had slightly softened their touch, perhaps because the rational-success narrative had outlasted its opposition, as even critics like Edwards never seriously questioned its most basic assertions. While still concluding that Project Whirlwind, Lincoln Laboratory, and the MITRE and System Development corporations had "played major parts in the advancing the state of the art in computer technology"; "contributed heavily to the rise of command-and-control systems, setting the pattern for the military and space systems that followed"; "contributed to laying the R&D foundation for the Massachusetts mini-computer industry"; "revolutionized the information industry" as a whole; in addition to training "hundreds of digital-system engineers, thousands of computer programmers, and thousands of digital-computer field engineers"; as well breaking the ground in "computer-driven displays, on-line terminals, time-sharing, high-reliability computation, digital signal processing, digital transmission over telephone lines, digital track-while-scan, digital simulation, core memories, computer networking, duplex computers," among others; and above all, teaching "the American computer industry how to design and build large, interconnected, real-time data-processing systems," thus marking the point at which "computer systems as we know them today came into existence"; the book's final passage tried to strike a faintly equivocal chord. "Whether the techniques learned from that lesson would serve as a basis for further successful efforts in the United States and the rest of the world to place modern science and technology more efficiently and securely in the service of humanity remained to be seen."[34]

More than anyone, Smith, and certainly Redmond, knew the problems associated with the development of SAGE. One of Redmond's secret histories, *Air Defense Management, 1950–1960: The Air Defense Systems Integration Division*, which he co-authored in 1961 with Harry C. Jordan, the official Air Force historian at Hanscom Field, thoroughly documented the

34. Redmond and Smith, *From Whirlwind to MITRE*, 442–443.

program's incessant, severe, and quite often embarrassing administrative missteps and indiscretions.[35] Although Redmond's later work with Smith occasionally referenced these events, the perspective of the Air Force bureaucracy all but disappeared from the record presented to the public, likely for reasons having less to do with security classification than the need to appeal to the interests of their new sponsors. So far, only Stephen B. Johnson's *The United States Air Force and the Culture of Innovation, 1945–1960*, commissioned and published by the Air Force History and Museums Program, has recalled some of the historical memory documented by this earlier study and others like it.[36]

In most cases unwittingly, the many "success" and "failure" narratives, which borrowed their basic premise from Redmond and Smith, have effectively perpetuated a story that the Hanscom community told itself, as further evidenced by the contents of interviews, papers, and memoirs promulgated by project leaders—mostly at the end of their careers, though already well-formed by the time of the 1967 manuscript.[37] But their tendency to define "success" on their own terms, or in opposition to peers, cannot be so easily dismissed as an instance of an expert community, insular and self-satisfied, developing an acute sensitivity to the opinion, commonly held, that their prime technical achievement represented nothing more than an obsolescent boondoggle. Indeed, Redmond and Smith may very well have known better than to try to settle the question based on parameters set by SAGE's using organizations—the United States Air Force, generally; and the Air Defense Command, more specifically—*because there were none*.

It is merely canonical to restate the claim that the Air Force wanted to improve its

35. Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA. It is unclear, however, when the contents of this study would have become available to the public; the copy in AFHRA's possession was declassified in 1996, though due to the vagaries of executive privilege, a copy held by another agency might have been cleared earlier.

36. Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington: Air Force History and Museums Program, 2002).

37. A non-exhaustive list of the most prolific of these participants would include Herbert D. Benington, Robert R. Everett, Jay W. Forrester, John V. Harrington, C. W. Halligan, Albert G. Hill, John F. Jacobs, F. Wheeler Loomis, Carl F. J. Overhage, Norman H. Taylor, George E. Valley, C. Robert Wieser, Jerome Wiesner, and Charles A. Zraket.

capability to defend the North American continent following the first Soviet atomic test in 1949. Although essentially correct, the statement is so imprecise, so unobjectionable as to have been emptied almost entirely of significance. The "Air Force" is not a singular unit of intentionality; it cannot be said to "want" or to possess a "capability" without parsing what this language means in the case of a bureaucracy, rather than an individual.

But to abuse that language for a moment—or, rather, repeatedly, as expository convenience demands—while the "Air Force" may have indeed "wanted" to improve its capability to defend the North American continent, it did not really know it wanted digital computers to help improve that capability, or even that it was in the process of obtaining them for the purpose, *until after it had already gotten them.*

The garbage can model of organizational choice

In 1963, a RAND analyst named Norman F. Kristy conducted a field study of several active SAGE sectors, as well as sites performing key—albeit, by that point, routine—functions in maintenance, training, documentation, and software production. As a liaison to the Air Defense Command since 1956, Kristy would have been a face familiar to old hands from every arm of SAGE development and operations.[38] In summarizing perceptions reinforced by his interviews with both military personnel and civilian technicians, he reported that "it has been stated many times that SAGE was designed backward":

> That is, from Project Charles and the Whirlwind I computer there emerged the idea that a digital computer could assist in Air Defense operations. The concept was that the large-internal memory digital computer then newly designed and looking for a job was capable of real-time data-processing on a large scale. Simultaneously, air defense of the United States, a vast real-time data-processing problem, was looking for improved solutions. Thus it is that these two were brought together.[39]

38. Kristy was appointed as a "permanent representative" to the Air Defense Command according to the November 1956 issue of RAND's company newsletter: "Excerpts from the RANDom News," System Development Division, RAND Corporation, Santa Monica, California, 1956, Internet Archive, Bitsavers Collection, https://archive.org/details/bitsavers_sdcsageRAN_3915327 .

39. N. F. Kristy, *Man in a Large Information Processing System: His Changing Role in SAGE,* RM-3206-PR (Santa Monica: RAND Corporation, February 1963), AFHRA (0907065), 4.

Later that decade, the philosopher Abraham Kaplan and the psychologist Abraham Maslow independently popularized the modern aphorism, "when all you have is a hammer, everything looks like a nail," with phrasings so similar they likely replicated an existing English-language proverb.[40] While diagnosing the "solution in search of a problem" as a form of cognitive bias among scientific researchers, Kristy's publication suggests a phenomenon already familiar in more casual circumstances; in his case, the experience of adapting to the products of engineering.

If it is possible for a "solution" to exist even before a corresponding "problem" has been identified for it to solve, then the ostensibly self-evident logic of so-called "rational" or "willful" choice becomes entirely suspect. "The standard explanation provided for the actions of individuals or institutions involves two assertions," according to James G. March and Johan P. Olsen, two of the most influential organizational sociologists of the last half-century. "First, someone decided to have something happen…[and]…second, the decision was made because it was in the self-interest of the decision maker to make it." The extension to social groups, including formal organizations, is as straightforward as a single corollary: "different people, in their own self-interest, wanted different things and got what they wanted in proportion to their power." Whether in the context of the individual or the mass collective, a problem is supposed to arise from changes in the social or natural environment, and the solution—whether correct, or not; efficient, or not; effective, or not—should, at least the very least, have been premeditated in response to need.[41]

Of course, March qualified that "the concept of choice as a focus for interpreting and guiding human behavior has rarely had an easy time in the realm of ideas,"[42] On the contrary,

40. Abraham Kaplan, *The Conduct of Inquiry: Methodology for Behavioral Science* (San Francisco: Chandler, 1964), 21 tried to define "the law of the instrument" with the expression, "give a small boy a hammer, and he will find that everything he encounters needs pounding"; while Abraham H. Maslow, *The Psychology of Science: A Reconnaissance* (New York: Harper & Row, 1966), 15, on the other hand, wrote, "I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail."

41. James G. March and Johan P. Olsen, "Garbage Can Models of Decision Making in Organizations," in *Ambiguity and Command: Organizational Perspectives on Military Decision Making*, ed. James G. March and Roger Weissinger–Baylon (Marshfield, MA: Pitman, 1986), 13.

42. James G. March, "The Technology of Foolishness," in *Ambiguity and Choice in Organizations*, ed. James G.

it has been a source of continual disputation in philosophy, theology, psychology, and the methodologies of the human sciences overall, from the ancient past to the present. But "choice is a faith as well as a theory," at least it is commonly applied. "It is linked to the ideologies of the Enlightenment and associated with definitions of the nature of the species," most notably, the hypothetical *homo economicus*.[43] "A reading of the leading newspapers and journals of any Western country will show that the primary interpretive model used by individuals in these societies is one of willful choice," and that rational decision-making provides the "standard terms of discourse for answering the generic questions: Why did it happen? Why did you do it?"[44]

As the most retrospective aspect of this discourse, history reflects the same assumptions: the "pre-existence of purpose," the "necessity of consistency" between purposes and options, and the "primacy of rationality" in deciding among options, as identified by March.[45] While historiography has long recognized the danger inherent in the uncritical ascription of such properties to actors generally, and, in diverse instances, developed methods to confront it, the case of the organizational actor remains comparatively under-theorized.[46] In other

March and Johan P. Olsen, 2nd ed. (Bergen: Universitetsforlaget, 1979), 69. This is not for a lack of parry and riposte, however; see, for instance, S. M. Amadae, *Rationalizing Capitalist Democracy: The Cold War Origins of Rational Choice Liberalism* (Chicago: University of Chicago Press, 2003); Angus Burgin, *The Great Persuasion: Reinventing Free Markets Since the Depression* (Harvard University Press: Cambridge, 2012); or Philip Mirowski and Dieter Plehwe, eds., *The Road From Mont Pèlerin: The Making of the Neoliberal Thought Collective* (Cambridge: Harvard University Press, 2009).

43. Here, echoes of Herbert A. Simon, *Models of Man, Social and Rational: Mathematical Essays on Rational Human Behavior in a Social Setting* (New York: Wiley, 1957) will already be discernible to the trained ear, but it is not Simon's thinking, which was still rationalist at its core, that I find as interesting as its influence on certain students, colleagues, and admirers who pushed a more radical interpretation of "bounded rationality."

44. March and Olsen, "Garbage Can Models of Decision Making in Organizations," 13.

45. March, "The Technology of Foolishness," 69–70.

46. There is, of course, the precedent of the so-called "organizational synthesis," first identified in the classic historiographical review, Louis Galambos, "The Emerging Organizational Synthesis in Modern American History," *The Business History Review* 44, no. 3 (Autumn 1970): 279–290, doi:10.2307/3112614; as well as its follow-ups: Louis Galambos, "Technology, Political Economy, and Professionalization: Central Themes of the Organizational Synthesis," *The Business History Review* 57, no. 4 (Winter 1983): 471–492, doi:10.2307/3114810 and Louis Galambos, "Recasting the Organizational Synthesis: Structure and Process in the Twentieth and Twenty-First Centuries," *The Business History Review* 79, no. 1 (Spring 2005): 1–38, doi:10.2307/25096990. Note that Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins University Press, 1983) was perceived as one of the key contributions to the school. Nevertheless, Brian Balogh,

words, despite acquiring a considerable degree of sociological sophistication in many respects, descriptions of organizations still tend to fall back onto "willful" or "rational" models of choice for lack of better vocabularies with which to represent their complexity.

Here, the language of "bureaucracy" frequently serves as a useful shorthand. Absent a close inspection of the tenets of bureaucracy, however, the thematic contradiction between organization as a rationally efficient machine—in the tradition of Max Weber—and organization as an imponderable hulk of senseless rules—in the style of Franz Kafka, Joseph Heller, or indeed, the lived experiences of most of us—will continue to typify historical writing as much as it does other forms of discourse, including the discourse that modern organizations generate in the process of managing themselves.[47] The historiographical challenge is as imposing as the imperative of meeting it, because large bureaucratic organizations have never suspended their natural tendency to consolidate political, economic, social, and cultural dominion, especially over science and technology, since first rising to prominence in the mid-to-late nineteenth century, creating the modern condition that Charles Perrow has diagnosed as a "society of organizations."[48]

"Reorganizing the Organizational Synthesis: Federal–Professional Relations in Modern America," *Studies in American Political Development* 5, no. 1 (Spring 1991): 119–172, doi:10.1017/S0898588X00000183 observed that while sociological considerations have proved highly significant to this historiographical tradition, it still tends to adopt naively Weberian assumptions about the nature of bureaucratic efficiency and a simplified Parsonian model of competing professional interests. Decades of advances in organizational sociology have yet to be applied to the "organizational synthesis," which is itself mainly circumscribed by studies of the America Progressive Era. However, Lynn Eden, *Whole World on Fire: Organizations, Knowledge, and Nuclear Weapons Devastation* (Ithaca: Cornell University Press, 2004) is one study that defies both these restraints and is an important motivation for this dissertation.

47. Although the history of their publication is not straightforward, Weber's writings on bureaucracy and bureaucratic authority are concentrated in two passages: Max Weber, *Economy and Society: An Outline of Interpretive Sociology*, ed. Guenther Roth and Claus Wittich, trans. Ephraim Fischoff et al. (Berkeley: University of California Press, 1978), 217–241 and 956–1005; Kieran Allen, *Max Weber: A Critical Introduction* (London: Pluto Press, 2004), chaps. 7 and 9 is a helpful exegesis. On the antimonies of bureaucracy, as expressed in art, discourse, and policy, see, for instance, James Dawes, "Language, Violence, and Bureaucracy: William Faulkner, Joseph Heller, and Organizational Sociology," in *The Language of War: Literature and Culture in the U.S. From the Civil War Through World War II* (Cambridge: Harvard University Press, 2002), 157–191 and Torben Beck Jørgensen, "Weber and Kafka: The Rational and the Enigmatic Bureaucracy," *Public Administration* 90, no. 1 (March 2012): 194–210, doi:10.1111/j.1467-9299.2011.01957.x.

48. That organizations provide the means for elites to concentrate their power, and thus represent the dominant actors in modern society, is the thesis of Charles Perrow, *Organizing America: Wealth, Power, and the Origins of Corporate Capitalism* (Princeton: Princeton University Press, 2002).

Nevertheless, this is not a dissertation on organization sociology, and it intends neither to stake an extra-disciplinary claim nor subordinate itself to the service of mere case study.[49] Its framework is eclectic and liable to simplifications insofar as they promote clarity rather than obfuscation. However, many, or perhaps most elisions result not as a matter of convenience alone, but of ambiguity in the historical record itself. Such ambiguities may be compounded by the passage of time, but they are not fundamental to it. The "normative model of choice"—purposeful, consistent, and rational—withstands no more scrutiny in the context of a large organization than it does that of the individual or the small group.

Indeed, organizational sociologists have supposed that retrospection is the one of the means by which bureaucracy effaces the ambiguity of the present, legitimizing its actions through rationalist narratives conceivable only after the fact. It was likely not by chance, then, that in 1963, N. F. Kristy reported a pervasive belief that "SAGE was designed backward." A decade later, Michael D. Cohen, James G. March, and Johan P. Olsen proposed an empirical model which abandoned the assumption that, in all circumstances, organizations "search" for solutions in "response" to problems they encounter. Instead, the "garbage can model or organizational choice," as they called it, did not presuppose *any* relationship between "problems" and "solutions," but rather, treated them as independent streams of inputs into a black-boxed decision-making process.[50]

"In pure form," March and Olsen explained, "the garbage can model assumes that problems, solutions, decision makers and choice opportunities are independent, exogenous streams flowing through a system" and linked "in a manner determined by their arrival and departure times." A number of "structural constraints" may be imposed on these

49. Indeed, applications of the case-study model to the same topic already exist, such as John P. Crecine, "Defense Resource Allocation: Garbage Can Analysis of C3 Procurement," in *Ambiguity and Command: Organizational Perspectives on Military Decision Making*, ed. James G. March and Roger Weissinger–Baylon (Marshfield, MA: Pitman, 1986), 72–119.

50. Michael D. Cohen, James G. March, and Johan P. Olsen, "A Garbage Can Model of Organizational Choice," *Administrative Sciences Quarterly* 17, no. 1 (March 1972): 1–25, doi:10.2307/2392088. The argument was later expanded in James G. March and Johan P. Olsen, eds., *Ambiguity and Choice in Organizations*, 2nd ed. (Bergen: Universitetsforlaget, 1979).

assumptions, but "in the absence of structural constraints…solutions are linked to problems, and decision makers to choices, primarily by their simultaneity."[51] In other words, outputs result more from a critical number of decision-makers agreeing on the existence of an opportunity to connect a problem with a solution, both sifted from the organization's "garbage can," regardless of the order in which the ideas entered it.

Although not all bureaucratic processes can be described as "garbage-can-like," one of the preconditions for its manifestation is an overabundance of potentially legitimate stakeholders in a particular issue relative to the number of actors who can realistically become involved in the decision. Put simply, not all of the parties who could stake a claim on the outcome actually do. The reasons may very, because the totality of an organization's affairs is beyond the ken of the individual human actor, who is inherently bound by both cognitive and physical limitations. Executives cannot perceive every option or foresee every possible eventuality, only act on the limited information that reaches them through the filter of the organization, and even then, time and energy must be conserved, as many different issues vie for each decision-maker's attention simultaneously.[52]

51. March and Olsen, "Garbage Can Models of Decision Making in Organizations," 17.

52. The concept of "bounded rationality" first emerged from Herbert A. Simon's early studies of public administration, especially Herbert A. Simon, *Administrative Behavior* (New York: Macmillan, 1947), which nonetheless owed an obvious debt to Chester I. Barnard, *The Functions of the Executive* (Cambridge: Harvard University Press, 1938). It became more widely recognized with the publications of James G. March and Herbert A. Simon, *Organizations*, 2nd ed. (1958; Malden, MA: Blackwell, 1993); and Richard M. Cyert and James G. March, *A Behavioral Theory of the Firm*, 2nd ed. (1963; Malden, MA: Blackwell, 1992). These are the three fundamental works of the so-called "Carnegie school" of behavioral economics and organizational sociology. For comments, see Hunter Crowther–Heyck, *Herbert A. Simon: The Bounds of Reason in Modern America* (Baltimore: Johns Hopkins University Press, 2005); Mie Augier, "James March, Richard Cyert, and the Evolving Field of Organizations," in *Oxford Handbook of Management Theorists*, ed. Morgan Witzel and Malcolm Warner (Oxford: Oxford University Press, 2013), 407–426; Augier, "James March, Richard Cyert, and the Evolving Field of Organizations"; the papers collected in Linda Argote and Henrich R. Grieve, eds., "*A Behavioral Theory of the Firm*: 40 Years and Counting," special issue, *Organization Science* 18, no. 3 (May–June 2007): Perspective, 491–542; and Olivier Germain and Laure Cabantous, eds., "Carnegie School and Organization Studies," Special Symposium, *European Management Journal* 31, no. 1 (February 2013): 67–103. Ultimately, however, I consider my outlook phenomenological rather than empirical; which is to say, I invoke organization science to thematize and clarify the historical narrative, and not to test theoretical hypotheses. What is most relevant to me is the tradition of reinterpreting Carnegie School ideas through various strains of social analysis: cf. Giovanni Gavetti, Daniel Levinthal, and William Ocasio, "Neo-Carnegie: The Carnegie School's Past, Present, and Reconstructing for the Future," *Organization Science* 18, no. 3 (May–June 2007): 523–536, doi:10.1287/orsc.1070.0277 and James G. March and Johan P. Olsen, "Elaborating the 'New Institutionalism'," in *Oxford Handbook of Political Institutions*, ed. R. A. W. Rhodes, Sarah A. Binder, and

Thus, the formal rules and structure of the organization cannot, in themselves, predict which actors will choose to participate and which will abstain. Participation depends on factors such as personality, group dynamics, and elements of pure chance, such as who happens to learn or care about the issue, and when. March, together with another collaborator, Pierre J. Romelaer, illustrated the scenario as "a round, sloped, multi-goal soccer field on which individuals play soccer":

> Many different people (but not everyone) can join the game (or leave it) at different times. Some people can throw balls into the game or remove them. Individuals while they are in the game try to kick whatever ball comes near them in the direction of goals they like and away from goals that they wish to avoid.[53]

Viewed from the outside, the process seems chaotic, if not nonsensical, but the results are not entirely random, because "the slope of the field produces a bias in how the balls fall and what goals are reached," and "after the fact, they may look rather obvious," even "normatively reassuring." Still, "the course of a specific decision and the actual outcomes are not easily anticipated."

When these conditions holds, decision-making tends to be dominated by "policy entrepreneurs": officials who may not possess the greatest degree of bureaucratic authority, but who most vigorously promote their preferred match between the perceived problem and a potential solution. The outputs, or "problem–solution pairs," tend to fail most criteria of economic efficiency. Rather than rigorously adhering to established bureaucratic procedures, they sift through the organization's "garbage"—to use the authors' guiding metaphor—in order to salvage from it pieces that fit together just well enough, usually suffices to keep business moving from day to day.[54] Once a match is accepted, however, the process is sub-

Bert A. Rockman (Oxford: Oxford University Press, 2006), 3–20.

53. James G. March and Pierre J. Romelaer, "Position and Presence in the Drift of Decisions," in *Ambiguity and Choice in Organizations*, ed. James G. March and Johan P. Olsen, 2nd ed. (Bergen: Universitetsforlaget, 1979), 276.

54. The concept of "satisficing"—which supposes that organizations do not pursue optimal outcomes, but rather, settle for the first satisfactory solution they discover—was introduced in March and Simon, *Organizations*, 158–172 and has since become a staple in studies of business, public administration, and rational choice. Cf. Michael Byron, ed., *Satisficing and Maximizing: Moral Theorists on Practical Reason* (Cambridge: Cambridge University Press, 2004).

jected to *ex post facto* rationalization, which is to say, that in the interest of maintaining the legitimacy of bureaucratic order, the outcome is stripped of its "nonrational" contingencies and incorporated into a narrative of logical inevitability, thereby recovering the myth of "willful choice."

Although the garbage-can model seems to affront our intuitive sense of rational order, empirical studies suggest it may express the *normal* form of bureaucratic activity—under the prescribed set of conditions—and not its perversion.[55] While a number of organizational sociologists have encouraged the field to reconsider its uncritical commitment to rationalist explanations and accept contingency as a phenomenon to be appreciated rather than a pathology to be eradicated, the implications are nonetheless unsettling when applied to decisions of momentous consequence, especially those involving inherently risky technologies, such as nuclear weapons.[56]

2 The organization of nuclear command-and-control

With the preliminaries now in hand, the primary claim of this dissertation can be stated as follows. SAGE should be understood neither as the product of rational management, nor an irrational enthusiasm for science, technology, or political commitments; but rather, as a

55. The "garbage can" hypothesis has generated a massive literature; for a retrospective, see Michael D. Cohen, James G. March, and Johan P. Olsen, "'A Garbage Can Model' at Forty: A Solution That Still Attracts Problems," in *The Garbage Can Model of Organizational Choice: Looking Forward at Forty*, ed. Alessandro Lomi and J. Richard Harrison. (Bingley, UK: Emerald, 2012), 19–31. Charles Perrow offered a synthetic assessment of its contribution to the theory of organization in Charles Perrow, *Complex Organizations: A Critical Essay*, 3rd ed. (New York: Random House, 1986), 119–156. Many authors, including March, have preferred to frame the issue in terms of how complex organizations make "sense" from "ambiguity." March himself summarized his own intellectual project in a series of lectures published as James G. March, *The Ambiguities of Experience* (Ithaca: Cornell University Press, 2010); for a brief intellectual biography, see Mie Augier, "James March, Richard Cyert, and the Evolving Field of Organizations," in *Oxford Handbook of Management Theorists*, ed. Morgen Witzel and Malcolm Warner (Oxford: Oxford University Press, 2013), 408–430. Another well-known publication by one of the more prominent figures working in this tradition is Karl E. Weick, *Sensemaking in Organizations* (Thousand Oaks, CA: Sage, 1995).

56. Cf. Charles Perrow, *Normal Accidents: Living With High-Risk Technologies* (New York: Basic Books, 1984); Scott D. Sagan, *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons* (Princeton: Princeton University Press, 1993); Diane Vaughn, *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA* (Chicago: University of Chicago Press, 1996).

nonrational outcome of bureaucratic processes too complex for the human actors to fully comprehend themselves. This is not a judgment with regard to "success" or "failure," for these words are superfluous when the "solution" is not affirmatively linked to the "problem" to be solved until such time as it becomes necessary to explain the outcome. Although the desire to incorporate them into our language is only natural—and indeed, extremely difficult to avoid—it nonetheless mischaracterizes the nature of choice in a bureaucratic environment. Organization is essential to modern technology as assuredly as technology is to modern organization; and as such, they must be appreciated by their relation to one another, and likewise, through their estrangement from the experience of the individual.[57]

Before proceeding, however, it remains to reflect on a peculiar phrase that has already infiltrated the passages above, mostly through direct quotation of sources that otherwise passed it over without comment. That phrase is "command and control," and the prevalence and presumptuous nature of its usage should have already signaled its centrality to the historical conceptualization of SAGE and other objects like it. Unfortunately, entire tracts have disappeared in the discursive fog of its seemingly endless definitions, connotations, associations, applications, extensions, and so on.[58]

57. Although I am unaware of a prior articulation of a thesis explicitly equating organization with technology, and technology with organization, it strongly resembles Lewis Mumford's theory of the modern "megamachine" in Lewis Mumford, *The Pentagon of Power*, vol. 2 of *The Myth of the Machine* (New York: Harcourt, Brace, Jovanovich, 1970). Without diverting into a lengthy excursus on the philosophy of technology, comparisons can also be drawn with the characterization of *technique* most familiar from Jacques Ellul, *The Technological Society*, trans. John Wilkinson (New York: Knopf, 1964), as well as the more expansive invocations of "technostructure"—which is to say, those not limited to a particular model of corporate governance—in John Kenneth Galbraith, *The New Industrial State* (Boston: Houghton Mifflin, 1967). While no substitute for the sources themselves, Val Dusek, *Philosophy of Technology: An Introduction* (Malden, MA: Blackwell, 2006) does touch upon all these concepts.

58. To be fair, a cottage industry for books attempting to demystify the concept for military officers, civilian officials, and other defense professionals began to prosper during the late Cold War: for instance, George E. Orr, *Combat Operations C^3I: Fundamentals and Interactions* (Maxwell AFB, AL: Air University Press, 1983), OCLC (50193503); Roger Beaumont, *The Nerves of War: Emerging Issues in and References to Command and Control* (Washington: AFCEA International Press, 1986); Jon L. Boyes and Stephen J. Andriole, eds., *Principles of Command and Control* (Washington: AFCEA International Press, 1987); Thomas P. Coakley, *Command and Control for War and Peace* (Washington: National Defense University Press, 1992); Carl H. Builder, Steven C. Bankes, and Richard Nordin, *Command Concepts: A Theory Derived From the Practice of Command and Control* (Santa Monica: RAND Corporation, 1999); Kenneth Allard, *Command, Control, and the Common Defense*, rev. ed. (1990; Washington: National Defense University Press, 1996); or see Frank M. Snyder, *Command and Control: The Literature and Commentaries* (Washington: National Defense University Press, 1993) for

A peculiar argot, popularized in the 1970s, only exacerbated the problem. First came the contraction of "command and control" into "C2" or "C^2" (pronounced as "C-two" or "C-squared," interchangeably). The trend appears to have begun around 1960 as a wry bit of workplace humor about the unwieldy acronyms attached to systems-management agencies like the aforementioned Air Force Command and Control Development Division, or "C^2D^2," in some stylings.[59] Over the years, jargoneers have spun various related concepts into and out of the same orbit: Reagan-era security discourse favored C^3I—"command, control, communications, and intelligence"—while the current trend within the defense community has been toward C^4ISR, for "command, control, communications, computers, intelligence, surveillance, and reconnaissance." The existence of even more exotic permutations, such as C^4I^2, C^5I, and C^4ISTAR, inspired one waggish commentator to postulate:

> C^{27}E: command, control, communications, computers, cohesion, counterintelligence, cryptanalysis, conformance, collaboration, conceptualization, correspondence, camaraderie, commissaries, camouflage, calculators, cannon, caissons, canteens, canoes, catapults, carpetbaggers, caddies, carabiners, carrier pigeons, corn whiskey, camp followers, calamine lotion, etc.[60]

Engaging a topic so amorphous as this on its own terms would be a prodigious task resulting in a very different kind of study than the one presented here.

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an extended bibliography. Many of these publications were, in some capacity, associated with Harvard's Program on Information Resource Policy (PIRP), which Anthony Oettinger, a professor of computer science, ran together John LeGates, a private consultant, from 1973 to 2011. Its Seminar on Command, Control, Communications, and Intelligence began meeting in 1980, attracting contributions from most of the authors cited above, as well as members of their audience and interlocutors; Thomas P. Coakley, ed., *C^3I: Issues of Command and Control* (Washington: National Defense University Press, 1991) condensed some of the proceedings to that point, though a complete list of transcripts and working papers remains available at http://www.pirp.harvard.edu/publications . Another source of print activity, whose affiliates partially overlapped with PIRP, was AFCEA, the Armed Forces Communications–Electronics Association, the industry group responsible for publishing the profession's leading periodical, *Signal*, since the late 1940s. The above excludes the more critical literature generated or circulated primarily in academia, which will be referenced separately.

59. Likewise, the Directorate of Command, Control, and Communications at Air Force Headquarters, an office organized in 1962, was similarly abbreviated to "D/C^3." The creation of the position of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence, or "ASD(C^3I)," in 1978 might also explain the preference for the acronym, "C^3I," which emerged around the same time.

60. Kenneth L. Moll, "Understanding Command and Control, Part 1," *Defense and Foreign Affairs* 6, no. 6 (June 1978): 41, quoted in Coakley, *Command and Control for War and Peace*, 9–10.

Rather than attempt a frontal assault on the conceptual fortress itself, the goal here is to leverage the advantage of historical observation. As a matter of lexical chronology, the official *Dictionary of United States Military Terms for Joint Usage* did not define "command and control" in 1958, though "command" and "control" independently referenced the "authority" that could be "vested" in and "exercised" by a human agent.[61] While neither term varied with the next edition, issued in 1962, the revision also introduced "command and control" as "an arrangement of personnel, facilities, and the means of information acquisition, processing, and dissemination employed by a commander in planning, directing, and controlling operations."[62] Command-and-control, in other words, is what command-and-control systems *do*. But if "command and control" asserted something irreducible either to "command" *or* "control," then why maintain its association with either at all?

No definitive text or critical utterance will settle the matter. Unlike some other terms of art, the language of "command and control" was not invented—it evolved, gradually mingling the substance of new ideas with the husks of old ones.[63] Nevertheless, it can be traced outward from the United States Air Force to the defense establishment at large, and thence to NATO allies and other nations and applications as well. So whatever happened must have happened between 1958 and 1962, which also corresponded to the years of SAGE's activation, as well as the initiation of research-and-development on dozens of other projects in some way inspired by it.

61. United States Departments of the Army, the Navy, and the Air Force, *Dictionary of United States Military Terms for Joint Usage,* 5th ed., DA Pam 320-1/OPNAV Instr 3020.1C/AFP 5-1-1/NAVMC 1177 (Washington: Government Printing Office, March 13, 1958), 29, 32, OCLC (691014335).

62. United States Joint Chiefs of Staff, *Dictionary of United States Military Terms for Joint Usage*, with change order no. 1, 2 July 1962, JCS Pub. 1 (Washington: Government Printing Office, February 1, 1962), 50, OCLC (691014335).

63. Allard, *Command, Control, and the Common Defense* can be read as an institutional history of American "command and control," though the term would be anachronistic during most the period covered. Moreover, John Keegan, *The Mask of Command* (New York: Viking, 1987) and Martin Van Creveld, *Command in War* (Cambridge: Harvard University Press, 1985) are both essentially military pre-histories of the idea and, despite their age, remain the standard texts in the field. Manuel de Landa, *War in the Age of Intelligent Machines* (New York: Zone, 1991) follows a more idiosyncratic approach, which is not the most relevant to the present project, but is nonetheless deserving of mention.

No source prior to 1958 describes SAGE as a "command-and-control system"; it was always an "air-defense system." Likewise, no source prior to 1958 describes something like SAGE as a "command-and-control system" either, but rather, a "management control system," or perhaps, a "military information system."[64] By 1960, however, the process of generalization and consolidation appears to have been approaching completion: both SAGE and "SAGE-like" systems had been gathered under the same banner, despite, in many cases, looking more different than they did alike. An observable effort must have been expended to accomplish a conceptual transformation as thorough as it was rapid—one that continues to serve a vast confederation of national-security interests.

The following chapters will unfold the story of how these interests came together, who they represented, what they accomplished, and why they chose the language they did. The conclusion offers another reading of what command-and-control means, and why it seemed necessary to promote it. For the time being, it is sufficient to observe that according to the most rigorous public accounting ever undertaken on the subject, the United States Government spent $921 billion (in constant 1996 value) on "nuclear command-and-control," broadly construed, during the Cold War. The total is only slightly less than the cost of US nuclear-weapons production—$403 billion—*plus* the $644-billion cost of all the missiles, aircraft, and submarines built to deliver them to their targets.[65]

Nevertheless, even a sum so magisterial as this was ultimately insufficient to resolve the underlying dilemma. By the 1980s, for instance, many experts observed that official policy had ossified the divisive, uncoordinated, inefficient systems of the 1950s into a monstrous

64. For instance, Donald G. Malcolm and Alan J. Rowe, eds., *Management Control Systems: The Proceedings of a Symposium Held at System Development Corporation, Santa Monica, California, July 29–31, 1959* (New York: Wiley, 1960); Edward Bennett, James Degan, and Joseph Spiegel, eds., *Military Information Systems: The Design of Computer-Aided Systems for Command* (New York: Frederick A. Praeger, 1964); or Robert N. Anthony, *Planning and Control Systems: A Framework for Analysis* (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1965).

65. Stephen I. Schwartz, ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940* (Washington: Brookings Institution, 1998). The grand tabulations presented in this study vary from the figures quoted here because, for the purposes at hand, it made sense to group certain subcategories together differently than the authors did, especially those related to air and ballistic-missile defense.

anatomy, distorted by incompatible, inconsistent, incoherent technological artifacts.[66] Many declared the objective failure to achieve anything approaching a reliable or even logically consistent method of nuclear command-and-control. In 1985, such as Bruce Blair, the most persistent among them, claimed in 1985 that "deficiencies in U.S. C^{3}I systems have been so severe for so long that developments in the size and complexity of the superpowers' arsenals have been practically irrelevant to the nuclear confrontation."[67] As early as 1960, many within the defense establishment had already begun to fear that only a handful of nuclear weapons, artfully employed, could end the political existence of the United States.[68]

66. Within the academic discourse, John Steinbruner, "Beyond Rational Deterrence: The Struggle for New Conceptions," *World Politics* 28, no. 2 (January 1976): 223–245, doi:10.2307/2009891 and John D. Steinbruner and Thomas M. Garwin, "Strategic Vulnerability: The Balance Between Prudence and Paranoia," *International Security* 1, no. 1 (Summer 1976): 138–181, doi:10.2307/2538581 are the earliest precedents, likely owing to the author's participation in the classified *History of the Strategic Arms Competition* project for the Office of the Secretary of Defense. Subsequently, the publication of Desmond Ball, *Can Nuclear War Be Controlled?*, Adelphi Papers, No. 169 (London: International Institute for Strategic Studies, 1981) seems to have revivified the study of nuclear command-and-control as an internal source of international instability; it also directly inspired the writing of the trade book, Daniel F. Ford, *The Button: The Pentagon's Strategic Command and Control System* (New York: Simon & Schuster, 1985). Other near-contemporaneous monographs that ask similar questions included Bracken, *The Command and Control of Nuclear Forces*; Fred Kaplan, *The Wizards of Armageddon* (New York: Simon & Schuster, 1983); William M. Arkin and Peter Pringle, *SIOP: The Secret U.S. Plan for Nuclear War* (New York: Norton, 1983); and Bruce G. Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Washington: Brookings Institution, 1985). Moreover, the papers collected in Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket, eds., *Managing Nuclear Operations* (Washington: Brookings Institution, 1987) and the proceedings recorded in Peter Stein and Peter Feaver, *Assuring Control of Nuclear Weapons*, CSIA Occassional Paper, No. 2 (Lanham, MD: University Press of America, 1987) represent the concrescence of a clear research agenda around the topic, which, unfortunately, evaporated with the Soviet bloc, and almost as precipitously as well. Stephen J. Cimbala, *Uncertainty and Control: Future Soviet and American Strategy* (London: Pinter, 1990); Peter Feaver, *Guarding the Guardians: Civilian Control of Nuclear Weapons in the United States* (Ithaca: Cornell University Press, 1992); Bruce G. Blair, *The Logic of Accidental Nuclear War* (Washington: Brookings Institution, 1993); and David E. Pearson, *The World Wide Military Command and Control System: Evolution and Effectiveness* (Maxwell AFB, AL: Air University Press, 2000) were among the later entries, the last of these deserving special attention, as its organizational-sociological approach is very similar to the one followed here.

67. Blair, *Strategic Command and Control*, 4.

68. In 1960, a study widely circulated among defense officials estimated that just nine ICBMs, directed against four key targets in the Chesapeake region, would almost certainly terminate the political existence of the United States: John Ponturo, *Analytical Support for the Joint Chiefs of Staff: The WSEG Experience, 1948–1976*, IDA Study S-507 (Alexandria, VA: Institute for Defense Analyses, International and Social Studies Division, July 1979), declassified copy, 129–151, DTIC (ADA090946). This substudy, contracted to the Institute for Defense Analyses, was completed before the main report—a broad-based systems analysis of the nation's strategic nuclear deterrent—and circulated separately on its own merit; several extended passages were quoted verbatim as L. Wainstein et al., *The Evolution of U.S. Strategic Command and Control and Warning, 1945–1972*, IDA Study S-467 (Alexandria, VA: Institute for Defense Analyses, International and Social Studies Division, June 1975), declassified copy, 239–248, DTIC (ADA331702). Incidentally, due to the prevailing regime of national-security

Since no one can know for certain, perhaps the most dire suggestion of all is the fact that even a trillion dollars did not significantly improve the state's confidence in the robustness, reliability, and performance of the nuclear command-and-control systems meant to ensure its own survival.[69]

3 Synopsis

For the most part, the argument will proceed chronologically, advancing for the early days of World War II to the dawn of the Missile Age. The main exception is chapter 4, which, for thematic purposes, returns to the 1940s in order to incorporate civilian technologists into what will have been, up to that point, primarily a story of military operations and federal bureaucracy. Consequently, the third chapter serves as a pivot, identifying a neglected historiographical route, while suggesting where it may yet lead.

Chapter One. Remember Opana Point

A number of historians have claimed that the prevailing regime of American security began not at Alamogordo, at Hiroshima, or even at Potsdam, but at Pearl Harbor. The "infamous" surprise attack, executed almost to perfection by the Imperial Japanese Navy, demonstrated the maturity of military aviation and portended a new era of great-power conflict in which America's historical sense of geographical invulnerability, inspired by its great transoceanic redoubts, finally evaporated. For nearly two centuries, the United States had prepared

secrecy, this latter study encapsulates virtually all that is definitely known about the topic during the period it covered.

69. Perhaps the best evidence is that the United States Government effectively gave up trying to do more than incrementally improve the token measures implemented in the 1960s, instead adopting the position that nuclear war could be controlled as an official fiction: see, for instance, William M. Arkin, "Nuclear War in Triplicate," *Bulletin of the Atomic Scientists* 42, no. 10 (December 1986): 6–7, doi:10.1080/00963402.1986.11459448. As Pearson, *The World Wide Military Command and Control System* observed, the technological measures implemented at the time could not surmount the underlying problems of organization and governance, and the system's architecture—to the extent it can even be called a unitary "system"—appears essentially unchanged in the latest *Nuclear Matters Handbook* (Washington: Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, 2011), https://fas.org/man/eprint/NMHB2011.pdf .

to defend itself by sea; by the end of World War II, it was confronted with the far more intimidating prospect of defending itself primarily in the skies.

The Battle of Britain will prove the natural point to begin tracking the dispersion of expertise with regard to building, operating, and analyzing air-defense "systems,"—or "networks," as they were still called, with roughly equal frequency. A defining feature of these systems, in contrast to other technological systems identified during the same period, is the extreme difficulty of separating their "technical" elements from the "organizational" ones. In other words, the organization's role was not merely to manage the system, but rather, to "integrate" it in some capacity. Although unlikely to have altered the outcome, the existence of a partly functioning, though ultimately ineffective, air-defense system on the Hawaiian Islands on December 7, 1941 contributed to the perception that the attack was a disaster that could and should have been prevented.

Chapter Two. "Atomic Pearl Harbor"

Even before the United States Air Force came formally into existence in September 1947, the Department of War had already created the Air Defense Command and charged it with preparing an "integrated" air-defense system for the continental United States. Amid the political stagnation of the immediate postwar period, however, this little headquarters lacked clear guidance about what it was supposed to "integrate." In the absence of real assets like radar stations, communications links, or interceptor squadrons, air-defense commanders could do little besides ratiocinate about an "integrated" air-defense system in abstract, organizational terms.

With the assistance of Air Force headquarters, however, the Air Defense Command eventually discovered a winning argument in an incrementalist philosophy of air-defense integration, which emphasized the need to build an infrastructural "nucleus." However minimal at first, this nucleus would adapt and expand, according to the latest fashions in technology or budgetary politics, through a process of gradual "evolution," rather than total "revolution." With no opportunities to exercise its components as interdependent, as opposed to isolated, activities, the organization could not even begin to know what it did not know about its capability to defend the nation from enemy aircraft.

Chapter Three. Holes in the Sky

Although expectations for the first air-defense "nucleus" were not high, the system still disappointed many observers when it entered service in 1949–1950. Their displeasure resulted less from the analytical findings than from a general impression of confusion, disorganization, and inefficiency—problems that could only be resolved through regular experiment and study. However, the cost of staging live exercises with real aircraft restricted both the scope and frequency of testing opportunities, limiting their usefulness as tools for self-examination and, just as importantly, crew training. Simulation promised an ideal supplement, but it was then, as yet, practically infeasible to "script" by hand the sheer number of actions to which an air-defense operations center had to respond during an exercise of even modest size and duration.

To address the issue, the Air Defense Command developed, through its relationship with the RAND Corporation, the System Training Program, a method of organizational simulation that likely represents the first industrial-scale application of computing technology to military operations and training. In replicating the hand-operated air-defense centers of the time, however, the experiments that led to the System Training Program accelerated a trend toward thinking of humans as mere components in a larger machine, and as irredeemably slow, expensive, and unreliable ones at that. The positive aspects of human intervention, which had proved essential to the functioning of air-defense systems in the past, were erased almost entirely, exposing the ambition to eliminate human liabilities through automation.

Chapter Four. Laboratories at War

When the MIT Radiation Laboratory dispersed in 1946, the Army Air Forces moved quickly to recruit as many of its former personnel as possible to work in its own laboratories, particularly the Cambridge Field Station, which had been established expressly for this purpose. Winning over employees proved difficult enough, though not nearly so difficult as transforming their institutional allegiances, as those who did take government jobs generally chafed against the imposition of management controls uncharacteristic of smaller, less formal, university-like environments. Facing intense competition from private industry, however, military managers perceived no option better than appeasing this privileged generation of technical talent, raised on the raucous, anti-bureaucratic style cultivated by the wartime Office of Scientific Research and Development.

The attempt to reconstitute the Radiation Laboratory split the Air Force's research program for ground electronics, which included high-power radar, but also equipment peripheral to it, such as automatic data-relays essential to centralizing air-defense operations. Although intended as a temporary post, the Cambridge Field Station refused to consolidate with Watson Laboratories, a larger, prewar military installation for electronics research, which the Air Force inherited from the Army Signal Corps, located in Red Bank, New Jersey, and subsequently relocated to Rome, New York. The Cambridge lab did report to the Rome lab for some time, but by 1950, the two had developed their own teams with their own partially overlapping agendas, creating the preconditions for internecine conflict over the future of research related to the automation of air defense.

Chapter Five. "The Maginot Line boys from MIT"

The fissure between Rome and Cambridge posed a dilemma for Air Force technology managers. On the one hand, the Rome lab, which had descended from a traditional government research center, remained closely tied to the headquarters of the Air Materiel Command at Wright–Patterson Air Force Base in Dayton, Ohio—the effective center of the USAF's military administration. Excepting payroll, Dayton disbursed most of the Air Force's annual appropriation, and its technical staff collectively represented the largest and most capable managerial force throughout the entire service. At some point, every action regarding industrial engineering, research, and procurement passed through Wright–Patterson, which consulted with laboratories, field units, and private contractors even more regularly than the Air Force's executive headquarters in the Pentagon.

Nevertheless, the Air Materiel Command was an agency preoccupied with the sprawling responsibilities of logistics, maintenance, purchasing, and supply. As the nation's organization for joint military research-and-development broke down in the late forties, a faction within Air Force headquarters arranged an end-run around Dayton's hegemony, carving out a small but sovereign space for formulating science-and-technology policy. Most of the individuals responsible had entered public service with Division 14, and they retained close ties to its successors in the greater Boston area. As it happened, the powerful "Cambridge lobby" took charge of a messy restructuring of the Air Force's research-and-development organization at precisely the wrong moment to lend the continental air-defense program the clarity it so badly needed.

Chapter Six. Crisis in Command

To grasp how the Cambridge lobby understood itself, what it was trying to do, and why, it will be necessary to read its proposals against the overlooked products of the Rome–Michigan alliance. While mastering the situation technically, as well as dominating their perceived opposition politically, advocates of the "Cambridge way" nevertheless neglected to build relationships with the ultimate users of their research products. The resulting misapprehension not only confused the Air Force rank-and-file, who feared the disruptiveness of an outside imposition, it extended even to industrial firms hesitant to assume liability for their roles in a program that appeared to have accelerated beyond their patron's ability to control. As much as the Cambridge lobby celebrated its managerial exceptionalism, both during and after the events in question, its disdain for bureaucratic channels likely cost more time, and certainly more money, than it saved.

Unaware of the irony, a major study guided by SAGE's former luminaries, expressed deep concern for the nation's uncoordinated rush toward real-time computing for nuclear operations—a course they feared would constrain the options available to future leaders to those foreseeable by the engineers who had designed the systems upon which the effectuation of national authority depended. This was the first real effort to interpret "command and control" as a type of technological–organizational phenomenon, a sort of higher-order property, or "system of systems," emerging from their interaction. The goal of command-and-control should be to maximize human agency, they argued, and yet no one authority could unite the many project organizations that specified the precise technical behavior of each system in virtual isolation from one another. Naturally, they offered the authority of their own expertise instead.

At this project's end, we will finally be in a position to appreciate this story's significance both to our present condition and our sense of how we reached it. Historians have diligently charted America's "state capacity," its power to administer programs on a national scale, which matured during the first half of the last century.[70] This is the "bigness" of government, its dimension of size, but the latter-twentieth century also forced the presence of *time*—the government of "now"—to the point that the President of the United States of America can now express his majesty by viewing a display, tracking a bomb, flying through a window, half a world away.[71]

70. The term comes from Stephen Skowronek, *Building a New American State: The Expansion of National Administrative Capacities, 1877–1920* (Cambridge: Cambridge University Press, 1982), one of the foundational texts in the field of American political development, which, though claimed mostly by departments of government, remains rooted in historical studies of the Progressive Era. See Karen Orren and Stephen Skowronek, *The Search for American Political Development* (Cambridge: Cambridge University Press, 2004) for an overview and a bibliography.

71. Like other centers of high command, the White House Situation Room's precise capabilities and functions

We ought to be astonished, and not with the marvels of mere research and development. Such power actually represents the antithesis of management, the abrogation of bureaucracy, because it is not—contrary to our perceptions—everywhere, all of the time. It is only ever *here* and *now*, present before the few, or even the *one*, thus recovering the qualities of charisma, arbitrariness, and particularism that we thought defined an age departed.

How did such a thing come about? How was it that rationalism, fairness, and universality turned on themselves? In a word, indeterminacy. Law still requires judgment, and action, however constrained, must still interpret procedure, for the rules can never follow themselves. What the United States sought, above all, was to formalize its authority over *crisis*: the conspiracy of circumstances, the specificities of which overwhelm whatever might have been foreseen generically, which arises so suddenly, and presents stakes so high and consequences so immediate, that any means not immediately at hand are irrelevant to its conclusion.

To govern crisis is to manage the unmanageable, with all the contradiction that entails. Command-and-control promised to prove the state's validity under the conditions most likely to call that validity into question, and to do so with all the apparent impartiality of nature itself, which is to say, the organization of technology, and the technology of organization.

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remain classified: Michael K. Bohn, *Nerve Center: Inside the White House Situation Room* (Washington: Brassey's, 2003) is one insider account, but it was written before the most recent improvement program began. A president might not personally direct or observe a drone strike in real-time even if it were technically possible, and the normal chain-of-command almost certainly does not call for it: Jeremy Scahill, ed., *The Assassination Complex: Inside the Government's Secret Drone Warfare Program* (New York: Simon & Schuster, 2016) documented virtually all that was known to journalists at the time it was published. Reality is ultimately beside the point, however, because what matters is perception, or rather, its imagination, and the ubiquity of images like the famous photograph of the Situation Room during Operation Neptune Spear in contemporary media amply demonstrates the public's fascination with bureaucratic technology as a kind of executive fantasy.

Chapter 1

Remember Opana Point

Command, Control, and Organizational Technology

> When I assumed command of the Strategic Air Command...General LeMay asked me point-blank, "Who do you remember from Pearl Harbor?"... I gave him the only reply that immediately came to mind: "Sir," I said, "I remember General Short and Admiral Kimmel"... "You are exactly right," he said. "The responsible military commanders are the ones remembered in disasters and defeats." He explained that history does not record, nor do people remember, all those others who may have abetted, or even caused, the debacle; it is the one with command responsibility who is charged with failure.[1]
>
> General Russell E. Dougherty, CINCSAC, 1974–1977

At dawn on December 7, 1941, the sound of low-flying aircraft woke Kenneth P. Bergquist in his quarters at Wheeler Field, a small airstrip in Oahu's central valley. A Navy exercise out of Pearl Harbor, Bergquist presumed, since his own unit, the 14th Pursuit Wing, was supposed to be enjoying its first lazy Sunday in six weeks. The first explosion could have been a plane crashing nearby, a misfortune witnessed commonly enough by a career officer in the United States Army Air Corps. "And then right after that, of course, a lot of bombs

1. Russell E. Dougherty, "The Psychological Climate of Nuclear Command," in *Managing Nuclear Operations*, ed. Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket (Washington: Brookings Institution, 1987), 407.

went off there at Wheeler," he later recalled.[2] After securing his young daughter as best he could, the 29-year-old major dressed quickly and left his home, evading "a string of machine gun bullets [that] went up the street" on his way to the wing command-post.

"All the airplanes were burning," he discovered upon his arrival. The wing's entire complement of P-40s had been left parked in tight formation, a measure ordered to guard against sabotage, but which greatly increased their vulnerability from the air. As director of operations, Bergquist's official duties meant little to an airfield in ruins. Most probably, he joined the scramble to clear the runway for the handful of aircraft that remained undamaged. Whatever his actions, however, the situation was so confused that he could not fully recall them during testimony recorded just a few weeks later.[3] Indeed, no evidence clearly establishes what happened that morning at Wheeler, except that a small flight of four antiquated P-36s took off around 8:50 AM, one hour after the initial attack.[4]

When the second wave raided the airfield shortly thereafter, Major Bergquist enjoined an enlisted man to drive him to Fort Shafter in Honolulu, fifteen miles down the Kamehameha Highway. Their marked staff-car almost immediately attracted a pair of Japanese fighters hunting for targets of opportunity. Under fire, the occupants abandoned the vehicle still in gear. The driver went for the brush while Bergquist tackled the rear bumper and scuffled slowly along the pavement behind the moving car.[5] After the first plane passed overhead, Bergquist took shelter from the second in the backseat. "My only injury of the

2. Interview, Maj. Gen. Kenneth P. Bergquist, Commander, Air Force Communications Service, with Arthur K. Marmor, USAF Historical Liaison Office, Washington, DC, October 1965, transcript dated April 14, 1972, AFHRA (1008200), 10.

3. Testimony of Maj. Kenneth P. Bergquist, December 24, 1941, in Joint Committee on the Investigation of the Pearl Harbor Attack, *Pearl Harbor Attack: Proceedings of the Roberts Commission* 79th Cong., 1st sess., 1946, pt. 22, 225–232, CIS (HRG-1946-PHB-0017). He later gave a more thorough statement to official investigators as Testimony of Col. Kenneth P. Bergquist, August 18, 1944, in Joint Committee on the Investigation of the Pearl Harbor Attack, *Pearl Harbor Attack: Proceedings of the Army Pearl Harbor Board* 79th Cong., 1st sess., 1946, pt. 27, 615–632, CIS (HRG-1946-PHB-0022). In the case of few minor discrepancies, I have favored the statements Bergquist made nearer the time of the attack over his oral history interview recorded a quarter-century later.

4. Leatrice R. Arakaki and John R. Kuborn, *7 December 1941: The Air Force Story* (Hickham AFB, HI: Pacific Air Forces, Office of History, 1991), 76–80.

5. Bergquist interview, October 1965, AFHRA, 10.

whole war is a little scar I have on my little finger from holding on to a fender." Unable to locate his driver—whom, as he learned later, lay bleeding from a stray round to the leg some distance away—Bergquist proceeded alone toward the columns of hot ash pluming from the harbor, visible even in the distance. The descending route allowed him a sweeping view of the devastation before he reached his destination: a small, temporary structure on the grounds of Fort Shafter, where, for the previous six months, Bergquist had labored—almost entirely on his own initiative—to transform a one-room wooden cantonment into a proper air-defense information center.

1 Organizational systems and technological control

This first chapter examines the most notorious air-defense "failure" in American history: the surprise attack on Pearl Harbor. The repercussions of this nationally traumatic event did not end with World War II; on the contrary, fear of an "atomic Pearl Harbor" refashioned the national-security politics of the United States, while also lending the postwar continental-defense mission a sense of military urgency.[6]

Before the war, the obstructions to establishing a working air-defense system on the Hawaiian Islands—as in the Philippines, the Panama Canal Zone, and the few other places where Americans had tried to do so—were not widely recognized beyond the small group of

6. While building upon prior arguments, Douglas T. Stuart, *Creating the National Security State: A History of the Law That Transformed America* (Princeton University Press: Princeton, 2008) advances the strongest thesis connecting the memory of Pearl Harbor with the military-political reforms implemented by the United States Government after the end of World War II, even going so far as to refer to the new regime as the "Pearl Harbor system." Other accounts, such as Michael J. Hogan, *A Cross of Iron: Harry S. Truman and the Origins of the National Security State, 1945–1954* (Cambridge University Press: Cambridge, 1998) and Aaron L. Friedberg, *In the Shadow of the Garrison State: America's Anti-Statism and Its Cold War Grand Strategy* (Princeton: Princeton University Press, 2000), stress the exigency of the Cold War in motivating this reorganization, but even though the context cannot be discounted, the fact remains that the National Security Act codified a structure evolved during the war, and broadly followed the outlines of proposals that had been under study and negotiation since 1943. Cf. John C. Ries, *The Management of Defense: Organization and Control of the U.S. Armed Services* (Baltimore: Johns Hopkins University Press, 1964); Edgar F. Raines Jr. and David R. Campbell, *The Army and the Joint Chiefs of Staff: Evolution of Army Ideas on the Command, Control, and Coordination of the U.S. Armed Forces, 1942–1985*, CMH Pub 93-3 (Washington: US Army Center of Military History, 1986); Herman S. Wolk, *Planning and Organizing the Postwar Air Force, 1943–1947* (Washington: Office of Air Force History, 1984).

officers actually responsible for it.[7] Although the Air Corps borrowed doctrine, tactics, and operating principles liberally from their more experienced counterparts in the Royal Air Force, certain features peculiar to the structure of the United States Government, as well as the American military tradition, induced frustrations of idiosyncratic nature and nontrivial consequence.

In particular, American military doctrine did not yet recognize "air defense" as a distinct military *function* that required a unitary chain of command. Rather, it represented a collection of secondary activities performed by each unit or agency staked in the defense of the area.[8] As such, Americans relied by necessity on an ungainly method of liaison, centered on the person of the "controller," who acted as a dispatch officer for defensive measures not formally under his command. This differed considerably from the construction of so-called "Dowding System" that the Royal Air Force employed during the Battle of Britain, in which the senior duty-officer exercised *direct* command authority over the entire air-defense organization during its operation.

By way of contrast, an American air-defense commander performed more of an *implementing* and *managerial* function: designing, exercising, and regulating the many cross-

7. America's preparations for the defense of the Western Hemisphere following the outbreak of hostilities in Europe and Asia, but before its own entry into conflict, are not widely known, except in diplomatic or grand-strategic terms. An overview of American military posture during this period can be found in Stetson Conn and Byron Fairchild, *The Framework of Hemispheric Defense*, The United States Army in World War II: The Western Hemisphere, CMH Pub 4-1 (1960; repr., Washington: US Army Center of Military History, 1989) and Stetson Conn, Rose C. Engelman, and Byron Fairchild, *Guarding the United States and Its Outposts*, The United States Army in World War II: The Western Hemisphere, CMH Pub 4-2 (1964; repr., Washington: US Army Center of Military History, 2000).

8. The principle of "unity of command" descended from the European military tradition before entering the management literature through Henri Fayol, *General and Industrial Management*, trans. Constance Storrs (1919; London: Pitman, 1949). It holds that every subordinate should be responsible to one, and only one, superior. By extension, in a military organization, a single officer should, ideally, have complete authority over all forces under his or her command, according to a textbook commonly used by American officers-in-training after World War II: John Robert Beishline, *Military Management for National Defense* (New York: Prentice–Hall, 1950). Except on small scales, however, the principle is rarely achievable in practice, however, and especially so in the American military tradition, which has evolved a convoluted "joint" doctrine in order to coordinate the efforts of its armed forces. Arrangements during the war, on the other hand, were almost completely *ad hoc*, because as cabinet-level departments, the prewar Army and Navy had relatively little occasion to interact except on matters of policy, such as United States Joint Board, *Joint Action of the Army and Navy* (Washington: GPO, 1927).

organizational agreements and mutual understandings necessary to operate the defense system, with or (usually) without his immediate presence. The element of authority, therefore, became embedded in the configuration of the system itself; its actions legitimated by their adherence to a premeditated set of standard operating procedures, as opposed to legal investiture in the controller *per se*.

Despite substantial differences in both organization and technique, American military professionals conceived of air defenses as expressions of "system," as did the British. While the case examined in this chapter arguably descended into pathology, Americans eventually did succeed in operating effective air-defense nets according to principles similar to the ones explained here. Still, persistent deficiencies pushed Americans toward the norm of unity-of-command, though full adoption of the model lay more than a decade in the future.

Given the historiographical deference to air defense in the evolution of "systems thinking," however, it is worth considering how such thinking was adapted to local contingencies, and thereby, created a body of operational experience.[9] The goal here is to begin forming a picture of organizational means *interacting* with technological means, eventually reaching the point where, in a later chapter, the apparently natural division between the *technical* and *organizational* elements of system can be challenged. While today the term "system integration" does, in certain restricted contexts, refer to a well codified body of engineering practices, in general, "integration" is more an ideal than a criterion, which supposes an almost ineffable harmony between designers and users, in opposition to a reality where

9. The introduction details the literature most relevant to the present discussion, which, in addition to automated air-defense, further overlaps with historical studies concerning radar, guidance, fire-control, operations research, and ballistic-missile defense, such as David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (Baltimore: Johns Hopkins University Press, 2002); Donald A. MacKenzie, *Inventing Accuracy: An Historical Sociology of Nuclear Missile Guidance* (Cambridge: MIT Press, 1990); Rebecca Slayton, *Arguments That Count: Physics, Computing, and Missile Defense, 1949–2012* (Cambridge: MIT Press, 2013); Erik P. Rau, "Technological Systems, Expertise, and Policy Making: The British Origins of Operational Research," in *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes*, ed. Michael Thad Allen and Gabrielle Hecht (Cambridge: MIT Press, 2001), 215–252; Peter Galison, "Laboratory War: Radar Philosophy and the Los Alamos Man," in *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997), 239–311, and Thomas P. Hughes and Agatha C. Hughes, introduction to *Systems, Experts, and Computers: The Systems Approach in Management and Engineering*, ed. Agatha C. Hughes and Thomas P. Hughes (Cambridge: MIT Press, 2000), 1–26.

system behavior is often unspecifiable, because it depends on the unanticipated reactions of the humans to be organized by the system.[10]

This chapter will proceed in two phases. First, it follows a small group of American officers who observed the RAF's air-defense organization in action during the Battle of Britain with an eye toward implementing similar provisions in the United States. In so doing, they registered opinions about what an air-defense "system" *should be*, while remaining realistic about the bureaucratic obstructions that would inhibit the adaptation of such systems to their own military establishment. The nature of this military-political environment is characterized, and, in the second part, its contingencies demonstrated in one specific yet memorable scenario: the Japanese attack on Pearl Harbor.

Although mindful of the fact that nothing the actors could have done would have likely altered the outcome—not to the mention the arguable significance of the outcome itself—the following may be considered an account of what is, in modern terms, one of the most famous command-and-control failures in modern military history. The cultural trauma of the event justifies exploring what they themselves perceived had "gone wrong," independent from the grand forces of military politics and international diplomacy.[11]

10. With respect to engineering practice, Harry H. Goode and Robert E. Machol, *System Engineering: An Introduction to the Design of Large-Scale Systems* (New York: McGraw–Hill, 1957) was perhaps the earliest textbook on "systems management" in widespread use, though Fremont E. Kast and James E. Rosenzweig, eds., *Science, Technology, and Management* (New York: McGraw–Hill, 1963) and George A. Steiner and William G. Ryan, *Industrial Project Management* (New York: Macmillan, 1968) provide more tangible glimpses into the evolving state-of-the-art at the time of their publications.

11. This is not an analytic study of military "failure" *per se*, as in, for instance, Richard K. Betts, *Surprise Attack: Lessons for Defense Planning* (Washington: Brookings Institution, 1982) or Eliot A. Cohen and John Gooch, *Military Misfortunes: The Anatomy of Failure in War* (New York: Simon & Schuster, 1990), whose concern lies mainly in extracting "lessons learned" for current and future officials. The perspective here is, by comparison, agnostic, holding that had the outcome been different, Americans might tell the same story as a sequence of happy accidents, rather than a systemic breakdown. That said, Roberta Wohlstetter, *Pearl Harbor: Warning and Decision* (Stanford: Stanford University Press, 1962), in particular, still stands apart for its meticulous reconstruction of the operational record, some portion of which will likewise follow, having been drawn from some of the same primary sources.

2 The first Air Defense Command

So long as historians continue to debate the origins of the Second World War, they will likely never agree whether the attack on Pearl Harbor *truly* surprised American officials—either in Washington or Hawaii—or if it *should* have surprised them, even if indeed it did. Regardless, the United States military *did* have sufficient opportunity to observe, and at least some occasion to incorporate, the state-of-the-art in air-defense operations as studied and practiced by the Royal Air Force during the Battle of Britain. Preparations on the strategically vital island of Oahu were already well advanced by the fall of 1941, a fact that still engenders a remorseful sense of missed opportunity, especially when further incited by the wrathful conspiracism of the historiographical fringe.[12]

Indeed, in March 1941, the Hawaiian Department had sent Major Bergquist to Mitchel Field, near Hempstead on Long Island, home to the newly established Air Defense Command, for instruction in the latest advances in "ground-controlled interception," or GCI, from across the Atlantic—knowledge he and others began to apply to Oahu eight months before the attack.[13] Some of the Army's first production-model SCR-270 radar followed not long after them. A radar-equipped Aircraft Warning Service that was, in theory, capable of supporting British-style GCI operations entered its first stage of operation in November.

Of course, a great deal has been said concerning the remarkable advancement in air-defense capabilities attributable to the development of radar, or what the British still called "RDF," for "range-and-direction finding."[14] To clarify, while Bergquist, like most other

12. The historiography and cultural history of the attack on Pearl Harbor is out-of-scope here, but see Emily S. Rosenberg, *A Date Which Will Live: Pearl Harbor in American Memory* (Durham: Duke University Press, 2003), particularly on the evolution of revisionist claims.

13. Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* (Washington: Office of Air Force History, 1991), 36–38. Although my presentation of ADC's organizational history largely parallels Schaffel's, I have expanded and in some cases revised his conclusions after consulting the primary sources, as indicated in the footnotes. Much of Schaffel's own material on World War II revisited Wesley Frank Craven and James Lea Cate, eds., *Men and Planes*, vol. 6 of *The Army Air Forces in World War II* (1954; repr., Washington: Office of Air Force History, 1983), chap. 3; see also Conn, Engelman, and Fairchild, *Guarding the United States and Its Outposts*, chaps. 1–3.

14. The historiography of radar is dominated by enthusiast histories of Anglo-American scientists and

students, had never heard of radar before attending the March School, this was not because famous "Tizard mission" to the United States had suddenly surprised American scientists and engineers with the miraculous discovery of the cavity magnetron. The magnetron created the possibility of *microwave* radar, the most pressing application of which was perceived to lie in the production of detectors with resolution sufficiently high to be useful for navigation and gun-laying while remaining small, light, and low-powered enough to mount on ships, aircraft, and motor vehicles, or easily transported by them.[15]

Sprawling air-defense networks, on the other hand, relied on large, fixed installations without such rigid technical requirements, and since existing equipment was considered sufficient for ground-based applications, they never achieved the priority necessary to earn allocations of microwave components in any quantity before the war's end. In fact, the early-warning stations guarding the English coast in 1940 operated in the *high-frequency* band, a rather pedestrian form of radar compared to a VHF set like the SCR-270, which was then entering service even in a military backwater like the United States.[16] A high-frequency

engineers and the application of their ingenuity to wartime problems; cf. Hartmut Petzold, "Some Problems of Radar Systems Historiography," in *Tracking the History of Radar,* ed. Oskar Blumtritt, Hartmut Petzold, and William Aspray (Piscataway: IEEE–Rutgers Center for the History of Electrical Engineering, 1994), 247–266, as well as relevant parts of other contributions to the same volume. Note that early British sources favored the term "RDF" but gradually adopted the Americanism, "RADAR," for "radio-detection and ranging." Although quickly "de-acronymized" to "radar," the all-caps styling continued to appear in technical writing at least until the mid-to-late forties. This text follows the British convention when historically appropriate and the modern convention in other cases.

15. James Phinney Baxter III, *Scientists Against Time,* Science in World War II (Boston: Little, Brown, 1946) remains the canonical account of the Tizard Mission, but a careful reading also reveals its overwhelming concern for miniaturized, low-power microwave radar. The application of microwaves to high-powered ground radar will be dealt with in chapter 4.

16. A Chain Home station consisted of two separate sites: a three- or four-mast curtain array that broadcast a high-frequency signal typical of commercial radio, and a four-element Adcock array to receive the backscatter. By 1941, the Army Signal Corps had already fielded a similarly capable set, the SCR-270, but in a smaller, mobile package. (The SCR-271 variant was identical except that its support equipment had been adapted for permanent installation.) Until 1943, however, the Air Force believed the British design performed better in the field, a perception the Signal Corps Laboratories attributed to the RAF's superior training, maintenance, and staffing levels, as well as the presence of supplemental detectors to fill gaps in the radiation pattern. The tension slackened as these issues were gradually addressed, and the SCR-270 remained the Army Air Force's primary search-radar throughout the war. George Raynor Thompson et al., *The Signal Corps: The Test, December 1941 to July 1943,* The United States Army in World War II: The Technical Services, CMH Pub 10-17 (1957; repr., Washington: US Army Center of Military History, 1978), 93–102; George Raynor Thompson and Dixie R. Harris, *The Signal Corps: The Outcome, Mid-1943 Through 1945,* The United States Army in World War II: The

Chain Home station could not follow a passing aircraft or reliably distinguish moving objects from surface clutter, except over open water, so after penetrating the coastline, tracking targets depended almost entirely upon more rudimentary methods, such as the volunteer aircraft-spotters in the Royal Observer Corps.

Therefore, the "Dowding system," so-called for Air Chief Marshal Sir Hugh Dowding, succeeded or faltered not by its technological marvels alone, but by the pace and certainty with which their readings could be rendered sensible as well. Even the finest instrumentation available today can only represent the *physical* characteristics of radio-frequency reflections; it is otherwise blind to all features of *organizational* significance. Echoes return no matter their identity or intention, to the extent they can be positively determined to possess intentionality at all. Thus, to become a "contact," with discernible relevance to the tactical situation, a signal must be processed through a variety of mechanisms, some of which rely primarily on humans, and others on machines.[17]

Measured on the scale of decades, the balance between human and machine has tilted substantially toward the latter, and yet what the Battle of Britain demonstrated—even to the few Americans sent to observe—was that, evolving from one moment to the next, the equilibrium between organization and technology is a furiously dynamic thing. As such, it could not assume the same form in the United States, with its different military tradition, as it did in Great Britain, despite the similarities in terms of equipment and installations.

Technical Services, CMH Pub 10-18 (1966; repr., Washington: US Army Center of Military History, 1991), 468–477. The AAF's recollection was, of course, discrepant, and apparently confused by the distinction between high-frequency and microwave radar. Cf. Craven and Cate, *Men and Planes*, 82–84; Schaffel, *The Emerging Shield*, 29. It is true, however, that the Air Corps' rank-and-file was generally unaware of radar technology of any kind, as the development program during the 1930s remained a small one under recondite Signal Corps administration: Harry M. Davis, ed., *The Signal Corps Development of U.S. Army Radar Equipment*, 3 pts., Signal Corps Historical Project A-1–3 (Washington: Historical Section, Office of the Chief Signal Officer, November 1945), declassified manuscripts provided by Historical Office, United States Army Communications–Electronics Command (CECOM), Aberdeen Proving Ground, MD.

17. Cf. Denys Volan, *The Identification Problem in the Air Defense of the United States*, ADC Historical Study No. 3 (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, June 30, 1954), OCLC (31413878). Incidentally, modern sensors are capable of extracting some physical characteristics of a remote body with the aid of sophisticated digital-signal processing. Since the analysis is statistical, however, it cannot reliably distinguish between aircraft with similar structural features, rendering methods such as transponders, flight-tracking, and voice communication as necessary today as they were during World War II.

The Dowding System: Judgment, representation, and action

The city of London suffered its first aerial bombardment on May 30, 1915, the beginning of a series of nighttime strikes conducted by German zeppelins. After the lighter-than-air offensive proved ineffectual, the *Luftstreitkräfte* suspended its bombing of English cities until May 1917, when a flight of 23 Gotha G.IV biplanes attempted to attack London, in broad daylight, before diverting to their secondary targets in Kent. That summer, Gotha raids killed thousands on the southeastern coast, and soon the metropolis again found itself besieged almost nightly by air.[18]

Within a year, a provisional unit called the London Air Defence Area (LADA) belted the Thames Estuary with concentric rings of observers, searchlights, fighter patrols, barrage balloons, and antiaircraft artillery crewed by over 20,000 personnel. At each of the area's 25 control rooms, tellers relayed local observations by telephone to a central control facility at Whitehall, where a team of plotters pushed colored blocks around a large map table with wooden rakes. "I sat overlooking the map from a raised gallery," recalled Major-General Edward Ashmore, "in effect, I could follow the course of all aircraft flying over the country, as the counters crept across the map."[19] Given their relatively high velocity, the organization's paramount parameter was, according to its own language, "time lag": the delay between an observation and the organization's response, usually through an order issued over radio or telephone circuits to air or gun crews.

Even primitive Gotha bombers could still travel over a mile with each minute that lapsed

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18. See the relevant passages in Raymond H. Fredette, *The Sky on Fire: The First Battle of Britain, 1917–1918* (1966; repr., Tuscaloosa: University of Alabama Press, 2007), which, in addition to further detail on LADA, contextualizes the foundation of the Royal Air Force in 1918, the organization that established the modern precedent for segregating at least some portion of military aviation from the command of ground and naval forces, and, to the continued aggravation of officers in the Army Air Corps, a precedent not followed by the United States until the National Security Act of 1947.

19. E. B. Ashmore, *Air Defence* (London: Longmans, Green, and Co., 1929), 93. The London Air Defence Area commenced operation soon after the infamous Folkstone raid in May 1917 and consolidated antiaircraft measures initially developed to defend against zeppelins. See Sir Percy Scott, *Fifty Years in the Royal Navy* (London: John Murray, 1919), chap. 18, the memoir of the naval artillery officer who began installing them in 1915.

from the initial sighting, so to make the defense credible, Ashmore needed to prove his claim that "the time when an observer at one of the stations in the country saw a machine over him, to the time when the counter representing it appeared on my map, was not, as a rule, more than half a minute."[20] In practice, the figure was likely aspirational. To order-of-magnitude, though, it represented a significant achievement of organizational and technological control. Since the advent of electric communication, observation-response cycles with comparable "time lags" had previously been achieved militarily only across limited spatial extents: in naval gunnery, for instance, or indirect artillery-fire.[21] LADA, on the other hand, became the standing precedent for how to organize a military operation across a large geographical area coordinated to within a minute or less.

By 1940, attack and pursuit aircraft alike could reach speeds exceeding 300 miles-per-hour, rendering the organizational "time lag" of air defenses even more critical. During the previous war, Ashmore needed only to concentrate patrols along the enemy's flight path. Once relative velocities approached 10 miles-per-minute, however, hostiles could no longer be merely cut off *en route* to their targets; they had to be *intercepted*—the proverbial

20. Carrying a 110-pound payload, a Gotha G.V could only cruise around 70 miles-per-hour—only 10–15 miles-per-hour above its stall speed at altitude. Simply maintaining level flight could not have been easy even under ideal conditions, let alone angry gunfire, and so it is unsurprising that more Gothas were lost to accidents than enemy action. Laurence K. Loftin Jr., *Quest for Performance: The Evolution of Modern Aircraft*, NASA SP-468 (Washington: Scientific and Technical Information Branch, National Aeronautics and Space Administration, 1985), 48–50.

21. The operations room aboard a naval vessel is probably the closest historical analogue to an air-defense control center, both reaching similar levels of sophistication at roughly the same time: Timothy S. Wolters, *Information at Sea: Shipboard Command and Control in the U.S. Navy, From Mobile Bay to Okinawa* (Baltimore: Johns Hopkins University Press, 2013) and Mindell, *Between Human and Machine*; see also Norman Friedman, *Naval Firepower: Battleship Guns and Gunnery in the Dreadnought Era* (Annapolis: Naval Institute Press, 2007) or John Brooks, *Dreadnought Gunnery and the Battle of Jutland: The Question of Fire Control* (New York: Routledge, 2005) for more on the practice of shipboard gunnery and fire-control. Field artillery experienced a similar evolution in both methods, tactics, and supporting equipment as guns increased in range and accuracy, to the point where battlefield commanders required electrical communications and more centralized headquarters in order to to coordinate "indirect fire" (i.e. beyond sight of the gunnery crews) on positions spotted by forward observers: John J. McGrath, *Fire for Effect: Field Artillery and Close Air Support in the US Army* (Fort Leavenworth, KS: US Army Combined Arms Center, Combat Studies Institute Press, 2011). Nevertheless, one of the best, if overlooked historical comparisons for both the organizational and technological context of a large-area air-defense system is quite possibly the construction of harbor and seacoast defenses during the late-nineteenth can early twentieth centuries; *Seacoast Artillery: Basic Tactics and Technique* (Harrisburg: Military Service Publishing, 1944), though a pedagogical treatise compiled from Army field manuals and regulations, gives a sense of how such area defenses were constructed and operated.

striking of a bullet with another bullet—imposing hard limits on uncertainty, let alone second chances. Even the sharpest-eyed pilots could not reliably spot another aircraft at distances greater than five miles, or as little as one mile when separated by at least 5,000 feet of altitude. If ground controllers missed either parameter by comparable margins, an interceptor would probably not catch the intruder in time to disrupt its attack, presuming contact could be established at all.[22]

Dowding now had the advantage of a coastal RDF network, an undeniable improvement over the crude acoustical devices employed, to varying degrees of effectiveness, during World War I. Nevertheless, by increasing the detection radius by an order of magnitude, radio observation also multiplied spurious and redundant reports, which, as British operational analysts learned before the war, cascaded greater and greater confusion the farther they propagated along the command chain.[23] The German *Luftwaffe* had witnessed as much in its own prewar experiments and fully expected mass raids to oversaturate the opponent's organizational capacity, the basic principles of which had not changed appreciably between the wars.[24]

22. United States Department of War, *Air Defense*, Army Air Forces Field Manual (FM) 1-25 (Washington: GPO, June 15, 1943), OCLC (56664963) described some of the technical elements of computing interceptions, which provided a baseline for instruction during the war. While the underlying calculations are similar to those used by gunners, air-defense crews had to refine their own tools and methods for performing them, such as the ubiquitous "Tizzy angle," so named for Henry Tizard of "Tizard mission" fame, which proved an efficient means for an air-defense controller (or pursuit officer, in the American case) to eyeball an intercept vector straight from the plotting board; see David Zimmerman, *Britain's Shield: Radar and the Defeat of the* Luftwaffe (Stroud, UK: Sutton, 2001), 110–117. On the tactical limitations confronting interceptor pilots, cf. Stephen Bungay, *The Most Dangerous Enemy: A History of the Battle of Britain* (London: Aurum, 2000), 239–267 or Mark Kendall Wells, "Aviators and Air Combat: A Study of the U.S. Eighth Air Force and R.A.F. Bomber Command," (PhD diss., King's College London, 1992), DTIC (ADA265349), the latter of which, while concerned primarily with stress and morale, lucidly describes the fighting environment of British and American air crews.

23. The following passage draws mainly from David Zimmerman, "Information and the Air Defence Revolution," *Journal of Strategic Studies* 27, no. 2 (June 2004): 370–394, doi:10.1080/0140239042000255968, a condensation of the author's earlier Zimmerman, *Britain's Shield*, which is worth consulting for additional detail. Some military-historical elements come from Robin Higham, "The RAF and the Battle of Britain," in *Case Studies in the Achievement of Air Superiority*, ed. Benjamin Franklin Cooling (Washington: Air Force History and Museums Program, 1994), 115–178, which also includes a helpful bibliographic essay. The literature on the Battle of Britain is vast but duplicative.

24. In fact, though some German officers suspected the British must have had some form of radar-based air-defense system, electronic surveillance failed to identify it correctly, presuming that, given the low operating frequency of Chain Home stations compared to German VHF sets, the high-power emissions were generated by

Furthermore, in addition to sorting through potentially specious reports, Dowding's "system" also needed to account for the movements of friendly and civilian aircraft, as well as to distinguish between them. The methods for so doing included—when possible—sophisticated communications-electronics such as multi-band VHF, airborne transponder beacons, and radio direction-finding ("R/DF," not to be confused with "RDF"), as well as more mundane techniques such as controlled airspaces, visual inspection, and the recording and conveyance of flight plans. These myriad, mostly paper-based reports required correlation with RDF returns before the situation in the air became clear enough to compute and relay interception vectors, a process that imposed its own "time lag" as well.[25]

Considering the far greater premium now placed on organizational latency, it is perhaps paradoxical that the RAF discovered an unavoidable need to *filter* and *reduce* incoming reports, even when such manipulations could potentially delay the response by precious seconds, or more likely, minutes. Compared to Ashmore's defense provisions, what the Dowding System did was physically separate the responsibility to *represent* the air-battle from

commercial broadcasting, or some other form of interference. Thus, the *Luftwaffe* remained largely unaware of the defenses arrayed against them until after beginning its assault on Great Britain in 1940. Zimmerman, *Britain's Shield*, 204–205.

25. Popular sources, including Bungay, *The Most Dangerous Enemy*; James Holland, *The Battle of Britain: Five Months That Changed History: May–October 1940* (New York: St. Martin's, 2010); Robert Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (New York: Simon & Schuster, 1996); and Louis Brown, *A Radar History of World War II: Technical and Military Imperatives* (Bristol, UK: Institute of Physics, 1999); as well as canonical accounts, such as Derek Wood and Derek Dempster, *The Narrow Margin: The Battle of Britain and the Rise of Air Power, 1930–1940* (New York: McGraw–Hill, 1961); Len Deighton, *Fighter: The True Story of the Battle of Britain* (New York: Knopf, 1978); and the official histories: Basil Collier, *The Defence of the United Kingdom* (London: HMSO, 1957) and Denis Richards, *The Fight at Odds*, vol. 1 of *The Royal Air Force, 1939–1945*, ed. Denis Richards (London: HMSO, 1953) describe, in varying levels of detail, the idealized operation of the Dowding System. The majority tend not to question the orthodox view, shaped during the administration of Winston Churchill, and cemented by his postwar self-hagiography—in particular, Winston S. Churchill, *Their Finest Hour*, vol. 2 of *The Second World War* (Boston: Houghton Mifflin, 1949)—that British air-defenses had proved decisive due to their technical, administrative, and moral superiority. Even specialty volumes, such as Henry Probert and Sebastian Cox, eds., *The Battle Re-Thought: A Symposium on the Battle of Britain, 25 June 1990* (Shrewsbury, UK: Airlife Publishing, 1991), have, while emphasizing previously neglected aspects of the campaign, nevertheless continued to soft-pedal the hard questions. Only as the old-guard has retired have more recent studies, like the work of David Zimmerman, cited elsewhere, and Richard Overy, *The Battle of Britain: The Myth and the Reality* (New York: W. W. Norton, 2001), expressed more willingness to question, or at least complicate, the received story. See Anthony J. Cumming, "Did Radar Win the Battle of Britain?" *The Historian* 69, no. 4 (Winter 2007): 688–705, doi:10.1111/j.1540-6563.2007.00194.x.

the responsibility to *act* upon it. Discerning a raid was "simply and solely an assessment of probability," according to one researcher, "a weighing of the accuracy of various sources of information or the estimation of the accuracy of any source of information."[26] As such, it required the judgment of one familiar with the quirks of individual RDF stations and the qualities of the teller relaying each observation, a task not only distinct from directing an interception, but a distraction frequently inimical to it.

At Fighter Command headquarters, then, the controllers in the operations room saw only a plot constructed from reports received *indirectly* through an intermediate "filter room," rather than directly from the observations themselves. Next door, the filter officer acted as a sort of plotting umpire: sensitive to ambiguity while also communicating a measured degree of certainty—more or less depending on his judgment of the situation—in order to avoid confusing, misleading, or otherwise belaboring the controllers. According to the procedure's engineer, the filter officer addressed "the problem of ensuring that the *most probable* data on position, track and speed, and composition of each individual track and speed, and composition of each individual raid are extracted from the incompletely accurate and incompletely concordant reports of several RDF stations, and that the identification of defensive and friendly formations is made secure *as may be*."[27] The position was perhaps the most crucial to the entire operation, and the most significant arguments within the administration concerned the specifics of how to do it.

While the Battle of Britain remains positively mythic in popular memory, specialists seriously doubt whether the Dowding System truly crested the grandiloquent peaks of Churchillian oratory.[28] Indeed, the German offensive eventually *did* overstress its capacity,

26. E. C. Williams, a chemical engineer, assigned to the Operations Research section at RAF Fighter Command in 1939; quoted in Zimmerman, *Britain's Shield*, 182–183. For a brief account of British OR activities with respect to air defense, see Maurice W. Kirby, *Operational Research in War and Peace: The British Experience From the 1930s to 1970* (London: Imperial College Press, 2003), chap. 3.

27. Edmund Dixon, a communications engineer, who had worked for the British Post Office before joining the RAF's Bawdsey Research Station (later, the Telecommunications Research Establishment) in 1936; quoted in Zimmerman, *Britain's Shield*, 126 (emphasis added).

28. See note above on the predominance of laudatory histories of the role of technology and system in the

and by September 1940, its uncounterable shift to nighttime "terror bombing" had cost Dowding his command.[29] His successor, Air Marshal Sir Sholto Douglas, represented a faction that opposed Dowding personally perhaps more than his "system," the eponymous attribution of which, moreover, effaces the work of the RAF's Bawdsey Research Station, the core of what later became the Telecommunications Research Establishment—a key site in the development of modern operations-analysis. Nevertheless, under Douglas, Fighter Command's sophisticated ground-based techniques were largely supplanted by indiscriminate sweeps by large formations of aircraft over and across the English Channel.[30] While this "big wing" doctrine essentially revived the outmoded tactics of the previous war, by that time, the Battle of Britain had already depleted the *Luftwaffe* of both aircraft and experienced pilots and navigators.

Notwithstanding Dowding's political undoing, the Royal Air Force established the Anglo-American precedent for unitary air-defense, organized separately from, yet interdependent with, other military stakeholders operating in the same area. From Fighter Command's headquarters in Bentley Priory, the controller issued orders to subordinates units, including guns and aircraft, configured both technically and legally along relatively clear channels of communication and responsibility. Although the representation he perceived was heavily mediated, and even calibrated to his abilities, he acted directly on his own authority as a

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Battle of Britain. The genesis and perpetuation of the traditional narrative has received some scrutiny of late: Garry Campion, *The Good Fight: Battle of Britain Wartime Propaganda and the Few* (New York: Palgrave Macmillan, 2009); S. P. MacKenzie, *The Battle of Britain on Screen: "The Few" in British Film and Television Drama* (Edinburgh: University of Edinburgh Press, 2007); as well as the polemical Richard North, *The Many Not the Few: The Stolen History of the Battle of Britain* (London: Bloomsbury, 2012).

29. David Zimmerman, "British Radar Organization and the Failure to Stop the Night-time Blitz," *Journal of Strategic Studies* 21, no. 3 (September 1998): 86–106, doi:10.1080/01402399808437728.

30. As a point of tangential interest, Dowding's purported "knifing" by political enemies, eager to claim his achievements for themselves, remains a tender issue in the mustier corners of British military history, redolent of the grievance concerning the public sword-fallings of Walter Short and Husband Kimmel following the attack on Pearl Harbor. While the present argument need stake no claim in this, John Ray, *The Battle of Britain: Dowding and the First Victory, 1940* (London: Cassell, 2000) and David E. Fisher, *A Summer Bright and Terrible: Winston Churchill, Lord Dowding, Radar, and the Impossible Triumph of the Battle of Britain* (Washington: Shoemaker & Hoard, 2005) provide some interesting, though perhaps obsessive, documentary insights into the conduct of a specific military-political affair, particularly the latter, which highlights Dowding's rather eccentric personality.

commanding officer.

Exercise and indoctrination: The ADC March School

Whatever deficiencies they later displayed, the British clearly surpassed the aimless preparations of the United States, where air defense remained outside the mainstream of military thinking throughout the 1930s. As a political matter, however, lack of immediate relevance did not dissuade the Army or the Navy—beleaguered as they were by the Great Depression—from arguing as vigorously as they did pedantically about their respective duties to defend America's shores from enemy aircraft. Dispute persisted even within the War Department as to whether the ultimate responsibility should lie with the Coast Artillery, which administered the guns and fortifications; the Signal Corps, who ran the observation posts and the communications between them, or, perhaps unlikeliest of all, the Air Corps' petulant "pilotocracy." At an air-defense exercise in Florida in 1935, for instance, one squadron leader went so far as to refuse radio instructions from ground controllers, invoking the rather chivalric premise that the pilot is always the captain of his own aircraft.[31]

With an international conflict on the horizon, the War Department proceeded in 1937, albeit tepidly, to follow after the Royal Air Force. American air-defense exercises held in 1938 and 1939 reconfirmed the painful state of misapprehension between the Air Corps, the Coast Artillery, and the Signal Corps. On December 15, 1939, the Secretary of War ordered the Chief Signal Officer of the Hawaiian Department to organize one of the nation's first "aircraft warning services," the capabilities of which would nevertheless be sharply limited by the lack of cross-organizational consensus on command authority.[32] A department circular published a few months later delegated to the Signal Corps the task of "development,

31. A general officer, who was merely observing, eventually defused the situation by commanding the pilot to obey all orders as if the general had issued them personally. Schaffel, *The Emerging Shield*, 6–19.

32. Signal Office, Central Basic Base Command, "Report on the Establishment of an AWS in Hawaii," August 31, 1944, exhibit 58 in Joint Committee on the Investigation of the Pearl Harbor Attack, *Pearl Harbor Attack: Proceedings of the Army Pearl Harbor Board* 79th Cong., 1st sess., 1946, pt. 31, 3139–3158, CIS (HRG-1946-PHB-0022) recounts, in stifling detail, the sequence of administrative actions concerning the air-defense of the Hawaiian Islands sampled in this chapter, including the one above.

procurement, storage, and issue of all electrical apparatus for determining the location of radio stations, aircraft, and marine craft, and all the electrical apparatus associated with range finding," as well as "such other equipment and supplies as may be designated…in connection with the installation, operation, and maintenance of an aircraft warning service"—in short, to provide the technical infrastructure for air defenses, while leaving the necessary methods of inter-operation unspecified.[33]

Such formalistic inconsistencies were typical of the American military tradition.[34] The comparatively fractious evolution of military organization in the United States imposed a premium on *coordination* on the air-defense controller, who was legally *not* a commander, in most cases, but rather, a sort of human switch for delegating facts to an appropriate action officer. While the Dowding System similarly depended on a tenuous military-political consensus among senior British Government officials, the American model had to emerge, case by case, from the military assets specific to the area, each of which generally lacked "unity of command," and hence, the equivalent of a singular controller–commander.[35] In

33. War Department Circular No. 57, 1940, section 1, changes to Army Regulation (AR) 105-5, in United States, Department of War, *Compilation of War Department General Orders, Bulletins, and Circulars* (Washington: GPO, September 1, 1940), 189. The prescribed methods of operating antiaircraft artillery, in conjunction with the Aircraft Warning Service, were printed in United States Department of War, *Antiaircraft Artillery, Organization and Tactics*, Coast Artillery Field Manual (FM) 4-15 (Washington: GPO, August 12, 1940), OCLC (44441654) and United States Department of War, *Aircraft Warning Service*, Signal Corps Field Manual (FM) 11-25 (Washington: GPO, August 3, 1942), OCLC (744464401). It should be remembered, however, that military regulations, manuals, statements of doctrine, and the like only represent the subject in terms of pedagogy, procedure, or administrative law. While sometimes illustrative, in the absence of other sources, they do not demonstrate how their provisions were put into practice, if at all. Official publications issued from Washington often responded to a perceived lack of uniformity in the field, rather than dictating it proactively, and were neither circulated nor observed consistently. For example, consider the thwarted ambition behind *The Air Force in Theaters of Operations*, published in 1943, as described in Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force*, vol. 1 of (1971; repr., Maxwell AFB, AL: Air University Press, 1989), 68, or indeed, the difficult stories of the many other official promulgations considered in the same volume.

34. For perspective, see, for instance: Kenneth Allard, *Command, Control, and the Common Defense*, rev. ed. (1990; Washington: National Defense University Press, 1996); Jonathan M. House, *Toward Combined Arms Warfare: A Survey of 20th-Century Tactics, Doctrine, and Organization*, Combat Studies Institute Research Survey No. 2 (Fort Leavenworth, KS: US Army Command and General Staff College, 1984); James A. Winnefield and Dana J. Johnson, *Joint Air Operations: Pursuit of Unity in Command and Control, 1942–1991* (Annapolis: Naval Institute Press, 1993).

35. Perhaps to belabor the obvious, the same *person* could not have supervised RAF Fighter Command's operations every hour of every day for months on end. So-called "duty controllers" were assigned through a system of deputation.

other words, whereas a British duty-controller possessed the rank *and* legal investiture necessary to command all defensive measures at his disposal *on his own authority*, his counterpart in an American air-defense organization usually did not. While the area's air-defense commander might also assume the controller's chair as a matter of course, his primary responsibility was understood to lie primarily in *negotiating the parameters* for the system's operation between the interested parties.

In February 1940, the War Department tepidly acknowledged the need to accelerate these negotiations by establishing the Air Defense Command (ADC), though only as a planning activity of the Air Corps, with billets alloted for only five officers, who occupied a crowded office in the base headquarters building at Mitchel Field. As the contingent grew, they were eventually moved into a wooden lean-to built against the side of a hangar. "The discomfort of the personnel who had no choice but to sit at their desks bundled up in winter clothing in an unheated wooden building could more easily be imagined than endured," wrote the command historian, who spared few words in lambasting the hardscrabble conditions imposed on the small organization.[36] It had no combat units of its own and none to train—only a few signal companies to operate its radar and communications equipment during the field tests it had been charged with preparing.

In October, the War Department sent the commander of the Air Defense Command, Major General James E. Chaney, together with his executive, Captain Gordon P. Saville, to study the Dowding System in action. Probably no officer in the Air Corps could claim more experience with air defenses than Saville, whose involvement dated back to the Florida exercise in 1935. Problems that Americans only encountered in drills, the British had already confronted under fire, even if their inability to effectively counter the Blitz called at least some of these responses into question.[37] Thus, while Chaney and Saville returned

36. *History of the Air Defense Command, 26 Feb 1940–2 Jun 1941* (Hempstead, NY: I Fighter Command, n.d. [1942?]), AFHRA (0198206), 13. Most references to the "first" Air Defense Command, i.e. the one that existed from 1940 to 1941, invoke the first chapter of this report.

37. For background on Saville, see Schaffel, *The Emerging Shield*, 13–16, 24-29, 35.

from England with a list of 16 immediate recommendations, their observations increased the number of questions that needed answers when ADC began operating its own "test sector" in the northeastern United States, as scheduled, in January 1941.[38]

While the first exercise in August 1940 produced superficially encouraging results, "the main lesson learned," according to its chief signal officer, "was that the previous conceptions of what the Information Center should be, how the information came to the evaluating and intercept officers, and the methods employed to sort out that information and translate it into proper action for handling several raids, needed considerable revision." Or, to put it bluntly, "when a raid condition was imposed...the whole system fell apart."[39] Among the most serious issues uncovered was that as the Information Center expanded from a clearinghouse to a command post, no single official possessed the authority to give orders to all the air-defense units in the field.[40]

"To explain this," again quoting ADC's chief signal officer, "it must be understood that an area defense, particularly a territorial defense system has to function under a detailed plan of operation and that on such matters concerning the various scope of action and responsibility on the part of all agencies this has been previously worked out":

> In other words, this Controller on duty is just the operator of the organization for a particular duty period within the twenty-four hour period. He has at his side liaison officers from anti-aircraft artillery, balloons, air raid precaution agencies, pursuit aviation, radio communications officer, wire communications officer, officers and others whose individual duties during the time they are on duty are also integrated as a part of the operations and Information Center service. The Controller gives his orders to the respective agencies through those liaison channels.[41]

38. Maj. Gen. James E. Chaney, Commanding General, Air Defense Command, to Assistant Chief of Staff, G-2, War Department, "subj: Observations on a Trip to England," February 12, 1941, exhibit 30 in *History of ADC, 1940–1941*, AFHRA, 9, 41–45.

39. Interview, Lt. Col. Paul S. Edwards, Signal Corps, by Lt. Col. W. W. Irving, Coast Artillery Corps, and Maj. Ralph Snavely, Air Corps, Mitchell Field, New York, January 22, 1941, exhibit 5 in Report of C&GSS observers on Air Defense Command Test Exercise, Jan 21–23, 1941, Lt. Col. W. W. Irving, Coast Artillery Corps, to Commandant, Command and General Staff School, January 29, 1941, OCLC (822028802), 3; cf. *History of ADC, 1940–1941*, AFHRA, 219–261.

40. The British had actually begun to decentralize the functions performed at Fighter Command headquarters, but for reasons having to do with efficiency, rather than bureaucratic authority.

41. Edwards interview, ADC Test Exercise Report, OCLC (822028802), 6.

Recalling the chivalrous interceptor pilot from 1935, the legal-philosophical foundation for air-defense command rested on a mutual agreement between representative agencies concerning the system's general mode of operation. Delegation freed the controller to assign tracks without becoming overwhelmed by the task of directing interception, gunfire, and other defensive measures, but it also depended critically on officers willing to cooperate beyond the limits of their institutional chains of command.

The ADC test sector ran at full-scale for only three days, however, and while it did produce badly needed data on plotting, telling, and filtering performance, as well as equipment, training, and personnel requirements, given the artificial nature of the exercise, the necessary spirit of cooperativeness could be taken for granted.[42] The effectiveness of high-level command relationships thus remained largely untested, a fact apparently not lost on the staff that convened a group of 60 students, including Kenneth Bergquist, for the "Air Defense Orientation and Indoctrination Course" at Mitchel Field in March of 1941. In his introductory address, Captain Saville emphasized the importance of unifying "operational control" over all air-defense measures within the operating area, a statement lifted from the official report of his trip overseas with General Chaney. Still, he implicitly acknowledged that such unity would be difficult to achieve in the field.[43]

Meanwhile, ADC officers introduced attendees to the latest tactical and administrative procedures observed in Great Britain and implemented in the Northeastern Test Sector. But with little operational experience even among the instructors, the March School proceeded less like a training course than a mutual lesson in collaborative problem-solving. When Bergquist and others were asked to prepare their own five-step "Air Defense Estimate and Plan," adapted to the geography of their areas and keyed to the resources potentially available to them, students and teachers alike puzzled over how to approach the astonishing

42. While massaging the criticism, *History of ADC, 1940–1941,* AFHRA, 262-314 recorded the plans and key findings of the test-sector exercise.

43. The lecture is summarized in *History of ADC, 1940–1941,* AFHRA, 206–209. It was later revised and formally promulgated as *Air Defense* (see below).

variety of technical, personal, and organizational contingencies at work throughout their respective jurisdictions. After the school concluded in April, its graduates transferred rapidly to assignments in the nation's outlying territories: Alaska, Hawaii, the Philippines, and the Panama Canal Zone, where command staffs furthermore requested copies of ADC's instruction material, which established for them the first unofficial doctrine for air-defense organization and tactics.[44]

Despite an ambitious start, the War Department declared the planning mission of the Air Defense Command complete in June 1941, and deactivated its headquarters immediately thereafter. Armed with only a few weeks of informal training and wanting for a definite place in the institutional structure, the first American officers who can reasonably be identified as air defense "professionals" could rely on little more than the personal support of their superior officers in order to accomplish the duties in which they had been instructed.

3 The air defense of the Hawaiian Islands

It is doubtful that even whole squadrons of American pilots rising to meet Japanese forces in the skies could have blunted the force of the attack on Pearl Harbor.[45] Once Admiral Chūichi Nagumo's fleet successfully evaded the United States Navy *en route* to its launching point, only a spectacular operational failure, such as a serious blunder of aerial navigation, might have plausibly altered the outcome, the actual military effect of which seems far

44. *History of ADC, 1940–1941*, AFHRA, 195–213.

45. Of course, exercises in counterfactuality are a common feature of military history, not all of which can be dismissed as the product of its high proportion of popular and enthusiast publications. Having been stigmatized by the mainstream of academic history, military history primarily serves the needs of professional military education, where normative assessments fulfill an important pedagogical function. Cf. Jeremy Black, *Rethinking Military History* (London: Routledge, 2004), 26–65; Michael Howard, "Military History and the History of War," in *The Past as Prologue: The Importance of History to the Military Profession*, ed. Williamson Murray and Richard Hart Sinnreich (Cambridge: Cambridge University Press, 2006), 12–20. Thus, the fruitfulness of debating the possibility of mitigating, or even averting, the attack on Pearl Harbor remains dubious, but their centrality to the discourse is difficult to ignore. Alan D. Zimm, *Attack on Pearl Harbor: Strategy, Combat, Myths, Deceptions* (Philadelphia: Casemate, 2011), 267–288, for instance, reaches a more sanguine conclusion about the American defensive capabilities by employing standard wargaming techniques.

less significant now than it did at the time.[46] Nevertheless, by failing to consider such possibilities, the many subsequent investigations helped unbridle America's increasingly absolutist mentality with respect to surprise attack—an expedience more political than military. Official inquiries tended to lead witnesses toward an uncomplicated narrative that concentrated blame on the supreme military authorities in the Hawaiian Islands: Lieutenant General Walter C. Short, commander of the Hawaiian Department, and Admiral Husband E. Kimmel, commander-in-chief of the US Pacific Fleet.[47]

Although the testimonies did reveal a systemic neglect of air defenses—to say nothing of intelligence gathering, handling, and a myriad of other organizational deficiencies—the questioning generally presumed that the attack constituted a *disaster* that might have otherwise been *prevented*.[48] A fact unknown at the time was that the Japanese plan included a *third* wave targeting the harbor's infrastructure—facilities which, left nearly unscathed, allowed the Navy to rebuild and resupply the Pacific Fleet with almost inconceivable rapidity—but that Admiral Nagumo had decided to withhold it because the second wave sustained losses heavier than the first. While the greatest damage was inflicted by uncoordinated antiaircraft fire rather any coherent response, Japanese commanders did not know that Hawaii's air-defenses were not yet fully organized. Fearing greater attrition yet, Nagumo elected to conserve his remaining aircraft for a potential counter-attack from the Pacific

46. Still, the military significance of the Japanese raid remains largely overstated in America's cultural-historical memory, which tends to take it for granted. See, for instance, John Mueller, "Pearl Harbor: Military Inconvenience, Political Disaster," *International Security* 16, no. 3 (Winter 1991–1992): 172–203, doi:10.2307/2539091; also Mark Parillo, "The United States in the Pacific," in *Why Air Forces Fail*, ed. Robert Higham and Stephen J. Harris (Lexington: University Press of Kentucky, 2006), 287–313, especially the bibliographic essay, for an historiographical review.

47. Cf. Kenneth Kitts, "The Politics of Infamy: The Roberts Commission and Pearl Harbor," in *Presidential Commissions and National Security: The Politics of Damage Control* (Boulder: Lynne Rienner, 2006), 17–46. Also see the following note on the cultural history of the attack.

48. In addition to Rosenberg, *A Date Which Will Live*, Walter Hixson, ed., *Pearl Harbor in History and Memory*, vol. 4 of *The American Experience in World War II* (New York: Routledge, 2003) collects important reflections and historiographical commentary on the attack itself and its enduring political and cultural significance. For an historical perspective with even greater relevance to the present, see John W. Dower, *Cultures of War: Pearl Harbor, Hiroshima, 9–11, Iraq* (New York: Norton, 2010).

Fleet, whose carrier groups had still not been located.[49]

As the following account illustrates, Hawaii's air defenses had been organized well enough to *see* the attack coming, but not well enough to *perceive* it as a threat, let alone respond. On December 7, only the Signal Corps component—the Aircraft Warning Service—had entered even a tentative state of operation. The Army and Navy elements it was supposed to *warn*, however, had thus far participated in air-defense preparations to a limited extent, and then only at the insistence of officers with few legal powers of their own. Without unilateral command authority, as in the British model, coordinating measures of organizational control would depend on the enthusiasm of their superiors.

The Aircraft Warning Service: Control through coordination

Upon returning from the March School, Major Bergquist found little of this enthusiasm forthcoming from the military administration in Honolulu. "I got back there in April and was placed on approximately two weeks special duty to write up a report on what should be done in Hawaii," he testified in 1944. "I did that and submitted it, and I have never seen it since."[50] Thus the task devolved on a few mid-ranking officers, including Major Bergquist, to effect the necessary coordination between the Signal Corps, which operated the search radars, and various other Army, Navy, and civilian concerns scattered throughout the islands.[51]

Working informally, the air-defense group had to appeal to superiors who could rarely commit attention or resources to an activity they neither appreciated nor understood. In

49. Once again, Zimm, *Attack on Pearl Harbor*, 301–322 hypothesizes on alternative courses of actions, but more significantly, narrates the evolution of the "re-attack controversy."

50. Bergquist testimony, August 18, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 627.

51. In addition to Bergquist, the principals included Cmdr. William E. G. Taylor, the naval liaison officer; Col. Lorry N. Tindal, the bomber liaison officer; and Capt. Wilfred H. Tetley, commander of the signal company. Together they participated in a semi-official air-defense committee that issued period recommendations, which appeared to have little influence on the Hawaiian Department or the Pacific Fleet. With the exception of Tetley, their testimonies were also reprinted in the proceedings of the congressional investigation.

his own words, Bergquist's mostly nominal role entailed:

> getting the proper interest by the various agencies that had to cooperate with us on setting up and making this go; such as furnishing liaison officers, getting them to agree to putting operational control in our hands, in the hands of the Interceptor Command, in the person of the controller to operate all the various agencies involved, such as the antiaircraft not only of the Army but of the Navy in Pearl Harbor, and controlling all the radio stations, commercial radio stations, controlling the movements of all aircraft; not so much to the exact telling of them what to do—for instance, the bombers—but to insure that they abide by the principles that we operated under, in that we would know at all times where they were so that we could filter out any plots that we received.[52]

After months of delay, the Signal Corps eventually constructed the small Information Center where Bergquist, in addition to performing his regular duty at Wheeler Field, attempted to train a team of plotters, controllers, and liaison officers. Unfortunately, the Army and the Navy curtailed his initiative by assigning only part-time personnel, and too few of them even then. "My instructions…were verbal to these officers: that they were to go down there during the times I specified, acquaint themselves with the whole setup as far as they possibly could, and if anything went wrong they were to notify me."[53]

Beneath the frustration lay a basic misapprehension about who was supposed to be in charge. Although the Signal Corps did install five SCR-270 search radars on Oahu over the summer, officially, they belonged the the War Department's Aircraft Warning Service, or AWS, which, much as the named suggested, issued *warnings* rather than commands.[54] Lacking the authority to direct air, naval, or artillery units, or even regular means to communicate with them, it could only report observations to the local Information Center. "What the Aircraft Warning Service was to do was to be plotted on a large board and a group of

52. Bergquist testimony, August 18, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 619.

53. Bergquist testimony, December 24, 1941, in Pearl Harbor Committee, *Proceedings of the Roberts Commission*, pt. 22, 227.

54. See Craven and Cate, *Men and Planes*, 78–112; Conn, Engelman, and Fairchild, *Guarding the United States and Its Outposts*, 54–64 on the national Aircraft Warning Service. Dulany Terrett, *The Signal Corps: The Emergency, to December 1941*, The United States Army in World War II: The Technical Services, CMH Pub 10-16-1 (1956; repr., Washington: US Army Center of Military History, 1994), 301–305 digests the congressional testimony concerning the radar situation before the attack. War Department, FM 11-25, Signal Corps Field Manual, *Aircraft Warning Service* (Washington, GPO: August 3, 1942), OCLC (744464401), 1–29 defined the formal arrangement between the Signal Corps and the other agencies concerned.

decision-makers from the various branches of the service would look at it, and they decided what kind of a situation had occurred," remembered Wilfred Tetley, the former commander of the signal company, and a fellow graduate of the March School.[55]

Without any full-time personnel, however, the Hawaiian Interceptor Command was an organization only on paper. Rather than specially assign blame, however, Bergquist later explained the problem more diplomatically as "a lack of people understanding the influence of airpower and the requirements for air defense."[56] These requirements were unique, and their apprehension so rare, because they cut across the functional boundaries that defined conventional military practice: intelligence versus operations, artillery versus aviation, operations versus support, and so on. Air defense, on the other hand, was a new and complex function, for which a dedicated organization did not exist.

To wit, the Chief Signal Officer refused to turn the radars over to the AWS and insisted on operating them only from 4:00 to 7:00 in the morning, thereby limiting the effective training time to just three hours per day. Breakdowns and equipment shortages, especially with the gas generators, reduced it further still. Most of the sites were extremely remote; by December, Bergquist had yet to convince the Hawaiian Department to provide fixed power and communications or secured the approval of the National Park Service necessary to begin permanent construction. The island's high peaks did provide excellent positions from which to surveil the open ocean, but superior coverage created an incidental problem: a larger area to monitor, especially since an enemy might approach from any direction.

Oahu's rich topography, moreover, seriously challenged untrained crews, who had to teach themselves to read the complex radio properties of the terrain. "It was not easy to run the scope," recalled Tetley, "because the average person would go in and look at it and say, 'My god, what's this?' ":

Echoes everywhere, and you have to know how to pick out from all this "grass," as they

55. Interview, Wilfred Tetley, with Steven Haller, Honolulu, HI, December 8, 1991, transcript, National Park Service, Washington, DC, URL: http://www.nps.gov/valr/learn/historyculture/upload/WilfredTetley.pdf, 3.

56. Bergquist interview, October 1965, AFHRA, 8.

> called it, what was a target…Each site was different. You had to learn the site. First of all, they have to learn to take signals out of the grass. Then you have to learn how to take signals out of the grass at a particular site, because the interference patterns at each site were different. So it took a while to break in an operator, and you didn't like to switch operators from site to site unless you really had to do it.[57]

The large military presence on the islands further ensured an airspace already congested with aircraft belonging to both the Army and the Navy, which would have required strong cross-organizational relationships in order to filter and identify consistently.

Altogether, the air-defense network was tested only once during a practice drill in November 1941, which Tetley described in detail:

> We have an environment with radar sets in it…and those radar sets, they know everything that's in the air space—they don't know who they belong to, but they know they're there. Our Achilles heel was the fact that we could not identify those aircraft. We could only see there were objects in the airspace and plot them on the board.
>
> Then there was a very large liaison section that worked with the bomber people, the Navy, Coast Guard—everybody who had aircraft flying in the area—and they would say, "ah, that's my flight," or, "that's my flight." So then we've got this one over here, and nobody's owned it. What are we going to do about it? Well, he would be an intruder, so we had to find out whether or not he was a friendly intruder or not.
>
> So the action taken would be to go out and take a look at it. Since the senior controller [i.e. Major Bergquist] was from the 14th Pursuit Wing, he would pass it down to his pursuit officer and tell the pursuit officer to investigate that particular flight.[58]

The exercise successfully intercepted a simulated air-raid, launched from a carrier 80 miles out to sea, less than four weeks before the attack.[59]

Two weeks later, Bergquist and his colleagues reported that a preliminary air-defense, though still wanting badly for equipment and training, could transition to 24-hour operation as soon as it received sufficient staff. Presuming full cooperation, they estimated the shift would take place no later than December 8. Their recommendation failed to move higher authorities, who offered no response before the attack. Once again, Bergquist later supposed that "the main reason for lack of cooperation from mostly the higher headquarters was

57. Tetley interview, National Park Service, 1991, 7 (lightly edited from the rough transcript).

58. Tetley interview, National Park Service, 1991, 4 (edited for clarity).

59. Arakaki and Kuborn, *7 December 1941*, 11–16.

a lack of education as to what air defense was and what it could do and what the setup could do."[60] When he reached Fort Shafter on the morning of December 7, he found all the components functioning individually, though certainly not collectively.

AWS Station Opana: Early morning, early warning

It was not until some hours after arriving at Fort Shafter on the morning of the attack that Major Bergquist learned the SCR-270 stationed at Opana Point, on Oahu's northern tip, had actually detected the first wave approaching from the north. "We were going to close down," Joseph Lockard recalled, "but we figured that we might as well play around, because the truck had not come in yet to take us back for chow."[61] At 7:02 AM, the two young privates on began puzzling over the outrageously strong echo showing at a distance of 137 miles.

Lockard's companion, George Elliot, had been looking forward to his first session at the scope. "Private Lockard looked at me and laughed and told me I was crazy for wanting to send in that reading," said Elliott, who spent the next fifteen minutes plotting the signal while Lockard rechecked the equipment.[62] The track evolved convincingly like an actual formation. Since the Opana site was fortunate enough to have a landline, Private Elliot tried calling the Information Center, where Lieutenant Kermit Tyler kept watch alone except for the switchboard operator. At first, the operator indicated that no one was available to take the call. The plotting team had retired when the other radars shut down at 7:00, leaving Tyler, a pilot from the 78th Pursuit Squadron, with nothing to do but wait for the shift to change. Lockard called back a few minutes later and persuaded the operator, whom he knew personally, to get the officer on the phone anyway.

60. Bergquist testimony, August 18, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 619.

61. Testimony of 1st Lt. Joseph L. Lockard, August 17, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 531.

62. Statement of Sgt. George E. Elliott, August 17, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 521.

Bergquist had not yet found time to train Lieutenant Tyler in his anticipated role as a pursuit officer. Without any of the liaisons around, he did his best to make his own sense of the call from Opana Point. "I had a friend who was a bomber pilot," he later testified:

> He told me any time that they play this Hawaiian music all night, it is a very good indication that our B-17s are coming over from the mainland, because they use it for homing; and when I reported for duty at 4 o'clock in the morning, I listened to this Hawaiian music all the way into town, and so I figured then that we had a flight of B-17s coming in; so that came to my mind as soon as I got this call from [Private Elliott].[63]

Tyler inferred as much correctly: twelve B-17s had indeed flown overnight from San Francisco, arriving in the thick of the first wave, which, coincidentally, had followed the broadcast to Honolulu as well.[64] He also knew that the USS *Enterprise* was expected back in port soon (the very same day, as it so happened) and supposed the flight could have been the carrier wing returning to its shore base on Ford Island. "I thought that was just about an equal probability of the two."

Despite Private Lockard's obvious excitement at the strength of the signal, Tyler, despite his limited experience, told him not to bother with it. "I had previously only once seen the board in operation":

> There was no activity on the board, as near as I remember, until, I suppose, 6:10 or thereabouts. At that time a number of plots or indications, some arrows, appeared on the board to show that there were aircraft flying around the islands...I had seen just the same setup on the board, saw these plots all over the place, and I had no reason to suspect, so far as I am concerned, that there was anything irregular going on.[65]

Even if Tyler had been more suspicious, he had only his verbal instruction to call Major Bergquist in case of trouble, whom he surmised—again, correctly—was likely asleep in bed.

63. Testimony of Lt. Col. Kermit A. Tyler, August 17, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 569.

64. One aircraft crashed attempting to land under fire, and another was destroyed on the ground, killing one. The remainder sustained only superficial damage, though one was forced down on a golf course. Arakaki and Kuborn, *7 December 1941*, 72–76

65. Testimony of Lt. Kermit A. Tyler, December 24, 1941, in Pearl Harbor Committee, *Proceedings of the Roberts Commission*, pt. 22, 220–221.

At Opana Point, Elliot and Lockard shut down the generator and returned to camp as soon as the truck arrived. "I was due at 8 o'clock to be relieved," Tyler said, "and there being nothing going on, I just stepped outside of the door":

> I got a breath of fresh air, and I actually saw the planes coming down on Pearl Harbor; but even then, I thought they were Navy planes; and I saw antiaircraft shooting, which I thought was practicing antiaircraft.[66]

That morning, the whole island awakened to what many quite reasonably believed to be some kind of military exercise. The military presence on Oahu so dominated the experience of everyday living that many witnesses recounted an epiphany as sudden and disorienting as Tyler's or Bergquist's, even after observing for the first blasts of warheads and gunfire.[67] December 7 was the morning that everyone happened to be wrong.[68]

4 Conclusion: Models for command-and-control

Air defense distinguished itself as the first flying activity to be controlled predominantly from the ground.[69] Having literally detached from the surface of the earth, perhaps nothing

66. Tyler testimony, August 17, 1944, in Pearl Harbor Committee, *Proceedings of the Army Pearl Harbor Board*, pt. 27, 569.

67. Such anecdotes are something of a trope in popular accounts, as in Walter Lord, *Day of Infamy* (1957; repr., New York: Henry Holt, 2001) or Gordon W. Prange, Donald M. Goldstein, and Katherine V. Dillon, *At Dawn We Slept: The Untold Story of Pearl Harbor* (1981; repr., New York: Penguin, 2001), which are the canonical military histories of the operation and its aftermath.

68. In her Bancroft prize-winning study, Roberta Wohlstetter wrote, "if the study of Pearl Harbor has anything to offer the future, it is this: We have to accept the fact of uncertainty and live with it. No magic, in code or otherwise, will provide certainty. Our plans must work without it." Wohlstetter, *Pearl Harbor*, 401. Ultimately, her conclusion about the infeasibility of separating an unambiguous "signal" from the inevitable "noise" said as much about the nuclear confrontation at the time of the book's publication as it did about 1941.

69. The concurrent development of civilian and military "airways," e.g. air navigation, air–ground communications, and air-traffic control, might also lay claim to this distinction. However, while government agencies had taken measures to establish a regulated system of air movement within the United States by 1945, it depended largely on the voluntary participation of private pilots and commercial air-carriers, and had not yet developed the methods, and certainly did not have access to the kind of equipment, as military air-defense. For instance, radar systems were not commonly used in civilian air-operations until the late 1950s, and formal air-traffic control procedures were often observed only in the immediate vicinities of major airports. See Nick A. Komons, *Bonfires to Beacons: Federal Civil Aviation Policy Under the Air Commerce Act, 1926–1938* (Washington: Federal Aviation Administration, 1978) and John R. M. Wilson, *Turbulence Aloft: The Civil Aeronautics Administration Amid Wars and Rumors of Wars, 1938–1953* (Washington: Federal Aviation Administration, 1979); or, for an account concerned primarily with policy, Alan P. Dobson, *FDR and Civil Aviation: Flying Strong, Flying Free*

of human artifice can appear so unencumbered by merely terrestrial exertions as an aircraft in flight. Nevertheless, the accumulation of rapid and reliable ground-based techniques for observation, communication, and navigation eventually convinced pilots that superior altitude alone did not imply superior knowledge of their surroundings. The development of a "ground environment" for directing and monitoring the movements of aircraft profoundly changed the nature of the aircraft as well, steering its actions closer to the goals of the organization, increasingly from moment to moment. As the war continued, newer aircraft bristled with increasingly conspicuous whip, loop, and wire antennas that could tie their motion to the ground almost as firmly as to the cockpit.[70] Before the surface-to-air missile, the ground-controlled interceptor performed essentially the same task, though, for better and worse, with more human mediation.

The Air Force's postwar anxieties about "systems" and "integration" with respect to its ground environment were thus firmly fixed as early as 1941, though they hinged on a subtle and unfamiliar notion of "control." The controller in an Information Center did not issue orders by direct or even delegated authority; rather, the instructions carried force within the regular parameters of an operational whole. The commander's responsibility was to configure the "system" by ensuring cooperation between cross-organizational stakeholders—in essence, to establish the preconditions for *control*—not to direct operations from one moment to the next. In other words, the impersonal workings of the system *itself* had to become authoritative, or else it would be unable to handle the resources necessary to coordinate an effective response, especially under duress.

(New York: Palgrave Macmillan, 2011). Less has been written about the history of federal regulation of air traffic, and even so regarding the military's role in the evolution of the modern air-transport system, though Thomas S. Snyder, ed., *The Air Force Communications Command: Providing the Reins of Command, 1938–1981—An Illustrated History* (Scott AFB, IL: Office of History, Air Force Communications Command, 1981), 1–78 and Wesley Frank Craven and James Lea Cate, eds., *Services Around the World*, vol. 7 of *The Army Air Forces in World War II* (1958; repr., Washington: Office of Air Force History, 1983), 339–362 provide at least a cursory glimpse.

70. A simple catalogue of major airborne radio-electronic components, printed in five parts during 1945–1946, exceeded 300 pages, despite excluding equipment specific to the Navy or else built into the aircraft. United States, Army Air Forces, Air Technical Services Command, *Graphic Survey of Radio and Radar Equipment Used by the Army Air Forces*, 5 vols. (Wright Field, OH: Air Technical Services Command, 1945), Internet Archive, https://archive.org/details/GraphicSurveyOfRadioAndRadarEquipmentUsedByTheArmyAirForces .

Although The British had pioneered the development of organizational equipment and procedures that could perform this coordination with relative rapidity, the difficulty of the underlying problem demanded as much from people willing to think beyond their institutional surroundings as it did from formalization and routine. In the American context, this outcome depended on mutually reinforcing interactions between multiple technologies and the organizations that administered them: pursuit aviation in the Air Corps, antiaircraft artillery in the Army and the Navy; radio, radar observation, and wire-line communication in the Signal Corps; civil-defense measures such as air-raid warnings, shelters, and blackout and radio-broadcast restrictions; as well as the all-important identification of flight paths belonging to civilian and friendly military aircraft.[71] Indeed, "air defense," as practiced at the time, should be more properly understood as coordination between two or more of these and other elements, rather than a unitary function in and of itself.

Six months after Pearl Harbor, for instance, the War Department reassigned Kenneth Bergquist to New Caledonia to set up another air-defense net like the one he eventually brought together in Hawaii.[72] "At the time the Japs were on the move and we sort of expected them in there any day," he recalled the stakes of the assignment. "There were some real difficult decisions to make down there," he remarked, faulting once again the "lack of people understanding...the requirements for air defense." In particular:

I had a great difficulty with the Army staff that was running the place down there.

71. According to US military doctrine at the time, certain civil-defense measures, such as blackout and commercial-broadcasting restrictions, counted as "passive" forms of air defense, since they had the potential to thwart the objectives of enemy aircraft even without attacking them. However, despite the wealth of literature on civil defense during the Cold War, relatively little has been written about its World War II genesis—excepting, of course, the notable case of Japanese-American internment, which was also implemented as a "civil defense" measure. On the national administration of civil defense, see the relevant passages in Conn, Engelman, and Fairchild, *Guarding the United States and Its Outposts*.

72. The archipelago of New Caledonia was (and still is) a French possession on the eastern edge of the Coral Sea, whose main island lies roughly on the midpoint between Queensland and Fiji, about 800 miles from each. It was one of several strategic positions the Japanese military intended to seize in order to break the air and shipping lanes between Australasia and the United States. Although the Allies prepared to defend against the invasion, it never came to pass, as the Japanese advance stalled in the Solomon Islands, most notably Guadalcanal, during 1942. John Miller Jr., *Guadalcanal: The First Offensive*, The United States Army in World War II: The War in the Pacific, CMH Pub 5-3 (1949; repr., Washington: Center of Military History, 1995), chap. 1.

> Things like one man who...when I tried to put in some requisitions for various types of radio equipment we needed, he made the rather classic remark: "Well now, young man, I just came out of the Pentagon and I know how things will work, and those people in the Pentagon know our problem and they will send us what we need. We don't have to send in this requisition of yours." I thought that was one of the stupidest attitudes I had ever seen.[73]

Perhaps unbecoming of his rank as a field-grade officer, Bergquist possessed the implacable mentality of a shirt-sleeve troubleshooter. "The way I got my radio equipment was to...send a little personal note up to a very good friend of mine who was still in the Army, who had been working on the air defense system with me up in Hawaii, and told him to scrounge, steal, or anything, what he could find in the way of the following radio equipment and get it on the next airplane coming down here—which he did. That was the only way I got my radio equipment."

Decades would pass before the armed forces formalized a professional identity for officers with responsibilities such as Kenneth Bergquist's. In anachronistic terms, these were the first specialists in operating command-and-control systems. However, the problems they encountered and their strategies for resolving them remained so specific to each "system," and their practitioners so isolated from one another, that the broad similarities did not become evident until the late 1950s. Then, it was predominately an aspect of technology—namely, the application of the digital electronic computer—that provided the unifying logic, rather than an aspect of organization, from which the ultimate purpose of the mechanism it had been extracted. Bergquist himself would have a hand to play in this later saga as well, though, once again, an unlucky one.

What did emerge immediately after the war was a tendency to cast people as *liabilities*: remedial sources of error and delay (as well they can be, compared to certain types of machinery), while at the same time, diminishing the human ability to regulate the social instabilities in the systems they operated. In this, career officers expressed an eagerness equal to the scientists, pundits, and politicians who hurried the promotion of automatic

73. Bergquist interview, October 1965, AFHRA, 6–7.

control, which promised improved performance by uncontroversially displacing women and enlisted men of low status. The nuclear threat introduced the possibility of total annihilation, and thus, a demand for absolute information and precision. While those experienced in air-defense operations remained skeptical of the more radical claims about the revolutionary potential of new technologies, with America still anguished over its humiliating "day of infamy," no one would be caught responsible for enabling a vastly more destructive "atomic Pearl Harbor."[74]

74. The expression "atomic Pearl Harbor" (later modified to "nuclear Pearl Harbor") appeared to enter the public discourse almost immediately after the atomic bombings of Japan. The connection between the attack on Pearl Harbor and the destruction of Hiroshima and Nagasaki appears to have been so obvious to the American mind that no single source can be credited for inventing the term, though its early invocations by the esteemed science writer, Hanson W. Baldwin, as in "Atom's Role in War," *New York Times*, October 23, 1945, ProQuest (107390952), may have encouraged its use.

Chapter 2

Atomic Pearl Harbor

Conceiving a Continental Air-Defense System

> Since 1933 much has been accomplished in establishing a system of military air defense and in integrating into that system the defense capabilities of the entire nation. The progress had not been smooth, being impeded by interservice rivalries and misunderstandings, by national complacency, by constitutional barriers and historical traditions making for lack of inter-agency rapport, and by the maladjustments caused by a second World War and its bewildering aftermath.[1]
>
> Historical Services, Headquarters, Air Defense Command, 1952

If the United States ever did have its "atomic Pearl Harbor," it happened on March 27, 1948. On that day, General Carl Spaatz, Chief of Staff of the United States Air Force, issued an urgent and unexpected order to General George E. Stratemeyer, Commanding General of the Air Defense Command, instructing him to immediately establish an emergency air-defense network surrounding the Hanford Works in central Washington state.[2] The

1. Thomas A. Sturm et al., *The Air Defense of the United States: A Study of the Work of the Air Defense Command and Its Predecessors Through June 1951* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, February 1952), 1, OCLC (818296057).

2. The following events were recounted in three interrelated manuscripts prepared by Air Defense Command historians around the same time: *The Air Defense of AEC Installations, Part 1: 1946–1948* (Colorado Springs: Directorate of Historical Services, Headquarters, Air Defense Command, n.d. [1952?]), AFHRA (0500631), 5–8, apparently an early draft of *The Air Defense of Atomic Energy Installations, March 1946–December 1952*, vol. 1, Narrative (Colorado Springs: Directorate of Historical Services, Headquarters, Air Defense Command, 1953), AFHRA (0500632), 1–8, which was further reworked into Sturm et al., *The Air Defense of the United States*, 61–63. Historians working for Air Force headquarters later incorporated ADC's files with some of their own to render

primary objective, as communicated by Spaatz, was to protect the nuclear-weapons plant, as well as regional power-generation facilities along the Spokane and Columbia rivers, from a potential sneak-attack by Soviet bombers. Stratemeyer quickly relayed more specific instructions to the headquarters of the Fourth Air Force at Hamilton Field on the north shore of San Francisco Bay.[3] The skies above North America have been subjected to continuous electronic surveillance by agents of the state ever since.

The defense of Hanford itself, however, was an operational embarrassment. At the time of the March order, the entirety of the "warning system" for the western United States consisted of just two AN/CPS-5 radar stations—one north of Seattle and the other south of San Francisco—both activated only for occasional training purposes. While the Washington site shifted immediately into 24-hour operation, four war-surplus AN/TPS-1 mobile radars had to be uncrated from storage at a warehouse in Sacramento and shipped expeditiously to temporary emplacements in Spokane, Walla Walla, the town of Seaside in Oregon, and the mouth of Puget Sound.

Under Stratemeyer's discretion, the Fourth Air Force established a provisional unit called the Northwest Air Defense Wing to combine tactical direction for the 505th Aircraft Control and Warning (AC&W) Group, which operated the ground electronics, with the two fighter groups detailed by USAF headquarters: the 325th, flying P-61 night-fighters out of Hamilton Field; and the 27th, a P-51 outfit loaned from a Strategic Air Command base in Nebraska. An improvised command center came together abruptly at McChord Field in

a top-level perspective in C. L. Grant, *The Development of Continental Air Defense to 1 September 1954*, USAF Historical Study No. 126 (Maxwell AFB, AL: Historical Studies Division, Air University, October 1954), AFHRA (0467710), 19–22. The treatment in Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* (Washington: Office of Air Force History, 1991), 77–81 largely parallels the latter source, while the brief mention in Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996), 87–88 follows from Schaffel. Since these accounts do not agree in every respect, I have cited the primary source documents appended to the ADC manuscripts when possible. Additional details have also been incorporated from the after-action reports of the units involved, as noted below.

3. TWX, Commanding General, Air Defense Command to Commanding General, Fourth Air Force, March 27, 1948, exhibit 1 in *The Air Defense of Atomic Energy Installations, March 1946–December 1952*, vol. 2, Supporting Documents (Colorado Springs: Directorate of Historical Services, Headquarters, Air Defense Command, 1953), AFHRA (0500633).

Tacoma.[4]

Nevertheless, on April 15, the Air Defense Command had no choice but to admit its defeat to USAF headquarters. To start, the demanding assignment had simply overwhelmed the already limited resources of the 505th AC&W Group. "All personnel ready on hand are tired and overworked," one cable explained. "The portable type equipment now being used also will not stand continuous operation. Sets are frequently out of commission for repairs, and the small portable power units which are the only source of power presently available frequently break down."[5] Securing land and access rights, moreover, delayed occupancy at some of the more remote sites.

Meanwhile, the 325th Fighter Group had only three crews qualified to operate their aircraft's onboard radar, and consequently, never left its base in California.[6] The 27th Fighter Group, on the other hand, was normally assigned to a long-range bomber-escort mission, with pilots completely untrained in ground-controlled interception, though poor weather kept them mostly on the tarmac anyway. When the planes did make it aloft, they chased spurious observations as often as real aircraft, which invariably turned out to be nonmilitary, since Fourth Air Force had no control over civil aviation, or friendlies who had failed to identify themselves properly.[7]

On April 22, Stratemeyer relaxed the 24-hour requirement and allowed the tactical wing to operate radars in rotation, granting the crews more time to rest and repair equipment.[8]

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4. *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 1, Narrative, AFHRA, 1–8.

5. Maj. Gen. Howard M. Turner, Vice Commander, Air Defense Command to Gen. Carl A. Spaatz, Chief of Staff, United States Air Force, "Status of Continental Air Defense," April 15, 1948, exhibit 16 in *Air Defense of AEC Installations, 1946–1948*, AFHRA, 2–3.

6. TWX, Headquarters, Fourth Air Force to Headquarters, Air Defense Command, April 8, 1948, exhibit 9 in *Air Defense of AEC Installations, 1946–1948*, AFHRA.

7. Headquarters, 505th Aircraft Control & Warning Group, "Analysis of Maneuvers Conducted in the Northwest Defense Area," for the commanding officer, Maj. J. O. Ducheanne, Adjutant, May 22, 1948, appendix 3 in Gerald S. Chapman, "History of 505th Aircraft Control & Warning Group, 28 March–30 June 1948," undated manuscript [1948?], AFHRA (0097704).

8. TWX, Commanding General, Air Defense Command to Commanding General, Fourth Air Force, April 22, 1948, exhibit 2 in *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 2, Supporting Documents, AFHRA.

Air Force headquarters likewise acknowledged the obvious and called off the emergency shortly thereafter. In Washington, the dismal episode was politically humiliating, especially since on March 14, as part of the "Key West Agreement," the Joint Chiefs of Staff had, after long insistence, finally designated the Air Force as the agent primarily responsible for defending the United States and its territorial possessions from enemy aircraft.[9]

The cause for the alarm is something of a puzzle. While USAF officials possessed few illusions about their miserable defenses, the gravity of the threat was, to state it generously, conjectural.[10] In February, the Air Force Director of Intelligence had approved an estimate stating that "it is considered unlikely that in the immediate future the USSR will resort deliberately to overt military aggression which would involve war with the Unites States." Moreover, "against the Continental United States, the USSR has limited capabilities to reach any industrial concentration in the United States with one-way bombing attacks, but not in sufficient force to be seriously damaging."[11] The apprehension must have instead emanated personally from the Air Force's senior leadership, who experienced recent world events with increasing levels of anxiety. Spaatz may have been further spooked by informal reports from an overseas commander about unusual flight tracks around Japan.[12] Another order,

9. The final text of the agreement, dated April 21, 1948, appears in Richard I. Wolf, ed., *The United States Air Force: Basic Documents on Roles and Missions* (Washington: Office of Air Force History, 1987), 151–166; President Truman issued an executive order the same day, superseding his initial order implementing the National Security Act with the Key West accord. There are numerous accounts of the conference and the context of national-security politics at the time, but Steven L. Rearden, *The Formative Years, 1947–1950*, vol. 1 of *History of the Office of the Secretary of Defense*, ed. Alfred L. Goldberg (Washington: Historical Office, Office of the Secretary of Defense, 1984), chap. 14 provides an adequate summary.

10. In 1953, ADC's historical office conceded that despite some investigation, it could not explain precisely why USAF headquarters had issued the emergency orders of March 1948. *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 1, Narrative, AFHRA, 1. Speculation concerned on the general deterioration in US–Soviet relations, and specifically, the February coup of Czechoslovakia. Grant, *Development of Continental Air Defense*, AFHRA, 19–20 posits similarly.

11. Report, Joint Intelligence Committee to Joint Strategic Plans Committee, "Estimates of the Intentions and Capabilities of the USSR against the Continental United States and the Approaches Thereto, 1948–1957," enclosure in Joint Secretariat to Joint Intelligence Committee, "Estimate of the Intentions and Capabilities of the USSR against the Continental United States and the Approaches Thereto, 1948–1957," J.I.C. 380/2, February 16, 1948, in Randolph Boehm and Paul Kesaris, eds., *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States* (Washington: University Publications of America, 1980), microfilm, reel 2, 61, 65, OCLC (7108262).

12. Schaffel inferred this from Spaatz's personal correspondence with General Ennis C. Whitehead, the

dated March 26, declared a similar emergency along the Alaskan frontier.

Whatever the reason, General Stratemeyer excoriated Air Force headquarters on April 24. "Adequate defense of the continental United States is not possible even though the total forces, resources, and facilities presently available to the United States Air Force were placed at my disposal," he fumed.[13] In order to prepare for such a crisis, Stratemeyer's staff had submitted four plans in the last two years, none of which received any response from Washington, let alone the funding needed to implement them. Now the entire service faced "accusations of our having cried 'wolf' without any justification," while ADC had to ameliorate a "morale problem resulting from the precipitous movement of personnel from families to bases ill-prepared for habitation, or operations."[14] In the future, the Air Staff would have to "take a firm decision to establish an air defense system in being and to maintain an air defense system in being," or else it should not expect the impossible.[15]

1 Air-defense systems and the meaning of "integration"

Two years prior, on March 12, 1946, General Spaatz had, in the process of reactivating the Air Defense Command for the first time since 1941, tasked it with an "interim mission" to

commander of the Far East Air Forces, in early 1948. Schaffel, *The Emerging Shield*, 78–80. Though hardly conclusive, it provides some insight into the mentality of senior officials at the time. Formally, no such incidents appeared in Alexander L. George, *Case Studies of Actual and Alleged Overflights, 1930–1953*, RM-1349 (Santa Monica: RAND Corporation, August 15, 1955), http://www.rand.org/pubs/research_memoranda/RM1349.html ; however, given the frequency of spurious or unidentifiable tracks, casual suspicions could well have circulated within the intelligence section of a general staff. The Air Force may have also wanted to solidify its political gains at the Key West Conference by implementing as quickly as possible its newly won responsibility to defend North America from enemy aircraft: *Air Defense of AEC Installations, 1946–1948*, AFHRA, 5–8.

13. Lt. Gen. George E. Stratemeyer, Commander, Air Defense Command to Gen. Carl A. Spaatz, Chief of Staff, United States Air Force, "subj: Air Defense of the United States," April 24, 1948, exhibit 15 in *Air Defense of AEC Installations, 1946–1948*, AFHRA.

14. Staff study, "Preparations for Air Defense," April 14, 1948, enclosure 2 in Stratemayer to Spaatz, "Air Defense of the United States," April 24, 1948, exhibit 15 in *Air Defense of AEC Installations, 1946–1948*, AFHRA, 4.

15. Stratemeyer to Spaatz, "Air Defense of the United States," April 24, 1948, exhibit 15 in *Air Defense of AEC Installations, 1946–1948*, AFHRA.

"organize and administer the *integrated air defense system* of the Continental United States."[16] Despite lingering uncertainty regarding the Army Air Forces' legal authority to actually delegate the assignment, General Stratemeyer recapitulated Spaatz's directive to his subordinates on April 26 while further indicating that this "interim mission" could not wait on the machinations of the War Department—less so on Congress's slog through national-security legislation—and so all commanders must presume full responsibility to plan for the "integrated system," however it was to be interpreted.[17]

Considering their wartime experience, it was natural that air-defense officials would adopt the language of "system" to describe their environment and understand its challenges. Beginning around 1945, Air Force planners introduced the apparently redundant idea of an "integrated air-defense system." As the word is commonly used, "system" already implies at least some measure of "integration," though means and components may remain ambiguous. This chapter examines the evolution of that "integrated system," in rhetoric and reality, during the early postwar era, noting that its meanings remained unstable, and mostly unrelated in the emerging practices of "systems engineering" or "systems integration."[18]

Clearly a great deal depended on the contextual meaning of "integrated system"; indeed, its implications swept across the entire spectrum of organizational–technological problems associated with continental air-defense from 1945 to 1960. Scientists, engineers, and military and civilian officials would continually explain their decisions in terms of "integration,"

16. Gen. Carl A. Spaatz, Commanding General, Army Air Forces to Commanding General, Air Defense Command, "Interim Mission," March 12, 1946, exhibit 2 in *Air Defense Command History, March 1946–June 1947* (Mitchel AFB, NY: Historical Branch, Headquarters, Air Defense Command, November 1948), AFHRA (0198207).

17. Lt. Gen. George E. Stratemeyer, Commanding General, Air Defense Command to Commanding Generals, All Air Forces, Air Defense Command, "Mission of the Air Defense Command," June 11, 1946, tab C in United States Air Force, Air Defense Command, "Responsibilities for Air Defense," July 19, 1946, annex #1 to OPD file no. 373.24 (3 May 1946) Sec. 1 (oversize), NARA, RG 341, NM-15 335-A, box 308. The correspondence appended to this report provide numerous insights into the relationship between Air Force headquarters and the Air Defense Command during the period immediately following its formation. However, it would be tedious to continue to cite each one of its many brief dispatches except when referenced directly in the text.

18. Organization is, of course, central to these practices, as evinced especially in the term "systems management." However, as noted elsewhere, the difference being drawn here is between organization as a *means* for engineering technological systems, and organization as a technological system *in its own right*.

offering "system" as a self-evident good, while suppressing the inconvenient consequences for American military politics and administration.

In the context of air defense, integration could refer to the specific interworkings of the network itself: the capabilities of radar and communications equipment; the telling, identification, and display of flight-track information in the operations center; the actions of ground controllers; as well as the responsiveness of "active" defensive measures like interceptors and anti-aircraft artillery. At the same time, an air-defense system on the American continent could not be isolated from the emerging electronic "airways," which included radio-navigation and other instrument-flying aids, radar-assisted air-traffic control, and robust air-to-ground communications for both military and civilian aircraft.[19]

By the end of the 1940s, the Air Force had begun to speak of a ubiquitous electronic "ground environment," within which the air-defense system would perform a role inextricable role, but whose implications nonetheless surpassed the legal prerogative of any single agency.[20] The term encompassed everything from conventional systems-engineering concerns about avoiding duplication and mitigating RF interference to more operational problems such as how to reliably identify unknown flights or disencumber a potential combat area from a swarm of private planes. So "integration," then, might also refer to

19. During the war, the Army Air Forces fought a jurisdictional battle on two fronts. Although Air Corps personnel operated the Army Airways and Communications System (AACS), the Signal Corps retained control over procurement, purchasing, and construction until 1945. Moreover, the communication and air-navigation networks within each theater of operations also remained within the purview of the theater commander. The specific practice of military aviation thus depended highly on the organizational circumstances of the flying area; in general, the AAF was best able to maintain regularity of procedure within the United States and the transoceanic "ferrying" services. Wesley Frank Craven and James Lea Cate, eds., *Services Around the World*, vol. 7 of *The Army Air Forces in World War II* (1958; repr., Washington: Office of Air Force History, 1983), 339–362; George Raynor Thompson et al., *The Signal Corps: The Test, December 1941 to July 1943*, The United States Army in World War II: The Technical Services, CMH Pub 10-17 (1957; repr., Washington: US Army Center of Military History, 1978), 277–296. Greater, though by no means full autonomy only came with the establishment of the United States Air Force, which assumed full administration of the AACS: see the relevant chapters of Thomas S. Snyder, ed., *The Air Force Communications Command: Providing the Reins of Command, 1938–1981—An Illustrated History* (Scott AFB, IL: Office of History, Air Force Communications Command, 1981). Also recall the note from the conclusion of chapter 1 on the development of civilian airways during the same period.

20. Consider, for instance, L. A. DuBridge et al., *Radar and Communications: A Report of the AAF Scientific Advisory Group* (Wright Field, Dayton: Headquarters, Air Materiel Command, 1946), OCLC (18735698). A later chapter will examine another aspect of this report in detail.

the amalgamated effort required to build, maintain, and operate such an environment coherently, whether by inter-organizational coordination or unified command.

As the first section observes, initial talk of an “integrated system” suggested more of an *organizational* system: a unifying structure for exercising the full range of defensive measures necessary to protect the continental United States from air attack. Although the Army Air Forces had created an organization dedicated to continental defense as early as 1946, its ambitions had to be circumscribed within the service’s push for independence and the subsequent resolution of contested roles and missions with the departments of the Army and the Navy. Absent a material base to fight over, organization was the default subject for a different kind of “systems thinking,” one which, at the time, concerned politics as much as it did operations, training, or logistics.

Even within the new Air Force, however, a competing faction advanced its own idea of an “integrated system” motivated more directly by the problem of allocating radar equipment. Officials working in communications and electronics had to weigh the overwhelming demand for supplies of scarce electronic commodities against their potential utility in multiple applications including, but not limited to continental air-defense, such as air-traffic control and tactical air–ground operations. Given the known deficiencies in war-vintage equipment, would it not be more efficient to conceive of a future “integrated system” as a technological whole, emphasizing long-term research and development over immediate deployment?

The second section explores this issue, which was forced in March 1948, when USAF headquarters ordered several crash mobilizations, most notably to protect the Hanford Works. The alarming realization that the units could not sustain their operations provoked a fundamental rethinking of radar procurement policy. The course that eventually earned political and bureaucratic approval in September 1948 most closely resembled one that air-defense officials had favored years earlier. The “integrated system” would not be unfolded all at once, but rather, built incrementally around a small operational “nucleus,” the exercise of which should guide the development of tactics, procedures, and future equipment.

Altogether, the mid-to-late forties were very much a time of stagnation with respect to continental defense. The challenges inherent in operating large area-defense nets had been appreciated since the war, and no foreseeable development in technology or organization seemed likely to ease their expansion to continental scale. As we will see in a later chapter, this includes digital computing, and even the probability—and eventual realization—of the Soviet atomic bomb. Instead, the innovation of the period lies in the concept—borne of rhetoric, but later adapted to practice—of a system in tension between its "evolutionary" and "revolutionary" implications.

2 The second Air Defense Command

The mainland United States never faced a serious threat of attack from the air during World War II. Provisions for its defense continued nonetheless, though after the shuttering of the Air Defense Command in mid-1941, the responsibility devolved to the I and IV Interceptor Commands, which reported to the First and Fourth air forces in New York and San Francisco, respectively. By the end of 1942, the Aircraft Warning Service (AWS), administered by the Department of War, had constructed about 95 coastal radar stations, mostly along the Pacific Coast. More than a million Americans volunteered to help watch the skies at one of the 14,000 posts established by the Ground Observer Corps, a civilian adjunct to the AWS, with additional support from enthusiastic citizen-fliers in the Civil Air Patrol.[21]

21. Considering Americans' general ambivalence to civil defense, the Ground Observer Corps remained a surprisingly popular program, enduring even into the radar-surveillance era of the 1950s. See Denys Volan, "The History of the Ground Observer Corps," (PhD diss., University of Colorado, 1969), ProQuest (6913439), an account written by one long-serving official historian of the Air Defense Command. Likewise, the Civil Air Patrol (CAP) is still active today, having been recognized by Congress as the Air Force's civilian auxiliary in 1947. With elements of a patriotic-youth organization, a home guard, and an active militia, CAP was founded in 1941 to prevent the total grounding of private aircraft during the war. Although several trade-press accounts of CAP's exploits were published immediately following the war, compilations of regulations and training materials, such as *Civil Air Patrol Handbook*, rev. ed. (Dallas: Southern Flight, 1944), provide a clearer view of its organization and functions, which were only loosely supervised by the AAF.

To collect and relay reports from both military and civilian sources, the AWS staffed ten information centers, mostly with volunteer women, in cities from Boston to Miami, and five more between Seattle and San Diego.[22] "The physical setting of the information center matched the drama of its role as a nerve center of the [Aircraft Warning Service]," wrote one official historian:

> On a balcony overlooking the operations board was stationed the controller, the officer who commanded all air defense activities in the wing; he was surrounded by a pursuit officer, a radio officer, a radar officer, an antiaircraft officer, plus liaison officers from the bomber command, the Navy, the Civil Aeronautics Authority, and the civilian air raid organization. In addition, he was assisted by a FCC representative who relayed orders for radio silence and an air officer who was responsible for alerting civilian warning districts. The controller was linked by telephone to his intercept officers—in another room—who stood ready to direct fighters to meet any hostile flights.[23]

None ever came, fortunately, because the system's ineptness was something of an open secret.

In truth, the American continental defense had never been fully organized, and the practical infeasibility of discriminating among the multitudinous tracks produced by the military's own flying activities rendered it virtually useless except for training purposes.[24] After the anxious early months of 1942, the probability of attack appeared so remote that defensive measures remained in place primarily to maintain public confidence, and even then, they were reduced to token status by the middle of 1943. The mission of the interceptor commands became increasingly nominal, essentially a part-time duty to prepare new pilots before shipping them overseas.

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22. Cf. William A. Goss, "Air Defense of the Western Hemisphere," in *Plans and Early Operations, January 1939 to August 1942*, vol. 1 of *The Army Air Forces in World War II*, ed. Wesley Frank Craven and James Lea Cate (1948; repr., Washington: Office of Air Force History, 1983), 271–309; Wesley Frank Craven and James Lea Cate, eds., *Men and Planes*, vol. 6 of *The Army Air Forces in World War II* (1954; repr., Washington: Office of Air Force History, 1983), 96–112; Stetson Conn, Rose C. Engelman, and Byron Fairchild, *Guarding the United States and Its Outposts*, The United States Army in World War II: The Western Hemisphere, CMH Pub 4-2 (1964; repr., Washington: US Army Center of Military History, 2000), chap. 4.

23. Craven and Cate, *Men and Planes*, 102.

24. Denys Volan, *The Identification Problem in the Air Defense of the United States*, ADC Historical Study No. 3 (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, June 30, 1954), 1–4, OCLC (31413878).

System as organizational mission

The framework for a postwar defense of the continental United States would thus have to be constructed on bare foundations.[25] This is not to say that the Air Force had learned nothing about defending the skies, nor that it failed to appreciate its purpose. On the contrary, protecting Allied advances overseas provided numerous opportunities for air commanders to test their technical and organizational provisions for so-called "theater defense": guarding friendly forces, their stations and supply lines, in active combat areas, including the Alaskan frontier.[26] However, preventing a few enemy aircraft from harassing engineers on a beachhead or troops at a staging area was very different than defending a large civilian population from unrelenting mass raids.

General Hoyt S. Vandenberg, the Assistant Chief of Air Staff for Plans, conceded as much in a request to the Army Air Forces Center, the service's "proving ground" for tactics and equipment, in December 1945. While "most of our air defense doctrine in the past has been based on the primary assumption that we enjoy air superiority," it stated, "too little consideration has been given to the aspects of air defense which would exist in the event our own Air Forces had been depleted, rendered temporarily ineffective through surprise blows, or otherwise weakened through loss of fuel, supplies, lack of trained crews, or loss of bases." Vandenberg suggested that "there are many lessons to be learned from the mistakes made by our enemies in the past war when they faced air superiority or overwhelming air supremacy," as well as "our own 'back to the wall' situations"—especially Pearl Harbor—and

25. This theme pervades the interpretation in Richard F. McMullen, *Air Defense and National Policy, 1945–1950*, ADC Historical Study No. 22 (Ent AFB, CO: Headquarters, Air Defense Command, 1964), OCLC (18906119).

26. Conn, Engelman, and Fairchild, *Guarding the United States and Its Outposts*, chaps. 9–10. See also C. L. Grant, *AAF Air Defense Activities in the Mediterranean, 1942–20 September 1944*, USAF Historical Study No. 66 (Maxwell AFB, AL: Air University, USAF Historical Studies Division, October 1954), AFHRA (0467655); United States Department of War, Army Air Forces, Air Staff, Assistant Chief of Air Staff Intelligence, Historical Division, *Alaskan Air Defense and the Japanese Invasion of the Aleutians*, Army Air Forces Historical Study No. 4 (Washington: Headquarters, Army Air Forces, April 1944), AFHRA (0467596); and *IX Air Defense Command, Historical and Statistical Summary, 1 January 1944–1 June 1945* (Bad Neustadt an der Saale, Germany: Headquarters, IX Air Defense Command, US Army Air Forces), OCLC (962025444). The lattermost source especially suggests the progress toward combining the efforts of both air- and ground-based defenses at the level of theater command.

asked that "our Air Defense doctrine be reviewed and brought up to the required standards of probable future warfare and possible surprise atom bomb attacks designed to cripple our nation in a few days."[27]

Within this climate of austerity and confusion, a "second" Air Defense Command was reactivated under General Stratemeyer in March 1946 following the dismantlement of a headquarters called the Continental Air Forces, which had unified command over the four "home" air forces in December 1944 in anticipation of transferring units from the European to Pacific theaters—a contingency obviated by Japan's surrender.[28] Instead, the Army Air Forces divided its stateside organization between the newly formed Strategic Air Command (SAC), Tactical Air Command (TAC), and Air Defense Command (ADC), each of which assumed a *functional* rather than a geographical responsibility.[29]

For half a decade, the continental air-defense organization stumbled along lacking

27. Gen. Hoyt S. Vandenberg, AC/AS-3 (Plans) to Commanding General, Army Air Forces Center, "Air Defense," December 24, 1945, exhibit 7 in Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol 2, Supporting Documents 1–109 (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474352).

28. The First, Second, Third, and Fourth air forces constituted the four "home" air forces, which corresponded to the four regions the Army established to raise new units before assigning them to combat areas overseas. Craven and Cate, *Men and Planes*, 70–75; Conn, Engelman, and Fairchild, *Guarding the United States and Its Outposts*, 33-44. The Army Air Forces had never been entirely pleased with this arrangement and established the Continental Air Forces (CAF) partly to build its own "strategic reserve" of long-range bomber units based in the United States, where the AAF could control them directly, instead of indirectly through an overseas commander. Herman S. Wolk, *Planning and Organizing the Postwar Air Force, 1943–1947* (Washington: Office of Air Force History, 1984), 114–138. After the war ended, CAF became the chief administrator for the AAF's demobilization program.

29. The change followed from the insistence of General Eisenhower, who had, by 1946, replaced George C. Marshall as Chief of Staff of the United States Army. The move came as part of a major restructuring the War Department intended to recover some of the *status quo* that had been upended by the recently concluded conflict, attenuating the influence of the conglomerated Army Air Forces, Army Ground Forces, and Army Service Forces and returning a more traditional measure of power to bureau chiefs and theater commanders. With respect to the AAF, Eisenhower wanted to ensure that its leadership would not neglect the roles of air defense and tactical air-support that had proved essential to the ground war in Europe. James E. Hewes Jr., *From Root to McNamara: Army Organization and Administration, 1900–1963*, CMH Pub 40-1 (Washington: Center of Military History, 1975), 154–162; Herman S. Wolk, *The Struggle for Air Force Independence, 1943–1947*, rev. ed. (1984; Washington: Air Force History and Museums Program, 1997), 124–150. Again, to clarify, ADC, SAC, and TAC were all *stateside* organizations with primary missions to train and equip units for combat assignments with the AAF's *overseas* commands, otherwise not mentioned, such as the United States Air Forces in Europe and the Far East Air Forces, although the militarization of the Western Hemisphere at the start of the Cold War tended to erode this distinction.

clear direction concerning its mission, authority, and professional identity. Rather like its predecessor—the prewar planning agency that had existed only briefly—the new Air Defense Command actually commanded very little: only the First and Fourth air forces reported directly to General Stratemeyer at Mitchel Field, and these were both training organizations preoccupied with keeping up reservists and stand-by units in the Air National Guard. Despite the commanding general's insistence, Air Force headquarters declined to assign him any of its (admittedly few) active-duty combat units, nor did it offer much assurance that such units would be made available except in unusual circumstances, such as the Hanford emergency. With an ill-defined responsibility to formulate plans and effect coordination for units that did not exist, and no guarantee it would control them if they did, ADC was effectively merged with TAC, to form a new headquarters called the Continental Air Command (ConAC) in December 1948.[30]

Although the reorganization succeeded in consolidating all stateside combat units under a single commander (excepting, of course, SAC's precious bomber fleet), the responsibility to prepare fighter units for assignment overseas, as well as to administer the reserves, interfered with ConAC's primary assignment to defend the United States. Only as the nation mobilized to fight the Korean War did the Air Force choose in January 1951 to revitalize ADC as a proper "combat command," with a definite combat mission and Regular Air Force units assigned specifically to perform it. Technically, it was this "third" Air Defense Command that eventually served the greater part of the Cold War as the Air Force component to NORAD, the US–Canadian mutual-defense organization chartered in 1957.[31]

30. The subtlety of the ConAC reorganization is not easy to explain. Essentially, ADC lost its status as a "major command," with a headquarters reporting directly to Washington, and moved to occupy the top rung in the air defense "para-organization" described in the next chapter. In other words, beyond its responsibility to assemble the AC&W network, its combat capability existed only insofar as ConAC assigned it units to control—as would be expected in an emergency, but was otherwise done mainly for training exercises. ConAC abolished the vestigial ADC entirely in June 1950, hence, it will be convenient to conflate "ADC–ConAC" while discussing the years between 1948 and 1951. Sturm et al., *The Air Defense of the United States*, 197–216.

31. Explaining the status of ADC throughout these later developments is also not straightforward. Within the USAF organization, the Air Defense Command remained a "major command" continuously from the time of its reactivation until 1975, though it was renamed the "Aerospace Defense Command" (ADCOM) in 1968. Beginning in 1954, however, ADC (and later ADCOM) served as the USAF component of a "joint

Beginning in 1946, however, ADC's thinking about the continental air-defense "system" clearly implied an *organizational* system—an aspirational concept both inspired and undermined by the instability of its own organization. On August 5, 1946, Stratemeyer addressed a letter to Spaatz requesting further specification of his duties as the nation's top air-defense commander, especially the instruction to "organize and administer the integrated air defense system of the Continental United States." As stated, "these missions are necessarily so broad, and the resources of the Air Defense Command so limited, that it is apparent that my entire means might easily be dissipated without satisfactorily achieving any one portion of your directive," he wrote. "In view of the widely varying interpretations possible," the letter enclosed an outline of ADC's understanding of its "interim mission," which Stratemeyer asked the Army Air Forces to ratify.[32]

According to the gloss, Spaatz's injunction to "organize and administer the integrated air defense system of the Continental United States" required seven distinct "methods of accomplishment," which ranged from preparing air-defense plans, tactics, and doctrine to implementing an "air defense system in being in the most critical areas and avenues of approach to the United States" that would "integrate...the additional military forces required and civilian agencies involved."[33] The proposed methods clearly exceeded the province of the Army Air Forces, as well as that of the War Department, which seemed to neglect the political difficulties of interservice and interagency cooperation. Stratemeyer

command" called CONAD—the Continental Air Defense Command—which reported to the Joint Chiefs of Staff and included headquarters representation from the Army Anti-Aircraft Command (ARAACOM, later ARADCOM) and Naval Forces CONAD (NAVFORCONAD). Then, in turn, CONAD became the United States component of NORAD (North American Air Defense Command) through a binational agreement with the Canadian Government in 1957, with ADC/ADCOM remaining as the USAF element in both. Schaffel, *The Emerging Shield*, 241–254. Fortunately, such trivia are of only minor relevance here, though issues regarding the legal authority of CONAD and NORAD will arise briefly in a later chapter.

32. Lt. Gen. George C. Stratemeyer, Commanding General, Air Defense Command to Commanding General, Army Air Forces, "Mission of the Air Defense Command," August 5, 1946, appendix 4 to *Air Defense Command History, 1946–1947*, AFHRA.

33. "Methods of Accomplishing the Mission of the Air Defense Command," staff study, enclosure to Stratemeyer to CG, AAF, "Mission of the Air Defense Command," August 5, 1946, in exhibit 4 in *Air Defense Command History, 1946–1947*, AFHRA.

remained steadfast in his call for an expeditious resolution, but Washington offered no substantive response beyond its own request "that a plan for the air defense Continental United States be submitted to this headquarters on or before 15 November 1946, in order that the requirements for implementation of this activity may be analyzed."[34]

Consequently, on November 22, ADC submitted its plan for the "Establishment of an Air Defense in Being," the first of several issued over the following year. "It is generally recognized that this country will most likely be the initial objective of any future aggressor and that the start of hostilities is very apt to take the form of a surprise attack against the United States," read the endorsement letter. "Our security therefore depends, unless this country is prepared to initiate offensive operations, wholly upon the establishment of a permanent air defense in the most vital areas in this country."[35] The plan itself was relatively modest: twelve fighter groups for interception, two bomber groups for testing and reconnaissance, eight AC&W groups, and seventy antiaircraft emplacements, all to be phased into service over the next three years.

In the meantime, scale mattered less to Stratemeyer than the maintenance of an operational "nucleus" around which more elaborate defenses might eventually be constructed, such as those outlined in the more ambitious long-term plan, which ADC submitted the following April.[36] As a matter of urgency, however, the general requested that the Army Air Forces press the War Department to allocate the necessary resources and grant him control over the collection of units he needed to begin conducting training and exercises.

34. Brig. Gen. Reuben C. Hood, Jr., Deputy Chief of Air Staff to Commanding General, Air Defense Command, September 19, 1946, in exhibit 4 in *Air Defense Command History, 1946–1947*, AFHRA

35. Lt. Gen. George E. Stratemeyer, Commanding General, Air Defense Command to Commanding General, Army Air Forces, cover letter to United States Air Force, Air Defense Command, "Establishment of an Air Defense in Being," November 22, 1946, annex #4 to OPD file no. 373.24 (3 May 1946) Sec. 1 (oversize), NARA, RG 341, NM-15 335-A, box 308.

36. United States Air Force, Air Defense Command, "Air Defense Plan: Long Term," April 4, 1947, annex #5 to OPD file no. 373.24 (3 May 1946) Sec. 1 (oversize), NARA, RG 341, NM-15 335-A, box 308.

Integration as unity-of-command

While ADC's early plans never inspired any action directly, the studies sketched a rhetorical agenda for the future. These statements were clearly calibrated to address the primary concern within the Army Air Forces at the time: the military reorganization pending legislation of the National Security Act and the nature of the independent air force for which it would provide. As an example, some saw the proceeding as an opportunity to bring antiaircraft artillery units (AAA) along with the rest of the forces to be extracted from the Army.[37]

On June 6, 1946, the Air Board approved a statement acknowledging that while "the Army Air Force is charged with the mission of air defense," it "has no officially adopted policies with respect to the personnel and organization of air defense." Since "War Department thinking is not crystallized to the point that we know what they will favor," the board desired comment on a series of proposals, the first of which "involved integrations of the antiaircraft [artillery units] into the Air Forces."[38] On June 20, ADC responded that "within the Continental United States active means for air defense...must be coordinated under a single agency," and that "defense forces and measures engaged in defense against air attack must be under a single commander."[39] The possibility of transferring AAA units entirely to the Army Air Forces had been contemplated during the war, but the compromise solution kept them under the Army Ground Forces (AGF) while deferring "operational control"—chiefly, the decision to hold or open fire—to the local air-defense commander.[40] In Stratemeyer's

37. Cf. Wolk, *Air Force Independence*, 115–121.

38. "Responsibilities of the Air Defense Command," staff study no. 17, enclosure to Lt. Gen. George E. Stratemeyer, Commanding General, Air Defense Command to Maj. Gen. Hugh J. Knerr, Secretary of the Air Board, Headquarters, Army Air Forces, July 20, 1946, in Air Defense Command, "Responsibilities for Air Defense," July 19, 1946, RG 341, 2.

39. "Responsibilities of the Air Defense Command," enclosure to Stratemeyer to Knerr, July 20, 1946, in Air Defense Command, "Responsibilities for Air Defense," July 19, 1946, RG 341, 8.

40. The proposition was, in fact, entertained several times, because the poor state of antiaircraft units sent into the field continued to be a source of embarrassment, as well as casualties to friendly pilots, causing even General Lesley J. McNair, Devers' predecessor as commander of the Army Ground Forces, to encourage the transfer of AAA training and operations to the Army Air Forces. However, General Marshall preempted action in each instance, and the crisis subsided as the tempo of antiaircraft mobilization assumed a less frantic pace in 1944. Cf. Kent Roberts Greenfield, Robert R. Palmer, and Bell I. Wiley, *The Organization of Ground Troops*,

opinion, any proposal that did not respect at least this one basic principle would prove unworkable in action.

It is worth reflecting on the arguments employed here because they begin to show how the language of "integration" would be applied and adapted to specific disputations. "The requirement for coordination of anti-aircraft, a ground firing weapon, and aircraft, an air firing weapon, is not a new problem," ADC claimed:

> There are in being various formulas and solutions which have had practical demonstrations during World War II. The difficulties presented by past handling of the problem are still existing and are generally well-known. Fundamentally, the difficulties arise from two forces operating within the same air space. Other difficulties, relating to priorities and logistics of operations, are solvable by command decision but combined operations require careful technical coordination of the most complex nature.[41]

The increasing range, velocity, and altitude of air weapons would necessarily demand a more efficient form of organization.

However, "there is no apparent advantage in a divided command for the direction of air defenses," the study concluded, "there are, however, a number of disadvantages." In particular, "speed in coordinating air action and utmost flexibility in operations can only be secured by integrity of command. The ability to create strong chain of command will be a decisive factor in defeating sudden and perhaps almost overwhelming air attacks," or so planners anticipated.[42] While technically agnostic about whose uniform an antiaircraft unit should wear, ADC presented an expansive case for Air Force control over any weapon assigned to the air-defense mission. The Air Board subsequently adopted a sympathetic statement as a matter of policy.

Naturally, the Army Ground Forces contended the opposite, though its logical gymnastics betrayed the relative weakness of this position. Its strongest argument was the one

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The United States Army in World War II: The Army Ground Forces, CMH Pub 2-1 (1947; repr., Washington: Center of Military History, 1987), 418–423; Craven and Cate, *Men and Planes*, 107–109.

41. "Responsibilities of the Air Defense Command," enclosure to Stratemeyer to Knerr, July 20, 1946, in Air Defense Command, "Responsibilities for Air Defense," July 19, 1946, RG 341, 3.

42. "Responsibilities of the Air Defense Command," enclosure to Stratemeyer to Knerr, July 20, 1946, in Air Defense Command, "Responsibilities for Air Defense," July 19, 1946, RG 341, 5.

deployed most consistently thereafter: that antiaircraft artillery (AAA, or "triple-A") was still *artillery* and should therefore remain with the organization better prepared to train, equip, and support artillery units of any kind, which was to say, the United States Army.[43] It is likely, however, that General Jacob L. Devers, the commander of the Army Ground Forces, intentionally minimized this claim in order to skirt the question of surface-to-air missiles, a program the Army badly wanted to keep despite its more dubious analogy to conventional artillery.[44]

Instead, the AGF study proposed to abolish the prevailing doctrine of "air defense" entirely and replace it with two others, "defense by air" and "antiaircraft defense," which respected an ostensibly natural division between air- and ground-based weapons. During the war, battery commanders had at times found it galling that their fire could be preempted by Air Force officers who protected their own aircraft more aggressively than they sought to destroy the enemy's. "Large numbers of AAA guns have been held silent because of the presence of a single or few fighters in the area," the AGF accused.[45] While this may well have been the case, it led to the bizarre supposition that air-defense commanders had become lazy from their right to preemption, which allowed them simply to withhold fire instead of properly solving the ultimate problem of distinguishing friendly from hostile aircraft. In Devers' proposal, aircraft would screen the perimeter of the defended area while artillery commanders shot indiscriminately at anything that moved within range of their

43. Devers had come out strongly in favor of maintaining an "integrated" artillery corps after the war, an opinion not universally shared among specialists in antiaircraft gunnery, but neither one they vigorously opposed: John A. Hamilton, *Blazing Skies: Air Defense Artillery on Fort Bliss, Texas, 1940–2009* (Washington: GPO, 2009), 94–98.

44. Cf. Edmund Beard, *Developing the ICBM: A Study in Bureaucratic Politics* (New York: Columbia University Press, 1976), chaps. 1–3 on the tri-service rivalry for funding, and concomitant roles and missions, for their guided-missile programs in the immediate postwar era, or John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, USACERL Special Report 97/01 (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, November 1996), 19–28 for a more succinct account.

45. "Security from Enemy Air Attack," staff study, enclosure to memo, Gen. Jacob L. Devers, Commanding General, Army Ground Forces to Gen. Spaatz, Commanding General, Army Air Forces, "Responsibilities for Air Defense," June 14, 1946, tab A in Air Defense Command, "Responsibilities for Air Defense," July 19, 1946, RG 341, 3.

guns, reiterating the doctrine of the London Air Defence Area from 1918.[46]

The Ground Forces probably overstated the case in order to preserve the *status quo*. In September the War Department approved a statement substantively affirming Stratemeyer's position. Although soon superseded by subsequent agreements, the precedent stood: AAA units would stay with the Army, but air defense would be a "joint" activity responsive to a single Air Force officer. What the arrangement left unsettled was how the Army and the Air Force should coordinate their planning for units that had not yet been assigned to a combat commander.[47] For instance, research and development remained a *service* responsibility, pursued independently by the Army and the Air Force, despite an air-defense commander's manifest interest in the numbers and capabilities of weapons that might become available in the near future.[48]

The surface-to-air missile question was only one of many other disputes that had to be litigated and relitigated long after the War Department dissolved in 1947.[49] Agreements also

46. Early air-defense practice was to divide a defended airspace into concentric rings (or, technically, cylindrical shells), interspersing areas designated for aerial combat with free-fire zones for antiaircraft artillery. Allied air-defenses sometimes followed similar procedures around populated regions during World War II, though the increasing capabilities of ground-controlled interception emphasized coordination of guns and fighters over blanket restrictions on airspace. See the discussion in the previous chapter.

47. Before the aforementioned establishment of CONAD in 1954, Army–Air Force arrangements regarding their combined air-defense effort had to be worked out directly between the two headquarters, or through the Joint Chiefs of Staff if the two services failed to achieve resolution on their own. Mediation was narrowly avoided in the case of the so-called "Vandenberg–Collins agreement," outlined in 1950, which specified the working relationship between field officers of the Army and Air Force with respect to their air-defense responsibilities much more precisely than had the Key West Agreement of 1948. It is reproduced in Wolf, *The United States Air Force,* 219–222. See also *History of Strategic Air and Ballistic Missile Defense*, 2 vols. (1972; repr., Washington: US Army Center of Military History, 2009), vol. 1, 144–146 for a brief summary, though note that this a reprint of a previously classified study, contracted to the BDM Corporation, as part of the Department of Defense's *History of the Strategic Arms Competition* project. It is useful mainly as a digest of staff histories that are more difficult to obtain.

48. Cf. Elliot V. Converse III, *Rearming for the Cold War, 1945–1960,* vol. 1 of *History of Acquisition in the Department of Defense* (Washington: Historical Office, Office of the Secretary of Defense, 2012).

49. The departments of both the Army and the Air Force did not entirely separate immediately upon the passage of the National Security Act of 1947. Certain aspects of their administration remained deeply entangled, particularly duties performed by the staff and support personnel working for major headquarters and service organizations. The text of the "Army–Air Force Agreements as to the Implementation of the National Security Act of 1947," date September 15, 1947, is printed in Wolf, *The United States Air Force*, 91–149. However, the two components of the former War Department continued to issue transfer orders, and even joint regulations, until mid-1949, and a hybrid class of units called SCARWAFs, for "Special Category Army Reassigned with Air Force," persisted into the mid-1950s, mostly to transition functions related to construction, communications,

had to be reached concerning communications, joint exercises, standard operating procedures, rules of engagement, and the countless vicissitudes of day-to-day activity that varied according to the locations and personalities involved. Accepting the standing precedent as a statement of doctrine still did not suggest a pattern for reconciling issues so detailed as these.[50]

Furthermore, Devers had been right to point out that the intractable problem with air defense—more so even than detecting an aircraft—was the problem of identifying one. At the time, air-to-ground communications were unreliable and radio transponders had not been standardized; thus, the only known solution, short of scrambling an interceptor to visually inspect every unknown flight, was to correlate prefiled flight plans with evolving radar tracks. Achieving the necessary compliance from the Department of the Navy and the Civil Aeronautics Administration would require "integration" on an order even higher than resolving control over the Army's antiaircraft guns.[51]

3 The radar fence

It is difficult to review sources from the immediate postwar era without feeling the rip current of an almost overpowering pessimism flowing beneath the surface. Some of this can likely be attributed to poor morale among air-defense officers during a period of acute bureaucratic frustration.[52] Nevertheless, they also made numerous statements suggesting that, even presuming that air defense had already proven its value in World War II, the future

and installations. Wolk, *Air Force Independence*, 212–226.

50. While defying a description so simple as a "pattern," the National Military Establishment was at least intended to provide an organization for such resolving disputes, though the intent fell short of reality. See Rearden, *The Formative Years* for a baseline on this expansive literature.

51. The problem, though familiar, did not become a serious one until ADC–ConAC began active interceptions in 1950. Volan, *The Identification Problem in the Air Defense of the United States*; Schaffel, *The Emerging Shield*, 122–127.

52. So much is evident from the narrative portion of *Air Defense Command History, 1946–1947*, AFHRA, though the sentiment is discernible in statements scattered across a wide variety of archival material dating to this period.

would be qualitatively different. The irony is that most prognostications did so by identifying trends that were decidedly quantitative in nature, such as exponential increases in airspeed, operating altitudes, and the blast effects of atomic versus conventional warheads.[53]

This future loomed all but certain. Nuclear weapons, jet aircraft, and guided missiles had all entered operational service before the end of World War II—in limited quantities, of course, but the victorious nations—especially the Soviet Union—had moved immediately to exploit these new technologies as expeditiously as possible, even amid the disruption of reconverting, or even rebuilding completely, their industrial economies. Meanwhile, effective counters to such weapons could not as yet be clearly foreseen. Microwave radar promised numerous opportunities for practical refinement, but it would never defeat the physics of the radio horizon; the possibility of over-the-horizon radar remained at best hypothetical; the utility of electronic fire-control systems would be limited by the capabilities of radar; and the digital computer still inspired less hope than mystery.[54]

Consider, for example, the whimsy of ADC's recommendation for an "in-place defense" from its long-term plan of 1947:

> There is an urgent requirement for the development of an entirely new approach to the problem of air defense...An air defense system is needed that does not depend on early warning and ground controlled interception; one which is activated by the mere presence of an enemy plane or missile and so designed that this enemy by his own approach over the defended area actuates the force which will destroy him; a defense which is not affected by the numbers of approaching planes or missiles nor dependent upon any accuracy or volume of defense activity. The design should be such

53. Although statements intended for the general population remained almost uniformly positive, an interesting dialectic emerged in the Air Force's professional literature, which, while unclassified, received limited circulation, and hence, mixed soothing tones of public assurance with dissonant bursts of private deliberation. In response to officers critical of expensive and seemingly quixotic attempts to defend against the atomic bomb, as in Harry M. Pike, "Limitations of an Air Defense System," *Air University Quarterly Review* 3, no. 2 (Fall 1949): 46–47, others, such as Peter J. Schenk, "Problems in Air Defense," *Air University Quarterly Review* 5, no. 2 (Spring 1952): 39–53, countered that the progress of technology would eventually rise to the challenge.

54. Continuing from the preceding note, professional assessments like Wendell W. Bowman, "Electronics in Air War," *Air University Quarterly Review* 3, no. 1 (Summer 1949): 48–56 demonstrated that while electronic systems were beginning to be recognized as indispensable to the military effectiveness of individual aircraft, their future application to operational control remained far less clear. For instance, in noting the impending bottlenecks in air-traffic and air-defense information handling, Bowman—who worked in the Air Communications Office during the preparation of SUPREMACY (see below)—referred only obliquely to the automation of ground facilities, and did not reference computing technology at all.

> that operating mechanisms are not in continuous action, but active only at the instant some airborne weapon has entered the zone of operation. It should be in a continuous state of readiness and capable of destroying any airborne weapon penetrating the defense zone.[55]

Before proceeding to speculate whether the author believed secretly in magic, consider also the pretension of even the most concrete proposal at the time. The long-term plan called for an early-warning belt patrolled by ships and aircraft, together with distant observation posts both tended and unattended, spanning a 10,000-mile arc from Hawaii to Puerto Rico by way of the Canadian Arctic.

While the "electronic frontier" built in the 1950s eventually assumed similar proportions, the 1947 plan estimated that full implementation, including the ground environment in the United States, would have required an almost unthinkably large force of 700,000 troops, 4,000 aircraft, 408 antiaircraft batteries, and an unspecified number of radar stations and control centers organized into 38 AC&W groups.[56] "In order to have the necessary forces available, completely manned, equipped and trained, at the time required…intelligence of impending war must have been gathered and evaluated, and a decision made to mobilize, two years prior to the time hostilities begin," the planners observed, most likely to point up the preposterousness of this scenario.[57] "The alternative is the maintenance on a permanent basis of a very large air defense in being," a solution they correctly judged infeasible in peacetime. What would be feasible in peacetime, however, frustrated even the most amicable of negotiations—negotiations which, on the whole, could rarely be praised for their amicability.

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55. Air Defense Command, "Long Term Plan," April 4, 1947, RG 341, app. H, 4.

56. Although the Distant Early Warning, or "DEW," line of radar stations built in the Canadian Far North provided the centerpiece of the hemispheric defense plans formulated in the early fifties, other initiatives included two parallel nets built further south (the "Pinetree" and "mid-Canada" lines), a cluster of offshore radar towers, and a fleet of naval picket ships and aircraft. By the late 1950s, when concern shifted from air to missile defense, the US, Canada, and Denmark were actively monitoring the North American Arctic across a band that stretched continuously from Alaska to Greenland. See Schaffel, *The Emerging Shield*, 209–224 or the relevant passages in *History of Strategic Air and Ballistic Missile Defense*; and Allan A. Needell, *Science, Cold War and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (2000; repr., London: Routledge, 2012), chaps. 8–9.

57. Air Defense Command, "Long Term Plan," April 4, 1947, RG 341, 4.

The politics of radar procurement

By the time of the Hanford debacle in the spring of 1948, USAF Headquarters had yet to act on any of ADC's proposals. Nevertheless, it responded to the operational breakdown by further increasing the burden on air-defense units. On April 23, General Spaatz not only instructed General Stratemeyer to continue pushing the flimsy air-defense network in the Pacific Northwest, but also to institute similar measures around the AEC facilities in New Mexico, as well as along the North Atlantic approach to the Eastern Seaboard. Toward the accomplishment of this even greater task, however, no additional resources would be forthcoming. "Until such time as funds are made available," the directive stated, "it will be necessary to limit the air defense dispositions and operations envisaged herein to such as can be effected without them."[58] The Air Force did begin to accelerate the reclamation of old radar and communications equipment from storage, but otherwise Stratemeyer would be on his own.

In fact, USAF headquarters had already devised its own plan for a "radar fence" under Major General Francis L. Ankenbrandt, the Air Staff's Director of Communications. Though Ankenbrandt's effort largely paralleled the work of Stratemeyer's staff in New York, the competing initiatives extended different bureaucratic lineages with overlapping but nonetheless distinctive purposes. Both weighed the prospective vulnerability of various regions within the United States against their perceived strategic value in order to achieve reasonably comprehensive radar coverage at a politically feasible price. As explained above, however, ADC's primary concern was organizational—an "integration" of *forces*—but the Directorate of Communications, as the Air Staff's specialty shop for ground-electronics planning and policy, approached the problem with *procurement* specifically in mind.[59]

58. Lt. Gen. Lauris Norstad, Deputy Chief of Staff, Operations, Headquarters, United States Air Force to Lt. Gen. George E. Stratemeyer, Commanding General, Air Defense Command, "subj: Air Defense of the Continental United States," April 23, 1948, exhibit 17 in *Air Defense of AEC Installations, 1946–1948*, AFHRA, 2.

59. For background on Ankenbrandt's office, and the political considerations at Air Force headquarters at the time, see Schaffel, *The Emerging Shield*, 67–73.

In other words, theirs was a plan to provide the ground-based *components* of an aircraft-control and warning (AC&W) system, rather than expostulate on unanswerable questions of "integration" that had confounded the issue to date. By November 1947, Ankenbrandt's group had secured General Spaatz's approval for the in-house plan, codenamed "SUPREMACY."[60] Stratemeyer's staff received the proposal tepidly, since its objective fell short of ADC's long-term plan, while further suggesting Washington's indifference to their labor. On the other hand, any sustained interest in air defense was manifestly superior to none.

SUPREMACY reflected more than two years of ambivalence over the state of radar production. The staff action can be traced to mid-1945, when AAF headquarters had to decide whether to curtail its procurement of state-of-the-art radar equipment, such as the "V-beam" AN/CPS-6, a combined range- and height-finding set.[61] With the war's end in sight, some planners recognized that the answers to such technical questions depended on intractable questions of postwar organization.[62] On April 4, 1945, AAF headquarters observed that "present trends toward an *integrated system* of aircraft warning, air traffic control, emergency rescue, flying safety, and air defense warrant a study of the newer types of ground radar sets for such a system" and expressed its desire "that the aircraft control

60. Typographic styles in military publishing vary, as in any discipline, but official practice fully capitalizes the code names of operational plans, in order to clarify their intended arbitrariness. Of course, operational plans often need to be "sold" to a particular audience and may, in the process of obfuscating the details, nonetheless encode a memorable or aspirational message: Gregory C. Sieminski, "The Art of Naming Operations," *Parameters* 25, no. 3 (Autumn 1995): 81–98. The text here follows the official convention, though it does not enforce uniformity by altering the typography of direct quotations.

61. A classic GCI-capable detector required two major pieces of radar equipment: a "search radar," with a vertical beam that swept horizontally to read azimuth, and a "height-finding" or "secondary radar," with a horizontal beam that swept vertically to read altitude (either type could return range). The "V-beam" detector, on the other hand, emitted a pair of azimuthal signals, one vertical and one slanted with respect to vertical, so that altitude could be calculated from the time difference between the two echoes. L. N. Ridenour et al., "The Gathering and Presentation of Radar Data," in *Radar System Engineering*, ed. Louis N. Ridenour, MIT Radiation Laboratory Series, No. 1 (New York: McGraw–Hill, 1947), 187–196. While considered a promising technology at the end of World War II, the USAF fielded it only in the AN/CPS-6 series, as improvements to the typical search-plus-secondary configuration obviated its advantages: David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, November 1997), 73–84.

62. Grant, *Development of Continental Air Defense*, AFHRA, 1–13. The sources for this narrative overlap considerably with those cited here.

and warning requirements in the [First and] Fourth Air Force be reviewed and a plan, or plans, be developed and submitted to this Headquarters which will utilize the new types of ground radar equipment for both present and postwar requirements within the capabilities of the equipment considered."[63]

In response, the Continental Air Forces asserted on July 21 that in order to fulfill the AAF's request, "it is necessary to set up several problems for critical examination with the understanding that the solution may or may not lie within the jurisdiction of this headquarters." While acknowledging that the impending procurements should and probably would comprise the backbone of the continent's "all-weather airways," CAF anticipated their utter uselessness against the threat of supersonic aircraft and ballistic missiles, even without knowing of the atomic bomb that had been successfully tested just five days prior.[64]

Disregarding the properties of the radar itself, the concomitant measures would be drastic indeed, requiring that all defenses be "completely installed," "under unified control," and "on a standby status with competent, full crews available in not more than twelve hours." Instead, "it is recommended that any and all actions taken be part of the ultimate postwar plan," including the deployment of radically new technology and the reorganization necessary to direct it, in order "to achieve the final integration with with a minimum of expenditure of time, effort, and material." Foreseeing no electronic breakthroughs of the magnitude suggested by CAF, the Army Air Forces elected to restrict its postwar defense planning to the equipment presently or very nearly at hand.

As fiscal and manufacturing problems delayed production after the war, however, the Air Force developed a critical shortage of radar equipment.[65] With dozens of other field

63. Brig. Gen. William F. McKee, Deputy Assistant Chief of Air Staff, Operations, Commitments, and Requirements to Commanding General, Fourth Air Force (identical letter addressed to First Air Force), "Aircraft Control and Warning System," April 4, 1945, exhibit 1 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA, emphasis added.

64. Headquarters, Army Air Forces to Commanding General, Continental Air Forces, July 21, 1945, exhibit 6 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA).

65. R&R, Maj. Gen. E. E. Partridge, Assistant Chief of Air Staff–3 (Operations) to Deputy Commander, AAF, "Acute Shortage of Ground Radar Equipment," September 6, 1946, exhibit 18 in Bagwell and Miller, *Case History*

agencies requesting deliveries, headquarters could not decide how to reconcile the massive requirements for a continental defense network with its limited supply of detectors. In January 1947, General William L. Richardson, the director of Guide Missiles, reported that "overall policies and programs affecting air defense are subject to considerable controversy inasmuch as as the means required for establishing air defense systems are excessive when compared with the amount of insurance gained and the actual need for air defense systems in the next few years has not been firmly established."[66]

Ankenbrandt's office added that "there is a considerable body of scientific opinion taking the position that some of the existing techniques and equipments for the detection of hostile airborne objects have been developed to the point of diminishing returns and that a fundamentally new approach is needed."[67] Due to the uncertain outlook, "military characteristics do not exist at present for Early Warning Radar Fence Equipment," a problem further ramified by a "general policy that [they] will not be published individually but rather will be compiled into a 'book' so as to assure complete integration of all elements of the system."[68] Insisting on a total, up-front design would obviously delay any production decision for as long as it took to approve the final component.

In March, Richardson and Ankenbrandt had their offices draft a policy paper for General Earle E. Partridge, Assistant Chief of Air Staff for Operations, affirming that "present systems are neither economical nor efficient" and that "consideration of the above leads to the single conclusion that fixed radar systems of World War II vintage will be ineffective in future wars":

of the AC&W System, vol. 2, Supporting Documents 1–109, AFHRA.

66. Memo, Brig. Gen. William L. Richardson, Chief, Guided Missiles and Air Defense Division to Assistant Chief of Air Staff–3 (Operations), "subj: Status of Air Defense," January 15, 1947, exhibit 31 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

67. Memo, Col. Wendell W. Bowman, Deputy Air Communications Officer to Requirements Division, AC/AS-3 (Operations), "Participation in Meeting of Scientific Advisory Board, 4 and 5 February," January 29, 1947, exhibit 33 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

68. R&R, Brig. Gen. Francis L. Ankenbrandt to Research and Engineering Division, AC/AS-4 (Operations), "Development of Early Warning Radar Fence Equipment," February 7, 1947, exhibit 35 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

> It, therefore, follows that the expenditure of significant sums of money for the rehabilitation of present systems or for the construction of new systems of this type would constitute a scandalous waste of public funds. More serious than the waste of funds, however, would be the creation of illusion in the public and military mind that an air defense system existed, where in fact it did not.[69]

The statement granted that "nuclei of aircraft control and warning systems will be established in the continental United States [and] Alaska," but "will have primarily a training mission" and "will be implemented as far as possible with present resources."

Instead, "the indisputable fact that no means for effective air defense exist or will exist in the near future, must be faced squarely and dealt with in terms of research and development on an emergency basis." In other words, any further procurement of existing equipment models would detract from the development of new ones, and conversely. Although such zero-sum thinking was eminently reasonable in light of the postwar military budget, the Richardson–Ankenbrandt proposal invoked a curious concern over *appearances* as well. Perhaps recalling the notorious Maginot Line—a favorite hobbyhorse for Air Force officials—it seemed to suggest that a sham defense would be worse than none at all.[70]

Nevertheless, General Otto P. Weyland, Assistant Chief of Air Staff of Plans, raised a serious objection on this point. "The subject study and proposed policy creates an impression that the AAF is taking a negative approach to the problem of air defense in the U.S.," read the memo.[71] "This must not occur," it warned, both militarily and politically. "The American

69. "Study on Proposed Aircraft Control and Warning Policy," enclosure 1 in memo, Maj. Gen. E. E. Partridge, Assistant Chief of Air Staff–3 (Operations) to Assistant Chief of Air Staff–4 (Plans), "Proposed Air Defense Policy," March 13, 1947, exhibit 37 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

70. One of Project RAND's earliest studies concluded precisely this: Schaffel, *The Emerging Shield*, 67–68. The term "Maginot Line thinking," or "Maginot Line mentality" (among other variations), was not exclusive to the Air Force, and appeared frequently in postwar security discourse, always with the connotation of hubris and complacency, and usually in the context of fiscal politics. Air Force leaders deployed it most pointedly whenever they faced pressure to divert funding from its long-range bomber fleet. The phrase became such an old saw that authors of later studies rebutted it specifically: Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force*, vol. 1 of (1971; repr., Maxwell AFB, AL: Air University Press, 1989), 327–333.

71. Memo, Maj. Gen. O. P. Weyland, Assistant Chief of Air Staff–5 (Plans) to Assistant Chief of Air Staff–3, "Proposed Air Defense Policy," March 27, 1947, exhibit 42 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

people would not tolerate uninterrupted attacks without warning against their cities by atomic bomb laden aircraft or guided missiles, even if the attacks were of a sporadic nature. They look to the Air Forces for their protection."

While agreeing with the premise that "we have a period of grace, estimated at approximately 5 years, during which we can afford to accept a calculated risk and not maintain an air defense in being":

> With respect to the air defense system itself there will always be equipment 'just around the corner' which will be far superior to that already in existence": For a few years we can afford to wait for this equipment. After that we can no longer wait—we must employ what we have on hand. While waiting the next few years, it seems there are many things we could be doing with the objective of progressively developing an air defense system.

In particular, "any type of system utilizing early warning, ground control, and interceptors will need an organization, control centers, and communications." The Air Force should still aim to provide "at least a skeleton system…into which we can fit new developments and with which we can formulate and test the techniques of air defense, such as the rapid deployments and control of interceptor forces." Weyland specifically called for revising the concept of the air-defense "nuclei" in the Richardson–Ankenbrandt statement "with a view to their utilization in wartime," not merely convenience in peacetime.

Although Weyland's memo substantiated General Stratemeyer's appeals from Mitchel Field, the issue at hand remained a fairly technical one involving production and priority allocation for the AN/CPS-6B, a straightforward improvement program that had unexpectedly become problematic. General Electric frustrated procurement officials with delays and cost increases, which the contractor in turn blamed on changing specifications that reflected headquarters' basic indecision about how the equipment would ultimately be applied.[72] As Air Communications Officer, General Ankenbrandt regarded continental defense as an extension of his overall concern for the electronic ground environment as a whole and pushed

72. Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol. 1, Narrative (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474351), 22–25 synopsized the convoluted story of the AN/CPS-6B procurement, documented at great length in the supporting volumes.

for a more versatile set. Meanwhile, General Richardson, the Director of Guided Missiles—whose office was also formally charged with air-defense matters—pointed to tests at White Sands that proved conventional detectors useless against rockets and thus wrote them off entirely. Exogenous pressure forced the issue, however, because by fall, the probability had emerged that the National Military Establishment would hold a newly independent Air Force politically responsible for defending the Atomic Energy Commission's critical facilities against air attack.[73]

The crash mobilization of 1948

On September 15, 1947, three days before the Army Air Forces became the USAF, General Curtis LeMay, acting then as a deputy chief for research and development, submitted an emergency air-defense plan that would cover the Los Alamos, Sandia, Hanford, and Oak Ridge sites, as well as the AAF's main depot in Dayton. "In order that ample time be available for fighter aircraft to take-off, gain altitude, and make interception before the enemy reaches the vital area, the early warning elements must be extended in all directions," the cover letter acknowledged. "Thus, in providing air defense four separate isolated installations, of comparatively small area, the cost in AAF manpower and equipment would be comparable with the cost of fighter and early warning coverage of equal effectiveness for a single area of 40,000 square miles."[74] Since LeMay's office supervised the AAF's critically important stake in the Armed Forces Special Weapons Project (successor to the Manhattan Project) the request effectively steered deliberations in an entirely different direction. To secure its public claim on continental defense, the Air Force would have to deploy the AN/CPS-6B, as well any other model it could put into production, primarily as an early-warning radar, on a crash basis, in quantities far larger than anticipated.

73. *Air Defense of AEC Installations, 1946–1948*, AFHRA, 1–5.

74. Memo, Maj. Gen. Curtis E. LeMay, Deputy Chief of Air Staff for Research and Development, to Director of Plans and Operations, War Department General Staff, "Air Defense of Vital Atomic Energy Commission Facilities," September 3, 1947, exhibit 53 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

In a rush to draft SUPREMACY, Ankenbrandt had to abandon his "calculated risk" mentality in favor of a massive five-year build-up of AC&W installations in the United States and Alaska. As briefed to General Spaatz on November 21, the proposal called for $388 million in spending on equipment, construction and installation from 1949 to 1953, as well as $243 million to raise the 21,860 additional troops required. At that point, continuing operations and maintenance were estimated at $150 million per year.[75] The object of the plan became known colloquially as the "radar fence," a term Ankenbrandt had previously reserved for a hypothetical future radar screen with a 1,000-mile detection radius, though as staff noted, no foreseeable technology could meet this potential "requirement."[76]

On January 19, General Weyland informed the Air Defense Command that it had been "designated as the implementing agency for this project" within the United States. Altogether it would receive 676 sets of radar equipment to install at 374 sites, approval to construct 14 regional control centers, and a total troop allocation of 33,526, about 14,000 of whom were to be provided by the Air National Guard.[77] (Under SUPREMACY, the Alaskan Air Command would build another 37 stations and four control centers in the northwestern territory, outside ADC's zone of operations.) ADC headquarters responded cautiously on April 8 that SUPREMACY "will provide the minimum aircraft control and warning coverage for the strategic areas of the continental United States within the inherent capabilities of presently available equipment." The statement was rather coy considering how the plan would expand ADC's operating stations from essentially zero to 374, but the staff still harbored misgivings about Washington's neglect of their own studies, which had articulated

75. "Conference memorandum on presentation to Chief of Staff, USAF on Aircraft Control and Warning Plan for United States and Alaska," November 30, 1947, exhibit 51 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

76. Maj. Harry R. Beamer, Headquarters, Air Defense Command to Commanding General, Army Air Forces, "EW Radar Fence (Outpost Radar," April 2, 1947, exhibit 48 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

77. Maj. Gen. O. P. Weyland, Acting Deputy Chief of Staff, Operations to Commanding General, Air Defense Command, "Aircraft Control and Warning Plan for the United States," January 19, 1948, exhibit 67 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

clearer requirements for provisions as essential as air-to-ground communications and radar-siting and calibration teams.[78]

Modest as it may have been by comparison, SUPREMACY misjudged the mood of the famous "Do-Nothing Congress."[79] In fairness, the appropriation procedure for the new National Military Establishment were as yet untested, so the plan's disposition hinged on several determinations by the Bureau of the Budget.[80] In December 1947, the bureau informed the Air Force that funding the $600 million radar fence would require specific legislation, which needed to be passed before the next fiscal year, which started in July, in order to satisfy the program's 1953 deadline. Moreover, the bureau found that since the National Military Establishment had not yet designated the Air Force as the agency solely responsible for continental air-defense, the departments of the Army and the Navy would both have to concur in proposing the bill.[81]

In May, however, when the Air Force finally submitted a coordinated draft for approval, the Budget Bureau returned it to the Secretary of Defense with a number of objections. "The program is of considerable magnitude and requires integration with related programs of the Army, Navy, Civil Aeronautic Administration, and Canada," the memo explained.[82]

78. Maj. Gen. H. M. Turner, Vice Commander, Air Defense Command to Chief of Staff, United States Air Force, "Aircraft Control and Warning Plan for the United States," April 8, 1948, exhibit 87 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

79. On the budgetary politics for Fiscal Year 1949, particularly with respect to national defense, see Rearden, *The Formative Years*, 309–328 and the relevant passages of Michael J. Hogan, *A Cross of Iron: Harry S. Truman and the Origins of the National Security State, 1945–1954* (Cambridge University Press: Cambridge, 1998). The issue was not so much congressional unwillingness to spend on defense projects—quite the contrary, in fact—but the antagonism between two branches of a divided government, especially in the months before the presidential election of November 1948. Susan M. Hartmann, *Truman and the 80th Congress* (Columbia: University of Missouri Press, 1971), 159–217.

80. Elias Huzar, *The Purse and the Sword: Control of the Army by Congress Through Military Appropriations, 1933–1950* (Ithaca: Cornell University Press, 1950) is a rather exhausting study concerned mainly with the role of Congress, but the author did observe the slow change in military budgeting procedures with respect to the relatively rapid change of organizational structure both during and after the war.

81. "Status of Air Warning and Control Screen for Alaska and the U.S." appendix "A" to memo, Gen. Hoyt S. Vandenberg, Chief of Staff, USAF to Secretary of the Air Force, "Comments on Mr. Forrestal's Memorandum to the Joint Chiefs of Staff, dated 1 July 1948," July 30, 1948, exhibit 121 in Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol. 3, Supporting Documents 110–213 (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474353).

82. Copy of memo, "U.S. Air Force Radar Fence Program," attached to Air Staff summary sheet, Maj. Gen. Fran-

Broadly speaking, budget officials wanted the NME to assess the impact of SUPREMACY on the *total* cost of a continental air-defense network, a much thornier tangle of interagency, and even international disagreements. Moreover, the Budget memo again invoked the lingering skepticism about prioritizing procurements for radar equipment expected to perform poorly against the range of threats anticipated in the future.

The bureau's skepticism resulted from a consultation with the Research and Development Board, Dr. Vannevar Bush presiding, which was also in the process of formulating its own proposal for how to proceed with the air-defense problem. "At the meeting which we had on 27 April, your staff outlined your immediate program to provide an operational aircraft warning and control system," Bush cautioned General Vandenberg. "It is recommended that commensurate effort be given to the research and development effort," he continued, alluding to the plan prepared by his own Electronics Panel. However, he did react favorably to the idea of "a model air defense system for the engineering and operational test evaluation of the various elements of the system," a sort of field laboratory, rather than an active defense net *per se*.[83]

Nevertheless, Bush's soggy opinion also dampened Secretary Forrestal's enthusiasm for the bill, who hoped to find a path between the two competing initiatives. "I understand that discussions of the developmental features of the program by the Air Force with the Research and Development Board have led to the conclusion that the types of air warning radar presently procurable, which are essentially of World War II vintage, would have limited effectiveness for continental defense, even against World War II aircraft, and more especially against advanced types of aircraft," he memorialized on July 1. "I understand further that, although the Research and Development Board thinks we cannot expect to

cis L. Ankenbrandt, Director of Communications, "U.S. Air Force Radar Fence Program," May 28, 1948, exhibit 100 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

83. Memo, Vannevar Bush, Chair, Research and Development Board to Chief of Staff, USAF, "Air Defense System," May 10, 1948, exhibit 95 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA. The Research and Development Board's handling of the air-defense issue will be revisited in a subsequent chapter.

obtain more adequate equipment from current development programs for about five years, the Air Force plans an orderly replacement of the older types when the new types become available, at as reasonable a cost as possible."[84]

Therefore, "on the one hand there are considerations of economy involved in spending a substantial amount of money on radar which now is not completely effective and which will probably be obsolete in a few years," while "on the other hand, there is the obvious fact that the use of the present types of radar would give us at least some protection against a surprise attack during the years in which superior types are being developed." His thinking merely reflected the Air Force's internal division on the matter, but the fact that it should rise to such a rarefied level of executive authority spoke to the organizational pathology of the early national-security state.

According to the Secretary, the existence of two competing criteria could mean only that "a fine question of judgment is involved." Unfortunately, the National Military Establishment had been deliberately constructed to prevent any single actor from imposing a hasty, unilateral decision on such "a fine question of judgment." As the chairman of a coordinating body, Vannevar Bush had no executive authority, and even James V. Forrestal, Secretary of Defense, seemed reluctant to test the legal definition of his own.[85] In his July 1 memorandum, then, he condemned SUPREMACY to months of time-consuming committee-work between the Joint Chiefs of Staff, a deferral that boded ill for Vandenberg's schedule.

So, in a provocative move, the Department of the Air Force advanced one final gambit to secure congressional approval for Fiscal Year 1949. Although it is unclear who initiated the liaison, Representative Carl Vinson, a Georgia Democrat, and Senator John Gurney, a Republican from South Dakota, both obtained drafts of the AC&W bill and introduced them into their respective chambers around June 1, where each was referred to committee. This

84. Memo, James V. Forrestal, Secretary of Defense to Joint Chiefs of Staff, July 1, 1948, exhibit 110 in Bagwell and Miller, *Case History of the AC&W System*, vol. 3, Supporting Documents 110–213, AFHRA.

85. Cf. Douglas T. Stuart, *Creating the National Security State: A History of the Law That Transformed America* (Princeton University Press: Princeton, 2008), chap. 6.

effectively short-circuited the National Military Establishment, as well as the Bureau of the Budget, and the Chief of Staff appeared to know it. Vandenberg wrote Stuart Symington, the Secretary of the Air Force, asserting that "Mr. Forrestal's memorandum to the Joint Chiefs of Staff, requesting an evaluation of the program, will not be affected by early congressional action on the radar fence legislation" and recommended "that you advise Mr. Forrestal personally of the Air Force position on this legislation" and "secure Mr. Forrestal's approval to contact Senator Gurney and Representative [Walter G.] Andrews [chairman of the House Armed Services Committee] for the purpose of obtaining their assistance in passing the Air Force radar fence legislation during this special session of the Congress."[86]

The hand-written notes passed between senior members of the Air Staff displayed anxiousness and confusion, until on August 6, General Norstad's executive finally informed the Assistant Vice Chief that he "did not know of any action [Secretary Symington] took on this. Appears to be a 'dead duck' until next session of Congress." The bill's failure marked the Air Force's second major disappointment over continental defense within the six months prior, following the self-inflicted wound at Hanford.

The Modified Plan: A "nuclear" experiment

Sensing defeat as early as June, Air Force headquarters recalled General Gordon P. Saville from the US military delegation to Brazil. Saville was the officer who had accompanied General Chaney, commander of the first Air Defense Command, to England in order to observe the Battle of Britain. After organizing the air defense of the Panama Canal Zone in 1942, Saville briefly administered the development of tactics at the Air Force proving ground

86. Memo, Gen. Hoyt S. Vandenberg, Chief of Staff, USAF to Secretary of the Air Force, "Comments on Mr. Forrestal's Memorandum to the Joint Chiefs of Staff, dated 1 July 1948," July 30, 1948, exhibit 121 in Bagwell and Miller, *Case History of the AC&W System*, vol. 3, Supporting Documents 110–213, AFHRA. Congress had actually voted to adjourn on June 20—before the bill could receive a hearing in either chamber—but was forced to reconvene from July 26 to August 7 for a special session called by President Truman in the midst of his tightly contested campaign to remain in the Oval Office. Flustered by the obvious gambit, the Republican majority blockaded the White House's legislative agenda and gave Truman the spectacle of stubbornness he needed to embarrass the opposing party. Hartmann, *Truman and the 80th Congress*, 192–202.

before transferring to a combat command in the Mediterranean Theater in 1943, where he dealt frequently with the problem of coordinating fighter aircraft with tactical controllers on the ground. Postwar assignments had spared his hands from wringing excessively over radar procurement policy and the air-defense mission in general, leaving them relatively uncalloused for the task ahead.[87]

Upon returning to Washington, the Air Staff granted Saville an informal position as a "special projects officer," a delicate styling for his disruptive new role as "czar" of continental air-defense. For the next six months, Saville essentially monopolized the planning staff at Air Force headquarters—where it was divided between Ankenbrandt's, Richardson's, and some minor offices—*and* Air Defense Command headquarters at Mitchel Field. This unusual arrangement had no organizational basis beyond the high-level push to salvage the wreck of SUPREMACY, a feat Saville attempted to perform by immediately extricating the "integrated system" from the paralytic politics of radar procurement. Whereas a specific piece of radar equipment might be replaced or modernized every few years, a radar *installation*—its roads, structures, physical plant, communications, utilities, and so on—might stand for decades.

Thus, the most pressing matter in the short term would be to survey, test, build, and calibrate sites with favorable strategic, logistical, and—just as importantly—radio-propagation features. "An air defense…is not a static thing," he told Secretary Forrestal during a briefing in September 1948:

> Nor is there such a thing as the "ultimate" air defense within the foreseeable future. An aircraft warning and control system is an elaborate and complex system of many equipments, geared together into a smooth-working and extensive whole. Each piece of equipment is subject to modification and improvement…The gearing of the various elements of the system is also subject to constant improvement and change, to meet changing conditions…We can develop new equipment, but we cannot have an effective air defense until we have a *system*.[88]

87. The following passage draws some details from Interview, Maj. Gen. Gordon P. Saville, United States Air Force (Retired), with Thomas A. Sturm, Office of Air Force History, Sun City, AZ, August 27, 1988, AFHRA (1085564).

88. "Interim Program for Aircraft Control and Warning System in the Continental United States and Alaska," transcript of briefing for James V. Forrestal, Secretary of Defense by Maj. Gen. Gordon P. Saville, Headquarters,

Compared to other military "systems," such as missiles and aircraft, "this systems problem is complex and vastly ramified," and ultimately "we must have such a system *in being* in order to guide our development, to work out the tactical problems as conditions change, and to serve as our active air defense in being." No amount of planning or design could teach the organization how to adapt itself to a continuously changing operating environment.

The statement essentially reiterated the core message of ADC's "Air Defense in Being" study from November 1946, which General Weyland had likewise expressed just before the SUPREMACY debacle. The difference was that Saville had a proposal that was both more concrete operationally and less intimidating politically, with full participation from both Air Force headquarters and the Air Defense Command. The "system in being" would proceed in two concurrent phases. The first program, designated LASHUP, would expedite the recovery of war-surplus equipment from storage, expanding the emergency deployment that had already begun with the Hanford order in March. Installation costs were to be minimized by compromising on site selection, limiting construction as much as possible to properties the government already owned and occupied.

LASHUP mostly abandoned the pretense of a comprehensive defense for the ideal of a "model system": a sort of continent-spanning laboratory for evaluating equipment, mapping radio features, and developing tactics, operating and maintenance procedures, training practices—or, in, short, an *organization*. "It would be utterly impossible for me to overstate the complete inadequacy of this deployment to provide aircraft warning and control in the event of air attack," he emphasized for Forrestal. "It is so wholly inadequate that it not only provides negligible air defense capability, but *does not even provide a sufficient system for the development of tactics, techniques and procedures* involved in any air defense system." Saville continued:

> We must have a limited air defense in being if we are to solve the many and varied systems problems involved in any reasonable time. Basic radar stations, control centers,

USAF, September 9, 1948, exhibit 19 in *Air Defense of AEC Installations, 1946–1948*, AFHRA, 6–7, emphasis in original.

> and interconnecting communications inevitably will be the skeleton upon which the whole air defense system is erected. Without that skeleton, we will have nothing to grow on.[89]

In other words, the pieces may as well not exist at all if they could not work together simultaneously. Training and proficiency with individual equipment would never speak to the experience of interoperating each element within a larger whole.

In October, Secretary Forrestal granted General Saville's request for a $706,000 disbursement to immediately begin expanding the temporary network. Forty-four stations would be constructed over the next two years, according to the schedule, which prioritized coverage along the northeastern and upper-midwestern industrial belts. Couched in the language of experiment, the revision also earned the endorsement of Vannevar Bush, which the Joint Chiefs seconded shortly thereafter. The Air Force actually committed most of the new money to LASHUP's successor, a plan at times labeled the "interim" or "modified" AC&W program before becoming known generally as the "permanent system."[90]

While the LASHUP network provided almost negligible protection, its construction would help ADC identify locations where the weather, topography, and geology might better accommodate the high-performance radar of the future. Saville ultimately wanted 75 permanent sites selected within the continental United States by the time LASHUP began phasing out in mid-1951, with an additional ten facilities allocated for area control-centers. Like SUPREMACY, the Modified Plan was not coordinated with any specific R&D goal and merely accelerated the procurement of the various wartime designs already on order, albeit models revised with meaningful, and in some cases, quite substantial improvements. Unlike SUPREMACY, however, the Permanent System presented a more nimble political target; framing it as an "interim" measure, for instance, subtly implied one or more future

89. Transcript, "Interim Program for Aircraft Control and Warning System in the Continental United States and Alaska," presentation for James V. Forrestal, Secretary of Defense, by Maj. Gen. Gordon P. Saville, Headquarters, USAF, September 9, 1948, exhibit 19 in *Air Defense of AEC Installations, 1946–1948*, AFHRA, 5, emphasis added.

90. Facts related to the establishment of the continental AC&W net follow mostly from Denys Volan, *The Development of an Air Defense System in Being*, vol. 3 of *History of the Continental Air Command for 1 January–30 June 1950* (Mitchel AFB, NY: Directorate of Historical Services, Headquarters, Continental Air Command, n.d. [1950?]), AFHRA (0198819).

"augmentations" that might eventually bring the defense net alongside the idealized radar-fence.[91]

The National Military Establishment signed off on the Modified Plan together with LASHUP in October 1948, which the Air Force took to Congress in January with a request for $85 million divided between the next two budget cycles. Although the authorization did pass in March, the bill declined to appropriate any money explicitly and thus left the schedule exposed to the vagaries of budgetary politics. For Fiscal Year 1950, USAF had to shunt $50 million from its other accounts in order to cover the initial construction costs. Even the announcement of a Soviet atomic explosion on September 23, 1949 did not galvanize so much as shuffle priorities. The Interim Plan slipped further behind as the deadlines advanced, mostly due to production shortfalls.[92] It ultimately achieved the milestone of 75 completed—though by no means effective—new stations, but as the "interim" label suggested, the Air Force had only teased the "system in being."

4 Conclusion: A nucleus for command-and-control

Ideas about an "integrated" continental air-defense system changed little between 1945 and 1950. The most important problems at the end of the decade—radar coverage, ground control, unity of command, interagency coordination, and so on—had all been diagnosed well before the end of World War II. Of these, radar coverage received disproportionate attention. As the attack on Pearl Harbor had shown, radar, though quite obviously *necessary*, was ultimately insufficient to ensure the overall effectiveness of an air-defense network. In

91. Winkler, *Searching the Skies* surveyed the sites constructed and equipment installed in connection with these programs, though most of the information appears to have been harvested from *Aerospace Defense Command Statistical Data Book: Radar*, vol. 3 of *Historical Data of the Aerospace Defense Command, 1946–1973*, ADCHO 73-4-12 (Ent AFB, CO: Office of Command History, Headquarters, Aerospace Defense Command, April 1973), AFHRA (1006100).

92. Once again, while Bagwell and Miller, *Case History of the AC&W System*, vol. 1, Narrative, AFHRA thoroughly documented the corresponding plans, budgets, and procurement contracts through its supporting volumes, the piecemeal and recondite nature of these sources makes the derivative works cited more intelligible on the whole.

the Pacific Northwest, for instance, many AC&W personnel were in fact highly proficient at operating and maintaining the equipment but lacked experience functioning as part of a command organization that incorporated multiple elements of telecommunication, military force, and civilian liaison. On the ground, "integration" made sense in terms of organization.

This interpretation also held for those responsible for both short- and long-term planning, at least within the Air Defense Command. The uncertainty and instability that beleaguered ADC–ConAC from 1946 to 1952 left a large bureaucratic space open to annexation by other agents, who tended to claim it for their own idiosyncratic concerns. Thus, radar technology, with its wide range of military applications, became the overriding concern, as opposed to organizational integrity. The process is understandable in light of the Air Force's immediate postwar predicament which, like the other armed services, faced unexpectedly stiff austerity measures from Congress and the Truman Administration.[93] Budget scarcity naturally drove officials whose interests overlapped with radar development to argue that air-defense needs would be more economically discharged in combination with closely related programs. Moreover, with operational activities curtailed so severely, policies formulated in Washington were necessarily future-oriented. Air Force headquarters could take minimal action on radar procurement without a large appropriation from Congress, but it could control its basic research and development priorities.

The importance of these events lies in the fundamental contradiction they would pose for national-security politics and technology management after the Korean War. To start, Air Force planners did well to realize early the unavoidable interdependencies between air-defense technologies, organizations, and related instruments of national security and transportation, such as civil defense and air-traffic control. More than mere cost-saving measures, questions of technical, political, and bureaucratic "integration" in continental

93. See the preceding note on President Truman's relationship with the 80th Congress, particularly as characterized in Hogan, *A Cross of Iron*.

defense would recur throughout the 1950s. At the same time, however, Air Force leaders continued to assert their dominance over the issue, which directed their focus toward internal programs and initiatives—a general though by no means inevitable symptom of the interservice rivalries that raged so intensely during the immediate postwar period.[94] The irony is that, as a young organization in an uncertain environment, the Air Force had yet to rationalize its own apparatus for planning, budgeting, and monitoring technology developments, or even maintaining basic operational readiness. Senior officials greatly increased their support for the air-defense mission after securing organizational independence, but as experts primarily in strategic bombing, few of them knew how to support it effectively.[95]

Thus, the first towers to rise in the "permanent system" also became the first stakes to fasten the Air Force of the future to the hurried decisions of the past. While some professionals recognized and sought to minimize this potentiality with their incremental

94. Virtually all of the literature cited above touches on some aspect of the notorious "interservice rivalries" exhibited most acutely during the early Cold War. It is worth noting, however—especially for future chapters—that explanations of the conflict tendency in American military politics tend to fall into two categories. The assumptions of "bureaucratic politics," in the tradition of such publications as Graham T. Allison, *Essence of Decision: Explaining the Cuban Missile Crisis* (Boston: Little, Brown, 1971) and Morton H. Halperin, *Bureaucratic Politics and Foreign Policy* (Washington: Brookings Institution, 1974), have generally predominated; in particular, Keith D. McFarland and David L. Roll, *Louis Johnson and the Arming of America: The Roosevelt and Truman Years* (Bloomington: Indiana University Press, 2005) is highly relevant to the above discussion of budgetary politics, though it is merely representative of a rather large body of work. On the other hand, a relatively smaller corpus emphasizes differences in doctrine, institutional culture, and the immaturity of the early defense organization; for instance, Kenneth Allard, *Command, Control, and the Common Defense*, rev. ed. (1990; Washington: National Defense University Press, 1996). Since the two views are more complementary than contradictory, the analysis here will incorporate elements of both.

95. The literature on air-power theory and the mentality of the USAF's founding leadership is relevant but too vast to detail. Futrell, *Ideas, Concepts, Doctrine* has been a standard reference for the "orthodox" interpretation, which has steadily accumulated publications—including the specialty journal, *Air Power History*—since the argument over the decisiveness and morality of the Allied air campaigns began immediately after World War II. However, Michael S. Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven: Yale University Press, 1987) and Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914–1945* (Princeton: Princeton University Press, 2002) are now well established as counterweights in a diffuse critique that has more recently provoked an intriguing strain of revisionism within the Air Force's intellectual culture as well; for instance, Mark Clodfelter, *Beneficial Bombing: The Progressive Foundations of American Air Power, 1917–1945* (Lincoln: University of Nebraska Press, 2010). The emphasis here, though, is less on doctrine and strategy than organizational development, a peripheral concern in the air-power literature, with the exception of the Strategic Air Command and its antecedents. While characteristically sanguine in outlook, and concerned more with personalities, George M. Watson, Jr., *The Office of the Secretary of the Air Force, 1947–1965* (Washington: Center for Air Force History, 1993) leaves an unusual impression of the department's central administration.

approach to system-building, an interim solution often becomes the permanent one. They may well have intended to design a defense net that could be flexible and scalable, but the reality of infrastructure is that future developments must always build on or around it to some extent. Even the ostensibly "revolutionary" change of computer automation could not reimagine the continental-defense program from first principles, since it had to rely on the same installations and many of the same personnel trained in a relatively static theory of operations. During the lengthy transition period, for instance, automated control-centers would have to interoperate with manually operated ones, a legacy that continued to register long after the old ones shut down.[96]

What did change between 1945 and 1950 is that the United States Air Force came to possess an air-defense "nucleus," however modest in extent, that it could begin applying to real operational activities. Arguments that could previously appeal only to a limited wartime experience, or else gesture vaguely at the abstract, would soon collide with observable results, as well as tangible consequences. During the Korean War, interest in the issue expanded beyond the Air Force, beyond the Department of Defense, growing large enough to include concerned scientists and the public at large. Air-defense officials faced the double bind of having to exploit their operational unreadiness for political leverage while, at the same time, expressing sufficient confidence to reassure a nation anxious enough to remove organizational power from their hands.

Indeed, the tension between so-called "evolutionary" and "revolutionary" change became so ubiquitous that it may well represent the central theme of what we now call "com-

96. A classic example of a "reverse salient," as identified by Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins University Press, 1983). It is worth remarking, however, that the dialectic between "evolutionary" and "revolutionary" change in nuclear command-and-control systems, which will continue in later chapters, may be construed as an unusual sensitivity to the phenomena of "path dependence" and "technological inertia" on the part of civilian experts and military officials, as well as a means of contextually exploiting the natural tension of system development in order to achieve a desired bureaucratic outcome. This is similar to the thesis advanced in Edward W. Constant II, *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins University Press, 1980) about the *ex ante* constraints on technological choice even when the appearance of reverse salients can be anticipated, except that in this case, the deferral of choice itself defined the "evolutionary" strategy, leading to a period of resistance and confusion when "revolutionary" changes could be avoided no longer.

mand-and-control systems." The discourse slips freely between them, emphasizing the pole most advantageous to its specific invocation, with no regard for coherence or consistency. Drastic shifts, such as the later introduction of computer automation, have at times been sold as merely "evolutionary" developments, while those of clearly lesser significance brand themselves indiscriminately as "revolutionary."[97] So while the immediate postwar years may seem to demand little intrinsic interest, due to the lack of appreciable movement on the issue of continental defense, it did, in fact, provide the rhetorical archetype for virtually every program that followed.

97. Cf. David E. Pearson, *The World Wide Military Command and Control System: Evolution and Effectiveness* (Maxwell AFB, AL: Air University Press, 2000), 343–358.

Chapter 3

Holes in the Sky

Air-Defense Operations Before Automation

> And along with all this better equipment, you, the individual, will have to be a better man. You will need to be better trained, more technically skilled, more resourceful, and more intelligent. You will have to become a better leader because you will fight in more dispersed and more concealed units. You will have to be better trained and more intelligent and resourceful because there will be little time to train you once hostilities begin. In an age of more fearsome weapons, and as we approach the era of push-button warfare, the individual becomes *more*, not less important.[1]
>
> "Push-Button Warfare," *Armed Forces Talk* no. 202, 1947

Few metaphors evoke the "openness" of open skies. In the brightness of daylight, a lonely aircraft appears as if suspended in empty space, naked to observation, and assailable from all directions. Such an intruder would seem to have nowhere to hide. Of course, the sky is both sunlit and clear less than half the time on average, but even visibly obscured, surely an all-metal airframe, bristling with reflective protuberances, cannot evade the illuminating gaze of microwave radiation. And indeed it cannot, insofar as the principle holds in practice. As should have become by now apparent, though, to perceive the air as a battlefield is to be

1. United States Army, Special Staff, Army Information Branch, Troop Information and Education Division, "Push-Button Warfare," *Armed Forces Talk* no. 202 (Washington: GPO, [December?] 1947), OCLC (940334655), 6. The War Department, and later the Department of the Army, distributed didactic pamphlets in the *Armed Forces Talk* series roughly once per week. They were intended as guides for officers to inform enlisted men of major events with military significance in an open-discussion format, including notes for handling questions and concerns.

anxiously aware, and perhaps slightly paranoid, about how often the principles do *not* hold in practice. To the air-defense commander, even open sky is as dense as a thicket, a radio-frequency jungle choking with figments and shrouded in meandering glooms, in which a sufficiently nimble aircraft can dangle as precariously between perception and illusion as an enemy soldier creeping indistinctly through the underbrush.

After the end of World War II, the American military seriously confronted, for the first time, the problem of defending its home skies. Officers charged with this responsibility knew that the surface area of the continental United States exceeds 3.1 million square-miles. It is also a curved and fractured surface, a pseudospherical region riven and palpitating with hills, mountains, rivers, lakes, valleys, and basins. What the radar sees, even atop the highest peak, is, roughly, an inverted cone, warped by the earth's receding slope, where the terrain casts shadows over large volumes of airspace, and the skies reverberate with random backscatter. The greater the distance from the receiver, the higher the altitude concealed, which is furthermore difficult to measure due to the effects of atmospheric refraction.[2]

Moreover, atmospheric propagation is so important to the effective "radio horizon" that the detection radius can vary wildly and almost unpredictably with the weather. In ideal conditions, a war-vintage radar might sweep out an area as large as 75,000 square-miles, but detection at any altitude, in any conditions, could only be assured in a small fraction of the total volume—presuming an enemy did not actively obscure its movements with RF noise or clouds of reflective metal strips called "chaff."[3]

2. While any textbook on radar theory will confirm the fundamentals, Louis N. Ridenour, ed., *Radar System Engineering*, MIT Radiation Laboratory Series, No. 1 (New York: McGraw–Hill, 1947) represents the state of technical development during the period under discussion.

3. In the decade after the war, techniques of what is now called "electronic warfare" (EW), which broadly includes the categories of "electronic countermeasures" (ECM)—equipment designed to frustrate an enemy's detection or communication capabilities—and "electronic counter-countermeasures" (ECCM)—equipment designed to mitigate an enemy's ECM—were secrets more closely guarded even than radar and less frequently discussed in the open literature. During the war, OSRD's Division 14 went so far as to devolve ECM research from the MIT Radiation Laboratory to the much smaller Harvard Radio Research Laboratory, less for security purposes than to prevent one group of engineers from anticipating the deceptions of the others. While dated now, Alfred Price, *Instruments of Darkness: The History of Electronic Warfare, 1939–1945*, rev. ed. (1967; London: Greenhill, 2005) is one of the few non-textbook sources on EW during this era.

So while a credible air defense for the United States clearly depended on high-performance, well-maintained, and meticulously calibrated radar, equipment was merely the first prerequisite. In order to screen a large area from attackers, official doctrine called for teaming multiple, geographically separated radar emplacements, with overlapping radiation patterns, together into a continuous "radar fence." Forming a complete "picture" of the defended airspace thus required an organizational process for relaying observations from distant outposts and then collecting and displaying them in places where decisions were made. All of these actions were highly interdependent and attended by inherent uncertainties, especially when they had to be performed exclusively by hand and voice.

Even when the equipment performed well and the operation proceeded smoothly, radar could only signal the existence of airborne objects, not determine their identities. Tracks could be correlated with known flight plans, but this required a reliable liaison with the agency responsible for them. Pilots could be raised by radio, but this required extensive air-to-ground communications. And though some military aircraft carried self-identifying transponders, many did not, and domestic airspaces teemed with private and commercial traffic all the while.[4]

In short, filling holes in the sky depended as much on communication and coordination as it did radar, and yet even the best set-ups could only generate a *pattern* of uncertainties,

4. United States Air Force, Air University, Evaluation Division, *Air Defense Tactics—Techniques: A Staff Study*, January 1, 1948, annex #7 to OPD file no. 373.24 (3 May 46) Sec. 1 (oversize), RG 341, NM-15 335-A, box 308 is a critical source for the remainder of this chapter, although as a very lengthy document, it will only be cited specifically as needed. Internal evidence suggests that the faculty of the Air University prepared the study as the first stage of a process that often resulted with codification in an official Air Force Manual (AFM). As the next step, a working group at USAF headquarters heavily revised the Air University material, yielding United States Air Force, Air Defense Committee, Tactics Panel, *Air Defense Tactics—Techniques: A Study of Air Defense Means and Standing Operating Procedures for Units Employed in Air Defense*, July 1, 1948, annex #10 to OPD file no. 373.24 (3 May 46) Sec. 1 (oversize), RG 341, NM-15 335-A, box 308. This version showed more polish but less comprehensiveness, containing only a small amount of information not covered more thoroughly in the original. The process appears not to have advanced any further, however; markings on the latter indicate it may have been circulated within the Air Defense Command, but the Air Adjutant General never published it as an AFM. It bears remarking that the original document was still a field study, and thus, observational and reductionist, calculated to produce a "lowest common denominator" for practice service-wide. The standard operating procedures for each facility in the AC&W network would have actually been a binder full of continually updated directives issued by lower headquarters.

discernible through experience, not eliminate them altogether. The worst of them reduced any sense to mere guesses. Commanders knew their plotting board captured only a shadow of the events in the air, with any contact potentially suspect; each speed, heading, and altitude clouded by limitations in the equipment and the reporting system, and the entire representation delayed by some unknowable period of time.

Thus, the study of air-defense operations accelerated as quickly as site teams could initiate services on the LASHUP network and phase them over to the Permanent System. Previous budgets had not allowed for comprehensive testing at any scale, so the operational exercises conducted during 1949–1950 were the Air Force's first clinical encounters with the full range of symptoms that a "system-in-being" could present. Expectations dimmed accordingly; indeed, officials took care to manage public perceptions by branding the operations as routine training actions, rather than "tests" or "exercises."[5] The Continental Air Command knew it was unready to begin defending the regions where it staged its first large-scale maneuvers, but it badly needed to identify its most grievous organizational and technical problems in order to their prioritize their improvement, or, at the very least, learn its limitations well enough to adjust to them.[6]

5. A week before DRUMMERBOY was scheduled to begin, a cable from Air Force headquarters stipulated that "publicity releases related to ConAC's Northwest Maneuver...make it advisable to reiterate that this is a training exercise only, and is in no way a test either of the Northwest Air Defense System or of the ability of SAC units to penetrate that system." TWX, Headquarters, United States Air Force to Commanding General, Strategic Air Command, copy to Commanding General, Continental Air Command, 10:15 PM UTC, October 24, 1949, exhibit in Thomas A. Sturm, *History of the Continental Air Command, 1 December 1948–31 December 1949*, vol. 3, pt. 2, Operations and Training (Mitchel AFB, NY: Directorate of Historical Services, Headquarters, Continental Air Command, n.d. [1950?]), AFHRA (0198810). Indeed, SAC's competence was in just as much question as ADC's at the time, with even greater political stakes. Cf. Harry R. Borowski, *Hollow Threat: Strategic Air Power and Containment Before Korea* (Westport, CT: Greenwood, 1982); William S. Borgiasz, *The Strategic Air Command: Evolution and Consolidation of Nuclear Forces, 1945–1955* (Westport, CT: Praeger, 1996).

6. Recall the subtle distinction between the Air Defense Command and the Continental Air Command explained in the previous chapter. Briefly, ADC was reduced from a major command to an operations staff, within ConAC headquarters, on December 1, 1948; it was abolished entirely on July 1, 1950 only to be reestablished, independently of ConAC, just six months later, on January 1, 1951. To simplify the narrative, the text prefers to conflate "ADC–ConAC" during this period, but sources quoted directly may refer to one or the other without consistency.

1 A system-in-being

This chapter adopts a perspective that is more interactive than comprehensive. In one sense, it means simply to explain how a manually operated air-defense system works. Who performed what kind of labor, with which materials, and in what sort of spaces? Central to this explanation, however, is the recognition that from the defender's view, an air battle is a rapidly evolving puzzle with no solution—only a range of possible responses, which, like the situation itself, compound from minute to minute. The goal is not necessarily to repel the invaders, but to frustrate them, disrupting their operations, forcing them to sacrifice offensive capabilities to protect their own aircraft, and dissuading an enemy from striking repeatedly without fear of substantial attrition.[7] While an opponent's plans might be broadly anticipated, each situation presents an element of novelty to which the defenders must instantaneously adapt.

As such, the nature of "command" in an large area-defense net is rather difficult to isolate, because discernment and discretion are both widely distributed among the ground and air crews, and even relatively routine judgments can induce broad systemic effects. Of course, the shadow of automation hangs portentously over the subjects in this chapter, but as its realization still seemed distant in 1950, that issue specifically will be deferred for now. Nevertheless, the course of mechanization followed perceptions of human deficiency introduced here, such that manually operated air-defenses provide the essential framing for the outcomes obtained later with respect to automatic control.

The years between 1948 and 1951 represent a key period of transition, when the Air Force consolidated its combat units together with their support organizations, a solution that had been infeasible within the former War Department. The first section describes a series of air-defense tests conducted in the Pacific Northwest in the midst of this continuing

7. A statement of doctrine from 1942 asserted that "the permanent effects of air combat are measured in terms of attrition of the forces engaged and reduction in vigor of the enemy's air operations." United States Department of War, *Tactics and Technique of Air Fighting,* Army Air Forces Field Manual (FM) 1-15 (Washington: GPO, April 10, 1942), 1, OCLC (952483809).

field reorganization. While the new policy greatly benefited the majority of Air Force units—especially bombardment wings, whose home bases could reasonably be confused with small cities—the task of defending an extended airspace required dispersing surveillance stations, as well as isolated squadrons of interceptors, across wide areas, a necessity not easily reconciled with the new correspondence between "wing" and "base."

The discrepancy gave rise to a peculiar dual command structure, specific to air defense, with significant consequences for training and organizational policy. Nevertheless, the tests performed during 1949–1950 represented the nation's first practical experience with air defenses on a scale comparable to the Royal Air Force's studies and evaluations preceding World War II. While many of the problems had been anticipated, the staging of these exercises was conceived as a sort of laboratory for experimenting with organization and procedure, not to mention a singular opportunity to train and familiarize pilots, ground controllers, and liaison officers with coordinated operations.

Consistent with their notion of an "integrated system," as explained in the previous chapter, air-defense officials maintained that such instances of "system training" cultivated skills distinct from proficiency with individual equipment or technique. Despite signs of incremental progress, however, the results inspired little confidence in operational readiness, especially because sufficiently realistic situations had proved so difficult to stage. Doubtful that resources could keep pace with expansion, officials hoped that simulation could replace costly cross-agency exercises as their primary method of crew training.

The second section considers the problem of reproducing the stress of battle on an air-defense operations center—which had to occur increasingly often, as more and more sites came online—but sparing the prohibitive cost of large-scale, live exercises. While genuine maneuvers could never be totally supplanted, their results would additionally serve to refine the assumptions upon which progressively more realistic system-training drills could be devised. During the era of hand-operated air-defense networks, simulation did not yet imply *computer* simulation, but the task of generating the thousands of data points needed to realistically mimic the appearance of fast-moving radar contacts, even over an interval as short as one hour, did require mechanical assistance.

As air-defense officials turned to the RAND Corporation for help with producing this data, as well as the equipment to overhaul their training methods nationwide, researchers themselves became interested in simulated exercises as a means to develop their own theories of "man–machine systems." But even though RAND's "air-defense experiments" proved highly influential the emerging fields of social psychology and systems engineering, the research itself told the Air Force little it had not already known for years. They were more than pleased, however, to adopt these "findings" in order to lend scientific legitimacy to the air-defense program in the eyes of the public as well as those of crews in training, thereby accelerating a trend toward the computerization of military operations in general.[8]

2 Postwar air-defense organization and exercises

Despite several earlier attempts, the Air Force neglected to publish an official statement of its air-defense doctrine until 1953.[9] While delicately restating the primacy of the offensive,

8. As well as Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996), 43–71, which was mentioned in the introduction, it is also worth considering Eric Schatzberg, *Wings of Wood, Wings of Metal: Culture and Technical Choice in American Airplane Materials, 1914–1945* (Princeton University Press: Princeton University Press, 1999). In particular, Schatzberg showed how the pursuit of cultural signifiers of progress and modernism can influence or even override technical and economic considerations—in his case, an exuberance for engineering all-metal airframes because wooden structures had become associated with obsolescence in other applications, such as naval architecture. Likewise, computer automation still had more to prove than it could claim to its credit even by the mid-1950s, and yet it received the benefit of every doubt due to a persistent bias in favor of its cultural signifiers. The conclusion to this chapter will meditate further on this point specifically.

9. The lateness of the date is unremarkable in itself. After separating from the Army in 1947, the USAF lagged in codifying its basic military doctrine until an embarrassing performance in Korea forced a brief reassessment, which ultimately circled back to the service's long-held presumptions anyway: James A. Mowbray, "Air Force Doctrine Problems, 1926–Present," *Airpower Journal* 9, no. 4 (Winter 1995): 5–8; see also Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force*, vol. 1 of (1971; repr., Maxwell AFB, AL: Air University Press, 1989), 190–203. Before this time, air-defense doctrine was still taught from United States Department of War, *Air Defense,* Army Air Forces Field Manual (FM) 1-25 (Washington: GPO, June 15, 1943), OCLC (56664963), which deferred most questions to the level of theater command. For illustrations of how this was handled in practice, cf. United States, Department of War, Headquarters, Army Air Forces, *Condensed Analysis of the Ninth Air Force in the European Theater of Operations* (1946; repr., Washington: Office of Air Force History, 1984).

the document showed that their roles as aggressors had taught even the most hardened bomber-generals how defensive measures, though perhaps unable to *stop* a sufficiently large raid, could favorably influence the attacker's *decisions*. "Air defense forces, in place and prepared for operations, are capable of exerting significant deterrent pressure against the enemy even before attack occurs," the manual read, because "the capability for effective defense confronts the enemy with the immediate threat of high losses in his attacking forces."[10]

The statement recalled the bloody fall of 1943, when severe attrition caused the Eighth Air Force to abandon bombing targets in Germany beyond the range of its fighter escorts.[11] The threat of interdiction, moreover, "imposes certain restrictive conditions upon the enemy and to a degree limits the courses of action that his forces can employ against the defended territory," such as by compromising the performance, payload, or path of the attacking aircraft in order to accommodate the weight of additional armor, guns, and other countermeasures needed for their self-protection. Perhaps most importantly, "an air defense system in being greatly reduces the enemy's chances of achieving an initial advantage through surprise in the first attack and may cause so many complications in his operations that major failure will occur," complications the Imperial Japanese Navy surmounted unopposed during its attack on Pearl Harbor.

So despite their overwhelming preference for the offensive, senior Air Force officials were nonetheless conscious of both the strategic and tactical value of a comprehensive air-defense network on the American continent. Indeed, even a decade after the first atomic bombings, nuclear weapons had yet to alter their mentality that air wars were still wars of

10. United States Department of the Air Force, *Air Defense Operations*, Air Force Manual (AFM) 1-8 (Washington: GPO, April 4, 1954), MSFRIC, 2.

11. The campaign culminated in the notorious Second Raid on Schweinfurt on October 14, a daytime attack on the German ball-bearing industry in which the defenders destroyed 71 of the 291 bombers launched against the production facilities and damaged an additional 121—killing over 650 American servicemen in a single mission. As a result, the Eighth Air Force decided not to attempt raiding targets located deep in defended airspace again until 1944, when long-range escort fighters first became available in sufficient quantities. Wesley Frank Craven and James Lea Cate, eds., *Europe: TORCH to POINTBLANK, August 1942 to December 1943*, vol. 2 of *The Army Air Forces in World War II* (1949; repr., Washington: Office of Air Force History, 1983), 696–706.

attrition, in which the adversary's air-defense systems "in being" could powerfully shape the execution of their respective campaigns.[12] But military doctrine is merely a collection of formalistic assertions about what wars are like, and how they may be lost and won. Although they are subjects for instruction and guides to strategy, policy, and organization, doctrines specify none of these in detail sufficient for action, neither do actions consistently interpret the official doctrine.[13] The *fact* was that the War Department expended little effort to preserve even the token defenses deployed during World War II, and as such, any high-level discussion of an air-defense "system in being" remained mostly speculative.

The threat to North America was then as yet so incredible that officials still anticipated an extended mobilization period to precede the commencement of major hostilities. National policy likewise reflected an attitude that defending the homeland was still the business of a militia, with ambitions, priorities, and budgets all constrained accordingly.[14] Moreover, due to the preeminence of strategic-bombing operations, air-defense commanders were preparing to accomplish a task that fit poorly within the Air Force's organizational scheme as a whole.

The Hobson Plan and air-defense "para-organization"

In 1948, following a year of trials, USAF headquarters directed its major commands to begin reorganizing units according to the so-called "wing–base plan." Also called the "Hobson plan" after Colonel Kenneth B. Hobson, whose office performed a series of field-organization studies between 1945 and 1947, the wing–base configuration intended to remedy several artifacts the Air Force had inherited from its former subordination to the United States

12. Cf. Edward Kaplan, *To Kill Nations: American Strategy in the Air-Atomic Age and the Rise of Mutually Assured Destruction* (Ithaca: Cornell, 2015).

13. The concept of "doctrine" remains an enduring source of lucubration in military-philosophical discourse, though in the field of security studies, Barry R. Posen, *The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars* (Ithaca: Cornell University Press, 1984) is the classic text.

14. Cf. Richard F. McMullen, *Air Defense and National Policy, 1945–1950,* ADC Historical Study No. 22 (Ent AFB, CO: Headquarters, Air Defense Command, 1964), OCLC (18906119).

Army. Prior to adopting the Hobson plan, the Air Force's basic field element had been a unit called the "group," which usually consisted of three or four "squadrons" that reported to a group headquarters. Although individual airmen typically confederated within their squadrons, the group performed a single mission (e.g. pursuit, bombardment, photographic reconnaissance, etc.) related to the type of aircraft with which its squadrons had been equipped.[15]

This was analogous to the correspondence between regiment and company in the Army infantry: soldiers congregated into companies, while companies typically acted together under the direction of a regimental headquarters. Like the regiment, the AAF regarded the group as the fundamental unit of its overall "force structure." An entire group would be planned, raised, trained, equipped, and deployed overseas together as one, while the number of groups assigned to a high-level commander provided a baseline measurement of total strength.[16] Altogether, a combat group roughly corresponded to the facilities and complement of a single airfield, which could generally support between 1,500 and 2,500 uniformed personnel and 36 to 72 aircraft.

Owing to its interdependence on the Army, however, a group was neither self-contained nor self-sufficient. For instance, the Medical Corps typically detached a dispensary unit to provide basic and emergency medical services; the Army also provided MPs, quartermasters, engineers, and performed other base-support functions such as finance, supply, and fire protection, depending on a variety of local circumstances. In many situations, the commander of the group *using* the base had little to no control over the running of the

15. The wartime field-organization was defined in the Army Air Force Regulation (AAFR) 20 publication series, an extensive set of documentation that is not readily available outside the Air University's library and archives, though many of them were glossed for the wartime publication of *The Air Force in Theaters of Operations: Organization and Functions*, 6 vols. (Washington: Headquarters, Army Air Forces, 1943), OCLC (8271514). However, it is described adequately in Maurer Maurer, ed., *Air Force Combat Units of World War II* (1961; repr., Washington: Office of Air Force History, 1983), 1–14; Martin W. Bowman, *The USAAF Handbook, 1939–1945* (Mechanicsburg, PA: Stackpole Books, 1996), 37–57; *The Official Guide to the Army Air Forces: A Directory, Almanac, and Chronicle of Achievement* (New York: Simon & Schuster, 1944), 8–37.

16. On the training of air and ground crews, see Wesley Frank Craven and James Lea Cate, eds., *Men and Planes*, vol. 6 of *The Army Air Forces in World War II* (1954; repr., Washington: Office of Air Force History, 1983), 600–673.

base itself, causing officials from different Army branches to contend over facilities and resources that directly affected the group's flying activities.[17]

Nowhere was this contested so fiercely as in the case of maintenance and materiel, where group commanders continually found themselves negotiating with service representatives over supplies, procurement, munitions-handling, and repairs. While day-to-day issues were most often worked out informally on-site, official points of contact between combat and service organizations could only be found at awkwardly rarefied heights of command, usually at the level of the theater itself. Ultimately, however, arrangements varied from theater to theater and even station to station, an unsightly lack of standardization that Hobson's studies both identified and sought to redress.[18]

Broadly speaking, the wing–base plan accomplished two things. First, it abolished the combat group as the Air Force's primary structural element and replaced it with the "wing": a more comprehensive unit that combined one or more combat squadrons, one or more maintenance and supply squadrons, and an airbase group under a single wing headquarters. Second, the base commander, who led the airbase group, reported directly to the wing commander, thereby consolidating all operating and supporting activities at a particular installation under a single authority.[19]

Although some important details varied with time and place, the change generally realigned the Air Force's field organization to correspond with its physical installations; at a

17. Accounts of jurisdictional conflicts over airbase facilities during World War II are spread throughout the official histories of the various Army branches, as well as the AAF's own series; among them, John D. Millett, *The Organization and Role of the Army Service Forces,* The United States Army in World War II: The Army Service Forces, CMH Pub 3-1 (1954; Washington: US Army Center of Military History, 1987), 124–137 has the highest density of information.

18. For instance, the Army in the European Theater never followed War Department policy for the maintenance and supply of air units, concluding formally that its own regulations were superior to those issued from Washington: *Organization, Operations, and Equipment of Air-Ground Liaison in All Echelons From Divisions Upward,* General Board Report No. 21 (Frankfurt, Germany: United States Forces, European Theater (USFET), G-3 Section, n.d. [1946?]), OCLC (18567318). See also Craven and Cate, *Men and Planes,* 362–397.

19. Gary D. Sheets, *A History of Wing–Base Organization and Considerations for Change,* Air War College Research Report No. 474 (Maxwell AFB, AL: Air University, April 1978), 4–37, DTIC (ADB029124); Borowski, *Hollow Threat,* 61–68.

standard airbase, in other words, the wing controlled everything from fence to fence. Of course, the wing still depended on regional depots for supplies and heavy maintenance, training centers for personnel, and so on, but the unit was considered self-sustaining in that it could, in principle, pack itself up and redeploy to another station (leaving the airbase group behind), affording some measure of mobility for what was effectively a mid-sized municipality.[20]

Hobson's recommendations had followed mainly from the experience of bomber units and intended to benefit them most of all. Once the Eighth Air Force deployed to England in 1942, for example, airfields resembled the operating activities of a large industrial firm, such as a mine or assembly plant, and so it made sense to build them up functionally, homogeneously, and as self-sufficiently as possible.[21] Geography presented only relatively minor concerns, because the distance between airfields was typically small compared to the flying radius of the aircraft they stationed.

The wing–base plan served a strategic-bombing organization well, but an *air-defense* organization, on the other hand, was by nature heterogeneous, interdependent, and heavily constrained by the geography of the area to be protected. As one study of doctrine explained:

> In air defense the principal equipments employed in discharging the functions of surveillance and control are the ground based radars, operations rooms, telephones, and radios. The geographical organization of an air surveillance system is therefore keyed to the reliable range of radar detection; reliable range of GCI control, and the target and communications traffic handling capabilities of a single radar station. These capabilities largely determine both the geographical disposition of the systems' radar components and the composition of its military organization.[22]

Thus the fundamental "unit" in an air-defense network corresponded to the detection radius

20. This was defined in United States Air Force, "Organization of Air Force Combat Wings," Air Force Regulation (AFR) no. 20-15 (Washington: Department of the Air Force, December 13, 1948) in Air Force Policy Book, "Organization," 0-1 to 0-25, loose-leaf binder [n.d.], NARA, RG 341, NM-15 339-A, box 6, the regulation that implemented the Hobson Plan.

21. Cf. Wesley Frank Craven and James Lea Cate, eds., *Plans and Early Operations, January 1939 to August 1942*, vol. 1 of *The Army Air Forces in World War II* (1948; repr., Washington: Office of Air Force History, 1983), 612–654.

22. Air Defense Command, *Air Defense Tactics*, RG 341, 36.

of an individual radar station, which meant that the whole would have to be organized around the geographic distribution of physical facilities, not the other way around.[23]

Moreover, an area defense called for dispersing relatively small contingents of interceptors—usually not more than a squadron of one or two dozen aircraft—at stations spread throughout the defended region, rather than concentrating large fleets of aircraft at isolated bases. Since squadrons were too small to justify installations of their own, commanders had to negotiate with each base's primary tenant—usually, other Air Force units—in order to provide facilities, logistical support, and runway rights, reproducing many of the same problems the Hobson Plan had been intended to solve. To name one example, base commanders typically required pilots to prefile a flight plan if they needed to fly beyond a 100-mile radius of the airfield. While intended to discourage costly long-distance "joy rides" among pilots who needed the flying hours to maintain an active flight-rating, the restriction also rendered realistic "scramble" drills virtually impossible, since a simulated attack vector would intersect the pre-authorized flying area for only a few minutes.[24]

Consequently, a sort of "para-organization" evolved in order to reconcile the atypical form of an air-defense network with the push for standardization in the field. Air-defense commanders preferred to organize operations and training around the "sector," a geographical area that corresponded roughly to the detection range of a particular GCI (ground-controlled interception) station and any peripheral stations reporting to it. A GCI employed both a high-power search radar and a supplemental height-finding radar in order to vector interceptors to their targets; a search radar alone could only relay early-warning information, or in the case of a lower-powered set, fill gaps in the primary station's radiation pattern.

23. While the preceding document was never officially promulgated (see note above), United States Air Force, Air Defense Command, *Organization and Functions for Air Defense*, Air Defense Command Manual (ADCM) 50-3 (Colorado Springs: Headquarters, Air Defense Command, October 25, 1951), MSFRIC affirmed the same basic principles of air-defense organization, though as a publication immediately following the reestablishment of the Air Defense Command in January 1951, its specific provisions superseded the problematic "para-organization" discussed here.

24. Thomas A. Sturm, *History of the Continental Air Command, 1 December 1948–31 December 1949*, vol. 3, Operations and Training (Mitchel AFB, NY: Directorate of Historical Services, Headquarters, Continental Air Command, n.d. [1950?]), AFHRA (0198809), 70–71.

The observation post at a GCI station doubled as the sector's operations room, called an Air Defense Direction Center (ADDC).[25]

Ideally, several partially overlapping sectors would cast a continuous radar screen across a larger region: the air-defense "division," whose operations room was known as an Air Defense Control Center (ADCC). Unlike a direction center, however, the control center lacked any detection equipment of its own; rather, the division received flight-track information indirectly from its reporting sectors. Typically, a sector or division staffed its operations room with personnel "dual-assigned" from an aircraft control and warning (AC&W) squadron attached to the post. In all other capacities, however, the squadrons reported to an AC&W group spread across a region parallel to, yet independent from the air-defense division.[26]

In other words, the division "owned" the aircraft-warning network *as a system* while lacking any control over the pieces. All the AC&W groups and fighter wings in a division's operating area officially reported to the local numbered air force, outside the air-defense chain-of-command. The division commander, for instance, could not unilaterally redistribute interceptors at bases throughout the region in order to concentrate forces against an anticipated attack.

An elegant wing–base organization this was not. Each unit served two masters: one for administrative and specialty-training purposes, the other for so-called "system training" and combat if it were to come about.[27] Nevertheless, every element had to mesh synchronously before ADC–ConAC could even begin to exercise the core system. Since Saville's intervention in 1948, air-defense officials had repeatedly claimed that cultivating proficiencies in

25. See preceding notes referencing both published and unpublished sources of air-defense doctrine and operational procedure.

26. Thomas A. Sturm et al., *The Air Defense of the United States: A Study of the Work of the Air Defense Command and Its Predecessors Through June 1951* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, February 1952), 197–216, OCLC (818296057) synthesized a description of this "para-organization" from passages scattered across ADC–ConAC's semiannual historical reports, some of which are also cited individually here as well.

27. Sturm, *History of ConAC, 1949*, vol. 3, Operations and Training, AFHRA, 65–70.

isolated skills such as scope-reading or air-to-air gunnery would not collectively sum to general organizational competence with the mission at hand. For them, knowledge of the "integrated system" was both distinct from, and irreducible to, knowledge of its constituent systems.[28]

For a commander, "system" was what happened in the operations room, where observers had to anticipate the workload on the tellers, tellers had to modulate reports for the plotters, and controllers needed to learn to think like the pilots they controlled. While operational procedures had already reached a state of relative maturity by 1948, the exercises scheduled for 1949–1950 provided the first opportunity to test and modify them in response to actual experience with the crews and equipment that were beginning to enter the field in quantities substantially larger than at any time since the early days of World War II.[29]

Altogether, the Continental Air Command conducted four operational exercises between June 1, 1949 and June 24, 1950: BLACKJACK, LOOKOUT, DRUMMERBOY, and WHIPSTOCK, in chronological sequence.[30] Operations BLACKJACK and LOOKOUT were staged along the northern approach to the Eastern Seaboard, but the latter two—DRUMMERBOY and WHIPSTOCK—both took place in the Pacific Northwest, and thus provide a useful continuity with the emergency maneuvers surrounding the Hanford Works in 1948. ADC–ConAC had reshuffled the area's tentative organization several times since then, ultimately

28. Recall the discussion of "Interim Program for Aircraft Control and Warning System in the Continental United States and Alaska," transcript of briefing for James V. Forrestal, Secretary of Defense by Maj. Gen. Gordon P. Saville, Headquarters, USAF, September 9, 1948, exhibit 19 in *The Air Defense of AEC Installations, Part 1: 1946–1948* (Colorado Springs: Directorate of Historical Services, Headquarters, Air Defense Command, n.d. [1952?]), AFHRA (0500631), cited in the previous chapter.

29. In addition to the expansion of radar facilities documented in the previous chapter, the number of enlisted personnel assigned to air-defense duties nearly trebled, from 20,974 in mid-1948 to 58,856 in mid-1951, including an influx of 25,143 men during the first six months of 1951 alone. The officer corps likewise expanded, from 3,857 to 7,664, but not quickly enough to keep pace with the size of the total air-defense force. *Aerospace Defense Command Statistical Data Book: Budget, Personnel, and Air Bases*, vol. 1 of *Historical Data of the Aerospace Defense Command, 1946–1973*, ADCHO 73-4-12 (Ent AFB, CO: Office of Command History, Headquarters, Aerospace Defense Command, April 1973), AFHRA (1006100), sec. 3.

30. Sturm, *History of ConAC, 1949*, vol. 3, Operations and Training, AFHRA, 72–86; Thomas A. Sturm, *History of the Continental Air Command, 1 January 1950–30 June 1950*, vol. 6, Operations and Training (Mitchel AFB, NY: Directorate of Historical Services, Headquarters, Continental Air Command, n.d. [1950?]), AFHRA (0198823), 79–89

designating the 25th Air Division as the unit responsible for protecting the Pacific Northwest. Although the division reported to the newly established Western Air Defense Forces (WADF)—an upper tier in the air-defense "para-organization"—all the fighter units in the area still belonged to the Fourth Air Force.[31]

Operation DRUMMERBOY: Coping with para-organization

During DRUMMERBOY, the provisional radar-network first set up in 1948 remained largely the same: the 505th AC&W Group operated the division's two GCI stations near Seattle and Moses Lake, each equipped with an AN/CPS-5 search and AN/CPS-4 height-finding radar, while the sites at Spokane and Neah Bay, still lacking height finders, could only relay early-warning reports. The AN/CPS-5 on the Oregon coastline was moved north to the shores west of Olympia as part of the LASHUP program, which continued to augment the network in the months between DRUMMERBOY and WHIPSTOCK, including the activation of three early-warning stations along the Columbia River between Hanford and the Pacific Ocean. The 25th Air Division, meanwhile, ran an Air Defense Control Center from its headquarters at Paine Field north of Seattle.

Although the division had implemented a "system training" program in mid-1949 to begin familiarizing ground and air crews with integrated air-defense operations, DRUMMERBOY and WHIPSTOCK both overshadowed the routine drills in size and intensity. The plan called for the Strategic Air Command to launch simulated attacks against the Hanford Works, the hydroelectric dams on the Columbia River, Boeing's main assembly plant in Seattle, the Bremerton naval yards, and major airfields throughout the region. Due to the logistical limits on both the attacking and defending forces, however, neither came close to reproducing the conditions of a sustained air-battle, a fact that ramified concerns over the

31. In the following passage, background on the air-defense network in the Pacific Northwest has been drawn mostly from *The Air Defense of Atomic Energy Installations, March 1946–December 1952*, vol. 1, Narrative (Colorado Springs: Directorate of Historical Services, Headquarters, Air Defense Command, 1953), AFHRA (0500632), 13–40.

unimpressive results, despite the generally positive tone of the official reports.

The circumspection in these statements betrayed deep anxiety over the first Soviet atomic-test, announced just two months before DRUMMERBOY, as well as the deepening Korean crisis, which erupted in open hostilities the day after the end of WHIPSTOCK. The Air Force still considered the Pacific Northwest an "active" air-defense area, with 24-hour operations resuming on February 6, 1950 for the first time since the Hanford debacle of 1948. President Truman had banned overflights around the AEC's facilities at Hanford, Oak Ridge, and Los Alamos since the issuance of Executive Order 9925 in January 1948, so ConAC's commander, General Ennis C. Whitehead, began to authorize pilots to fire on aircraft violating the restricted airspace if, in their judgment, they did so with manifestly hostile intent. Air Force headquarters quickly overruled him, likely realizing that ambitious fighter pilots posed a greater threat to civilian air-traffic than a hypothetical Russian strike-force. Nevertheless, the stakes had clearly been raised, with DRUMMERBOY and WHIPSTOCK accelerating the effort to execute the militarily toothless edicts decreed over the preceding years.[32]

During the exercises, officials monitored the interaction between adjacent direction centers, the direction centers and the control center, as well as the performance internal to each, among numerous other factors. Unfortunately, the Continental Air Command had only just established its Operations Analysis Division before the start of DRUMMERBOY, which ran from November 4 to November 14, 1949. Lacking guidance, the participating units reported daily activities too sparsely and unevenly for a satisfactory quantitative analysis; moreover, the same bad weather that had (literally) clouded the Hanford maneuvers also more figuratively fogged over the meager data that could be collected. Instead, the most consequential assessment of DRUMMERBOY appeared in a special report submitted by the

32. *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 1, Narrative, AFHRA, 27–33; or see Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* (Washington: Office of Air Force History, 1991), 122–127.

Air Force's regional inspector, whom ConAC had invited to observe.[33]

While focused mainly on the need for "all-weather" interceptors, the inspectors also seemed thoroughly unimpressed with both the organization and operational procedures for aircraft control and warning. "Exercise 'Drummer Boy' should have been a normal routine operation for the 25th Air Division," they wrote.[34] Although the report acknowledged that DRUMMERBOY itself "was well planned and implemented," it stipulated that "the present air defense establishment, organization, system and procedures appear to be in a nebulous state of transition from the remnants of the World War II set-up toward some ultimate but vague future objective." Consequently, "the temporary active air defenses provided for the Northwest Area during the period of this exercise should not be construed as a measure of air defense in being."

ConAC's peculiar double-organization for air defense received a special excoriation. "The command structure precludes a rapid reallocation or redeployment of forces to meet a surprise attack," the inspectors claimed. "The exercise general mission [*sic*]...is the normal mission of the 25th Air Division, except that it normally operates on the principle of operational control of four fighter aircraft rather than within the maximum capability of fighter aircraft assigned to the Fourth Air Force and deployed in the defended area." Indeed, fighter squadrons had to be selected and specifically assigned to the 25th Air Division for the duration of the exercises, because officially, all combat units in the area still reported directly to the Fourth Air Force.

As explained previously, the abstruse relationship had evolved in an attempt to fit all the pieces of a working air-defense network within the Air Force's regular field organization, but the Inspector General perceived little sense to it. "Air Defense must be prearranged

33. Memo, Frederick M. Varney, Operations Analyst to Deputy for Operations, Continental Air Command, "Operations Analysis, Air Defense," n.d. [October 1, 1949?], exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

34. Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force, "Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

with forces deployed in the best operational facilities and under a single commander with complete jurisdiction over administration, training, operations, and logistics." In aggregate, however, "very little change in operational procedures since World War II was noted," prompting the conclusion that "the planned air defense, organization, and procedures are believed in need of a complete review, analysis and clarification of ultimate objectives."

While the participating air-defense commanders could not have agreed more fervently in the need for permanent, unified command over both air and ground units within their areas of operations, Colonel Clinton D. Vincent, commander of the 25th Air Division, proposed that "it should be borne in mind by future reviewing headquarters that the present Air Defense system in the northwest is an interim system and everyone concerned is well aware of its capabilities and limitations."[35] General Hugo P. Rush, commander of the Western Air Defense Force, added that "the air defense systems, organizations, and procedures are constantly undergoing review and analysis." Furthermore, "this headquarters considers that the ultimate objectives are well-defined," and though "a single chain of command would be highly desirable...this would require a major USAF-wide reorganization," because under "the present wing base structure...a single chain of command is not possible" for the air-defense mission.[36]

Rush also disagreed with negative assessments of the Air Defense Control Center, "a cumbersome manual operation in which information is displayed on a large scale more for liaison intelligence purposes than actual command and intercept purposes," at least according to the inspector's report, which further alleged that it had merely been "copied from the British system."[37] Apparently the inspectors found even this venerable precedent neither

35. Col. Clinton D. Vincent, Commander, 25th Air Division (Defense), December 2, 1949, first endorsement in Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force, "Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

36. Brig. Gen. Hugo P. Rush, Commander, Western Air Defense Force, December 20, 1949, second endorsement in Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force, "Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

37. Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force,

expedient nor economical. "The Air Defense Control Center is a large installation," they wrote, "expensive in construction and manpower and provides for a multitude of functions of a liaison and passive nature for which the USAF is bearing the construction, communications, and operating costs." If air defense represented a true interagency commitment, its financial burden should be distributed as well.

Rush argued that "while the ADCC is somewhat similar to those used in the RAF...the present and future air defense systems have removed large portions of the air defense operation through decentralization, to the GCI."[38] His counter-argument was at most half true; the proper division of labor between GCIs (i.e. direction centers) and the control center remained a matter of considerable debate, which the exercise did little to settle. Moreover, the 25th Air Division's control center did in fact closely resemble the regional air-defense information centers set up during World War II. Tellers instructed plotters how to push wooden blocks around a large map table by headset, with the staff seated on elevated platforms around them. As contacts appeared, the staff in the Movement Identification Section would attempt to identify them based on information provided by representatives from the Civil Aeronautics Administration, the National Guard, and other Air Force and Navy units operating in the vicinity.[39]

As configured during DRUMMERBOY, only the duty controller at the division level had the authority to scramble fighters to intercept an unidentified track; upon reaching altitude, the pilots were then handed off to the appropriate GCI station for vectoring to their targets. Previous exercises had experimented with devolving scramble authority to the direction centers in order to reduce reaction times, but the data against the prevailing opinion, which

"Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

38. Brig. Gen. Hugo P. Rush, Commander, Western Air Defense Force, December 20, 1949, second endorsement in Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force, "Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

39. Air University, *Air Defense Tactics—Techniques*, RG 341, 83–163 thoroughly described the basic operating principles of a postwar, hand-operated Air Defense Control Center.

still held that the division maintained a superior view of the total situation, was as yet relatively sparse. On the other hand, while Rush and Vincent wanted more identification functions pushed out of the ADCC and into the GCIs, both commanders considered this infeasible so long as the CAA lacked the power to enforce important flying regulations, especially the flight-plan requirement within defended airspace.[40]

Operation WHIPSTOCK: Fundamentals of manual control

It is suggestive that Colonel Vincent proposed that DRUMMERBOY's success should be judged "not in the number of interceptions completed, but in the laboratory situation it provided for study and critical analysis of the Air Defense System."[41] This was perhaps the greatest measure of optimism possible in light of the finding, later determined by ConAC's operations analysts, that fighters had intercepted only 18% of the simulated attacks before they reached their bomb-release lines. Nevertheless, Vincent could soon point to the interception rate of 33% recorded during Operation WHIPSTOCK, which ran from June 18 to June 24, 1950, as evidence that the 25th Air Division was making tangible progress toward its ultimate goal of defending the Pacific Northwest.[42]

The achievement was not unqualified; the radar screen, for instance, had failed even to detect half the raids launched against the Hanford Works, despite the addition of several LASHUP stations and a steady stream of equipment upgrades throughout the region. Bad weather again limited the utility of ConAC's newer aircraft, especially the F-86 Saber, which was quickly emerging as the air-to-air fighter of choice even though it lacked the onboard electronics necessary for navigation and pursuit in darkness or other low visibility conditions.

40. The question of whether "movement identification" should be centralized in the ADCC, or decentralized to the ADDCs, had proponents on either side, and had been tested, inclusively, in other exercises as well: Sturm, *History of ConAC, 1949*, vol. 3, Operations and Training, AFHRA, 75–77.

41. Quoted in *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 1, Narrative, AFHRA, 22.

42. Sturm, *History of ConAC, Jan.–Jun. 1950*, vol. 6, Operations and Training, AFHRA, 86–89.

Still, the division's operational readiness had measurably improved in the six months between the two exercises, a development due primarily to continued training and increasing manpower. Curtis LeMay's initiatives to retool the Strategic Air Command had an indirect but powerful effect, because a viable air-defense network also created a more realistic environment for bomber crews to practice evasion and defensive gunnery. Early in 1950, ConAC began to regularly partner fighter with bomber units for airborne skirmishes inside the air-defense zone. Within a few months, Vincent was routinely being granted control over as many as one-third of the fighters based in his area in order to conduct "system training," often in conjunction with SAC.[43]

While generating useful data on fighter and radar performance in the region, WHIPSTOCK revealed few problems that had not already been recognized at least qualitatively. The operational plan proceeded almost identically to DRUMMERBOY's, excepting one experimental change, which devolved some responsibility for identifying unknown tracks from the ADCC to the individual GCI stations. Here the results yielded little clarity. The division report suggested that "it can be recommended as a sound step. However, the concept of having this very important function performed *solely* in the GCI station...is not believed sound" because "the Air Defense Commander should have a supervisory identification section which has all the information available to the GCI stations and which can check and modify decisions regarding identification as indicated."[44]

The addition of Air National Guard units to the defending force also led to mixed results. "The ANG F-51s did a fine job," the report offered before complaining about how "again we were beset by cries of 'not enough flying.' Fighter units commanders don't seem to understand that air defense operations consist mainly of sitting and waiting." Indeed, pilots

43. Sturm, *History of ConAC, Jan.–Jun. 1950*, vol. 6, Operations and Training, AFHRA, 76–79.

44. Col. Clinton D. Vincent, "Division Commander's Summary," in *Report on Exercise "Whipstock," 18 June–24 June 1950*, (Everett, WA: Headquarters, 25th Air Division (Defense), n.d. [July 1950?]), exhibit 28 in *The Air Defense of Atomic Energy Installations, March 1946–December 1952*, vol. 2, Supporting Documents (Colorado Springs: Directorate of Historical Services, Headquarters, Air Defense Command, 1953), AFHRA (0500633), 6, emphasis in original.

from the Washington Air National Guard frequently made unannounced training flights during the exercise, contravening ConAC's operations order and greatly confusing radar observers on the ground.[45]

Earlier tests had already exposed the tension that existed between pilots and ground controllers who were insufficiently familiar with one another. At the conclusion of DRUMMERBOY, General Ennis C. Whitehead had felt compelled "to emphasize the necessity for the fighters and the AC&W to operate and train together continuously, for fine and close teamwork is necessary." For example, the two groups lacked proficiency with JANAP 142—the standard air-to-ground communications protocol—leading to excessive voice chatter and congested the frequency bands.[46] During WHIPSTOCK, "a few voice controllers failed to modulate their voices resulting in a 'panicky' type of control," complained Colonel Clay Tice, the commander of the 81st Fighter-Interceptor Group. "One controller in particular…pushed the panic button on every transmission. It is essential that controllers give instruction in a calm, well-modulated voice that will indicate to interceptor pilots that the situation is under control."[47] The general shortage of flight-trained ground controllers often put pilots under the direction of officers (and sometimes even enlisted men) of inferior rank or with little familiarity with the performance, capabilities, and limitations of the fighters they directed. Rates of turn and climb varied by model, as did their maximum speeds and endurance with altitude, which left the individual pilot to account for factors unapparent from the ground. "On one occasion when the pilot informed the controller that he was low on fuel," the colonel continued, "the controller attempted to vector him farther from the

45. Vincent, "Division Commander's Summary," in *Report on Exercise "Whipstock,"* exhibit 28 in *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 2, Supporting Documents, AFHRA, 4.

46. Lt. Gen. Ennis C. Whitehead, Commanding General, Continental Air Command to Chief of Staff, USAF, "Preliminary Report on Operations 'DRUMMERBOY'," November 16, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA. JANAP: "Joint Army–Navy–Air Force Publication"; the *Joint Air Warning and Air Defense Code*, issued under the JANAP 142-series, prescribed a voice-communication protocol to be observed uniformly by American forces in air-defense operations.

47. Lt. Col. Clay Tice, Commanding, 81st Fighter-Interceptor Group to Commanding General, 81st Fighter-Interceptor Wing, "Whipstock Critique," June 27, 1950, exhibit 29 in *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 2, Supporting Documents, AFHRA.

base."

More fundamentally, though, pilots tended to distrust the instructions they received from the ground, resulting in "frequent cases of irritation and a 'to hell with it' attitude," according to Tice. Pilots knew from experience that ground controllers could not reliably track the movements of potential enemies, let alone their own aircraft. Much of the fault belonged to the radar network itself: the poorly sited, hastily calibrated, and inexpertly staffed stations in the LASHUP system suffered chronically from unexpected shadows, echoes, and other anomalies that caused tracks to disappear, reappear, divide, multiply, or travel in impossible trajectories. While acknowledging all these difficulties, the 637th Radar Squadron, which operated the McChord direction center, also blamed the pilots for demonstrating "a lack of knowledge in GCI procedures and capabilities and exhibited an unfriendly attitude toward the station."[48]

ADC–ConAC seemed confident that the rapport between pilots and controllers would grow with training and personal familiarity. At the same time, however, officials expressed an almost implacable skepticism about the flaws in their operations centers. Newer and better maintained equipment promised a few near-term improvements, but beneath these shallow hopes flowed an overwhelming stream of doubts concerning the irreducible limits of human labor. During WHIPSTOCK, the unusually crowded airspace had nearly overloaded the AC&W network. "Presentation of the air picture on the operations board at the Control Center was below acceptable standard," the 25th Air Division admitted in its final report, which faulted "the inability of scope readers, plotters, and tellers to adequately handle all air traffic and to the severe limitations of the mechanics of displaying this information on the plotting board." A single observation passed through four pairs of hands to reach the control center directly from the GCI; six, if it originated from an early-warning radar reporting to a GCI. Consequently, "the delays and inaccuracies in the present system preclude the Air

48. Maj. Edwin L. Murrill, 637th Radar Squadron to Commanding General, 25th Air Division (Defense), "Operation Whipstock Critique," June 28, 1950, exhibit 30 in *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 2, Supporting Documents, AFHRA.

Division Commander from making timely decisions relative to diversion of fighter strength, effect passive defense measures on the part of the military, issue warning to civil defense agencies and exercise the desired control over Anti-Aircraft Artillery installations."[49] All these problems became ramified in the control center, but they originated in the direction centers.

The layout and procedure at a direction center shared broad similarities with the control center in that both employed tellers and plotters to represent the air-battle for the duty controller in as close to "real time" as possible. During the LASHUP era, an ADDC typically occupied a small, single-room structure, with the command and liaison staff seated in rows facing a wide plexiglass screen, flanked by two status boards, positioned at the front of the hutment.[50] To accommodate the scope readers, these cramped, noisy, and sometimes swelteringly hot spaces were kept dark except for the sector map, overlaid with grid coordinates, etched in reflective paint on the side-lit screen. A team of plotters sat behind the screen wearing headsets connected to the intercom, illustrating the flight-tracks reported to them with grease pencils, marking them up with symbols written backward, from their perspective, so as to avoid obstructing the controller's view from the front. Plotters similarly updated the two flanking panels, summarizing the list of active tracks on the left and the status of friendly interceptor forces on the right.[51]

As configured for WHIPSTOCK, direction centers relayed radar observations from the early-warning posts, as well as their own radar, to the division's control center—a communication called "forward-telling." Even in the best conditions, however, a single station could

49. "Operations," annex III to *Report on Exercise "Whipstock,"* exhibit 28 in *Air Defense of Atomic Energy Installations, 1946–1952,* vol. 2, Supporting Documents, AFHRA, 3–4.

50. Note that the application of the term "real time" is anachronistic in this context, having not appeared widely until after the introduction of computer automation in the 1960s. Analogous concepts did exist, such as the operational "time lag" introduced in the first chapter, but contemporary usages appear inconsistent.

51. Air University, *Air Defense Tactics—Techniques,* RG 341; Air Defense Command, *Air Defense Tactics,* RG 341. Although written during the peak of the "manual system," Don Murray, "They Guard the Ramparts," *Saturday Evening Post,* June 11, 1955, EBSCO (19566485) described the bleak conditions typical of a GCI station in the Permanent System, which had actually improved greatly since the late forties, at least in terms of human comfort, even if the work itself remained mostly the same, as did the basic equipment.

track a jet aircraft for half an hour at most—not including gaps in the radiation pattern—so a practical interception required teaming together multiple stations with overlapping coverage patterns. When a flight track approached the boundary between adjacent sectors, the direction center was also expected to "cross-tell" the information to the corresponding operations room.[52]

In controllers, the vicissitudes of radar and the unreliability of the reporting network promoted misapprehensions just as it did in pilots. "A radar station is supposed to start overlap telling of track information to an adjacent station when the track reaches a defined overlap zone between the two stations," according to an operations analysis report issued during WHIPSTOCK, which continued:

> Uncertainty exists occasionally as to which adjacent station should be told track information, stemming partly from the teller's doubts about which way the aircraft will go. Decision must be made on each track as to when and to whom overlap telling should be started and as to how long it should continue. Because of the complexity in the air situation, the decision is often either a poor one, made too late, or not made at all.[53]

As a result, "the typical controller in a GCI station tends too often to scramble his fighter aircraft only when the bogey appears on his scope, often so late that his fighters cannot take off and climb to altitude in time to intercept. This reluctance to scramble on the basis of overlap track information comes partly from the controller's real knowledge of the unreliability of the overlap telling, but it also seems to arise from the fact that the controller, *as an officer*, instinctively distrusts the overlap telling produced by a loose chain of men in an adjacent station whom he knows…to be of doubtful preciseness and alertness." Likewise, the division control center tended to receive conflicting reports about the overlapping regions, reducing confidence in any track moving along the boundary between two stations.

52. Most functions of an Air Defense Direction Center were analogous to those of the Air Defense Control Center and are subsumed by a preceding passage and its corresponding sources. More specific procedures were documented in Air University, *Air Defense Tactics—Techniques*, RG 341, 164–180.

53. Headquarters, Air Defense Command, Operations Analysis Technical Memo No. 2, June 24, 1950, excerpted in Sturm et al., *The Air Defense of the United States*, 433 (emphasis added).

Manual systems and the depreciation of "the human element"

The operations analysis of WHIPSTOCK clarified the dynamics of trust in an air-defense organization, at least from the perspective of a well-educated headquarters staff. Officials preferred to register these concerns in the abstract, including a statement in the same report, which concluded that "the present radar net is inefficient, cumbersome, expensive, and easily overloaded, largely as a result of its overdependence on *the human element*."[54] Among the officer corps, as well as their civilian allies, "the human element" encoded a range of judgments about the class, gender, race, and professional identity of the air-defense system's rank-and-file. "The work of scope watching and reporting, plotting, telling, recording, and replotting is characteristically exceedingly monotonous," the analysts observed:

> During World War II when the voice and manual system originated, the large numbers of competent men required were available. Under the stress of war, monotony was at a premium, and the work was in fact, reasonably well done. The problem in peacetime is quite different. Monotony is the rule, good men able to stand it are scarce, and the work is ill done.[55]

Women performed most of these tasks during the war, and within the continental United States, ubiquitously so. As the Air Force began to rebuild the wartime network in the late forties, women yielded their positions to enlisted men, many of whom had been conscripted or else volunteered due to a lack of other socioeconomic opportunities.[56]

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54. HQ ADC, Operations Analysis Technical Memo No. 2, excerpted in Sturm et al., *The Air Defense of the United States*, 431 (emphasis added).

55. HQ ADC, Operations Analysis Tech. Memo No. 2, excerpted in Sturm et al., *The Air Defense of the United States*, 432.

56. As of September 1942, the Aircraft Warning Service was operated almost entirely by about 6,000 civilian women. Although women recruits began displacing unpaid volunteers shortly after Congress created the Women's Army Auxiliary Corps (WAAC) in March 1942, civilian staffing resumed after the Women's Army Corps (WAC) superseded the WAAC in July 1943. With the exception of Women Airforce Service Pilots (WASPs), who ferried military aircraft within the United States, "Air WACs," like other women in the military, generally assumed traditionally "pink collar" roles as nurses, orderlies, clerks, secretaries, and operators of telecommunication equipment. Many of these tasks were vital to the functioning of air-defense, air-traffic control, and air navigation both in the continental United States and in theaters overseas. Wesley Frank Craven and James Lea Cate, eds., *Services Around the World*, vol. 7 of *The Army Air Forces in World War II* (1958; repr., Washington: Office of Air Force History, 1983), 503–541. On the organizational history of the Women's Army Corps more generally: Mattie E. Treadwell, *The Women's Army Corps*, The United States Army in World War II: Special Studies, CMH Pub 11-8 (1954; repr., Washington: US Army Center of Military History, 1991) and Bettie J. Morden, *The Women's Army Corps, 1945–1978*, CMH Pub 30-4 (Washington: US Army Center of Military History,

As of January 31, 1951 (the first date for which these statistics were compiled), 68% of all Air Force officers had attended college, and 31% of them held a four-year degree. Only 15% of enlisted men had ever enrolled in higher education, however, with 2.7% going on to obtain a degree. On the other hand, 38% of enlisted men lacked even a high-school diploma, while 11% had never attended high school at all. Within the officer corps, these figures were 3.6% and 1.1%, respectively.[57] The contrast is sharp, though ultimately unsurprising considering the structural distinctions between the two cadres. Officers generally earned their commissions through some kind of postsecondary officer-training program, such as the service academies, and included a large contingent of career military professionals. Of the 14,695 field-grade officers—the majors and the colonels, who predominated in positions of operational command and planning—only 1,171 (0.7%) were under the age of 31, and 3,785 (26%) were older than 40.[58]

On the other hand, 238,905 of 310,441 (77%) privates and corporals—the primary workers in the air-defense system—had yet to turn 22. Most enlistees entered four-year terms of service, whether voluntarily or through the draft, and peacetime reenlistment rates remained characteristically low: during 1949, for instance, 69% of the men eligible to return to civilian life elected to do so. Furthermore, although USAF statistics classified 5.6% of 548,841 enlisted men as "negro," they tabulated only 433 black officers—a mere 0.06% of the total—of whom just 23 had advanced to a field-grade rank.[59] President Truman had not

1990). So far, little has been written specifically about either wartime Air WACs or postwar WAFs (Women in the Air Force), as distinct from women in the United States military more generally.

57. United States Department of the Air Force, Air Staff, Director of Statistical Services, Deputy Chief of Staff, Comptroller, *United States Air Force Statistical Digest, Fiscal Year 1951*, 6th ed. (Washington: Headquarters, United States Air Force, November 18, 1952), table 241, https://media.defense.gov/2011/Apr/05/2001329929/-1/-1/0/AFD-110405-028.pdf .

58. Personnel policy and career management is a supremely important yet rarely appreciated aspect of military administration. For background: Mark R. Grandstaff, *Foundation of the Force: Air Force Enlisted Personnel Policy, 1907–1956* (Washington: Air Force History and Museums Program, 1997); Vance O. Mitchell, *Air Force Officers: Personnel Policy Development, 1944–1974* (Washington: Air Force History and Museums Program, 1996).

59. *United States Air Force Statistical Digest, Fiscal Year 1951*, tables 214 and 245; United States Department of the Air Force, Air Staff, Director of Statistical Services, Deputy Chief of Staff, Comptroller, *United States Air Force Statistical Digest, January 1949–June 1950*, 5th ed. (Washington: Headquarters, United States Air Force, April 25, 1951), table 38, https://media.defense.gov/2011/Apr/05/2001329940/-1/-1/0/AFD-110405-027.pdf .

ordered the armed forces to desegregate until June 1948, a policy the departments had yet to fully implement officially, let alone sufficiently, with the Air Force lagging even with respect to the Army and Navy.[60]

In short, operating the AC&W network brought the Air Force's professional "middle managers" into daily contact with comparatively less-educated young men—some of them women or minorities, and usually little more than teenagers—who tended to serve short terms of enlistment, which afforded scarce time for training, instead of committing to a military career. So commanders had more than one "human element" in mind when they fixated on personnel as the single greatest impediment to air defense. They also meant humans of a particular sort.[61]

For instance, the aforementioned operations-analysis report stated that "the work of the plotter behind the vertical plotting board to whom the radar reporter reports the position of his blips is even more monotonous" than already tedious tasks, such as scope reading:

> A phlegmatic disposition helps, but the man who is phlegmatic and who has at the same time a capacity for sudden alertness and keen sense of responsibility, both of which are necessary, is rare indeed. The result is that men not well suited to the job must be used, that few plotters can be kept long on the job, and that inaccurate and incomplete plotting is the rule rather than the exception.[62]

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60. Cf. Morris J. MacGregor Jr., *Integration of the Armed Forces, 1940–1965*, Defense Studies Series, CMH Pub 50-1-1 (1981; repr., Washington: US Army Center of Military History, 2001); Alan L. Gropman, *The Air Force Integrates, 1945–1964* (1978; repr., Washington: Office of Air Force History, 1985). The celebration of the "Tuskegee airmen" (or, more precisely, the 332nd Fighter Group) offers the exception that proves a more general rule about the altogether dismal record of the AAF/USAF during the era of segregation and integration: Robert J. Jakeman, *The Divided Skies: Establishing Segregated Flight Training at Tuskegee, Alabama, 1934–1942* (Tuscaloosa: University of Alabama Press, 1992). The reasons are too complex to describe in full, but they range from the Air Force's origin as an elite corps with self-selecting entrance criteria to the preponderance of key facilities situated in communities especially hostile to racial minorities, due to the superior year-round flying conditions in the American South: Alan M. Osur, *Blacks in the Army Air Forces During World War II: The Problems of Race Relations* (1976; repr., Washington: Office of Air Force History, 1986); Ulysses Lee, *The Employment of Negro Troops*, The United States Army in World War II: Special Studies, CMH Pub 11-4-1 (1963; repr., Washington: US Army Center of Military History, 2001). Note that while the works cited above are among the most commonly referenced on the topic, in some cases, their datedness must be considered as well.

61. While Wendell A. Hammer, "Which Officers Should Be Educated?" *Air University Quarterly Review* 6, no. 1 (Spring 1953): 74–82 displays no evident bias toward any social group, it does describe the mechanisms by which institutional bias is commonly enforced, including the self-selection of candidates for officer training and the administration of battery tests for "intelligence" and "psychological aptitude" for skilled occupations.

62. HQ ADC, Operations Analysis Tech. Memo No. 2, excerpted in Sturm et al., *The Air Defense of the United*

As a result, “the plotter appears to be one of the slowest and weakest links in the long chain.” Other menial task-workers received criticism in kind.

This is not to suggest that air-defense officials might have otherwise achieved their ambitious goals purely on the basis of human labor. Well trained, highly motivated, and thoroughly experienced workers commit errors as well, and even correct actions can never overcome certain limitations of physiology and cognition. Moreover, a prospective surge of air-defense personnel raised the genuine possibility of a crisis in training and discipline. What is significant is that by 1950, the discourse had ceased to weigh human deficiencies against even the slightest potential benefit and begun instead to regard low-ranking air-defense workers purely as a constraint. During the Battle of Britain, the radar and communications networks had been primitive enough to require continuous human intervention—even at very elementary levels—to modulate the rate and content of reports according to situational pressure and uncertainty.

However, as technical capabilities increased while training, experience, and urgency all decreased, this adaptive phenomenon appeared neither obvious nor especially relevant. In one of many similar pronouncements, the 25th Air Division’s report on WHIPSTOCK, submitted on behalf of Colonel Vincent, concluded that “an automatic system for the transmission and display of target information from early warning to GCI sites, and from GCI’s to the control center is direly needed” and recommended that “a project be initiated on crash basis” to supplement or entirely replace the existing manual operation.[63]

Vincent’s assessment may have seemed to contravene that his immediate superior, General Rush, who had previously bristled at the suggestion that “air defense must be automatic any more so than any other military operation.” Although he did qualify the remark by adding that “the only portions of the system which should be permitted to become

States, 433.

63. “Operations,” annex III, 3–4, and Col. Clinton D. Vincent, “Division Commander’s Summary,” 10, both in *Report on Exercise “Whipstock”*,(Everett, WA: Headquarters, 25th Air Division (Defense), n.d. [July 1950?]), exhibit 28 in *Air Defense of Atomic Energy Installations, 1946–1952*, vol. 2, Supporting Documents, AFHRA.

automatic are the individual highly technical pieces of equipment with which the system operates," the gap in Rush's statement yawned as widely as any in the region's spotty radar coverage.[64] Would PPI scopes and plotting boards be considered among these "individual highly technical pieces of equipment," and if so, what of their operators? Should automating such devices merely make them more convenient to use or render their users superfluous? Their answers would change according to future developments, the course of which air-defense officials could not yet anticipate.

Thus, these men were not mere observers to the march of technological progress. One month after WHIPSTOCK, for instance, ConAC submitted to USAF headquarters its requirement for "a partially automatic information handling system" to perform five functions, from collecting radar data to filtering and transmitting it to displaying real-time flight-tracks for the GCI and division controllers.[65] By intent, automation would assist the officers in performing their conventional roles while obviating the need for them to rely so heavily upon the work of enlisted men.

Of course, the most routinized tasks were also the ones most likely to benefit from the means of technological remediation feasible at the time, but it should still be noted that this approach remained consistent with the tradition and identity of the professional officer. So when General Rush hesitated to say that "air defense must be automatic any more so than any other military operation," he most likely meant to exempt the decisions of the command staff, as distinguished from the organization supporting them. While the latter would be studied and mechanized extensively over the coming decade, the former generally resisted the intrusion of social science and engineering.[66]

64. Brig. Gen. Hugo P. Rush, Commander, Western Air Defense Force, December 20, 1949, second endorsement in Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force, "Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Sturm, *History of ConAC, 1949*, vol. 3, pt. 2, Operations and Training, AFHRA.

65. Headquarters, ConAC to Headquarters, USAF, "Improvement of Means of Handling AC&W Information," July 22, 1950, quoted in Sturm et al., *The Air Defense of the United States*, 434.

66. In the early sixties, the so-called "Threat Evaluation and Assessment Studies" (TEAS), conducted by the Operational Applications Laboratory of the Air Force Electronics Systems Division, actually did take the air-

3 System as simulation

Recalling the early years of air-defense operations and training, Herbert Ray, then a captain with the 32nd Air Division, wrote that "commanders of air defense units throughout North America and overseas saw the need for synthetic air defense training, and they filled the requirements as best they could," despite the lack of direction or resources from higher headquarters. "The procedures and equipment used varied from squadron to squadron," but they generally involved "simulated attack environments…indiscriminately concocted at the start of the operations crew's eight-hour shift." At each radar site, the surveillance section would devise "canned tracks" in order to create more opportunities for tellers to practice passing reports from station to station, for plotters to exercise their grease pencils, and for intercept controllers to spin their whiz wheels.[67]

Altogether, though, these "unsophisticated, poorly planned ventures into air defense simulation" failed to substantially advance ADC's "system training" agenda, which asserted that an air-defense network's true behavior became apparent—and hence, subject to improvement—only when all of its elements were activated simultaneously. Ray did add that while "this training was dull and laborious to say the least, there were times when 'Yankee ingenuity' devised ways and means to 'put a little sparkle into the training schedule.'" For example:

Those on aircraft control and warning (ACW) duty in northern Japan during the early

defense commander as their experimental subject. The laboratory completed only a few runs, however, as the program failed to generate much interest and concluded due to lack of funding. The MITRE Corporation, the System Development Corporation, and the Air Force Cambridge Center designed other studies of lesser scope and ambition than TEAS, but these efforts also produced minimal results. See H. McIlvaine Parsons, *Man-Machine System Experiments* (Baltimore: Johns Hopkins University Press, 1972), 303–313, 339–350, 365–370 for comments and citations, though many reports circulated only as "gray literature." Note also the prevalence of air-traffic control studies inspired by the air-defense experiments described in the following section.

67. A "whiz wheel" generally refers to a circular slide-rule, but the term is most common to aviation, where such devices are still used to compute angles, distances, times, velocities, rates of turn, climb, and fuel consumption, and other flight-critical information. Before automation, ground controllers also employed such instruments, often calibrated to the performance of a specific model aircraft, to vector pilots in, through, and out of local airspace. United States Air Force, Air Training Command, *Intercept Controller*, ATC Manual (ATCM) 355-1 (Scott AFB, IL: Headquarters, Air Training Command, July 1955), MSFRIC was the basic orientation to the theory and calculation of intercept geometry provided to trainees at the time.

> Fifties vividly recall running simulated tracks toward Russian territory. Soon the heavy radars adjacent to Sakhalin and the Kuriles were painting live Russian aircraft that had scrambled out to patrol the line against aircraft reportedly in the area. Obviously, other ears were tuned to the [high-frequency] net. The thought of scrambling pilots out on a wintry Siberian night in pursuit of a simulated track apparently beefed up the "fun factor" for ACW personnel.

Nevertheless, "such locally devised training programs served to pass the time, perhaps, but the value in skill upgrading was, of course, quite restricted" and "crews soon became bored with the whole effort."[68] Merely keeping graveyarders awake at their posts ranked among their primary benefits.

Although live exercises like WHIPSTOCK and DRUMMERBOY proved more engaging, they too were highly artificial, which, when compounded by the tight fiscal, political, and logistical constraints on their size and frequency, likewise lacked the realism and intensity to truly test the limits of an air-defense organization. At the start of the fighting on the Korean peninsula, these limits remained as yet so severe that systems choked even under the relatively minor strains induced by the first round of tentative operational exercises. Over the next few years, however, the Air Force anticipated an exponential increase in capacity as it executed the most aggressive continental-defense program in its history, activating dozens of interceptor squadrons and command centers, and hundreds of observation posts, as well as taking on the hundreds of thousands of personnel required to maintain and operate them.

Consequently, the Air Defense Command fully embraced the expansion of synthetic training—along the same lines as the *ad hoc* practices described by Ray—as soon as the possibility appeared more than hypothetical. The overriding problem was that the buildup for the Korean War paled against the national mobilization for World War II. A new army of the skies would likely not be complemented by a proportionately sized army of labor tasked with the calculation of simulated "training problems," which required the production of numbers on an industrial scale. Other training aids would need to be developed and

68. Herbert E. Ray, "Air Defense Simulation Through the Years," *Air University Review* 17, no. 6 (September–October 1966): 63–64.

manufactured as well, though the equipment problem was predicated on the computational problem, since the nature of output depended on the form and quantity of the input.

To that end, ADC pursued through what eventually became known as the System Training Program (STP), the first major application of computer automation directly to the performance of military operations. While already identified as an important and perhaps necessary precedent for the SAGE computer-programming effort, especially considering the size and skill of the workforce bequeathed from one to the next, the System Training Program did not begin with the intent to improve the methods of operational training *per se*. Neither did it end with training, but rather, in a numbers factory, readily retooled for tasks inconceivable at the time of its establishment.

Project Simulator and the Casey experiment

The story of the RAND Systems Research Laboratory (SRL) and its "air-defense experiments," as they were called, has been interpreted many times.[69] Little remains to be gained by dwelling on their common points. It is worth observing, however, that the historiogra-

69. Although initially reported in a number of gray papers and publications, what can be considered the concluding statement of the laboratory's founders eventually appeared as Robert L. Chapman et al., "The Systems Research Laboratory's Air Defense Experiments," *Management Science* 5, no. 3 (April 1959): 250–269, doi:10.1287/mnsc.5.3.250, which revised and expanded most of its existing corpus; this was later supplemented by Anders Sweetland and William W. Haythorn, "An Analysis of the Decision-making Functions of a Simulated Air Defense Direction Center," *Behavioral Science* 6, no. 2 (April 1961): 105–116, doi:10.1002/bs.3830060202. By the time Elias H. Porter, *Manpower Development: The System Training Concept* (New York: Harper & Row, 1964) was printed, SRL veterans had succeeded in promoting their results to "textbook knowledge" in the fields of social psychology and human engineering. Parsons, *Man-Machine System Experiments*, 161–186 is the most thorough account of the laboratory and the experiments themselves; Claude Baum, *The System Builders: The Story of SDC* (Santa Monica: System Development Corporation, 1981), 11–29 is an insider organizational history. As SDC partisans, both authors presumed the same teleology regarding SRL's genetic role in the study of group behavior. Meanwhile, Willis H. Ware, *RAND and the Information Evolution: A History in Essays and Vignettes* (Santa Monica: RAND Corporation, 2008), 94–98 displays all the limitations to be expected of a cheery, post-retirement memoir, but the perspective of a computer engineer who remained with RAND, rather than social scientist who migrated to SDC, is at least different from those above. Critical reinterpretions, such as Edwards, *The Closed World*, 121–125 and Sharon Ghamari–Tabrizi, "Cognitive and Perceptual Training in the Cold War Man-Machine System," in *Uncertain Empire: American History and the Idea of the Cold War*, ed. Joel Isaac and Duncan Bell (Oxford: Oxford University Press, 2012), 267–293, draw mainly from these sources, though Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington: Air Force History and Museums Program, 2002), 151–156 did contribute some new information gleaned by examining what remains of SDC's archival collection.

phy of SRL is itself a contested "success narrative" similar to the one manifested by the historiography of air-defense automation in general. Well known and highly influential within the fields of systems theory, social psychology, and human-factors research, the air-defense experiments began generating resistance as ergonomics matured as an engineering discipline during the 1960s. Having failed to produce many useful findings, or even an indisputably "scientific" methodology, large-scale simulations of organizational behavior quickly fell out of favor, leading proponents of the classic studies to assume a protective crouch.[70] The historical literature expresses the same rhetorical pivot toward precedential claims regarding the performative logic of simulation as microcosmic of the Cold War condition as a whole.[71]

To a significant degree, this lack of narrative diversity can be attributed to the dearth of sources independent from the experimenters themselves.[72] For the sake of commentary, however, it will be necessary to recapitulate some basic elements.[73] The Systems Research

70. For instance, Parsons, *Man-Machine System Experiments*, 466–514. As Parsons wrote elsewhere, a few extensions and generalizations on the air-defense experiments were attempted in the early-to-mid 1960s, mostly by the System Development Corporation, which constructed a large simulation facility for the purpose. Supposedly the potential for this style of research proved not worth the cost, though Parsons implicated other causes in its demise, such as the stifling limitations of the military procurement system.

71. Edwards, *The Closed World* and Ghamari–Tabrizi, "Cognitive and Perceptual Training in the Cold War Man-Machine System" especially.

72. While identifying and obtaining sources produced by Air Force field agencies is difficult enough, the Air Defense Command presents an even more problematic case due to the additional layer of opacity imposed by the establishment of NORAD in 1957. At that point, ADC's records descended into a legal netherworld; in principle, documents pertaining exclusively to its performance as an activity of the United States Air Force should be covered by federal disclosure laws, but documents related to its assignment to NORAD would remain privileged as "diplomatic" material. The two categories are practically inseparable, however, and thus, the management and release of virtually all records at the discretion of NORAD alone. Unfortunately, this applies to ADC's files prior to 1957 as well, since any document in its possession at the time of the union fell under the same policy.

73. The following passage mainly incorporates Parsons, *Man-Machine System Experiments*, 161–186, which was itself written from the original reports, with some unattributed details presumably contributed by the author's personal experience; as well as Robert L. Chapman and John L. Kennedy, *The Background and Implications of the Systems Research Laboratory Studies*, P-740 (Santa Monica: RAND Corporation, September 21, 1955), DTIC (AD0604949) and F. N. Marzocco, *The Story of SDD*, SD-1094 (Santa Monica: System Development Corporation, October 1, 1956), CBI 90, ser. 98, box 1, folder 16, both frequent reference for the sources above. In addition, L. J. Henderson, Jr., Assistant Director, System Training Project to Gen. L. S. Stranathan, Director of Development Planning, Headquarters, United States Air Force, "History of the System Training Project," WL-1298, October 3, 1955, CBI 90, ser. 98, box 8, folder 11 and its attachments filled in a few gaps in the chronology, although according to another copy of the enclosed document list filed in CBI 90, ser. 98, box 22, folder 14, SDC later

Laboratory began largely at the instigation of John Lyon Kennedy, a former member of OSRD's Applied Psychology Panel and director of the Institute of Applied Experimental Psychology at Tufts College at the time that RAND convened an interdisciplinary conference, motivated by Edward J. Barlow's ongoing investigation of the nation's air-defense capabilities, in August 1950.[74]

As a result of ADC's operational exercises, such as the recently concluded WHIPSTOCK, Barlow's team had realized both the significance and the difficulty of quantifying GCI crew performance. It seemed clear, for instance, that the organization's response to "load," as measured by the number of unknown or hostile contacts in the airspace, did not simply approach a stable maximum, but actually tended to break down under stress, leading to a condition of "degradation," wherein the crew handled significantly *fewer* contacts than it did before exceeding its peak capacity. Reacting to a panel session, Kennedy articulated the need to quantify the phenomenon not only for the sake of application, but also to answer a basic question of social psychology. Having recently edited one of the earliest compilations of human-engineering data for the Office of Naval Research, Kennedy became a natural target for recruitment and joined RAND's Social Science Division a few months later.[75]

While still at Tufts, Kennedy learned of, and possibly witnessed, an experiment designed by Alex Bavelas, a social psychologist trained under Kurt Lewin, which MIT's Research Laboratory of Electronics ran from August 1949 to April 1952. In fact, RAND even began funding the work of the Bavelas group, possibly due to Kennedy's personal interest in its

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destroyed many papers relating to the foundation of SRL still in its possession by 1960.

74. Barlow's was the effort that culminated in Project Air Force, *Air Defense Study*, RAND Report R-227 (Abridged) (Santa Monica: RAND Corporation, November 15, 1951), DTIC (ADA41260), to be discussed later in chapter 5. On Kennedy's career: Paul Stager, "John L. Kennedy, 1913–1984," *American Psychologist* 42, no. 12 (December 1987): 1127, doi:10.1037.h0092016; and on the Applied Psychology Panel: James H. Capshew, *Psychologists on the March: Science, Practice, and Professional Identity in America, 1929–1969* (Cambridge: Cambridge University Press, 1999), 51–54.

75. The volume in question is John L. Kennedy, ed., *Handbook of Human Engineering Data for Design Engineers*, SDC 199-1-1/NavExos P-643 (Medford, MA: Tufts College, Institute of Applied Experimental Psychology, December 1, 1949), which was actually printed as a loose-leaf binder so that it could be updated continuously, though only one follow-up edition, dated 1951, appears in any catalog. Today, the subject would be called "human-factors engineering," but that term was only just beginning to enter common use.

methods and findings.[76] Using a relatively simple apparatus, consisting of a partitioned table rigged with mechanical recording devices, the experimenters watched five subjects, who could neither see nor speak to one another, pass written messages through slots according to various topological restrictions: a daisy chain, a spoke hub, a fully connected network, and so on. During a trial, each participant was given a piece of some kind of puzzle that could only be solved collectively, while the recorders registered the passage of message cards in order to quantify the load distribution characteristic of each topology, as well as its overall efficiency in terms of the total number of messages exchanged.

Kennedy evidently considered the operation of an Air Defense Direction Center as fundamentally the same class of phenomenon: a task that could only be completed by communication between positions with access to partial information—and concluded it could be studied the same way: by constructing an experimental apparatus to manipulate, observe, and record. It is unclear whether RAND hired Kennedy in order to perform these experiments or merely to design them, but by October 1951, he had enticed two other psychologists in the Social Science Division, William C. Biel and Robert L. Chapman, as well as Allen Newell, a mathematician, to attempt the former in a vacant space rented from a seedy Santa Monica pool hall. Perhaps already cognizant of its tenuous relationship to the methodology of contemporary behavioral psychology, they chose to call the work "Project Simulator," an ambivalent term which, while not necessarily precluding the scientific rigor implied by "experiment," also shied from totally embracing it.

Simulation had already established itself as a training vernacular—in pilot training, most prominently—but since the war, all branches of the United States military had incorporated electromechanical training aids into their instruction courses for individual radar

76. A brief initial report on the "Group Networks Laboratory," as it fashioned itself, was published as Alex Bavelas, "Communication Patterns in Task-Oriented Groups," *Journal of the American Acoustical Society* 22, no. 6 (November 1950): 725–730, doi:10.1121/1.1906679; a book-length final report followed in May 1952, later reprinted as Lee S. Christie, R. Duncan Luce, and Josiah Macy, *Communication and Learning in Task-Oriented Groups*, RM-1163 (Santa Monica: RAND Corporation, December 1, 1953), OCLC (41083915).

operators.[77] The device most relevant to ground-crew training was the 15-J-1c "moving target simulator," a hand-operated console that could generate electrical signals mimicking those of a genuine radar set, allowing prospective scope-readers to learn on the same equipment they would later encounter in the field. Although a single target generator could feed an entire bank of PPI scopes and thus accommodate multiple students at once, the complexity and fidelity of the simulation depended on the instructor's ability to "eyeball" the movement of real aircraft with manual controls, which studies showed was limited to two or three simultaneous contacts.[78]

As the Air Defense Command would later state, the key contribution of Project Simulator—and, indeed, the Systems Research Laboratory—was, from its perspective, the mechanization of the generation of radar tracks, as well as other inputs related to the operation of an ADDC, and the development of equipment to produce and execute these synthetic "training problems" on an organizational scale. While Newell has received the most attention with respect to SRL's computational achievements, the team borrowed liberally from the staff of the Numerical Analysis Department, including John Clifford Shaw, Wesley S. Melahn, Willis Ware, and many other unacknowledged programmers and technicians to implement its algorithms on RAND's electronic calculators, which, at the time, consisted of six IBM 604s, two IBM CPCs, and one heavily modified Reeves Electronic Analogue Computer, or REAC.[79] Moreover, its source of custom apparatus, and primary contact with the Air Defense

77. Parsons, *Man-Machine System Experiments* discussed such training aids in some of its early chapters; moreover, Rebecca Hancock Cameron, *Training to Fly: Military Flight Training, 1907–1945* (Washington: Air Force History and Museums Program, 1999) specifically examines the role of simulators in Army pilot-training programs. It may recalled from other sources that Jay Forrester originally pitched Project Whirlwind to the Navy as a digital processing element for a flight simulator.

78. Carl A. Lohrenz and Bertram L. Zymet, *Synthesized Equipment for Ground Based Radar Systems: I. Radar Operator Training—The Man, the Machine, and the Simulator*, ASD TR-61-411(I) (Wright–Patterson AFB, OH: Behavioral Sciences Laboratory, Aeronautical Systems Division, Air Force Systems Command, October 1961), OCLC (24290029) catalogued the 15-J-1c, also called the AN/UPS-T5, as well as other instruction devices in use at the time.

79. F. J. Gruenberger, *The History of the JOHNNIAC*, RM-5654-PR (Santa Monica: RAND Corporation, October 1968), 2–3, OCLC (227514277); Ware, *RAND and the Information Evolution*, 45–53 loosely reminisces on this period as well. According to Charles J. Bashe et al., *IBM's Early Computers* (Cambridge: MIT Press, 1986), 59–72, these models, first introduced in the late 1940s, would be classified today as programmable electronic

Command, was an engineer from the Electronics Division named Melvin O. Kappler, who had already been collaborating on the development of radar training-aids for several years by the time Kennedy arrived in early 1951. By the fall, Kappler had helped procure manuals and regulations from the 25th Air Division and arranged for William Biel to observe the activity of the 505th AC&W Group, which had operated an Air Defense Direction Center at McChord Air Force Base in Tacoma, Washington since the USAF-declared emergency of March 1948.

Constructing a reasonable facsimile of the McChord ADDC was the goal that the Systems Research Laboratory set for Project Simulator. Most of the work proceeded straightforwardly. Since the tasks performed by a contemporary GCI crew depended exclusively on voice telling and hand plotting and calculating, the formerly abandoned space was easily outfitted with wooden tables, platforms, status boards, and telephone circuits configured according to the model layout.[80] The 25th Air Division's Standard Operating Procedures became orientation material for the experimental subjects—a group of 28 university students, both graduate and undergraduate, but all men, recruited predominately from nearby UCLA—whom the researchers observed from behind the pane of one-way glass that obscured the overlooking mezzanine.[81] Like the Bavelas experiments, the room and its communications were rigged with automatic recording devices, though the design of "Casey," the codename of the first run, which consisted of 54 four-hour trials conducted from February to June 1952, never called for varying the network of connections between participants, nor the nature of the task to be completed. A few changes needed to be made in order to ensure the subjects'

calculators, rather than as computers *per se*, since their "programming" entailed physically rewiring a number of user-accessible plugboards.

80. R. L. Chapman, *The Systems Research Laboratory and Its Program*, RM-890 (Santa Monica: RAND Corporation, January 7, 1952), OCLC (227358605) was the preliminary report on the experimental setup. The paper derailed on an excursus concerning an organismic philosophy of organizational systems so similar to ADSEC's 1950 treatise, to be discussed in chapter 5, that it would be redundant to examine it here.

81. Loose papers documenting the orientation sessions for Casey subjects are accumulated in CBI 90, ser. 98, box 16, folder 11. A later experiment conducted with military personnel featured its own mock-up SOPs formatted just like official Air Force regulations, which can be found in folder 16 of the same box.

isolation from the experimenters, but otherwise, Project Simulator remained unapologetic about its faithfulness to the structure and procedure of the McChord operations room.

As already mentioned, however, the one crucial element that Kennedy's group could not easily fabricate was the display of visual radar information. The computational complexity of the problem had already stymied crews in the field from concocting *ad hoc* simulations challenging enough to hold their interest, and the Systems Research Laboratory could not evade it either.[82] The region under artificial surveillance corresponded to 100,000 square-miles of physical airspace—an area expected to yield hundreds of distinct flight-tracks during a four-hour trial, and potentially many times more in a wartime scenario. Even after halving the 4-RPM rotation speed of a typical search radar, a four-hour period of low traffic, averaging 20 planes in the air at any one time, required at least 10,000 values to be computed prior to each session. These values were not arbitrary; in order to convince the crew, they needed to time-evolve like real aircraft, with logical flight paths along common airways, or toward defended targets, while also respecting the coverage pattern of the detector, including the electromagnetic shadows it cast against the rough topography of the Olympic region.[83] For Casey, the 48-hour interval scheduled between consecutive trials left very little time to produce them, even with the equipment available to RAND, which was, at the time, among of the largest private computing centers in the world.

The scheme worked out between Newell, Shaw, and the staff of the Numerical Analysis Department involved algorithmically generating a punch-card library of several thousand tracks. Like an actual radar receiver, they intended at least some percentage of contacts to represent irrelevant or transitory signals, while candidates that behaved too confusingly, such as by accelerating to unbelievable speeds, climbing to impossible altitudes, or flying

82. The following is described briefly in Chapman et al., "The Systems Research Laboratory's Air Defense Experiments," 259–263 and expanded somewhat in Parsons, *Man-Machine System Experiments*, 165–168. Parsons also noted that while RAND remained culturally averse to performing experiments aside from simple wargames, the Social Science Division was marginal enough for SRL to escape notice—until it began monopolizing the computer center.

83. Later trials increased the complexity by an order of magnitude, though it is unclear how early in the process the experimenters began to think about scaling up beyond the lighter loads projected for Casey.

directly through terrain, were pruned from the deck. Then, prior to a trial, operators would direct the computers to shuffle together a subset of tracks selected from the library according to the instructions of the experimenters, who played with varying the quantity, frequency, and concentration of radar information, interpolating the intermediate values and printing a sequence of simulated PPI displays—with a numeral "one" indicating a possible single aircraft, and a numeral "eight" representing a probable multi-plane formation—onto 1600-sheet stacks of continuous paper. To present the images, Kappler and his colleagues designed a wooden cabinet shaped like a CRT unit, inside of which the stacks were spooled and advanced by a motor twice per minute, with an interior bulb to illuminate the sheet representing the radar's current sweep against a plastic screen.

Despite performing the heaviest calculations upfront, the production of a single training problem nonetheless required the computing center to work round-the-clock shifts throughout the duration of Casey's four-month run. This greatly displeased RAND's other research divisions, which found themselves unexpectedly locked out of the company's computer resources. Meanwhile, the experiment itself yielded few results that would have impressed anyone familiar with the study and operation of ground-based air-defenses since the Royal Air Force first opened the Bawdsey Research Station in 1936.[84] According to their reports, Kennedy, Chapman, Biel, and Newell appeared most surprised that the student subjects outperformed the military crew observed in Tacoma from the start, and, as they became more capable of prioritizing their attention, began handling similar loads with progressively less effort by quickly learning to suppress irrelevant or spurious reports.[85] Prior recognition of this behavior had inspired the RAF to introduce the filtering officer—or filtering section, depending on the size of the crew—into the very organizational structure the study had replicated with such meticulousness.

84. This was among the subjects discussed in chapter 1, drawing mainly upon David Zimmerman, *Britain's Shield: Radar and the Defeat of the* Luftwaffe (Stroud, UK: Sutton, 2001).

85. Systems Research Laboratory Staff, *The Performance of the Experimental Crew in Project Simulator: Preliminary Report*, RM-887 (Santa Monica: RAND Corporation, July 2, 1952), CBI 90, ser. 98, box 22, folder 13.

Suspicious of perhaps having induced a Hawthorne effect, the experimenters decided to end the experiment with a pair of seven-hour sessions featuring substantially more complicated training problems.[86] The students dispensed with the first additional session impressively, but the strain imposed during the final hours of the second finally precipitated a period of "degradation," when the crew's rate of successful identification and interception fell well below the standards set by its previous performance record. Curiously, despite having induced the expected behavior, one paper later characterized the entire Casey run as a kind of failure, albeit a propitious one, notwithstanding the fact that it had reproduced in a laboratory the phenomena of organizational adaptation and disintegration that Kennedy had first sought to quantify.[87]

The System Training Program

In truth, the outcome may well have disappointed them. Despite their agenda's obvious extrusion from RAND's air-defense analyses, Kennedy, Chapman, Biel, and Newell searched assiduously for more rigorous justifications. Their first working paper, for example, written before the Casey experiment in 1952, attempted to reverse the arrow of causality, suggesting that studying the behavior of a general "information-processing center" had *always* been the goal, and that the McChord ADDC had merely presented itself as a convenient choice.[88] Claims about objectives, methods, analyses, and findings varied over the years, culminating in a 1959 article in *Management Science*—the only contribution the original team ever made to the open literature—which mixed virtuosity and ambivalence in equal measure. "We collected as much data about the crews and their behavior as we could because we were

86. Since the orthodoxy of the Hawthorne experiments had yet to be seriously challenged, they were, of course, working from Elton Mayo's now-dubious interpretation of their results; cf. Richard Gillespie, *Manufacturing Knowledge: A History of the Hawthorne Experiments* (Cambridge: Cambridge University Press, 1991).

87. Specifically, the RAND memorandum later republished as Chapman et al., "The Systems Research Laboratory's Air Defense Experiments".

88. Chapman, *The Systems Research Laboratory and Its Program.* The narrative was repeated, albeit less emphatically, in Chapman and Kennedy, *The Background and Implications of the Systems Research Laboratory Studies.*

searching for a framework rather than testing a hypothesis," they famously prevaricated:

> Only part of the data has been successfully coded or explored at any length although literally hundreds of very pretty hypotheses have been lost in it. Although much of this data has been used only to explain specific incidents, it should prove of more general value once we know the appropriate questions to ask of it.[89]

This would never come to pass, as the four principals had already dispersed by the time of their final publication in the open literature, leaving cabinets full of files undigested and soon to be destroyed.

The tone of *apologia* likely reflected the course the Systems Research Laboratory had taken as early as September 1954, when RAND purged the pretense of a "research laboratory" even from its name, briefly reorganizing it as the System Training Project, and then, in early 1955, as the System Development Division (SDD). These were the peak years for the team's disciplinary activities—which must have been considered meager, given the scale of the experimental work—including Chapman's oft-cited talk at a 1957 symposium sponsored jointly by the American Institute of Industrial Engineers, the Operations Research Society of America, and the Institute of Management Sciences.[90] They were also years when SRL and its successor units added dozens of new hires each month, reaching 450 employees by the end of 1955, 850 less than a year later, and exceeding 2,000 by mid-1958, six months after RAND devolved the whole of SDD into the independent System Development Corporation, or SDC.[91] As the number of participants increased exponentially, the "senior staff" of the erstwhile Systems Research Laboratory begrudgingly relinquished proprietorship over the meaning and application of the experiments they designed.

89. Chapman et al., "The Systems Research Laboratory's Air Defense Experiments," 263.

90. Preprinted as Robert L. Chapman, *Simulation in RAND's System Research Laboratory*, P-1074 (Santa Monica: RAND Corporation, April 30, 1957), DTIC (AD0606372). Note the inconsistent usage of "*System* Research Laboratory," as opposed to "*Systems* Research Laboratory"; this appears to have been relatively common, raising some question as to how official the operation was—even by RAND's relatively anti-bureaucratic standards—but contemporaneous sources tended to prefer the latter styling, and so it is followed here as well.

91. According to Marzocco, *The Story of SDD* and the early chapters of Baum, *The System Builders*, which overlap this period as well.

What Casey had shown was that the operation of an Air Defense Direction Center could be sufficiently well mimicked to facilitate crew training without the cost of staging live exercises. Among the various "frameworks" that Kennedy, Chapman, Biel, and Newell tried articulating, they lingered frequently on the benefits of deducing "principles" for maximizing the capabilities of "man-machine systems" such as an ADDC. While these statements varied, they most commonly claimed to have discovered four: that equipment, human operators, and organizational structure should be considered an irreducible whole and designed and exercised accordingly; that individual human "components" functioned best when they understood how their actions contributed to the achievement an organizational objective; that a human-machine system's capacity could be increased by exposing it to workloads of graduated intensity; and, that operators learned most efficiently when grouped consistently with the same crew, which should be subjected to relatively informal debriefing sessions, wherein they critiqued their own performance and suggested solutions collaboratively and spontaneously, rather than through surveillance and seemingly arbitrary dispensation of punishment or regulation.[92]

Without hypotheses, variables, or controls, stricter analysis of the observational data could neither confirm nor deny any of these supposedly landmark findings even if it had been performed, but this was besides the point. Like the experimental setup itself, SRL had purchased wholesale knowledge their patrons already accepted as standard training doctrine, with a possible exception for the format of the debriefing session. For centuries, armies had raised, trained, and deployed units together in order to maximize cohesion, and the Army Air Forces had observed the same practice during its mobilization for World War II, as noted previously.[93] Even the term, "system training," had been borrowed from the Air Defense Command, which began using it to refer to exercises involving all parts of its ground

92. Although it is unclear when the shift to this training-oriented "principles" occurred, it likely began as the program itself pivoted toward crew-training applications in 1953; Chapman and Kennedy, *The Background and Implications of the Systems Research Laboratory Studies* featured such language prominently, as did Chapman, *Simulation in RAND's System Research Laboratory*.

93. Specifically from Craven and Cate, *Men and Planes*, 600–673.

and air crews, no matter how small, as early as 1949. Nevertheless, ADC swiftly expressed interest in buying back its own training practices at a bulk rate it could not have otherwise afforded, repackaged with the legitimacy of scientific research it could have otherwise accomplished. Due to the crosstalk between the real organization and its simulacrum in the laboratory, air-defense commanders had little to learn from SRL's perspective, but much to gain from its technique.

RAND recognized this first, electing to alert the Air Force to Project Simulator's potential application to operational training even before Casey ended its run in June 1952.[94] That May, Frank R. Collbohm, the president of the RAND Corporation, solicited a visit from General Frederic H. Smith, the vice commander of the Air Defense Command, writing, "I think you will be interested in seeing some of the work of our Systems Research Laboratory, which has been studying the load-capacity of an ADDC under realistic laboratory conditions." It is unclear whether Collbohm himself knew that the concept of "system training" had, in fact, originated with ADC, because he briefly restated its basic premise as if he expected Smith to admire its novelty. In either case, he proceeded quickly to the real substance of RAND's offer. While the "attainment of [a system] training program has been hampered by the difficulty and expense of providing a realistic and controllable radar input to the ADDC," Collbohm claimed that SRL had "found a technique for generating and presenting a sufficiently characteristic input in a reliable and economical fashion. The necessary steps have been carried through in detail...and the feasibility of the entire device has been established." In other words, RAND was proposing a method for manufacturing training

94. Evidently, the company did so despite its reluctance to assume the responsibilities of a prime contractor in a military development program—a role inconsistent with its core identity as a quasi-academic think-tank—likely because of the fear and urgency surrounding the Korean War. MIT felt the same about Project Whirlwind when it too accelerated into a major development program around the same time, a discomfort that became more acute as Korea's importance receded from view. The decisions arrived in each case were similar: the devolution of engineering and systems-management responsibilities from the parent institution to a non-profit entity: Lincoln Laboratory, and ultimately, the MITRE Corporation, in the case of MIT and Whirlwind; and the System Development Corporation for RAND and the System Training Program. Cf. Kent C. Redmond and Thomas M. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge: MIT Press, 2000), 109–127, 411–428; Baum, *The System Builders*, 26–29.

problems of greater complexity than could be achieved with real aircraft for a marginal cost of about $500 per session.[95]

In response to Collbohm's invitation, as well his suggestion that the experiment should be repeated with military personnel in place of students, General Smith dispatched a representative to observe the final Casey trial—when the experimenters finally succeeded in overwhelming their subjects—on June 6. As a result, Kennedy traveled with his colleagues to Colorado Springs in August and explained Project Simulator to the headquarters staff of the Air Defense Command; he returned again in October to present SRL's plan for a new study, called "Cowboy," and secured temporary-duty authorization for 40 personnel, five of them officers, detailed from units in the Western Air Defense Force.[96] The setup remained essentially unchanged from Casey, except that the early-warning posts were augmented by two more stations: one representing an adjacent direction center, and the other, a control center, in order to simulate the tasks of cross- and forward-telling within an air-defense division. Also different from Casey was that the Cowboy crew would be exposed to training problems of graduated intensity from the start, rather than as an last-minute intervention, with the intent of quantifying the rate of "organizational learning."

Exactly what happened remains cryptic. Due to security restrictions, figures measuring Cowboy's performance never appeared in print, though qualitatively, the experimenters described observing the crew handling equivalent loads more efficiently even as they increased the complexity of successive training problems.[97] The run included 22 eight-hour trials, the duration of each session about the same as a standard shift, conducted from mid-January to early-February in 1953. More than a dozen ADC officers came to witness

95. F. R. Collbohm to Maj. Gen. Frederic H. Smith, Jr., Vice Commander, Air Defense Command, May 27, 1952, CBI 90, ser. 98, box 22, folder 13.

96. Memo, W. C. Biel and M. O. Kappler for L. J. Henderson, Jr., "Index and Abstracts," SM-647, September 27, 1955, 7, attachment to Henderson to Stranathan, "History of the System Training Project," October 3, 1955, CBI 90.

97. Chapman et al., "The Systems Research Laboratory's Air Defense Experiments" and Sweetland and Haythorn, "An Analysis of the Decision-making Functions of a Simulated Air Defense Direction Center" did include some plotted data, but with scales for the vertical axes omitted.

the performances, including General Smith on February 6, who wrote Kennedy shortly thereafter in order to express "how tremendously impressed I and other staff members were with the work you are carrying on," because "the problems you and your test team are attacking are those which have been extremely critical throughout the Air Defense Command throughout its inception," namely, the incremental improvement of equipment and procedure.[98]

One month later, Kennedy, Chapman, Kappler, and Newell presented another briefing in Colorado Springs, leading to the creation of a committee called the Joint ADC–RAND Study Group on the RAND System Training Program, with RAND supplying six of its nine members.[99] By May 15, it had drafted a substantial report proposing to scale up the production of simulated displays to accommodate two weekly training problems at 100 ADDCs, as well as to engineer an electronic "problem reproducer" unit, which could amplify signals encoded on 70-millimeter film, instead of printed paper, and inject them into standard PPI scopes, much like the hand-operated 15-J-1c.[100] The report also delineated responsibilities for the project, with RAND assuming the role of a prime contractor for equipment and services, though subcontracts would need to be let for industrial procurement.[101]

Then, on June 6, ADC headquarters officially petitioned the Air Staff for permission to proceed with the study's recommendation, beginning with a trial in the 27th Air Division, which operated four ADDCs in Southern California, with its control center at Norton Air

98. Maj. Gen. Frederic H. Smith, Jr., Vice Commander, Air Defense Command to John L. Kennedy, RAND Corporation, February 10, 1953, CBI 90, ser. 98, box 22, folder 13.

99. In addition to SRL's four principals—Kennedy, Biel, Chapman, and Newell—as well as Melvin Kappler, the RAND contingent included John F. Matousek, a computing specialist, and Charles W. Simon, another experimental psychologist. Two officers represented ADC headquarters, along with a civilian operations analyst.

100. In fact, manual target generators would still be employed to represent interceptors under the direction center's control, because responses to the training problem could not be calculated ahead of time. Of course, the tracks imprinted on the film could not be modified either, which meant that simulated contacts did not react to interceptors and would even continue to appear on scopes after they had been declared shot-down.

101. The recommendation was subsequently revised and formalized as System Training Program Staff, *The System Training Program for the Air Defense Command*, RM-1157-AD (Santa Monica: RAND Corporation, November 3, 1953), CBI 90, ser. 98, box 22, folder 13. Manuscript, "Report of the Joint ADC–RAND Study Group on the RAND System Training Program," draft, May 15, 1953, CBI 90, ser. 98, box 22, folder 13.

Force Base in San Bernadino.[102] "The decision to adopt the Lincoln Transition System [i.e. SAGE] as the *future* ground environment for air defense and the need for constant improvement requires immediate action on the part of Air Defense Command to take all means possible in order to improve the present system," began the request:

> One such item is the Air Defense Systems Training Program which offers the most outstanding improvement of all items being considered. This program can be implemented into the present manual system with little development and at low cost and has high potential for continued use with future systems. It is of such importance to ADC as to warrant being a separate issue and is the basis for this letter.[103]

Washington agreed after ADC provided it with a cost estimate and an accompanying schedule for the trial phase, approving $1.2 million in funding through September 1954. Subcontracts were duly let, with RCA taking on the production engineering and eventual manufacture of the problem-reproducer unit, designated AN/GPS-T2, while RAND commenced its hiring rampage.

Thus, the air-defense "experiments" became a *development* program no later than August 21, 1953, when RAND signed its first contract with the Air Defense Command, officially applying its effort to operational-training equipment.[104] For a short period, SRL's senior staff retained some pretension otherwise. They did preside over two additional runs, codenamed "Cobra" and "Cogwheel," both identical to Cowboy—except, in the latter case, the number and duration of training sessions—in February and June of 1954. However, Cobra's primary objective was to familiarize new staff with the work they had been hired to

102. For reference, the GCI units reporting to the 27th Air Division in mid-1953 consisted of the 669th and 670th AC&W squadrons, which operated stations P-15 and P-39 at Santa Rosa Island and San Clemente Island, respectively; and the 750th and 751st AC&W squadrons, which operated P-59 and P-76 near Edwards Air Force Base and at Mount Laguna, respectively. Data from Lloyd H. Corbett Jr. and Mildred W. Johnson, *A Handbook of Aerospace Defense Organization, 1946–1980* (Peterson AFB: Office of History, Aerospace Defense Center, December 31, 1980), AFHRA (1039702); David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, November 1997).

103. Maj. Gen. Jarred V. Crabb, Chief of Staff, Air Defense Command to Deputy Chief of Staff, Operations, Headquarters, United States Air Force, "Air Defense Systems Training Program," June 6, 1953, CBI 90, ser. 98, box 8, folder 11, emphasis in original. Note again the ambivalence regarding the use of "system" or "systems" as an adjective, except that in this case, the title was eventually formalized quite definitely as the "*System* Training Program."

104. Marzocco, *The Story of SDD* is once again the primary reference here for factual specifics.

continue, while Cogwheel likewise oriented the officers of the 27th Air Division who would soon have to supervise the project's field-testing phase. In each case, data was gathered and recordings made exactly as they had been for Casey and Cowboy, and the outcomes of the four runs were always considered cumulatively.[105] Nevertheless, of the four principals of the original Systems Research Laboratory, only William Biel remained after it was reorganized as the System Training Project in September 1954, assuming a co-directorship with Melvin Kappler.[106]

An operational requirement document followed ADC's preliminary request in June 1954, which headquarters validated in August, authorizing the Air Materiel Command to spend whatever was necessary to procure and install the System Training Program at 152 sites, and even awarded the project a coveted "1A" priority rating—a crash mobilization, in effect.[107] A field manual later published in 1956 showed how thoroughly the Air Defense Command incorporated STP's scientistic pretext. "The System Training Program is a set of specific procedures and training aids for putting some basic principles of team training into practice," declared the introduction. "The training principles are based on well-established psychological concepts that have been tested both in the laboratory and in the field."[108] Since SRL's "training principles" could be articulated plainly, succinctly, and intuitively, the didactic publication quickly proceeded to explain the complicated equipment, scripts, forms, rules, tests, briefs, and debriefs needed to conduct a synthetic-training session. The

105. Incidentally, each run took its name from the fictitious radio callsign used by the mock ADDC during the simulated training sessions.

106. Biel and Kappler would later become, respectively, the vice president and president of the System Development Corporation when RAND spun it off in December 1957.

107. Brig. Gen. R. E. Koon, Deputy Director of Operations, Office of the Deputy Chief of Staff, Operations, Headquarters, United States Air Force to Gen. Benjamin W. Chidlaw, Commander, Air Defense Command, "Air Defense Systems Training Program," August 10, 1953, CBI 90, ser. 98, box 8, folder 11; Col. Gilbert A. Meyers, Deputy Director of Requirements, Office of the Deputy Chief of Staff, Operations, Headquarters, United States Air Force to Gen. Benjamin W. Chidlaw, Commander, Air Defense Command, "Qualitative Operational Requirement, ADC–RAND System Training Program," August 16, 1954, CBI 90, ser. 98, box 8, folder 11.

108. United States Air Force, Air Defense Command, *System Training Program*, Air Defense Command Manual (ADCM) 50-15 (Colorado Springs: Headquarters, Air Defense Command, July 15, 1956), CBI 90, ser. 98, box. 22, folder 15, 1; see also Victor Milner, Jr., "Air Defense Systems Training Concept," *Air University Quarterly Review* 12, no. 2 (Summer 1960): 14–21.

tests it referenced had been limited almost entirely to the formidable task of shaking down the new electronic training-aids and teaching officers how to run the simulation.

Perhaps the clearest indication of ADC's unconditional interest in the System Training Program lies in the fact that controlled studies of its effectiveness were deferred until *after* it had already been deployed to a critical number of air-defense operations centers. Between 1956 and 1958, researchers from SDD, and later, SDC, compared the performance of crews at three sites; although the first experiment involved an entire air division, the second and third were limited to a single ADDC. In each case, some of the crews on rotation participated in training simulations while the others carried on without the STP regimen. Although two of the studies claimed to find statistically significant improvements in some of the recorded metrics, their confidence was undermined by persistent problems with equipment and other factors beyond the experimenters' control, such as individual crew turnover and sessions canceled or truncated for operational reasons—one follow-up trial, for instance, had to be canceled due to the declaration of an air-defense emergency.[109] The lack of evidence concerning STP's effectiveness seemed not to faze the Air Defense Command, which continued to roll it out regardless, and even pushed for money to develop a version compatible with the computerized ADDCs expected to enter service during the SAGE era.[110]

Indeed, the most touted outcome of the saga begun in 1950 was its eventual contribution to the development of software for the AN/FSQ-7 computer. In 1953, the Joint ADC–RAND Study Group had estimated that, based on an average intensity of 100 tracks per hour, a three-hour training problem would require the computation of 30,000 simulated radar "blips," corresponding to at least 7 million blips each year, if 100 ADDCs received two new problems every month. Thus, even following the same deck-construction method devised for Project Simulator, the complexity was orders of magnitude greater at production scale and, they

109. L. T. Alexander et al., *Problems Encountered in Developing and Maintaining a Field System Training Program*, SP-107 (Santa Monica: System Development Corporation, September 18, 1959), DTIC (AD0297443) likewise reported that similar obstacles frustrated the deployment of STP as a whole.

110. Parsons, *Man-Machine System Experiments*, 214–226 summarized and cited the relevant reports, some of which were circulated as gray literature, while others remained internal to SDC.

reasoned, could only be economically accomplished with the aid of stored-program digital-electronic computers. Since the preparation for Cobra included porting the logic previously used during Casey and Cowboy to RAND's new IBM 701, cutting the marginal computation time from days to hours, the study optimistically concluded that 2700 machine-hours per year could support the entire enterprise.[111] Nevertheless, even the rosiest projections would have still constituted the largest continuously running digital computation task in the world, occupying three IBM 701s at their maximum duty rate for a full year by mid-1955.[112] At that time, RAND accepted an additional responsibility to develop the AN/FSQ-7 system software, essentially by default, as no other organization involved in the project possessed the experience of sustaining a major computer-programming effort, nor had any desire to do so.[113]

With its legacy confused with a cause it never envisioned, its formalism doubted and neglected by the field, its novelty overstated, and the effectiveness of its final product unproven, the Systems Research Laboratory presents a difficult subject to evaluate. What does seem clear, however, is that measurably improving the performance of air-defense operations was, at best, a concern of secondary importance to its patrons, perhaps even qualifying as an organizational myth.[114] Rather, the mere act of doing *something* that made

111. "Report of the Joint ADC–RAND Study Group," May 15, 1953, CBI 90, VI-1–VI-19.

112. According to Martin H. Weik, *A Suvey of Domestic Electronic Digital Computing Systems*, Ballistics Research Laboratory Report No. 971 (Aberdeen Proving Ground, MD: Ordnance and Research Development Project, Ballistics Research Laboratory, US Army Ordnance Corps, December 1955), 67–70, OCLC (9357884), there were only 19 IBM 701s in use by 1955. The manufacturer claimed the average installation required a staff of about 80 technicians, programmers, and operators to keep each computer running.

113. The remainder of the story has been told best in Rebecca Slayton, *Arguments That Count: Physics, Computing, and Missile Defense, 1949–2012* (Cambridge: MIT Press, 2013), 17–39 and Johnson, *United States Air Force and the Culture of Innovation*, 156–164, though primarily from the perspective of Lincoln Laboratory. Technically, Lincoln only developed a "master program" for the XD-1 prototype of the AN/FSQ-7; RAND, and later, SDC assumed the much larger task of porting it to the production model, adapting the program to the specific configuration of each site, and continuing to support it with changes, fixes, and upgrades until the mid-1960s, when the Air Force briefly trained its own programmers in order to maintain the system. Baum, *The System Builders*, 31–63; Roger R. Klages, "Command and Control Computer Programming," *USAF Instructors Journal* 6, no. 4 (Spring 1969): 55–57, OCLC (985618742).

114. Although unimpressed with a perceived over-application, Charles Perrow, *Complex Organizations: A Critical Essay*, 3rd ed. (New York: Random House, 1986), 265–272 briefly summarized the theory of organizational myth and cited its formative studies.

intuitive sense functioned to legitimate a bureaucracy pressured to meet the speculative threat of attack by long-range Soviet bombers. As a relatively inexpensive project—certainly when compared with the totality of SAGE—the System Training Program proved a remarkably efficient manifestation of high-modernist idealism.[115]

But while it did later give rise to the SAGE System Training Program (SSTP), the "manual" STP was, in fact, a reaction *against* SAGE—or, the Lincoln Transition System, as the program was at first known—as ADC emphasized in its petition to Air Force headquarters in June 1953. As inevitable as air-defense automation appeared, when actually confronted with the possibility, air-defense commanders nonetheless insisted that it conform to their incremental model of organizational and technological change. Adopting the principles, and, more importantly, the equipment devised during the course of the Systems Research Laboratory's air-defense experiments helped plausibly reframe the potentially "revolutionary" disruption of computer automation as merely another "evolutionary" step toward a rational response to the threat of nuclear devastation.

4 Conclusion: Assessing command-and-control

There is an argument to be made, though not dwelled upon here, that the natural historiographical path to air-defense automation runs through the System Training Program rather Project Whirlwind. It is worth pausing momentarily to consider another possible history of computing in military command-and-control, one emphasizing the Air Force's subsidization of the postwar market for automated data-processing (ADP) equipment. A catchall term, encompassing a range of components from punched-card accounting machines to digital

115. Their modernist elements were specifically celebrated in several sponsored films, including *STP: The Story of the System Training Program*, digitized film media, produced by the RAND Corporation in association with the Air Defense Command (New York: American Film Producers, n.d. [1956?]), Internet Archive, https://archive.org/details/6251_Story_of_the_System_Training_Program_STP_The_01_00_54_20 ; and *System Technology*, digitized film media, produced by the System Development Corporation (Santa Monica: System Development Corporation, n.d. [1960?]), Internet Archive, https://archive.org/details/6240_System_Technology_01_29_28_19 . Like most sponsored films, however, it is difficult to ascertain their audience, intended or actual.

electronic computers, ADP systems evolved from, and intermingled with, the same unit-record equipment that had, among other feats, already mobilized the most extensively planned industrial economy in history: the United States in World War II.[116] Likewise, automated data-processing facilitated the organizational expansion of the United States Air Force more than the illustrious edifices of nuclear command-and-control, despite receiving considerably less celebration in our collective memorial to the "computer revolution."[117]

116. Although a tremendous amount has been written on the emergency management of the American war economy—perhaps nowhere more comprehensively than in Paul A. C. Koistinen, *Arsenal of World War II: The Political Economy of American Warfare, 1940–1945* (Lawrence: University of Kansas Press, 2004), part of the author's magisterial seven-volume treatment of the subject—only a few sources suggest the calculating demands placed on workers and equipment, aside from obscure postwar publications like David Novick and George A. Steiner, *Wartime Industrial Statistics* (Urbana: University of Illinois Press, 1949); David Novick, Melvin Anshen, and W. C. Truppner, *Wartime Production Controls* (New York: Columbia University Press, 1949); and the problematic (see John J. Rumbarger, "The War Production Board and Historical Research: Some Observations on Writing Public History," *The Public Historian* 6, no. 2 (Spring 1984): 5–19, doi:10.2307/3376911) United States, Civilian Production Administration, *Industrial Mobilization for War: History of the War Production Board and Predecessor Agencies, 1940–1945—Program and Administration* (Washington: GPO, 1947). However, James W. Cortada, *Before the Computer: IBM, NCR, Burroughs, and Remington Rand and the Industry They Created, 1865–1956* (Princeton: Princeton University Press, 1993), 189–221 does provide some insight into the wartime role of accounting machines indirectly through the business histories of their manufacturers. David Novick, incidentally, is a figure worthy of further study: a "statistical economist," specialized in reporting and calculation, who eventually migrated to the RAND Corporation after his tenure at the War Production Board; as an historical actor, he appears only in Philip Mirowski, *Machine Dreams: Economics Becomes a Cyborg Science* (Cambridge: Cambridge University Press, 2002), 394–406, where, owing to his unusual experience, he is characterized favorably as a disciplinary heterodox.

117. The following passage gestures toward a larger body of research and writing that could not be included in this dissertation. This work drew from, overlapped with, and built upon such inspirations as David F. Noble, *Forces of Production: A Social History of Industrial Automation*, 2nd ed. (1984; New Brunswick, NJ: Transaction, 2011); JoAnne Yates, *Control Through Communication: The Rise of System in American Management* (Baltimore: Johns Hopkins University Press, 1989); Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press, 1995); Jennifer S. Light, "When Computers Were Women," *Technology and Culture* 40, no. 3 (July 1999): 455–483, doi:10.1353/tech.1999.0128; Jon Agar, *The Government Machine: A Revolutionary History of the Computer* (Cambridge: MIT Press, 2003); Thomas David Haigh, "Technology, Information, and Power: Managerial Technicians in Corporate America, 1917–2000," (PhD diss., University of Pennsylvania, 2003), ProQuest (3087405); David Alan Grier, *When Computers Were Human* (Princeton: Princeton University Press, 2005); Lars Heide, *Punched-Card Systems and the Early Information Explosion, 1880–1945* (Baltimore: Johns Hopkins University Press, 2009); Nathan Ensmenger, *The Computer Boys Take Over: Computers, Programmers, and the Politics of Technical Expertise* (Cambridge: MIT Press, 2010); and Marie Hicks, *Programmed Inequality: How Britain Discarded Women Technologists and Lost Its Edge in Computing* (Cambridge: MIT Press, 2017), among others—many by the same authors. Key themes include the continuity between digital and pre-digital computing equipment, the adoption of modern computers as tools of administration, as well as their role in the social transformation of office culture and the structure of bureaucratic labor. The Air Force experience mostly paralleled the general trends identified in these and similar studies, but as the world's single largest computer-using organization from 1945 until at least 1960 (see below), it not only occupied a powerful position from which to drive change, but also a precipitous one from which to depend on it.

By 1968, digital computers in ADP centers far outnumbered those applied to military command-and-control systems, 867 to 201.[118] "When an organization is small, the top man knows all his people personally," Colonel Joseph F. Mooney wrote in the *Air University Quarterly Review*. In 1953 a 25-year veteran would have commissioned into an Army Air Corps with fewer than 1,000 officers. "He is well aware of what is going on at all times, and no elaborate reporting system is needed."[119] Clearly those days had passed. By 1956 the Air Force employed 1.34 million people and spent $17.7 billion—4% of the gross domestic product—to tend $70 billion in assets.[120] This was America's largest enterprise, a shadow over even the last of the old corporate behemoths: the AT&T Bell System, which, with 789,719 workers, earned $5.8 billion on a $16.2 billion capital investment during the same period.[121]

Mooney, the Director of Management Analysis at Air Defense Command headquarters, went on to claim that "if we apply the industrial definition of 'control'—'Control is the examination of results'—we find that it is as applicable and desirable in a large military organization as in any industry."[122] As an example, he described how his office produced its

118. United States General Services Administration, Federal Supply Service, *Inventory of Automatic Data Processing Equipment in the United States Government, Fiscal Year 1969* (Washington: GPO, 1971), 27, OCLC (664373708). See following note on the Brooks Act for definitions of "exempt" and "non-exempt" data-processing systems for purposes of classification in this and similar reports.

119. Joseph F. Mooney, "Air Defense Command Procedure for Executive Control," *Air University Quarterly Review* 6, no. 1 (Spring 1953): 101.

120. United States Department of Defense, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, January 1–June 30 1957* (Washington: GPO, 1958), 307–313, 341–346, 352–361, OCLC (8318528).

121. American Telephone and Telegraph Company, *1955 Annual Report* (New York: American Telephone and Telegraph Company, 1956), ProQuest Historical Annual Reports (88190813).

122. As a consequence of the AAF's unprecedented regime of statistical data collection, aggregation, and presentation during the war, the USAF became the first of the armed forces to feature a military comptroller on its general staff, a program rapidly expanded to every headquarters unit at wing-level and above: Frances Acomb, *Statistical Control in the Army Air Forces*, Air Historical Study No. 57 (Maxwell AFB, AL: USAF Historical Division, Air University, January 1952), AFHRA (0467646); David Lowell Hay, "Bomber Businessmen: The Army Air Forces and the Rise of Statistical Control, 1940–1945," (PhD diss., University of Notre Dame, 1994), ProQuest (9422401); Lt. Gen. Edwin W. Rawlings, "Report on Comptrollership Within the Air Force, 1946–1951," undated manuscript [1951?], AFHRA (1145201); Frank A. Bogart, "Air Force Comptroller 1964," *Air University Review* 15, no. 4 (May–June 1964): 10–16. More than mere financial accountants, early Air Force comptrollers performed functions analogous to a "chief information officer," responsible for providing commanders with

quarterly Kill Effectiveness Report, characterizing "kill effectiveness," the percentage of enemy aircraft expected to be destroyed before reaching their bomb-release lines, as "the net profit of the Air Defense Command":

> Before this computation can be made, numerous items of information are required: probable enemy force; combat ready aircraft available for defense; combat ready crews available for defense; per cent of scramble sorties ordered airborne; gunnery qualifications of crews; combat ammunition on hand; detection range capability of air control and warning system; positive identification capability; detection time to scramble order; force (combat aircraft) which can "scramble on"; scramble order time to airborne time; airborne time to intercept time; time for earliest identification as hostile; combat time; destruction capability; and antiaircraft destruction capability.[123]

Altogether, 304 types of forms gathered data on thousands of reporting items. In Colorado Springs, hundreds of women worked shifts in a mechanized accounting shop to aggregate the numbers for Mooney's "Command Data Book" with commercial ADP equipment.

As a literal center of calculation, ADC headquarters could stand against the largest industrial firms even on its own right, but it was only one of many within the United States Air Force. In Dayton, the Air Materiel Command ran perhaps the single largest data-processing operation in the world in order to administer its purchasing, stockpiling, and inventory-management programs, while in Denver, nearly 3,000 clerks, typists, and technicians—two-thirds of them women—cranked payrolls and ledgers for the Air Force Finance Center.[124]

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data on all matters of operational or administrative significance, as well as for managing their organization's data-processing equipment and activities: United States Department of the Air Force, *Management Analysis*, Air Force Manual (AFM) 170-2 (St. Louis: Air Force–Universal Printing Co., September 1954), OCLC (320212883) and United States Department of the Air Force, *Comptroller—Functions and Responsibilities*, Air Force Manual (AFM) 170-6 (Washington: GPO, April 15, 1958), OCLC (320200300). See also Robert H. Lassman, "Into a Wild New Yonder: The United States Air Force and the Origins of Its Information Age," (PhD diss., University of South Carolina, 2013), ProQuest (3608597).

123. Mooney, "Air Defense Command Procedure for Executive Control," 101, 103. The Strategic Air Command, the USAF's preeminent field organization, operated an even more elaborate reporting system on a much larger scale than did the Air Defense Command: Albert L. Pearl, "SAC Management Control System," *Air University Quarterly Review* 13, no. 4 (Summer 1962): 17–27.

124. *Air Force Accounting and Finance Center: 40 Years of Excellence, 1951–1991* (Denver: Defense Finance and Accounting Service, n.d. [1991?]), OCLC (23130356). In 1961, the first year for which this data was compiled, there were 19 computer-equipped ADP centers supporting activities at Wright–Patterson Air Force Base. By way of comparison, NASA, the single largest computer-using agency outside the defense-nuclear complex, operated 19 computer centers *in total*. Moreover, the Air Force Logistics Command, created during a major reorganization in 1960, possessed 64 centers overall—ten more than the Atomic Energy Commission, whose figure includes the entirety of the national-laboratory system: United States Bureau of the Budget, *Inventory of*

Each of these field activities collected, tabulated, and studied its own data to serve its own ends. Even the Air Force's headquarters in Washington itself represented merely another idiosyncratic data maw, one more funnel among funnels rather than some pyramidal Eye of Providence.[125]

Thus, while the 1950s did not diminish the heady blend of excitement, fear, wonder, and confusion that had attended the digital electronic computer from the start, the end of the decade did bring the first sort of reckoning. No longer cloistered among of code-crackers and atom-smashers, the computer had emerged from obscurity and into commodity, one to be weighed against less disruptive and more traditional methods of accomplishing the same tasks. While only a few hundred of the most upmarket firm could afford a gilt-trim colossus from Sperry Rand, IBM surpassed even its high-end success with the mid-range Model 650, which reached 1,500 customers before the newly announced 1401—starting at just $2,500 per month—secured an incredible 5,200 orders in October 1959 alone.[126]

Commercialization had called the commodity to account. Since "the first electronic computer system installed to handle business data-processing problems has been in use for six years," declared the editor of the *Harvard Business Review* in 1957, the time had come to "look at the field with perspective and to distinguish fact from fancy."[127] Its promise at last had to meet the balance sheet before corporate boards and congressional subcommittees,

Automated Data Processing (ADP) Equipment in the Federal Government, Including Costs, Categories of Use, and Personnel Utilization (Washington: GPO, October 1962), OCLC (760366657).

125. Like its many sub-agencies, Air Force headquarters gathered and processed reporting information for to serve its own managerial purposes, complementing by an independent computer-development program: *Air Force Command and Control Users' Symposium*, proceedings held at the RAND Corporation, Santa Monica, CA, December 6–8, 1965, n.d. [1966?], AFHRA (0907035); "Recurring Reports Prepared for the Air Staff," Reports Management Group, Directorate of Data Systems and Statistics, Headquarters, United States Air Force, June 30, 1962, AFHRA (1107965); Thomas A. Sturm, *The Air Force Command and Control System, 1950–1966* (Washington: USAF Historical Division Liaison Office, August 1967), https://media.defense.gov/2011/Apr/29/2001330159/-1/-1/0/AFD-110429-030.pdf ; Paul Erickson et al., *How Reason Almost Lost Its Mind* (Chicago: University of Chicago Press, 2013), 51–80.

126. Martin Campbell–Kelly et al., *Computer: A History of the Information Machine*, 3rd ed. (Boulder: Westview Press, 2014), 97–139; Bashe et al., *IBM's Early Computers*, 459–480.

127. Ralph F. Lewis, "Never Overestimate the Power of a Computer," *Harvard Business Review* 35, no. 5 (September–October 1957): 77, EBSCO (6769309).

together with case studies, management consultants, or the latest *Wall Street Journal*; or Walter Reuther and the UAW, George Meany and the AFL–CIO, and the Comptroller General of the United States.[128] A peculiar discrepancy emerged during such examinations, however, which still saw an inevitable future in the ambiguous, perhaps even undistinguished record of recent experience.

For instance, the *Review* claimed that "despite the ballyhoo that has been given computer systems for the last few years and in face of the undeniable future usefulness of the computer as a management tool, there are very few computer systems in use today which could be judged as economic from any standpoint." Apparently, "the number that are paying their way at this point can be counted on one hand, with some fingers left over." The misapprehension, the author reckoned, was that "little publicity has been given to the fact that all computing systems really add to present know-how is speed." Nevertheless, "computing systems will be a major boon to business," the *HBR* upheld, "but they are an evolutionary development, not a revolutionary one."[129] Whether private industry had borrowed this language from the military, or the military from private industry, is probably impossible to say, and perhaps even futile, given the profound interdependence between them, though it is first attested in the Air Force's internal dialogue.

The prevailing argument remained that computers cost more because they could *do* more, qualitatively more—things that humans could not feasibly accomplish at *any* price—and so the burden lay with customers to revise their strategies, organizations, and

128. The Employment Act of 1946 required the United States Congress to appoint a standing joint committee to monitor the effect of macroeconomic conditions on wages and unemployment. The Joint Economic Committee held its first hearings on computer automation during the 1950s, gathering statements and testimony from technologists, business executives, and union leaders, among others. Nothing came of them besides perfunctory recommendations to keep watch over future developments, though even the show of the hearings themselves fell off the committee's agenda over the following decades. Joint Economic Committee, *Automation and Technological Change: Hearings Before the Subcommittee on Economic Stabilization* 84th Cong., 1st sess., 1956, CIS (HRG-1955-ERJ-0005) and Joint Economic Committee, *Instrumentation and Automation: Hearings Before the Subcommittee on Economic Stabilization* 84th Cong., 2nd sess., 1957, CIS (HRG-1955-ERJ-0005) are representative of earlier proceedings, with higher levels of engagement than later ones. On the contemporaneous discussion of trends impacting business and government operations, see below.

129. Lewis, "Never Overestimate the Power of a Computer," 82, 77.

expectations correspondingly. To further guide and educate the modern executive, a new wave of management gurus shoveled monographs, white papers, and periodicals into the offices of the *Fortune* 500—not to the neglect of Washington, of course.[130] In 1960, John Diebold, the dean of all the computer-automation consultants, and no stranger to congressional testimony, submitted that "probably the most common, and the worst reason for embarking on an automation project is to save labor costs," one that "demotes to second place what should be the primary aim of any company installing automatic equipment; to exploit the fully potentialities of these machines for doing things that cannot be done well, or cannot be done at all, without them."[131]

Military command-and-control systems were supposed to be fundamentally different, and yet, for a brief period, industry experts conceived of ADP, whether in service of administration or real-time operations, merely as different types of "management control systems."[132] Indeed, digital and electromechanical equipment were, in general, operated side by side in major calculating centers, such as those that generated scripts for the System Training Program, and even the SAGE network itself, for many decades "Manual" air-defense centers—so called retroactively, after the ascendancy of automation—first implemented in

130. It is rather remarkable that a phenomenon as significant to the adoption of computer automation as consultancy ventures have as yet received so little attention from historians of computing. In particular, while the books, talks, articles, and reports John Diebold produced throughout his prolific career have been frequently cited, Jeffrey R. Yost, *Making IT Work: A History of the Computer Services Industry* (Cambridge: MIT Press, 2017), 19–45 is so far the only published attempt to more broadly evaluate him and his contemporaries.

131. Statement of John Diebold, President, Diebold Group of Management Consulting Companies, in Joint Economic Committee, *New Views on Automation: Papers Submitted to the Subcommittee on Automation and Energy Resources* 86th Cong., 2nd sess., 1960, 94–95, CIS (CMP-1960-ECJ-0021).

132. Cf. Donald G. Malcolm and Alan J. Rowe, eds., *Management Control Systems: The Proceedings of a Symposium Held at System Development Corporation, Santa Monica, California, July 29–31, 1959* (New York: Wiley, 1960); John A. Beckett, *Motivation and Systemation: New Realities for Industrial Management* (Durham, NH: Whittemore School of Business and Economics, University of New Hampshire, 1963); Robert N. Anthony, *Planning and Control Systems: A Framework for Analysis* (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1965). In addition, the professional nomenclature was also briefly offered term "military information system," as in Edward Bennett, James Degan, and Joseph Spiegel, eds., *Military Information Systems: The Design of Computer-Aided Systems for Command* (New York: Frederick A. Praeger, 1964), though the modern dichotomy between "command-and-control systems" and "automated data-processing systems" appears to have been firmly established by 1970, possibly as a consequence of the Brooks Act (described in a following note) in 1965.

the 1950s continued to operate, in some capacity, until the 1980s. Not only did they establish the operational pattern that automated systems would have to follow, they also hosted the bulk of human labor expended on North American air-defense throughout the Cold War.[133]

Despite sharing many features in common, however, the Air Force classified command-and-control systems not just by function but chiefly by *owner*, segregating them from ADP systems altogether. They were procured differently, operated separately, and managed independently. Whereas ADP equipment had to be purchased or leased from off the shelf, consolidated under a single office, and subjected to rigorous pricing, accounting, standardization, and other multifarious constraints imposed throughout the department and across the federal government at large, command-and-control systems remained unquestionably, and legally, exempt.[134] Each one delimited the petty fief of a prestigious battle staff, whose rosters implausibly swelled with greater automation.[135]

133. After starting at 42,489 in January 1951, the Air Defense Command's total allocation of personnel peaked at 122,254 in June 1958—the same month the first SAGE sector was declared operational. Force strength began declining immediately, however, falling to 102,386 by June 1962, and then following a very brief uptick, gradually slipped below 42,000 again in 1972, twenty years after ADC's reactivation. *Historical Data of the Aerospace Defense Command*, April 1973, AFHRA, sect. 3. Note that these figures do not include either the Alaskan Air Command, which was responsible for defending its own area of operations, or the Northeast Air Command, which was disestablished entirely in 1957.

134. The Brooks Act of 1965 (Pub. L. 89-306; 79 Stat. 1127; 40 U.S.C. §759), Congress's first information-technology policy, is an unappreciated landmark in the history of computing. After years of negative findings from the Comptroller General, which criticized the inefficiencies attributed to agency autonomy, the bill centralized procurement of automated-data processing equipment under the General Services Administration (GSA). Although the Department of Defense protested the lack of a statutory exemption for national-security programs, hearings and reports make clear legislators' understanding of military command-and-control systems as integrated "weapons systems," and thus, not subject to the provisions of the act: House Committee on Government Operations, *Automated Data Processing Equipment: Hearings Before a Subcommittee of the Committee on Government Operations on H.R. 4845* 89th Cong., 1st sess., 1965, 222–245, CIS (HRG-1965-OPH-0007); House Committee on Government Operations, *Automated Data Processing Equipment: Report of the Committee on Government Operations on H.R. 4845* 89th Cong., 1st sess., August 17, 1965, H. Rpt. 89-802, 34–35. In arguable cases, the GSA was expected to grant dispensation on its own authority, but the Defense Department later received a statutory exemption anyway. The bill struggled to achieve its intended purpose (cf. House Committee on Government Operations, *Administration of Public Law 89-306, Procurement of ADP Resources by the Federal Government: Thirty-Eighth Report by the Committee on Government Operations* 94th Cong., 2nd sess., October 1, 1976, H. Rpt. 94-1746) but remained in force until the Information Technology Management Reform (Clinger–Cohen) Act was passed in 1996.

135. Taken together, M. C. Heuston, *Concepts of the Staff Element in Air Force Command Control*, RM-3345-PR (Santa Monica: RAND Corporation, October 1962), OCLC (19286013); J. R. Brown, "The Effect of Automation on Organization," *Air University Review* 18, no. 5 (July–August 1967): 64–67; and Glenn F. Pribus, "Computer Impact on the Organization," *Air University Review* 26, no. 2 (January–February 1975): 68–75 sketch a chronicle

The distinction between "command and control" systems and "automated data processing" systems was thus constructed to reflect the similarly artificial distinction between "operations" and "administration" in a military organization. Applications touched by ADP, for instance, were rapidly depopulated and deskilled with little resistance. Command on control systems, on the other hand, threatened to turn automation *on the officer corps itself*, thus fomenting prodigious ratiocination about the integrity of the military institutions at every turn. It is telling that in the face of all the many scientific, medical, and engineering experiments conducted to understand and better discipline the performance of humans in system environments, whether as scope-readers in an air-defense operations center or as pilots of supersonic aircraft, no experiment of comparable scale or influence cast the same gaze on a commanding officer in a similar environment.[136] There can be no pretension, then, that compared to the vast quantity of shared experience accumulated in the process of organizing the nation for nuclear warfare, nuclear command-and-control systems represent more than a comparatively minor exception from the postwar bureaucratic order.

Certainly this is a dissonant on which to pivot toward more concentrated study of the very same artifacts. Nevertheless, there is little sense to be made of their incongruities without also acknowledging their profound deviance. None of the urgency, custom attention, or billion-dollar investments over the following decades earned the slightest credibility against the same insurmountable weakness—vulnerability—and yet the programs continued apace.[137] Whatever command-and-control systems lacked in scope or quantity or even coherence, they dominated through research and development. Having glanced at the broader horizon here, we can now approach this next peak from an appropriately sweeping distance.

of empirical observations, anticipated trends, and interim results during the era of headquarters automation.

136. Recall the preceding note referencing the studies (or, in some cases, aborted studies) described in Parsons, *Man-Machine System Experiments*.

137. See the corresponding remarks in the introduction and the conclusion.

Chapter 4

Laboratories at War

Watson, Cambridge, and the Origins of Air-Defense Automation

> The days are gone when military military men could sit on a pedestal, receive the advice of professional groups in neighboring fields who were maintained in a subordinate or tributary position, accept or reject such advice at will, discount its importance as they saw fit, and speak with omniscience on the overall conduct of war. For one thing, professional men in neighboring fields have no present intention of kowtowing to any military hierarchy, in a world where they know that other professional subjects are just as important in determining the course of future events in the nation's defense as are narrowly limited military considerations.[1]
>
> Vannevar Bush, *Modern Arms and Free Men*, 1949

On the night of June 12–13, 1944—one week after the invasion of Normandy—the German *Flakregiment* 155 launched 19 *Vergeltungswaffe* 1 "flying bombs" from makeshift camps in the north of France. The first salvo of nine missiles failed completely. During the second attempt, five crashed shortly after a steam-catapult propelled them up an inclined rail and into the air, and one more flew astray. But four flying bombs crossed the English Channel at a computed altitude and bearing. Each of them featured a gyro-stabilized servomechanism, which manipulated the control surfaces that kept the wobbly airframe steady, while a vane anemometer on the nose turned the odometer that ticked downward from its preset value.

1. Vannevar Bush, *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy* (New York: Simon & Schuster, 1949), 252.

When the odometer counted zero, a pair of explosive bolts locked the control surfaces and unhinged spoilers on the tail.

The weapon then fell into a dive, which sloshed fuel away from the pump to its noisy pulsejet, and after silently descending several thousand feet, delivered a one-ton warhead to some unfortunate spot of earth. Of the four V-1s that crossed the channel that night, one reached the East End of London at 4:25 AM, where the blast killed six people. Over the next 80 days, 10,473 more flying bombs would follow. A quarter of them malfunctioned or ran errant, and defenses claimed about half the remainder, but 2,419 fell within a few miles of their aiming point—the Tower Bridge—killing 6,184 civilians and wounding another 17,981.[2]

The carnage might have been much worse. The Allies had had more than a year to prepare for the attacks. Reconnaissance flights had discovered the Peenemünde test site in the spring of 1943, and the V-1 itself was sighted shortly thereafter. Intelligence officials knew fairly well how the weapon would perform and where it would be launched, allowing London to prepare for its defense. For the second time in four years, antiaircraft guns belted the city in concentric rings, balloons hoisted steel nets into the sky, and observers stood ready to relay sightings to British and American interceptors. A counter-offensive campaign, codenamed CROSSBOW, even succeeded in delaying the attacks for several months, primarily by bombing the launch sites. What the Supreme Command had not expected, however, was that the Germans would fly the V-1 so low: usually less than 3,000 feet from the ground. At speeds exceeding 350 miles per hour, these low-altitude "buzz

2. David A. Mindell, "Automation's Finest Hour: Radar and System Integration in World War II," in *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After*, ed. Agatha C. Hughes and Thomas P. Hughes (Cambridge: MIT Press, 2000), 27–56 is the classic study of the "robot war," which was subsequently expanded into David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (Baltimore: Johns Hopkins University Press, 2002), especially chap. 9. However, many of the details in the passage that follow have been selected from Kenneth P. Werrell., *The Evolution of the Cruise Missile* (Maxwell AFB, AL: Air University Press, 1985), 41–62 and Kenneth P. Werrell, *Archie, Flak, AAA, and SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell AFB, AL: Air University Press, 1988), chap. 1, as well as *Tactical Employment of Antiaircraft Artillery Units, Including Defense Against Pilotless Aircraft (V-1)*, General Board Report No. 38 (Frankfurt, Germany: United States Forces, European Theater [USFET], Antiaircraft Artillery Section, n.d. [1946?]), 38–46, OCLC (22281486), an important source of statistical data for all the preceding publications.

bombs" traversed the horizon faster than gunners could reliably track them. They came also in darkness and bad weather.[3]

Antiaircraft batteries in the joint British-American defense network had recently begun to equip three of the war's most celebrated inventions: the SCR-584 gun-laying radar, the M-9 targeting computer, and the "variable time" (VT) proximity fuse—all three of them products of the Office of Scientific Research and Development (OSRD)'s Radiation Laboratory. When used in combination, servos actuated the artillery piece to follow the course predicted by the M-9, updated continuously in response to input from the SCR-584, while VT fuses detonated shells aloft when their own miniature radios determined proximity to the target.[4] Since the German "pilotless aircraft" (PAC) did not maneuver, except for its terminal descent, its linear trajectory provided an ideal application for the Army's electromechanical fire-control system. Although the guns downed an unremarkable 17% of their targets at first (all measures combined for about 42%), their kill rate had increased nearly five-fold by the time the Allies overran the final launching sites in early September. During a twenty-four hour period during August 27–28, the defenses destroyed 97 of the 101 German PACs that approached the London area, all but seven of them with antiaircraft fire.[5]

Drawing on this experience, Supreme Headquarters ordered similar provisions for the defense of Antwerp after Allied troops captured the vital port city in September 1944. The V-1 attack began on October 24 and continued unabated for 154 days. The Germans sent 8,696 PACs against Antwerp during this period—between 100 and 200 each day at the

3. Hilary St. George Saunders, "The Flying Bomb," *Life*, November 20, 1944, 90. Although the military history of the German "vengeange weapons" [*Vergeltungswaffen*] has been well documented, most of it has been synthesized from the same information publicized by the Allied occupation forces, e.g. Benjamin King and Timothy J. Kutta, *Impact: The History of Germany's V-Weapons in World War II* (1998; repr., Cambridge, MA: Da Capo Press, 2003); Basil Collier, *The Battle of the V-Weapons, 1944–1945* (London: Hodder & Stoughton, 1964).

4. In addition to Mindell, on the development of the SCR-584, see Henry E. Guerlac, *Radar in World War II*, 2 vols. (College Park, MD: American Institute of Physics, 1987), vol.1, 480–490; on the M-9, M. D. Fagen, ed., *National Service in War and Peace, 1925–1975*, vol. 2 of *A History of Engineering and Science in the Bell System* (New York: Bell Telephone Laboratories, 1978), 133–150; and the VT fuse, James C. Boyce, ed., *New Weapons for Air Warfare: Fire-Control Equipment, Proximity Fuzes, and Guided Missiles*, Science in World War II (Boston: Little, Brown, 1947), 152–159.

5. *Tactical Employment of Antiaircraft Artillery Units, Including Defense Against Pilotless Aircraft (V-1)*, app. 2.

height of the offensive. Unlike, the "second battle of London," however, the defenders had to counter attacks from multiple directions, over land instead of sea, and with no assistance from friendly aircraft. In other words, gunners shouldered the burden alone, with relatively less warning and far greater stresses on logistics and mobility.[6]

But by the fall of 1944, most British and American antiaircraft units had been refitted with OSRD-sponsored fire-control units and electronically fused artillery shells. Of 4,883 PACs actually observed in the area, AA batteries engaged 2,759 headed for the city center, destroying 1,766 (64%) of them. As in the defense of London, the kill rate had started low (48%) before peaking near the end of the attack. During one six-day stretch in February–March 1945, the guns brought down 96% of the 97 targets they fired on. Altogether, only 211 flying bombs exploded in the designated "vital area" around the port of Antwerp—a mere 2.4% success rate from the German perspective, though nonetheless sufficient to inflict 10,145 casualties, most of them civilian.

To casual commentators, and many serious ones, the "battle of the flying bombs" represented, or at least portended, an entirely new era of warfare: a "robot war," as the newspapers sometimes called it—an electronic war that committed servo against servo, relay against relay, triode against triode.[7] Guns aimed by electrical feedback-loops opened fire on aircraft piloted by gyroscopes while humans participated only as witnesses, or perhaps victims. In his war memoir, Sir Frederick Pile, commander of the British Army's Anti-Aircraft Command, wrote that "the second Battle of London, the battle against the flying bomb, was as revolutionary in scope and in its implications has been those first

6. Figures derived from R. J. Backus, "The Defense of Antwerp Against the V-1 Missile," (master's thesis, Army Command and General Staff College, 1971), DTIC (AD0733387), which appears to have referenced *The Story of Antwerp X* (Antwerp: Headquarters, 50th Anti-Aircraft Artillery Brigade, United States Army, n.d. [1945?]), OCLC (5035053), as well as the aforementioned *Tactical Employment of Antiaircraft Artillery Units, Including Defense Against Pilotless Aircraft (V-1)*. See also *IX Air Defense Command, Historical and Statistical Summary, 1 January 1944–1 June 1945* (Bad Neustadt an der Saale, Germany: Headquarters, IX Air Defense Command, US Army Air Forces), OCLC (962025444).

7. The phrase "robot war," and variations thereon, seems to have appeared first in the London *Times* in 1944 and remained chiefly British; the scattered references in American papers were written mostly by their foreign correspondents. ProQuest Historical Newspapers, accessed April 21, 2017.

engagements against the Tabes and Gothas which had led the attack of the heavier-than-air-machine," referring to the First World War. "Now we saw beginning the first battle of the robots. Human error was being gradually eliminated from the contest: in future [*sic*], the machines would fight it out."[8] Indeed, they seemed to be fighting it out already, in the air.

1 Engineering the science of control

The conclusion to the Second World War impressed a profound irony upon the United States. Despite convincing the world of its military power, as well as the richness of its industrial and scientific resources, America nonetheless seemed more vulnerable than ever. A new era of warfare appeared to be at hand, one with no respect for the vast oceans to which the nation had previously owed its security from the Old World's travails, and for which, moreover, it felt woefully unprepared.[9] At a press conference announcing his retirement in August 1945, General Hap Arnold predicted that "aerial combat as we know it, fighters seeking out other fighters or bombers and exchanging gun fire in an attempt to shoot each other down, will disappear." Replacing it would be "great developments in the field of defense both against aircraft and against missiles by means of target-seeking anti-aircraft missiles or rocket or other type...automatically seeking out those planes and missiles and destroying them or some of them, in the air, or the stratosphere, or the ionosphere."[10] While the broad strokes of Arnold's vision had changed little since the German guided-missile attacks of 1944–1945, the American public had also learned recently that these weapons might soon carry *atomic* warheads as well.

8. Frederick Pile, *Ack-Ack: Britain's Defence Against Air Attack During the Second World War* (London: George G. Harrap and Co., 1949), 326.

9. Recall the sources referenced during a preceding discussion of the "Pearl Harbor mentality" in postwar American politics; in particular, Douglas T. Stuart, *Creating the National Security State: A History of the Law That Transformed America* (Princeton University Press: Princeton, 2008).

10. "Arnold Reveals Secret Weapons, Bomber Surpassing All Others," *New York Times*, August 18, 1945, ProQuest (107022185). Cf. H. Bruce Franklin, *War Stars: The Superweapon and the American Imagination* (Oxford: Oxford University Press, 1988); Spencer R. Weart, *Nuclear Fear: A History of Images* (Cambridge: Harvard University Press, 1988).

Fears of attack naturally turned to hopes of defense. Despite the overwhelmingly offensive nature of World War II, the "robot war" created at least one favorable precedent, which Allied air-defense commanders often attributed to the wit and vigor of American science and engineering. "The best radar equipment was the American S.C.R. 584," effused Pile, "which was specially designed to work with the B.T.L. [i.e. M-9] predictor":

> So ingenious a device was it that neither at the set nor at the predictor was there any manual operation once the target had been picked up. The guns had been fitted with remote-control apparatus—they, too, were directed without manual operation. It seemed to us that the obvious answer to the robot target of the flying-bomb…was a robot defence.[11]

If in electromechanical automation lay an advantage in future warfare as well, then the Rad Lab had already proved its methods could remove from the battlefield the unsteadiness of the human hand and the bleariness of the human eye.[12]

Its celebrated proximity fuze, for example, "would explode at almost anything"; even "birds and even heavy clouds sometimes set if off prematurely," though once configured correctly, "gunners used to bewail the fact that [automatic equipment]…made their good shooting look indifferent." Consequently, Pile reported that a number of crews outright "resented losing weapons on which they had been trained and the qualities of which they had learned to appreciate…Strong measures had to be taken…to make sure that officers brought the new equipment into action and withdrew the old by the dates that had been specified."[13] Always the Rad Lab's field engineers remained near at hand to help implement these "strong measures" against intransigents in uniform, typifying the emergence of the civilian expert as a new force to drive the military toward increasingly automatic tools of

11. Pile, *Ack-Ack*, 313–315.

12. Machines may have aimed the guns, but the automation of "robot war" remained vastly overstated. According to sources cited here, more than 20,000 antiaircraft troops were needed in the defense of London and Antwerp in order to load the guns, supply, move, and maintain them, as well as to direct them manually when the equipment failed or exceeded its design parameters. This massive diversion of resources toward the strategically insignificant but politically essential goal of mitigating civilian terror actually tipped the economic balance in favor of the German offensive, despite its relatively low success rate.

13. Pile, *Ack-Ack*, 340–341.

destruction and organization alike.[14]

Indeed, the final phase of World War II seemed to have focused America's collective imagination on automated war as the natural evolution of industrial war, and a possible response to the shock of the atomic bomb—provided, of course, that the nation committed the necessary funding and expertise to the problem. In November, "The 36-Hour War," a *Life* illustrated feature, depicted men attending to screens and control consoles in one highly mechanized underground command-post of the future. "In the picture above," the text explained, "radar has been applied to the war of the rockets...If such a radar were in use, it would give the U.S. about 30 minutes to get ready for the attack shown on these pages":

> But even 30 minutes is too little time for men to control the weapons of atomic war. Radar would detect enemy rockets, plot their course and feed data to electronic calculators in defensive rockets. These would then be launched in a matter of seconds to intercept the attackers.[15]

No one knew what sort of efficiency such a defense could ever be expected to achieve, but every strike to evade it would kill by the thousands. Against a danger so absolute as this, virtually any sum, any effort, any prophylactic, could be justified.

And yet, as this chapter observes, the early postwar period was not a time of plenty for the armed forces, and more specifically, their research-and-development programs. While still pouring more money into the institutions of America science than ever before, OSRD officially dissolved the Rad Lab in 1946, scattering its remains across the greater constellation of government laboratories and military procurement agencies built up during the late-nineteenth and early-twentieth centuries, with industry and academia claiming the rest.[16] Within this sprawling asterism, the first section picks out two distinct, but highly interactive,

14. See, for instance, Lincoln R. Thiesmeyer and John E. Burchard, *Combat Scientists*, ed. Alan T. Waterman, Science in World War II (Boston: Little, Brown, 1947).

15. "The 36-Hour War," *Life*, November 19, 1945, 27, 30. For commentary on this article, see Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (1985; repr., Chapel Hill: University of North Carolina Press, 1995), 67; Franklin, *War Stars*, 157.

16. On the demobilization of OSRD, see Irvin Stewart, *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development*, Science in World War II (Boston: Little, Brown, 1948), 299–320.

organizational lineages, neither of which can be entirely understand in isolation from the other.

A fuller account of the second genealogy, the Watson Laboratories, which the Air Force inherited from the Army Signal Corps, will be largely deferred to chapter 5. The one to be examined here is significantly better known: OSRD's Division 14, whose foremost responsibility was the administration of the Radiation Laboratory under contract with MIT. Rather than rehearse the classic narrative, however, the focus here lies on the relationship between Division 14, as well as its successors, and the armed forces.

After characterizing the nature of this relationship in wartime, the first section observes that the Army Air Forces, as one of the primary stakeholders in Division 14, moved quickly to assimilate the research organization's capabilities and expertise before it dispersed entirely. An aggressive recruiting drive resulted in the creation of the Cambridge Field Station (CFS), and later, the Air Force Cambridge Research Laboratories (AFCRL), in order to retain key personnel. While at least partly successful, the Air Force found itself surrendering some of its own autonomy as well. The new wave of talent brought with it the same boisterous ideal of military research that OSRD had cultivated in wartime, which often placed Cambridge-affiliated scientists and engineers in open defiance of attempts to absorb them into a conventional government-laboratory system.

Nevertheless, in struggling against the perceived restraints of military administration, civilians researchers ultimately cinched them even tighter, reproducing—however unintentionally—the classic bureaucratic dilemma of duplicative organizational subunits rife with internecine conflict. By the time the United States Air Force came officially into existence in 1947, it already possessed two effectively independent electronics research-centers: the atypical organization devolved from the Radiation Laboratory, and a larger, better regulated, but seemingly old-fashioned laboratory inherited from the Army Signal Corps.

Meanwhile, the second section moves on to more closely document the ideas and activities of these two laboratories, beginning with the Microwave Early Warning (MEW) project at the Radiation Laboratory. Although largely irrelevant to the war effort, "high power" microwave radar, such as the experimental MEW sets, fascinated engineers for reasons extending beyond the range and resolution of the detector. On one hand, the capabilities of MEW suggested new possibilities for radar as more than an instrument of surveillance, but an instrument of *organizational control*, a peerless tool for perceiving events at great distance, and then, with the aid of communications, manipulating their outcomes even as they unfolded. While radar and telecommunications had already been employed similarly in air-defense networks, the new regime would be qualitatively different, because it had the potential to facilitate virtually instantaneous response cycles for a wealth of applications previously unconsidered, such as long-range strategic-bombing operations and guided-missile warfare.

On the other hand, however, the voluminousness of the space that MEW could resolve with remarkable clarity also accompanied an order-of-magnitude increase in the quantity of information that needed to be handled and interpreted in order to remain intelligible. The problem inspired incidental studies and experiments, which remained incipient at the time Division 14 was closed, in compressing so-called "high-density information" for automatic transmission from remote detectors to centers of processing and control—a significant departure from the established practice of engineering the scope-reading apparatus, and even entire operations rooms, as part of the radar set itself. When the Cambridge Field Station inherited this work, it became incorporated into grander designs on "integrated" air-defenses for the North American continent.

It bears reminding, though, that, without budgets and schedules to impose a sense of realism, ideas generated in the course of benchtop engineering tend toward promising speculation. Chronically underfunded, Cambridge technicians could thus indulge themselves in the quiet pleasure of shoestring inventions, even if their interests were rather less unique than they perhaps cared to admit. Although serious disputes persisted about how much or how soon the Air Force should commit itself to automated air-defenses, most everyone took for granted that it eventually would. As such, work along similar lines, employing different but still apparently viable techniques, continued at other sites, most notably the Watson Laboratories, with the Headquarters USAF at least partly in the loop. In fact, Cambridge's incessant chafing against bureaucratic controls actually diminished awareness of its own efforts among military officials, establishing the preconditions for the conflict to be excavated further in the next chapter.

This dissertation has previously considered the ambiguity of building an "integrated" air-defense system, in the sense of whether *integration* connoted an organizational "system," a technological "system," or, as ultimately argued, an indeterminate confederation of both. In the pages that follow, the emphasis shifts from the "implementing organization"—the Air Defense Command, in the prior case—to the engines of national-security science that would push the effort forward. As the existing literature has amply demonstrated, these engines too had been machined for war. What remains under-appreciated, however, is the extent to which, in the climate of postwar budgetary retrenchment, they remained at war *among themselves*. Peacetime budgets failed to satisfy the ambitions of the former leaders of OSRD's predecessor, steering committee, and revolutionary vanguard: the National Defense Research Council (NDRC).

Since its inception in 1940, NDRC had understood itself as an attempt at an academic-industrial "coup" against what its members regarded as a ponderous, inefficient, and byzantine apparatus of government research-and-development. Their radically anti-bureaucratic methods succeeded so long as the pressure of global conflict overwhelmed the tension latent in their *ad hoc* association with the same institutions they so routinely disparaged—institutions which, moreover, they depended upon for critical material support. However, this mutual goodwill proved limited to the exception of total war, an amicability that could not survive the comparatively low stakes of peace, when the zero-sum politics of austerity sharpened the knives of bureaucratic combat once again.

More than merely background or context for the conceptualization of national military command-and-control, as it emerged in the late fifties, the structure of postwar science and technology proved as critical to the formation of ideas as it did to the production of equipment. In the future, civilian experts would become increasingly confident advising the military not only about the tools it should use, but also how to organize itself around them. By effectively factionalizing themselves, however, they reproduced the same organizational pathologies they intended to rationalize, diluting or even contradicting their own recommendations. From the haze of confusion, only one claim encapsulated them all: that problems of politics, bureaucracy, and global conflict could generally be reduced to technological problems and resolved with the same mentality. Nuclear command-and-control would ultimately come to reflect the organizational division of institutions of American science as much as they did its institutions of warfare and governance.

2 Recovering the Radiation Laboratory

Among the last official acts of the Radiation Laboratory, before being dismantled, along with the rest of OSRD, in mid-1946, was to prepare a prospectus on the future of radar and electronics research. Submitted in May of that year, the authors appeared to have had little time to consider the consequences of atomic energy, as the document passed over the topic almost in silence. However, George E. Valley, Jr., a technical director in OSRD's Division 7, did add a brief supplement to the eleventh volume of *Toward New Horizons*, the final report of the Army Air Forces' Scientific Advisory Group (SAG), entitled "Defense Against the Atomic Bomb."[17]

Since the SAG had likewise concluded most of its business before the atomic bombings, the thirteen volumes of the "von Kármán report," as it was called after its chair, the Caltech

17. Von Kármán's preliminary report, *Where We Stand*, as well as the summary volume, *Science, the Key to Air Supremacy*, were both republished as Michael H. Gorn, ed., *Prophecy Fulfilled: "Toward New Horizons" and Its Legacy* (Washington: Air Force History and Museums Program, 1994). See also Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944–1986* (Washington: Air Force History and Museums Program, 1988), chap. 1; Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944–1964* (1967; repr., Washington: Air Force History and Museums Program, 1986), 2–12.

aerodynamicist Thedore von Kármán, also said little explicitly about the possibilities of nuclear warfare. Valley's statement was thus exceptional in its specificity, and indeed, its moral urgency. "The effect of the atomic bomb on military tactics and weapons will be far-reaching," it commenced, wary of the political ramifications:

> At the present time, detailed analyses of what all of these effects may be cannot be given. The following notes seek only, therefore, to present some thoughts and speculations on this subject by members of the Radiation Laboratory. They are presented here more as a basis for discussion of the necessary research policies, than as definite suggestions of what those policies should indeed be.[18]

Disclaimer notwithstanding, Valley concluded with a very definite recommendation not for science policy, but *national* policy, indicating that "technologically, economically, and sociologically the simplest defense against atomic bombing is a world-wide police system whose purpose would be to prevent the manufacture of atomic bombs."[19] Indeed, Valley, a professor of electrical engineering at MIT, had at the time of his writing (presumably the spring of 1946) enlisted—as had many of his OSRD colleagues—in the postwar "scientists' movement," which lobbied for Bernard Baruch's plan for international control of atomic energy.[20]

Valley's logic was simple. The war had proved that "bomber fleets of at least 1000 aircraft can be produced and operated at one time." Furthermore, it also demonstrated that "one atomic bomb can wipe out a city of 300,000 inhabitants." Since the United States had an urban population of approximately 70 million, "in one raid, it is in principle possible that...[if] a fleet of 1000 aircraft were to be individually targeted against the different cities

18. George E. Valley, "Defense Against the Atomic Bomb," in *Radar and Communications: A Report of the AAF Scientific Advisory Group*, by L. A. DuBridge et al. (Wright Field, Dayton: Headquarters, Air Materiel Command, 1946), 167.

19. Valley, "Defense Against the Atomic Bomb," 172.

20. George E. Valley Jr., "How the SAGE Development Began," *IEEE Annals in the History of Computing* 7, no. 3 (July–September 1985): 197–198, doi:10.1109/MAHC.1985.10030; on the Scientists' Movement more generally, Alice Kimball Smith, *A Peril and a Hope: The Scientists' Movement in America, 1945–47,* rev. ed. (Cambridge: MIT Press, 1971). Lawrence Badash, *Scientists and the Development of Nuclear Weapons: From Fission to the Limited Test Ban Treaty* (Atlantic Highlands, NJ: Humanities Press, 1995), 63–79; Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge: Harvard University Press, 1995), 334–366 also survey the disciplinary and political circumstances.

inhabited by these 70,000,000, they and their works could be wiped out four times over." On purely economic grounds, then, he suggested that "massive multi plane raids against individual targets are things of the past":

> This means that formation flying and everything that it connotes to the aircraft and radar designer must be most carefully considered to determine whether or not it is obsolete. If this tactic is found to be obsolete, then it follows that the tactic of saturating the enemy's anti bomber defenses is also obsolete, for all practical purposes.[21]

Valley's tone suggested he believed that obsolescence was indeed imminent. "The situation then becomes very tactically like the Battle of the Buzz Bombs," he continued, insofar as "individual bombers (manned or pilotless, airborne or rocket) will seek individually to penetrate a massive defense. This battle is also of interest because it represents a nearly automatic defense (SCR-584 plus the M-9 director, plus the servo-driven 90-mm guns) against robot-controlled aircraft. It may, therefore, be regarded as setting the pattern for the future."

During the war, George Valley had worked for some time on the SCR-584 project.[22] He cited with some pride the kill rate for one day late in August 1945, when only three of the 105 V-1s detected crossing the channel broke through to their targets in London. "Now this was the best figure attained," he noted, acknowledging that "London would certainly have been wiped out had the V-1's carried atomic bombs even against such superlative defense measures." Ultimately, however, the kill rate was beside the point:

> What is most important to realize is that this defense required at least six weeks to reach its maximum efficiency, and this in spite of the fact that all the defense weapons were at hand, all the operators trained, and the whole country experienced and forewarned in war of this particular means of attack. In spite of all the training and availability of weapons and military experience the first attackers suffered little loss.[23]

He concluded, "the preeminent problem of defense with which we are now faced is: 'How can the defense be made to react to the first blow with all its potential efficiency?' "

21. Valley, "Defense Against the Atomic Bomb," 168–169.

22. According to his entry in *Radiation Laboratory Staff Members, 1940–1945* (Cambridge: MIT Radiation Laboratory, June 1946), 109, OCLC (17332117).

23. Valley, "Defense Against the Atomic Bomb," 169.

Valley identified three broad classes of "defensive" measures, only one of which corresponded to the War Department's official definition of an "active" air defense. The first combined elements of international diplomacy and what we would call a first-strike nuclear strategy. To enforce nuclear nonproliferation, the United States and its allies would need to constantly surveil the world for illicit production facilities and, if discovered, use their own atomic weapons to destroy them before they became operational. In addition to aerial reconnaissance, Valley pointed to the possibility of reconnoitering the globe from orbital—and even lunar—"observation posts," both manned and unmanned. The third class of atomic defense encompassed yet far exceeded the civil-defense procedures of World War II. Since blackouts, shelters, and evacuations would not suffice, and city-sized underground structures were likely infeasible, the devastation of atomic war could only be contained through a radical reconfiguration of America's urban geography, dispersing industry and populations in order to minimize the damage of any single explosion.

While dwelling on possible implementations, Valley did seem to recognize that the potentiality of his first and third classes of atomic defense depended on political, social, and cultural outcomes beyond the purview of the engineer. Before the failure of the Baruch Plan and the declension of civil defense from token to symbol, Valley could still express some hope that all three categories could be pursued concurrently and supplementarily.[24] Within a few short years, however, it would become apparent that American society could tolerate initiatives only of the second type: a so-called "active" air defense, in which aerial counter-weapons seek out and destroy immediate threats *en route* to their targets. "If we elect to defend ourselves by destroying all the missiles launched against us," he projected, "the defensive measures must be as nearly automatic as can be conceived. They must locate, recognize, load and fire their missiles automatically."

The technological challenge weighed heavy but surmountable, even necessary, because

24. Richard G. Hewlett and Oscar E. Anderson Jr., *The New World, 1939–1946*, vol. 1 of *A History of the United States Atomic Energy Commission* (University Park: Pennsylvania State University Press, 1962) is the canonical source on the political history of the control of atomic energy.

as Valley opined:

> Regardless of the size and training of our forces, there are enough equivalents of the Pearl Harbor attack in history to teach us that the human part of the defense force is not likely to be ready. Since only one attack will be necessary we cannot take the chance that the lessons of the past plus future good intentions will preserve us.[25]

For society, culture, and human incompetence, mechanism would have to compensate.

Prewar relations: Science and military self-sufficiency

Before the formation of the United States Air Force in 1947, the Army Air Forces had depended almost completely upon the Army Signal Corps for research, development, and procurement of electronic components. War Department policy essentially limited the AAF's own engineering activities—which were highly concentrated around the facilities at Wright Field in Dayton, Ohio—to applications specific to aeronautics, such as airfoils, airframes, and propulsion systems. Although the Aircraft Radio Laboratory did open at Wright Field in 1927, it remained a Signal Corps organization until 1944, concerned primarily with modifying parts to fit aircraft prototypes without too badly compromising their performance, reliability, and eventual production costs. The Signal Corps served the entire Army, so the AAF's engineers and procurement officials could only lobby for their priorities and often had to settle for equipment that split the difference between competing specifications from both the air and ground forces, and thus, tended to satisfy neither of them. The working relationship had been contentious enough during the war, and by 1945, its dissolution loomed as ineluctably as the War Department's own division into the departments of the Army and the Air Force.[26]

25. Valley, "Defense Against the Atomic Bomb," 171.

26. George Raynor Thompson et al., *The Signal Corps: The Test, December 1941 to July 1943*, The United States Army in World War II: The Technical Services, CMH Pub 10-17 (1957; repr., Washington: US Army Center of Military History, 1978), 78–83; 243–246; George Raynor Thompson and Dixie R. Harris, *The Signal Corps: The Outcome, Mid-1943 Through 1945*, The United States Army in World War II: The Technical Services, CMH Pub 10-18 (1966; repr., Washington: US Army Center of Military History, 1991), 427–448. Irving Brinton Holley Jr., *Buying Aircraft: Matériel Procurement for the Army Air Forces*, The United States Army in World War II: Special Studies, CMH Pub 11-2 (1964; repr., Washington: US Army Center of Military History, 1985), 480–487

Even had the organizational politics been otherwise, the service model was incompatible with the new absolutism regarding high-performance aircraft. For example, the B-29 Superfortress—the AAF's single largest industrial program, rivaling even the Manhattan Project in scale and expense—became the first aircraft to feature a significant number of electronic components integral to the airframe, particularly in its defensive fire-control system. While the B-29 also carried a full suite of Signal Corps-issue radar and communications gear, the centralized management strategy that permitted Boeing, the prime contractor, to reconcile the airframe with some of its subcontracted component systems during the design process, instead of "bolting" them onto a prototype.[27] The pattern would not be reversed in future projects demanding greater and greater sophistication. But to claim a stake in the development of military electronics, the Army Air Forces, and later the United States Air Force, needed to push its research-and-development capacity beyond its established competence in aeronautics and into areas previously dominated by the Army proper.

In 1929, the War Department consolidated its radio, electrical, and meteorological research organizations (excepting the aforementioned Aircraft Radio Laboratory) into a clutch of laboratories and field-test stations in the area surrounding Fort Monmouth in central New Jersey. This cluster of confederated agencies changed names and configuration several times during the war, but at the start it was called as the Signal Corps Laboratories (SCL), a title it retained colloquially though not officially.[28] Fully owned and operated by the

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discusses the AAF's issue with multi-sourced aircraft components, a practice called "cross procurement," more generally.

27. Jacob Vander Meulen, *Building the B-29* (Washington: Smithsonian Institution Press, 1995); Irving B. Holley, *The B-29, 1939–1945*, ATSC Historical Study No. 192 (Dayton, OH: Air Technical Services Command, April 21, 1945), AFHRA (1105703).

28. United States Army, Communications Electronics Command, Historical Office, *A History of Army Communications and Electronics at Fort Monmouth, New Jersey, 1917–2007* (Washington: GPO, 2008), 1–31; Rebecca Robbins Raines, *Getting the Message Through: A Branch History of the U.S. Army Signal Corps*, CMH Pub 30-17 (Washington: US Army Center of Military History, 1996), 229–240. The Department of the Navy also opened several of its own radio laboratories around the same time, which were soon consolidated into the Naval Research Laboratory in Washington, DC in 1923. Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory*, NRL Report 8300 (Washington: Naval Research Laboratory, 1979), chaps. 1–2, DTIC (ADA084225). See also Linwood S. Howeth, *History of Communications-Electronics in the United States Navy* (Washington: Bureau of Ships and Office of Naval History, United States Navy, 1963).

federal government, the Signal Corps labs exemplified what would prove to be a transitional system for technological development in the United States military. Before World War I, the War and Navy departments rarely distinguished science or technology from expertise in ordnance, signal, construction, supply, and so on—institutional traditions in which they pursued, and very often achieved, self-sufficiency.

In the nineteenth century, the Army Ordnance Department manufactured most of its own equipment in government-owned arsenals, where skilled craftsmen also experimented with new weapons, munitions, and production techniques. Likewise, the Navy's Bureau of Construction and Repair operated a network of dockyards to design, build, and maintain the fleet. Except in times of national mobilization, when production temporarily spilled over into privately owned facilities, military logisticians preferred the quiet workings of their in-house artisanal cultures to the tidal sloshing of capital. Indeed, top officials instinctively distrusted the motives of private enterprise, which too often schemed to profit on the exigence of war.[29] And though the Army's arsenal system and the Navy's yards and docks tended to result in incremental instead of revolutionary changes, American military thought generally resisted the thesis linking victory to absolute technological superiority well into the twentieth century.[30]

The greatest disturbance to the century-old pattern had unquestionably been the airplane, which lacked an obvious place within the military art and science that the United States had inherited from its European forbears. As a recent invention of civilian entrepreneurs, the airplane was not easily incorporated into an arsenal-like production system, and most attempts to do so succumbed to factionalism as well as external pressures. Domestic

29. Thomas C. Lassman, *Sources of Weapon Systems Innovation in the Department of Defense: The Role of Research and Development, 1945–2000*, CMH Pub 51-2-1 (Washington: US Army Center of Military History, 2008), chaps. 1–3; James F. Nagle, *A History of Government Contracting*, 2nd ed. (Washington: George Washington University Law School, 1999).

30. Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca: Cornell University Press, 1977); I. B. Holley Jr., *Ideas and Weapons: Exploitation of the Aerial Weapon by the United States During World War I–A Study in the Relationship of Technological Advance, Military Doctrine, and the Development of Weapons* (1953; repr., Washington: Air Force History and Museums Program, 1997), 3–22.

aircraft producers still lacked commercial viability during the interwar period and protested loudly at the possibility of competing directly with the government itself for the military patronage that kept them in business. Even the relatively few officers who favored greater self-sufficiency recognized that such a disruption could wreck the fragile aircraft industry before its skills and tooling could be replicated in-house. So while the Navy did manage to sustain a small aircraft factory in Philadelphia from 1917 to 1945, Air Corps policy forbade the Engineering Division at Wright Field from designing or manufacturing its own aircraft—even for experimental purposes—in 1925.[31]

The problem of developing Army electronics, however, displayed features of the arsenal system as well as the military's emerging dependence on private contractors for the design and manufacture of nontraditional items. Government laboratories such as the SCL successfully recruited top-flight scientific and engineering talent into federal employment and quickly established themselves as indispensable centers of research, but they lacked the facilities to bring prototypes into mass production, and neither did they strive to obtain them. With industrial titans such as AT&T, RCA, and General Electric already crowding the market and bristling with formidable industrial-research organizations of their own, the Signal Corps labs concentrated on relatively niche applications of electronics to military problems, such as the development of radar, in consultation with firms that would eventually serve as production contractors for government-owned designs.[32] For example, engineers at Fort Monmouth drew up blueprints for the SCR-270 early-warning radar before letting an initial contract to Westinghouse to produce a quantity sufficient for extended field-testing in 1938.[33] Additionally, the laboratory staff also tested and routinely modified designs for

31. Holley, *Buying Aircraft*, 80–94; Lawrence R. Benson, *Acquisition Management in the United States Air Force and Its Predecessors* (Washington: Air Force History and Museums Program, 1997), 7.

32. On the establishment and evolution of some of America's first and largest industrial laboratories, see Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876–1926* (Cambridge: Cambridge University Press, 1985); George Wise, *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research* (New York: Columbia University Press, 1985). BTL characterized its own services to the armed forces (favorably, of course) in Fagen, *National Service in War and Peace*.

33. Harry M. Davis, ed. *Long Range Radar: SCR-270 and SCR-271*, Signal Corps Historical Project A-3, pt. 3 of

new equipment proposed by the industry while evaluating their desirability for large-scale procurement.

Wartime relations: The armed forces as science-consumers

When the war began, the National Defense Research Committee, or NDRC—as well as OSRD, its subsequent parent agency—intruded quite purposefully on the established relationship between the military departments, government laboratories, and private contractors.[34] Recalling the toothless Council of National Defense that had disappointed its primarily academic proponents during World War I, Vannevar Bush, the first chairman of the NDRC, later explained that he and his colleagues pressed to secure two explicit privileges for its organizational successor: "it reported directly to the President, and it had its own funds with which to work."[35] In other words, NDRC/OSRD was never intended as a military-industrial-academic consulting or coordinating body, but as a civilian-controlled agency for directing military research-and-development independent of the military itself.

Wary of its controversial motives, OSRD's official administrative history observed delicately that upon appointing Bush to head the NDRC in June 1940, "President Roosevelt stated specifically that it was not intended that the work of the Committee should replace any of the 'excellent work' which the Army and Navy were carrying on either in their own laboratories or by contract with industry," but rather, "to 'supplement this activity by extending the research base and enlisting the aid of the scientists who can effectively contribute to the more rapid improvement of important devices, and by study determine where new effort

The Signal Corps Development of U.S. Army Radar Equipment (Washington: Historical Section, Office of the Chief Signal Officer, November 1945), declassified manuscript provided by Historical Office, United States Army Communications–Electronics Command (CECOM), Aberdeen Proving Ground, 14–23, 44–49.

34. In addition to OSRD's history series (the deficiencies of which are discussed below), see Kevles, *The Physicists*, chaps. 21–22 on the National Defense Research Committee, plus chaps. 8–9 for contrast with the National Research Council in World War I; and Allan A. Needell, *Science, Cold War and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (2000; repr., London: Routledge, 2012), chap. 3.

35. Vannevar Bush, *Pieces of the Action* (New York: Morrow, 1970), 31.

on new instrumentalities may be usefully employed.' "[36] In his memoirs, however, Bush did not dissemble. As he recalled, "there were those who protested that the action of setting up NDRC was an end run, a grab by which a small company of scientists and engineers, acting outside established channels, got hold of the authority and money for the program of developing new weapons. That, in fact, is exactly what it was."[37]

By the time of this publication, three decades after the fact, Bush had become badly disaffected by the organization of research and development in the United States. His disappointment with the postwar legislation and profoundly negative experience chairing the Research and Development Board vividly colored his prolific commentary on the subject, which dispensed business-school platitudes almost as often as his own recollections. "We should congratulate ourselves on having an excellent military organization," he opined, "yet look how it was put together!":

> It was built by a succession of Commanders in Chief, each laboring with a legislature and the democratic process. That process has built us an overall governmental structure which is a monstrosity, with overlapping authority, swelled bureaucracies, agencies with no base at all, muddled lines of command...Not only does Parkinson's law ensure obesity; agencies that are created nearly at random fail to disappear when obsolete.[38]

In his telling, as in many others, NDRC/OSRD was a heroic effort by conscientious citizens to save the military from itself in a time of crisis—a lesson the nation quickly forgot, if indeed, it had ever learned it at all.[39]

36. Stewart, *Organizing Scientific Research for War*, 8.

37. Bush, *Pieces of the Action*, 31–32. Likewise, one critical historian has called Bush's technocratic project "a conservative commando raid into the enemy territory of Democratic Washington, where he successfully established an associational camp staffed by like-minded figures and from which he oversaw an essentially privatized mobilization": Larry Owens, "The Counterproductive Management of Science in the Second World War: Vannevar Bush and the Office of Scientific Research and Development," *Business History Review* 68, no. 4 (Winter 1994): 451–482, doi:10.2307/3117197.

38. Bush, *Pieces of the Action*, 28. On *Pieces of the Action*, and Bush's later years more generally, see G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (1997; repr., Cambridge: MIT Press, 1999), 392–393.

39. OSRD's own historical series, headlined by James Phinney Baxter III, *Scientists Against Time*, Science in World War II (Boston: Little, Brown, 1946), particularly embellished this point of view. Although written by official historians, trade presses published and distributed them popularly under government contract. The thesis is itself, of course, contestable. Paradoxically, it was the defeated powers who often fielded more advanced weaponry in both the world wars, which rather suggests the decisiveness of industrial capacity. For

Although Bush wrote remarkably unselfconscious of his own role in compounding the bureaucratic morass he so frequently disclaimed, he nonetheless typified a certain obstreperousness that emerged among the technocratic elite immediately after the war. And while it would be overly reductionist to identify the root of their displeasure with the federal procurement system, the perceived onerousness of government contracting became the one issue virtually guaranteed to enter into any complaint against the organization of military research. "The essence of a sound military organization is that it should be tight," observed Bush in one of his characteristically aphoristic pronouncements. "But a tight organization does not lend itself to innovations in the technology of warfare."

So despite the existence of public resources such as the Signal Corps Laboratories and the Naval Radio and Sound Laboratory at the beginning of the war, NDRC/OSRD put itself to constructing a system of contracted research unburdened by the procurement restrictions imposed on the military departments by laws and regulations. Instead, public–private hybrids such as the MIT Radiation Laboratory (MIT-RL) provided the model for the future.[40] First established under the NDRC in mid-1940, OSRD's Division 14 contracted not only the laboratory's work directly to the university, but its very administration, until OSRD itself dissolved in early 1946.[41] In short, outside agencies had no control over its selection or prioritization of research programs. They had to be sorted out, case by case, in collaboration

discussion, see Alex Roland, "Science and War," *Osiris*, 2nd series, 1, no. 1 (1985): 247–272, doi:10.1086/368648.

40. Although historians have written consistently about military contracting for academic research—e.g. Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993); Rebecca S. Lowen, *Creating the Cold War University: The Transformation of Stanford* (Berkeley: University of California Press, 1997); Rebecca Slayton, "From a 'Dead Albatross' to Lincoln Labs: Applied Research and the Making of a Normal Cold War University," *Historical Studies in the Natural Sciences* 42, no. 4 (September 2012): 255–282, doi:10.1525/hsns.2012.42.4.255—the role of industrial firms has received considerably less attention, with some exception for quasi-academic non-profits such as the RAND Corporation: David Hounshell, "The Cold War, RAND, and the Generation of Knowledge, 1946–1962," *Historical Studies in the Physical and Biological Sciences* 27, no. 2 (1997): 237–267, doi:10.2307/27757779 and Martin J. Collins, *Cold War Laboratory: RAND, the Air Force, and the American State, 1945–1950* (Washington: Smithsonian Institution Press, 2002), among others. See Lassman, *Sources of Weapon Systems Innovation in the Department of Defense*, chap. 4, especially for bibliographic references, as well as commentary on the military-industrial complex in the final conclusion.

41. Cf. Stewart, *Organizing Scientific Research for War*; John Burchard, *Q. E. D.: M. I. T. In World War II* (New York: John Wiley & Sons, 1948).

between the laboratory's technical directors and the military's liaison officers.

"The relations were always as informal as was possible," reported Division 14 in its technical summary:

> MIT-RL did not await formal requests for undertaking projects, and never hesitated to propose new ideas for projects to Army and Navy representatives. On the other hand, the Army and Navy representatives never hesitated to discuss their problems informally with MIT-RL, and in this way nearly always came to general agreements before formal project requests were passed.[42]

The Rad Lab's official "yearbook," gifted to former employees in 1947, remarked on the novelty of this arrangement more whimsically:

> Suppose you were a Ruritanian and were going war on the Bucolicans, who had been broadcasting the wrong kind of music. And suppose that while you were lining up your rockets, space ships, atomic mines and so on, an adding-machine inventor came in to say it might be a good idea to look into directional weather, focused cosmic rays, controlled seismic tremors, and a few other new things. Would you sit down and write this stranger a blank check? And in the seismic-tremor business, suppose Research Unit 3 of your own Democratic Defense Department was already doing some promising windowbox work, while most of the new crowd had not even performed the classic mulch-inertia experiment. Would you let the new men go off on their own hook, without even a DDD man to keep them on the right track? Or would you just say, "Let's put these theorists in with RU-3?"[43]

Thus stated, the chances of the eventual outcome seemed positively remote ("about equal to those of a ten-horse parlay at Belmont"), and yet military and civilian officiants alike expressed great satisfaction with the products of their relationship and rarely registered their frustrations in public discourse.

Like most homefront narratives, however, urgency capped with the exultation of final victory tended to desaturate memory of the lab's more contentious dynamics.[44] Although Division 14 claimed that "from the day the laboratory was organized, close collaboration with

42. United States Office of Scientific Research and Development, Division 14, *Radar: Summary Reports and HARP Project*, vol. 1 of *Summary Technical Report of Division 14, NDRC* (Washington: National Defense Research Committee, 1946), 17, OCLC (9537588).

43. *Five Years at the Radiation Laboratory* (Cambridge: Massachusetts Institute of Technology, 1947), 20.

44. Cf, John Bodnar, *The "Good War" in American Memory* (Baltimore: Johns Hopkins University Press, 2010), which owes a debt, apparent in its title, to Studs Terkel, *"The Good War": An Oral History of World War Two* (New York: Pantheon Books, 1984), as well as historiography in the tradition of John Morton Blum, *V Was for Victory: Politics and American Culture During World War II* (New York: Harcourt Brace Jovanovich, 1976).

the Army and Navy was a watchword," civilians guarded the initiative they held very closely. According to OSRD, "the most important point which MIT-RL stressed in its relation with Army and Navy representatives was that the Army and Navy representatives come to MIT-RL not with technical problems for the design of an equipment of certain size and weight, or with certain power requirements, but rather that they bring to MIT-RL full information on the tactics of operations which were of importance and for which radar aids might be of use":

> This gave MIT-RL full access to information on the success and failure of various tactical methods. After acquiring a full understanding of the military problem, it would then be the job of the technical people in the laboratory to evolve suggestions and ideas for the best solution to the problem which they could visualize. The laboratory then would come up with a proposal for the technical design of equipment, accompanied, possibly, by proposals for the new tactics which would have to be adopted to make best use of such equipment. A thorough analysis of tactical and technical problems would then ensue until sometimes after weeks of consideration and discussion a final solution or method of approach would be agreed upon. From that time on the technical design of the equipment was left largely to the technical men in the laboratory, who served, in a sense, as the Army's or Navy's own technical consultants on the problem.[45]

Nevertheless, the staff clashed often with procurement officers about when or with whom to initiate contracts and under what conditions—or even whether scientists and engineers should influence such decisions at all.

"If you went to the Signal Corps," recalled Kenneth Bainbridge, "you finally got to Captain so-and-so, and he would hear you out. Then your proposal would go from the Captain to a Lieutenant Colonel to the Colonel to the General and back down maybe a different path. By that time weeks and weeks—maybe months—had gone by, and what you'd proposed had been 'improved on' so much that if they got it they'd be sorry because they wouldn't get the latest improvements."[46] Individual experiences varied, but the armed

45. Division 14, *Radar*, 16–17.

46. Interview, Kenneth T. Bainbridge, with John Bryant, Weston, MA, June 10, 1991, transcript, IEEE History Center, Stevens Institute of Technology, Hoboken, NJ, URL: https://www.ethw.org/Oral-History:Kenneth_T._Bainbridge.

forces never wholly accepted the incursion of an *ad hoc*, quasi-academic research center into their established military-industrial relations.

While the lab enjoyed remarkable freedom with respect to program management, the military departments still controlled the agencies responsible for coordinating mass-production with the industry. “In the first year of the Laboratory’s existence it was expected that the problem of producing radar sets would be relatively simple,” wrote Henry Guerlac, who served as the lab’s official historian:

> The Laboratory would develop a piece of radar equipment, prepare a “breadboard” model for trials, and then, if it were accepted by the Army or Navy, turn the model over to a large manufacturer who would take full responsibility for carrying it from the “breadboard” stage to final use in the field. Actually, this technique was only possible in a very few cases, and these were mostly cases where the equipment was manufactured by the Western Electric Company, whose entire facilities, together with the Bell Telephone Laboratories and their many subcontractors, were available to tackle the problem and carry it through to completion.[47]

Altogether, the Army and the Navy purchased nearly $1.5 billion of equipment derived from Division 14 designs—about half their total spending on radar devices—and though a few major firms won the overwhelming majority of contracts, subcontractors especially required Rad Lab expertise to help tool up for mass production. “All this meant that the Radiation Laboratory had to have contact with hundreds of manufacturers,” Guerlac continued, who also noted that “there was no single fixed pattern for handling the liaison between the Laboratory and the manufacturers and vendors.” As massive orders swamped the electronics industry, moreover, the Rad Lab had trouble fulfilling its own needs for relatively small numbers of specialized, often custom parts for benchtop work.

47. Guerlac, *Radar in World War II*, vol. 2, 687. These volumes, still the *de facto* history of the Radiation Laboratory, originated with Henry Guerlac, *Radar in World War II*, unpublished manuscript, 1947, OCLC (80477763), a typewritten draft that had circulated informally for decades due to the author’s hesitation to publish. Apparently, Guerlac, conscientious of his professional identity, considered it an official report rather than a proper work of history, a tension evident in the document’s excesses of narrative detail and relative lack of critique: Michael A. Dennis, “Echoes of the Past: Henry Guerlac and Radar’s Historiographic Problem,” in *Tracking the History of Radar*, ed. Oskar Blumtritt, Hartmut Petzold, and William Aspray (Piscataway: IEEE–Rudgers Center for the History of Electrical Engineering, 1994), 285–298, OCLC (918241811).

Further dismissing bureaucratic norms under the shadow of war, OSRD authorized the formation of the Research Construction Corporation in mid-1941, a non-profit contracted exclusively to Division 14, in order to provide short-run manufacturing services to Rad Lab engineering teams. By 1944, however, the RCC itself had been overrun with "crash" production of mature designs, which got small quantities into the field more quickly than government agents could have achieved through the military's industrial procurement channels, but also bypassed their usability, reliability, and maintenance standards. Crash production was necessarily limited to a few extremely urgent projects, such as initial runs of the H_2X (service designation: AN/APS-15) radar-bombing and navigation set.[48] "The Air Corps was perfectly willing to test sets," Ivan Getting remembered, because "it was an oddball branch" in which "a few airplanes could make a difference [for special missions]":

> But the Ground Forces doesn't do things that way. The Army has a table of basic allowances, tables of basic organizations and regulations. They train people by the tens of thousands...In the Army it's millions of people: it has to be organized, you have to have training, you have to have a logistics support line. You have to have all this, and that's different.[49]

As the war effort peaked, many Rad Lab technicians had to deploy overseas in order to troubleshoot problems in the field, suggest refinements to designs and production methods, and train military personnel how to use the cryptic new devices they received through the abnormal supply chain.[50] The laboratory staff itself also assumed some of the responsibility for operating the MIT Radar School in Boston, which trained nearly 9,000 uniformed specialists between June 1941 and June 1945.[51]

48. Guerlac, *Radar in World War II*, vol. 1, 285–291, vol. 2, 684–687.

49. Interview, Ivan A. Getting, with Frederik Nebeker, Boston, MA, June 11, 1991, transcript, IEEE History Center, Stevens Institute of Technology, Hoboken, NJ, URL: https://www.ethw.org/Oral-History:Ivan_A._Getting_(1991). The methods of troop mobilization to which Getting referred are described exhaustively in Robert W. Palmer, Bell I. Wiley, and William R. Keast, *The Procurement and Training of Ground Combat Troops*, The United States Army in World War II: The Army Ground Forces, CMH Pub 2-2 (1948; repr., Washington: US Army Center of Military History, 1991).

50. Division 14, *Radar*, 19–22.

51. Malcolm S. McIlroy and Henry J. Zimmermann, *History of the M.I.T. Radar School in Relation to Army Training From June 23, 1941 to June 30, 1945* (Cambridge: Massachusetts Institute of Technology, 1945), microfilm, OCLC (6535532).

Overall, Division 14 fulfilled its founders' intentions by making its services indispensable to the military, despite a critical bottleneck of tangible assets. Although, like other war-critical initiatives, it had effectively no budget, practical limits existed on space, equipment, staff, and most of all, time. Beginning in 1942, for instance, OSRD contractors entered into an intense competition with one another, as well as with the government's own laboratories, to staff their many highly skilled positions. While MIT did enjoy a privileged position here, it was as yet rather difficult to explain why even it struggled to recruit against an adversary so unlikely as the Manhattan Engineering District of the US Army Corps of Engineers.[52]

In turn, maintaining a sufficiently close relationship with the Rad Lab also strained the armed forces, who, in addition to the administrative overhead, had to put up the facilities, personnel, and hardware necessary to field-test prototypes for new equipment. In 1942, the Signal Corps assigned a detachment of officers from its own laboratories at Fort Monmouth to Cambridge in order to establish liaison with the MIT Radiation Laboratory, and later, the Harvard Radio Research Laboratory, which had taken over the institute's work on electronic countermeasures. Eventually the military assigned a complement of about 50 officers to full-time duty in Cambridge, split about evenly between the two departments.[53]

The Navy and the Army Air Forces also dedicated hundreds of other personnel, and dozens of aircraft, to support the lab's flight-testing program, which began at East Boston (now Logan International) Airport before graduating to more capacious facilities at Laurence G. Hanscom Field in nearby Bedford. The armed forces made space available at geographically scattered proving grounds for the installation of test equipment; the AAF, in primary, permanently allocated resources to Division 14's test programs at Eglin Field near Pensacola, Florida. Government activities continually hosted Rad Lab representatives for short and longer-term periods as well.

The proliferation of liaison channels provided a perpetual source of new puzzles to

52. Stewart, *Organizing Scientific Research for War*, 321–332; Division 14, *Radar*, 22–24.

53. Stewart, *Organizing Scientific Research for War*, 163–164, 165–167; Division 14, *Radar*, 17.

work out. By far the greatest muddle involved the aforementioned service relationship between the Signal Corps and the Army Air Forces. Although the AAF possessed autonomy sufficient to establish its priorities, the Signal Corps acted as the agent responsible for research-and-development work on electronic equipment as well as managing production contracts. By all accounts, the two branches of the War Department struggled to reconcile their discrepant interests or even to formalize a mechanism for doing so, an apparent absurdity of process that confused many outsiders.[54]

The AAF did send its own people to Cambridge; in fact, by the middle of 1944, the Army Air Forces had nearly as many officers detailed to liaison assignments as the Navy—about 20, not counting civilian employees—while the Signal Corps kept only five on site. At this point in the war, the ground army was fully mobilized: Allied troops had already invaded the European continent, and the Army Ground Forces' concerns had largely shifted from developing new equipment to maintaining its existing supply lines and production base.[55]

As an efficiency measure, the War Department transferred the Aircraft Radio Laboratory at Wright Field from the Signal Corps to the Air Technical Services Command (ATSC), the AAF's specialty logistics agency. The air forces still depended on the Signal Corps for the procurement of "common items"—the practical definition of which remained a point of tension—but it nonetheless received far greater control over electronics deemed "peculiar" to aviation, which subsumed the majority of active projects at the Rad Lab. In January, the War Department further approved the transfer of one Fort Monmouth facility, the Eatontown Signal Laboratory, which the ATSC reorganized into the Watson Laboratories, named for Paul E. Watson, the engineer who directed the Signal Corps radar program in the 1930s.[56]

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54. See the note above concerning "cross procurement" practices within the War Department, as well as between the departments of War and Navy.

55. Figures derived from the staff lists compiled in *Five Years at the Radiation Laboratory*. On full mobilization, see the relevant passages in Kent Roberts Greenfield, Robert R. Palmer, and Bell I. Wiley, *The Organization of Ground Troops,* The United States Army in World War II: The Army Ground Forces, CMH Pub 2-1 (1947; repr., Washington: Center of Military History, 1987), which is arranged topically rather than chronologically.

56. On the circumstances surrounding the establishment of the Watson Laboratories, Thompson and Harris,

Rad Lab administrators nonetheless prided themselves on the contrast between their responsive, exploratory mentality and the plodding product-oriented work at the military's own laboratories, about which they had admittedly known little beforehand. "That was the first time that most physicists had had much contact with government operations or military operations," recalled the director, Lee DuBridge:

> There was a sprinkling of physicists in the Naval Research Lab and Signal Corps laboratories and many industrial labs, but the academic physicists had been pretty well isolated from government, and especially the military, until the war. Then, bingo! they came together in a hurry and very closely. At first I think there was a little suspicion on both sides. I mean, we didn't know each other and didn't know the way the others worked, and we were a little uneasy about the military insistence on secrecy and security...And also they had a different feeling about how you approach a new thing. We would come to them for example and say, "Look, we've got a new idea about a radar you could put on your airplane and search out submarines," or something like that. They would say, "Well, we don't seem to have any military requirement for that. I don't find one any place in the book."[57]

One such project not found in "the book,"—what the laboratory called "Project II"—began as an experiment, initiated by Louis Ridenour, with an S-band radar installed on the building's roof.[58]

In early 1941, General Electric delivered a servo-actuated machine-gun mount to rotate the antenna according to feedback received from an electronic circuit provided by Bell Telephone Laboratories. Ridenour's group refitted the radar to an Army truck bed—later standardized as the SCR-584—while Bell Labs refined the targeting computer into the M-9 Director. As procurement items, the equipment remained administratively distinct, but the continued collaboration between MIT, Bell Labs, and General Electric preserved electrical compatibility so that units could be combined in the field as a fully or semi-automatic fire-

The Signal Corps, 449–457.

57. Interview, Lee DuBridge, with Finn Aaserud, Pasadena, CA, Feburary 14, 1986, transcript, Niels Bohr Library and Archives, American Institute of Physics, College Park, MD, URL: https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4582. The conditions DuBridge observed also resonate with the thesis of Peter Galison, "Laboratory War: Radar Philosophy and the Los Alamos Man," in *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997), 239–311.

58. Division 14, *Radar*, 43–45; Guerlac, *Radar in World War II*, vol. 1, 276–282.

control system for a 90-millimeter antiaircraft gun.[59] Chronicles of the Radiation Laboratory often count the SCR-584/M-9 tandem among OSRD's finest achievements: a new form of technological development—an "integrated system"—which the Army had not explicitly asked for and likely could not have administered itself, but which nevertheless arrived in Europe in time to help defend London, Antwerp, and other sites targeted by the flying bomb.[60]

Perhaps more significant than its technical achievements, however, the Rad Lab put into circulation a large cadre of scientists and engineers armed with years of practical experience in electronic systems, project management, and military–industrial relations, who despite their increased institutional fluidity, nonetheless retained more traditionally academic attitudes toward secrecy, bureaucracy, and formality. Even in the employment of government or industry, many remained loyal to their colleagues and identified with their former faculties and *almae matres*—MIT most commonly of all. While the AAF's single largest industrial program during the war had been the B-29, the Radiation Laboratory was its "Manhattan Project": a high-stakes, high-intensity collaboration between universities, government, and industry to field what was perceived as decisive, revolutionary new technology as quickly as possible. (Aside from modifying a few bombers and training their crews to the specification of the Manhattan District, the AAF played virtually no role in developing the atomic bomb.) It was not coincidence that six of the USAF's first seven chief scientists had the Radiation Laboratory: Ivan A. Getting, Louis N. Ridenour, David T. Griggs, Chalmers W. Sherwin, H. Guyford Stever, and George E. Valley Jr.[61]

59. Fagen, *National Service in War and Peace*, 139–155; Guerlac, *Radar in World War II*, vol. 1, 480–492, vol. 2, 891–896; see also notes at the beginning of this chapter.

60. For instance, Louis Brown, *A Radar History of World War II: Technical and Military Imperatives* (Bristol, UK: Institute of Physics, 1999), though the tradition stretches at least as far back to Baxter, *Scientists Against Time*, as well as other books in the series.

61. The one exception, Courtland D. Perkins, spent the war at a Wright Field aerodynamics lab, though he too had been MIT-trained. Dwayne A. Day, *Lightning Rod: A History of the Air Force Chief Scientist's Office* (Washington: Chief Scientist's Office, United States Air Force, 2000) stops just short of characterizing Division 14 as the Air Force's cradle for future research-and-development policy-makers, though it does document the specific connections that held open the revolving door between MIT and the Air Staff. Comparing *Radiation*

So while Division 14, and OSRD/NDRC overall, provided the Air Force with a robust pool of labor for future military-industrial developments, it also stacked its science-policy and project-management organizations with experienced, albeit like-minded and to some extent contrarian administrators. Largely insulated from military bureaucracies, the Rad Lab had for them been a comfortable working environment, a model for future scientific-technical innovation, and an incubator for the next generation of "systems thinking." It was a pattern they would insist on reproducing, often in the same places and with the same people, though conditions in the following decade would make the second attempt far more problematic than the first.[62]

The wartime experience had galvanized the nation with a sense of imminent peril, a state of both legal and social exception set aside notions so quotidian as procedure, efficiency, even financial accounting. The centers of power still did contend for control over other resources, but as supplies rose exponentially, the question of conservation almost always remained secondary to the imperative of an expeditious victory. As peacetime returned, however, organizational politics reverted to zero-sum calculations, with sums insufficient for those in whom the Cold War renewed the sense of national peril. A potential war with the Soviet Union became, under normal bureaucratic circumstances, a more actual fight within the institutions of research and development themselves—academic, industrial, and governmental.

Postwar relations: Contested models of military research

The application of digital automation to air-defense problems can be traced, both technically and organizationally, to the disposition of Division 14's projects, contracts, and property,

Laboratory Staff Members against the membership lists printed in Sturm, *The USAF Scientific Advisory Board*, app. C also makes clear the continuing presence of Rad Lab alumni in USAF science policy.

62. For example, the essays collected in Agatha C. Hughes and Thomas P. Hughes, eds., *Systems, Experts, and Computers: The Systems Approach in Management and Engineering* (Cambridge: MIT Press, 2000); Michael Thad Allen and Gabrielle Hecht, eds., *Technologies of Power: Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes* (Cambridge: MIT Press, 2001); Naomi Oreskes and John Krige, eds., *Science and Technology in the Global Cold War* (Cambridge: MIT Press, 2014).

as can the eventual conflict between the Air Force's civilian and military administrations concerning the proper management of advanced research-and-development programs. While high-level policy debates continued in Washington well into the 1950s, work in the laboratories proceeded apace. In radio- and communications-electronics, the list of active projects mixed short-to-intermediate-term engineering items that responded to needs articulated from the field—particularly navigation, traffic and landing aids, as well as support for ground-based radar—with a few more broadly scoped programs characterized by vague objectives and even vaguer budgets, schedules, and technical direction.[63]

Likewise, what would become the new electronic "ground environment" combined elements from both strains of research: the immediate and the unbounded, though not as a cohesive development that technology managers could readily anticipate, let alone control. Senior administrators indeed recognized how problematic this pattern had become during the period of relative austerity imposed on the military department during the mid-to-late forties, but their drive toward rational efficiency flagged under the weight of conflicted ambitions, as well as a generally reactive environment, in which attempts to plan the future suffered constant and often unanticipated intrusions from similar plans set in motion years before. In other words, despite renewed dedication to a hierarchical model of rational technology management, outcomes at the top replied—seemingly at random—to the distant rumblings in the vast middle of the Air Force's research-and-development apparatus.

Until 1950, the organizational epicenter of these institutional tremors, at least concerning electronics research, were the Watson Laboratories, which the Army Air Forces acquired from the Army Signal Corps on January 1, 1945. At the time, the AAF fully anticipated that the Watson lab would assume the same broad responsibility for in-house

63. At war's end, Division 14 had logged 750 project items, plus an additional 50 fabrication jobs at the Research Construction Corporation, though it is unclear how many remained active: United States Office of Scientific Research and Development, Division 14, *Radar: Final Project Report,* NDRC Report No. 565 (Cambridge: Massachusetts Institute of Technology, December 1945), iv-xxiv, OCLC (13275481). Watson Laboratories reported 186 open investigations during the same time period: *Watson Laboratories Quarterly Historical Report for 1 July–30 September 1945* (Red Bank, NJ: Watson Laboratories, Air Technical Services Command, n.d. [1946?]), AFHRA (0143983), 60–75.

military R&D, with production coordinated through private industry, as had its antecedent: the Eatontown Signal Laboratory, a former activity of the Signal Corps Laboratories at Fort Monmouth. Its primary mission was to continue the work already underway at Eatontown while facilitating the transition of projects and assets at MIT and Harvard from their quasi-academic administration under Division 14 to the Air Technical Services Command. To this end, the Watson lab began preparations to acquire real estate in Cambridge and hire staff from the Radiation Laboratory soon after NDRC announced in mid-1945 that all OSRD activities would be gradually discontinued over the next year.[64]

That September, the Cambridge Field Station (CFS) opened in a small manufactory recently vacated by the Research Construction Corporation with a complement of eleven civilians. Officially a satellite office of Watson Laboratories, which had recently moved from Eatontown to Red Bank, New Jersey, the expectation was that CFS would exist only so long as needed to assume the Rad Lab's outstanding contracts, liquidate its property, assimilate active projects of enduring value, and recruit as much of the scientific-technical talent accumulated in Cambridge as the AAF could afford to hire for itself. Once it had effected the hand-off, the station would be closed and the staff returned to Red Bank.[65] In fact, officials in the Air Technical Services Command initially planned to merge the Watson Laboratories into the Aircraft Radio Laboratory at Wright Field by mid-1946, according to the first estimation.[66]

Recruiting, however, proved more difficult than expected. After the war, government laboratories raced with universities and industrial firms to claim the best of the nation's scientific workforce as it demobilized, a contest that disadvantaged the public sector in many ways.[67] In October, 1945, AAF Headquarters asked Lee DuBridge to distribute a telegram

64. *Watson Laboratories Quarterly Historical Report, Jul.–Sep. 1945*, AFHRA, 17–21.

65. *Unit History of Watson Laboratories Cambridge Field Station, 3 September 1945–30 June 1946* (Cambridge, MA: Watson Laboratories, n.d. [1946?]), AFHRA (0144012), 1–3, 13–14.

66. *Watson Laboratories Quarterly Historical Report, Jul.–Sep. 1945*, AFHRA, 7–8.

67. Lassman, *Sources of Weapon Systems Innovation in the Department of Defense*, 1–7 contains a relatively recent bibliography on the subject; however, it notably omits Ann Markusen et al., *The Rise of the Gunbelt: The*

from General Arnold to all members of his staff. “I have been informed of the attempt now being made to by the Air Technical Services Command, Wright Field, Dayton, Ohio, to interest many of the senior Staff Members of the Radiation Laboratory, Massachusetts Institute of Technology, in accepting high-level positions with the Army Air Forces at the Cambridge Field Station,” it began. After explaining the purpose of the new organization, Arnold claimed, “I cannot overemphasize the importance to our future Air Force of research and development in the electronic field [*sic*],” and that “to this end I would appreciate your giving serious consideration to the proposals of the Air Technical Services Command for post-war employment.” Beyond the call to patriotic duty, the general appealed to personal pride, suggesting that “I would deem it a privilege to have you continue to work for the Army Air Forces to carry on the work you have so ably participated in during the war just ended.”[68]

Arnold’s offer seemed to generate as much skepticism as it did interest among prospective hires, with more than a hint of entitlement. On November 6, an unidentified group of Rad Lab employees dispatched a five-page missive to Edward L. Bowles, a professor of electrical engineering at MIT and a special assistant to the Secretary of War, demanding answers to a list of twelve questions. “The following points should be emphasized,” they wrote in summary:

> A preliminary report should be made to us in *one week* if possible on the following important issues, general location of the the permanent laboratory, life expectancy of the Cambridge Field Station, and close association to a University. A further more complete report should be made in perhaps a month or two. Some of us feel as the decision to when to move would be easier to make *after* the location is chosen. Minor details such as interruptions of college courses of junior members and schools for children would be at a minimum if the move was made in the summer.[69]

Military Remapping of Industrial America (Oxford: Oxford University Press, 1991), especially chap. 3, which analyzes the demographic shifts brought about by the new defense industry. In their personal and professional predilections for a seeking out employment consistent with their urbane lifestyles, engineers and scientists, in general, were no different than the subjects of David Kaiser, “The Postwar Suburbanization of American Physics,” *American Quarterly* 56, no. 4 (December 2004): 851–888, JSTOR (40068288).

68. Memo, L. A. DuBridge to all staff members, October 26, 1945, in *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, app. 8.

69. Letter to Dr. Edward L. Bowles, Expert Consultant, Office of the Secretary of War, November 6, 1945, 4, in *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, app. 6.

Remarkably, Bowles succeeded in coaxing the desired report from the office of General Laurence C. Craigie, the chief of engineering at Wright Field, by November 19—an exceedingly expeditious turnaround that indicates the gravity with which the AAF electronics establishment was considering the issue of staff retention. Craigie's response engaged the authors' concerns point-by-point while remaining frank about ATSC's plan to relocate all of its research workers to Dayton by the end of 1946.[70]

According to one reckoning, the Cambridge Field Station had succeeded in persuading about 40 former Rad Lab technicians to accept its offer of employment by June 1946.[71] The station's first published organization chart, dated the following April, showed that Rad Lab alumni directed four of the nine CFS laboratories, as well as 18 of their 37 research groups.[72] While certainly well represented, it is unclear exactly what officials in Dayton and Red Bank had hoped for Division 14; indeed, they may well have intended to replicate the Rad Lab more or less in miniature. Regarding the critical recruiting period from September 1945 to July 1946, the station historian wrote that "scientists and technicians showed a definite aversion to accepting employment with the government in a service laboratory":

> This was partially due to the fact that during the war, in some service laboratories, situations had existed which made them undesirable places of employment, and these had reflected badly upon *all* service laboratories. Some of these basic grievances were: the administration of scientific establishments by military men who were not qualified for such tasks by training, experience or sympathies; poor recruitment policies which brought in obviously unqualified persons who tended to lower the tone of the entire establishment. Other things which these people believed deterrents to accepting government employment were: strict Civil Service rules and procedures; cumbersome regulations for procurement and property; and insufficient funds being allotted for the necessary long distance calls, travel and other things vital to the efficient operation of

70. Letter, Brig. Gen. Tom C. Rives, Chief, Electronics Subdivision, Engineering Division, Air Technical Services Command to Dr. E. L. Bowles, Expert Consultant, Office of the Secretary of War, November 19, 1945, in *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, app. 6.

71. The bibliographic data compiled *Radiation Laboratory Staff Members* also contained the subject's current employer, if known.

72. The total number of former Rad Lab employees occupying these positions was 21, i.e. several persons held more than one such position: *Unit History of Watson Laboratories Cambridge Field Station, 1 July–31 December 1946* (Cambridge, MA: Watson Laboratories, n.d. [1947?]), AFHRA (0144013), app. 3.

a research establishment. In short, a fear of "government red tape" in general.[73] Nevertheless, the Cambridge Field Station grew quickly into a laboratory in its own right, employing 203 civilians by December 1945, with plans to hire an additional 500 technicians and support personnel within the next year.[74]

To further entice the staff, ATSC approved an unusual organization plan that called for a "flatter" structure in which civilian scientists and engineers could exercise more influence than usual over the laboratory's technical direction, as well as greater autonomy concerning their own work. As an additional reassurance, Watson Laboratories called on John W. Marchetti, a colleague of Paul E. Watson in the Signal Corps radar program, to head the station's military administration, which was intentionally kept very small (only 17 had permanent assignments as of December). Although Marchetti had been directly commissioned into the Army at the start of World War II, his distinctions in civilian life commanded greater trust and credibility among potential recruit than a career military officer might have otherwise.[75]

Despite these exceptional measures, the Cambridge Field Station apparently struggled to discharge its primary responsibility through 1946. ATSC's expectation that Division 14 operations required only a routine mopping up dissolved soon after the first representatives from Watson Laboratories arrived in Cambridge to survey of the projects considered for assimilation. The laboratory and administration grew to employ nearly 800 civilians, but turnover remained high, a fact blamed on the facility's perceived impermanence among technical workers—a significant number of whom were students just returning from the war—as well as the reimplementation of more rigorous peacetime civil-service requirements throughout the federal government. To relieve overcrowding, administrators scrambled to secure supplemental floor space at a dozen other government-owned buildings throughout

73. *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, 5.

74. According to the chart printed in *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, app. 5.

75. *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, 11–12. On Marchetti's work before and during the war: Office, *A History of Army Communications and Electronics at Fort Monmouth*, 15–16; Harold A. Zahl and John W. Marchetti, "Radar on 50 Centimeters," *Electronics* (January 1946): 98–104.

the Boston area, disturbing the work environment as equipment and personnel moved incessantly.[76]

Foremostly, however, the task of clearing out the Rad Lab quickly became rushed and unsystematic. "Conditions covering transfer were discouraging," reported the station historian. "It appeared that Radiation Laboratory had torn equipment from its benches, dumped it into a truck, and shipped it to Cambridge Field Station. On the shipping ticket it was listed as miscellaneous electronic equipment." The vast excess had to be diverted to a commercial warehouse 30 miles north of Boston where a team of 50 logisticians, detailed temporarily from a regional depot, began the long process of identifying, cataloging, and dispositioning the 120,000-square-foot cache of unsorted electronic parts. A reduction-in-force during the second half of 1946 further upset daily activities and depressed morale.[77]

Ironically, the disruptions seem to have forestalled the intended closure of the Cambridge Field Station long enough for the laboratory to distinguish itself as an important center of research. For more than a year, the few military officers on site remained too distracted by the large warehousing operation to closely monitor other projects. Earlier in 1946, the Army had discharged John Marchetti from active duty, transitioning him from his role as the station's military commander to its civilian director of research. With Marchetti effectively in charge, CFS laboratories carved out a niche for continuing work on projects that had already generated some interest but previously lacked an immediate application or else wound down along with industrial war-production.[78]

The agenda ranged from relatively basic studies to involvement in major procurement programs. Marchetti himself became involved in deliberations concerning the AAF's early

76. *History of the Cambridge Field Station, Jul.–Dec. 1946*, AFHRA, 1–4, 11–13.

77. *History of the Cambridge Field Station, Jul.–Dec. 1946*, AFHRA, 5–8; *Unit History of Watson Laboratories Cambridge Field Station, 1 January–31 March 1947* (Cambridge, MA: Watson Laboratories, n.d. [1947?]), AFHRA (0144014), 5–9.

78. *History of the Cambridge Field Station, Jan.–Mar. 1947*, AFHRA, 11–18. Although military bureaucrats made a token effort to bring the station in line with regulations, the research staff pushed back formally through the CFS Steering Committee, as well as informally, by open flaunting administrative controls.

"radar fence" proposals, the details of which depended greatly on resolving some design issues, particularly with the AN/CPS-6, that the Rad Lab had not remained open long enough to troubleshoot with the manufacturers. Other branches investigated dielectrics, components, and antenna theory, and after reclaiming the Rad Lab's field sites in Bedford and Ipswich, resumed measurements with air- and ground-based beacons and navigation aids. Detectors, beacons, and instrumentation for assisted landing and air-traffic handling remained an especially active area of study, with the Navigation Laboratory also mobilizing to support the V-2 testing program at White Sands with radio-telemetry data.[79]

By the middle of 1947, these and other concrete accomplishments began to muddle existing plans to shutter the Red Bank laboratory and its Cambridge field station as quickly as possible. In September, the Air Force became an executive department independent of the Army, and while Watson Laboratories had already been operating exclusively under AAF control for the last two-and-a-half years, their fate was immediately tied to a much more complex deliberation concerning the future of research-and-development policy within the organization as a whole. As such, the structure of the entire USAF laboratory system was opened fully to reconsideration.

On December 1, the Air Material Command—successor to the Air Technical Services Command—removed the Cambridge installation from the jurisdiction of Watson Laboratories and began administering it directly as an independent research center called, rather inauspiciously, the 4153rd Air Force Base Unit. (Although its official designation changed again to the similarly undistinguished 3160th Electronics Station in August 1948, documents attest "the Cambridge lab" as a stable informal title throughout this period.) Cambridge acquired a geophysics research unit from Red Bank around the same time, even as the Air Materiel Command insisted that both facilities were still scheduled for relocation, except that their destination had changed from Dayton to Griffiss Air Force Base in Upstate New

79. *History of the Cambridge Field Station, Jul.–Dec. 1946*, AFHRA, 14–15; *History of the Cambridge Field Station, Jan.–Mar. 1947*, AFHRA, 19–23.

York, the site of a regional supply depot. By the middle of 1948, however, rumors began circulating that the Department of the Air Force might delay the move indefinitely, or perhaps cancel it entirely.[80]

3 The normalization of automatic control

The research that would ultimately prove the most significant to the Cambridge laboratory, the Air Force, and the course of military technological development in the United States, originated in the Relay Systems Laboratory under Edward W. Samson, a Canadian-born physicist who had spent his final year at the Radiation Laboratory working on methods for multiplexing detector outputs into long-distance carrier signals.[81] Essentially a problem of telecommunications engineering, the project was an unusual choice for Division 14 and probably better suited to an experienced industrial-research team at Bell Labs than an assorted group of academic physicists.

Contrary to expectations, though, Rad Lab staff had generally been too pressed readying detectors and beacons for the field to consider the elements of surveillance and control more fundamentally—elements such as communications, information-handling, identification, and display. Moreover, development of fixed-placed "heavy radar," such as had proved critical during the Battle of Britain, lagged in comparison to the air, sea, and mobile configurations. Allied forces lacked the incentive to update their vintage early-warning networks as their war became an increasingly offensive one. Indeed, the AN/CPS-1, the first high-power, ground-based microwave detector, did not reach Europe until 1945, and in limited quantities even then. Still, the development that culminated in the production-

80. For instance, "unofficial sources" told the *Boston Herald* on July 7 that top officials wanted to keep the lab in Cambridge: Ruth P. Liebowitz, *From the Cambridge Field Station to the Air Force Geophysics Laboratory, 1945–1985*, AFGL TR-85-0201 (Hanscom AFB, MA: Air Force Geophysics Laboratory, September 6, 1985), 1–4, DTIC (ADA164501).

81. There are few obvious sources about Samson himself. A search of various databases of scientific-technical publications show that he remained with the Cambridge lab throughout the 1950s, continuing his work on digital signals.

model AN/CPS-1, a program called MEW, for Microwave Early Warning, deeply affected Division 14's thinking about the possibilities of ground radar, whether or not they could be realized before the end of the war.[82]

Tools for surveillance: High-power microwave radar

The first experimental MEW set, assembled on the roof of MIT's Building 6 in the fall of 1942, could, in some conditions, penetrate nearly to the theoretical radio horizon, equaling the range of conventional VHF signals, but with the fine resolution of a 10-centimeter beam. The radiation pattern was so robust that it presented a serious challenge to the indicators group, which struggled to devise a combination of scopes adequate to display the detector's volume and resolving power. The following summer, MEW No. 1, a prototype installed for service trials near Tampa performed so well it overwhelmed the local air-defense network. "With existing radar equipment it had been customary to report all isolated information to the Orlando filter center," Guerlac recounted, "but with the advent of the MEW, which on certain days could have reported as many as 12,000 plots, the filter center would have been jammed with information telephoned in from the MEW site."[83]

Consequently, the Rad Lab's site team collaborated with the AAF in designing a "pre-filter" operation for MEW No. 1, "centered around a semicircular [glass] table, 15 feet in diameter, with the Gulf Coast painted on it" on which "tracks were marked on from behind, while the controllers read their information directly off the front." A set of both polar and rectangular coordinates overlaid the map, so that scope readers could tell range and azimuth data directly to the plotters while still allowing tellers to read off the same grid positions recognized by the Orlando air-defense center. Although the the set impressed the AAF enough to ask for five additional prototypes, it deferred priority on a production variant

82. On high-power microwave radar programs generally, see *Radar*, 21.04–21.10; Division 14, *Radar*, 64–66; Guerlac, *Radar in World War II*, vol. 1, 437–459. Some details in the following passage originate from these sources.

83. Guerlac, *Radar in World War II*, vol. 1, 458.

until 1945.[84]

This initial lack of enthusiasm notwithstanding, MEW appeared to excite the already fervid imagination of Division 14, with sources remarking almost breathlessly on future possibilities, and later, even identifying the program as the cradle of modern air-transportation and military command-and-control systems. For instance, in the spring of 1944, the British Branch of the Radiation Laboratory (BBRL) constructed MEW No. 2 on the southern tip of the Devonshire coast with a view across the channel to the Cherbourg Peninsula. Although still an experimental set, British and American forces often operated it during daylight hours to assist pilots with navigation, air-sea rescue, and provided some limited tactical direction to ground-attack aircraft in the area. At night, BBRL's technicians continued to refine the equipment, particularly the scopes and indicators, often documenting what they happened to see through them.[85]

While taking photographs on June 2, Edwin G. Schneider, the MEW project director, began to notice unusual shipping and balloon activity along the English coast, culminating in a massive harbor operation on June 4–5. Evidently the news spread within BBRL because Schneider's boss, Ernest C. Pollard, was present overnight on June 5–6 to witness the Allied invasion—the timing of which remained an absolute secret—unfold in the MEW operations room: "a grandstand seat for this most gigantic of aerial displays," according to Guerlac. In a report rendered to senior staff, Pollard described the moment he "sat down at one of the vacated controller's scopes and started looking":

> First thing was two area raids leaving Portland and swinging out, one of them going north from Cherbourg. An area raid is really a fearsome thing to see if you have not seen one before. Something like a hundred planes are scattered over a range of 20 to 30 miles and width of ten miles or so. The MEW would really let you count them individually...Area raids were nothing new at this base...However, at 2345 [hours] something new appeared on the scope. A kind of target I had never seen before. A long streak was observed moving directly south having a length of upward of four miles and

84. Thompson and Harris, *The Signal Corps,* 274–276; Thompson and Harris, *The Signal Corps,* 468–477.

85. Guerlac, *Radar in World War II,* vol. 2, 846–852.

> the width of a single plane.[86]

Pollard guessed these were aircraft dragging some sort of tow line; they were, in fact, transport planes hauling gliders across the channel. Already convinced that the invasion had begun, a military liaison confirmed soon after midnight.

Several hours later, Pollard watched the predawn fighting as "fighters crossed and recrossed the tracks of the gliders":

> More area raids appeared. One can see now the broad plan as far as the station was able to perceive it. It looked as though the Cherbourg peninsula was the object of attack. One could see raids coming down around, crossing the channel, and being rather hard to pick up on account of the range being over 150 miles. These flew south, faded a little, then came in crossing the Cherbourg peninsula. This circular bombing continued all night.

Though obviously lacking context for what he saw, Pollard likely realized that even the Supreme Allied Command was incapable of monitoring the progress of Operation OVERLORD as clearly and instantly as he could through his scope.[87] BBRL arranged to have MEW No. 1 stripped from its mount in Florida and shipped to Corsica, where a similar scene played out during Operation DRAGOON, the Allied invasion of southern France, on August 15.[88]

MEW No. 2 provided its most important service as part of the air-defense network set up to confront the V-1 attacks on London, which began shortly after D-Day. In the three days between July 1 and 4, the system was crated up at its site in Devonshire and trucked off to another coastal emplacement in East Sussex, where it proved one of the more reliable tools for tracking the low-flying "divers," as BBRL called them, as they crossed the channel. Allied

86. Guerlac, *Radar in World War II,* vol. 2, 852.

87. Pollard reflected on his experience with the MEW program in Ernest C. Pollard, *Radiation: One Story of the M.I.T. Radiation Laboratory* (Durham, NC: Woodburn Press, 1982), 77-94, though his memoirs are desultory and obviously colored by several decades of retrospection on the significance of the events in questions.

88. Originally called Operation ANVIL, the DRAGOON landings were at first planned to coincide with OVERLORD (evident in its earlier codename, Operation SLEDGEHAMMER) in order to divide the German forces in France. The Allies effectively canceled it to avoid further complicating their preparations for OVERLORD only to reinstate the plan when the invasion outpaced the buildup of logistical capacity on the Normandy beachheads. Jeffrey J. Clarke and Robert Ross Smith, *Riviera to the Rhine,* The United States Army in World War II: The European Theater of Operations, CMH Pub 7-10 (Washington: US Army Center of Military History, 1991), 3–22 is the official chronicle.

air-defense forces used the early-warning information to dispatch fighters, alert gun crews along the missile's projected route, and infer the locations of launching sites in France. Unlike their military liaisons, however, Division 14 perceived this emergency service as further proof of the system's versatility rather than an indication of its specific facility for air defense. In speculative discussions, MEW did not simply represent "better radar," but the first step into a transformative new domain of large-area, real-time surveillance and control.[89]

As the Allies advanced across France, for example, BBRL tried to sell elements of the Supreme Command on MEW as a tool of offensive warfare as well, going so far as to propose that the Eighth Air Force abandon its existing doctrine for conducting strategic-bombing operations and direct them via ground radar, vectoring raids toward their targets as radar showed the air battle developing in real time. While air commanders rejected the scheme as impractical, it demonstrated an incipient consciousness among scientists and engineers that future developments in radar should not be classified narrowly as "detectors" and fitted singularly into compartmentalized applications such as early warning and traffic handling, but conceived more broadly as inputs to an *information system,* one capable of recording physical phenomena over thousands, even millions of square miles, and translating them instantly into military, economic, and social benefits on a potentially continental scale.[90]

Of course, the concept of a "radar network," in itself, offered little insight to air-defense professionals, who had already grappled tangibly with "aircraft control and warning" organizations for years, but the Rad Lab interacted with such persons only infrequently during the war. Unlike its British counterpart, the Telecommunications Research Establishment, Division 14 never performed operations analyses of active air-defenses and likely glimpsed

89. Guerlac, *Radar in World War II,* vol. 2, 851–853, 857–859.

90. Guerlac, *Radar in World War II,* vol. 2, 847–850, 1025–1041. The latter passage shows that opinions were beginning to shift by mid-1945, but the logistics of the Pacific Theater precluded MEW from common application. See also Thompson et al., *The Signal Corps,* 274–276; Thompson and Harris, *The Signal Corps,* 470–472; Wesley Frank Craven and James Lea Cate, eds., *The Pacific: Matterhorn to Nagasaki, January 1944 to August 1945,* vol. 5 of *The Army Air Forces in World War II* (1953; repr., Washington: Office of Air Force History, 1983), 582–583.

their vicissitudes only fleetingly through the MEW test program.[91] Indeed, the Rad Lab expressed only a passing interest in air defense in its contribution to *Toward New Horizons* in 1946. "It is probably not necessary to say much more about the defensive possibilities of ground-control radar," observed Lee DuBridge, Edward Purcell, and George Valley in its executive summary.[92]

While Valley did append his own thoughts on atomic defense—or, rather, its practical impossibility—the report otherwise reduced air defense to a special case of a more general problem. "The prime function of ground radar is rapidly becoming that of control," which subsumed both military and civilian applications from offensive warfare to commercial airways, law enforcement, public safety, meteorology, even scientific inquiry.[93] More than a national-security measure, what the authors strongly implied was that a network of MEW-like stations deployed across the entire country would become the foundation of a new system of transcontinental infrastructure as revolutionary as had been the railroad and the telegraph.

Nevertheless, the DuBridge–Purcell–Valley report included only brief speculation on how ground-based control could practically be achieved on such an immense scale. A simple schematic showed an idealized control organization, where "all control except a few

91. While the United States military was already developing applications for radar long before the war, it did absorb the nascent practice of operations research from its British counterparts. For organizational reasons, British expertise in radar and operations analysis both concentrated at the RAF's Bawdsey Research Station, which, as previously mentioned, produced the Telecommunications Research Establishment in 1940: Maurice W. Kirby, *Operational Research in War and Peace: The British Experience From the 1930s to 1970* (London: Imperial College Press, 2003), chaps. 3–5; and the relevant passages in David Zimmerman, *Britain's Shield: Radar and the Defeat of the* Luftwaffe (Stroud, UK: Sutton, 2001). Consequently, the largest center of American operations research during the war was actually located in England, at the headquarters of the Eighth Air Force: Charles R. Shrader, *History of Operations Research in the United States Army, 1942–1962*, CMH Pub 70-102-1 (Washington: Office of the Deputy Undersecretary for Operations Research, Department of the Army, 2006), chaps. 1–2; Charles W. McArthur, *Operations Analysis in the U.S. Army Eighth Air Force in World War II* (Providence, RI: American Mathematical Society, 1990). Although some techniques were quickly taken up in Washington, within the United States, operations research did not emerge as a proper discipline before the end of World War II. See especially William Thomas, *Rational Action: The Sciences of Policy in Britain and America, 1940–1960* (Cambridge: MIT Press, 2015).

92. L. A. DuBridge et al., *Radar and Communications: A Report of the AAF Scientific Advisory Group* (Wright Field, Dayton: Headquarters, Air Materiel Command, 1946), 14, OCLC (18735698).

93. DuBridge et al., *Radar and Communications*, 128.

specialized functions is concentrated a convenient location within the area." The authors claimed that "the main difference between this system and those now in use lies in the transmission of the radar data to indicators in the control center":

> Under present operational practice, data is transmitted to the control center by verbal relaying of coordinate positions. This step introduces delays and errors which make reliable control from the retold plots an impossibility. The alternate solution now in use is to pass control to the radar station. This is undesirable because the control is no longer centralized, resulting in difficulties in coordination between the operational planning group and the control group.

They concluded that "the use of a relay link to transmit the radar data to the control center avoids these difficulties."[94]

Although the report specifically invoked the term "relay" in connection with radar-observation data, it never contemplated the technical means of conveyance, except for one oblique reference to wideband television signals. Neither did the authors dwell on how any data so relayed should be processed and displayed, though they did perceive the latter problem as one demanding an immediate solution. Compared to its lavish descriptions of radio physics, component reliability, and navigational geometry, their sparing discussion of the fundamental problems of radar-facilitated ground control suggests that Division 14 officials found the concept intuitively trivial, and thus, had then yet to realize the technical and organizational implications. "The problem of the future is chiefly an economic one," the authors remarked, "to install sufficient stations to surround the country is possible and necessary."[95]

Tools for control: High-density data transmission

At the time of writing, the Rad Lab's first radar-relay circuit had been tested only preliminarily. Design work began early in 1945 under the MEW program, which had since refocused

94. DuBridge et al., *Radar and Communications,* 136.

95. DuBridge et al., *Radar and Communications,* 14. The Rad Lab's postwar summaries for OSRD give a similar impression as well; chiefly Division 14, *Radar,* as well as other volumes in the series.

on the production model, designated AN/CPS-1. By the fall Edward Samson's group had connected a prototype AN/CPS-1 at Bedford Army Air Field with a receiver on MIT property via a 300-megahertz carrier wave. The extraordinary resolution of the microwave detector necessitated the unusually high frequency of the transmission (for comparison, in 1940 the FCC allocated the VHF bands between 54–88 megahertz and 174–216 megahertz for television broadcasting), which had to carry a signal about 200 megahertz wide. Early circuit designs still did not produce a satisfactory picture, and synchronizing the azimuthal positions of the sending and receiving scopes remained troublesome as well.[96]

Progress stalled for several months while the MIT receiver was torn down and a new one prepared for installation at the Cambridge Field Station. While television would have sufficed for line-of-sight transmissions across a few dozen miles, the nature of the project changed early in 1946 when the AAF expressed interest in a long-distance radar relay, potentially connecting the Panama Canal Zone with the mainland United States—a distance greater than 1,000 miles. CFS replied that "the only method known whereby such information could be transmitted is by scanning a photographic picture of the PPI or plotting board by standard television methods sufficiently complete to give the required details, and sufficiently slow so that the frequency bandwidth is reduced to a satisfactory point for transmission in a low frequency communication channel." It was estimated that the image would require about 60–90 seconds to transmit, not counting the time needed to reproduce and project it photographically on the receiving end. The Relay Systems Laboratory disfavored this approach and noted simply that "at the present time there is no active project on this method of relaying information."[97]

In August, Samson explained some of his rationale in his first report to the lab's steering

96. *History of the Cambridge Field Station, Sep. 1945–Jun. 1946*, AFHRA, 17–18. On the Relay Systems Laboratory, see also John V. Harrington, "Radar Data Transmission," *IEEE Annals in the History of Computing* 5, no. 4 (October 1983): 370–372, doi:10.1109/MAHC.1983.10100.

97. E. W. Samson, "Historical Records of the High Density Transmission Project for the Period 1 July 1946 to 31 December 1946," Relay Systems Laboratory, Cambridge Field Station, July 10, 1947, exhibit in *History of the Cambridge Field Station, Jul.–Dec. 1946*, AFHRA, 1.

committee. "The complexity of information requiring relay transmission represents a field of continually increasing demands involving radar, television, remote control, telemetering, facsimile, and so forth," he elaborated:

> Simultaneous transmission of various kinds of information will be needed. Examples of complexity are [volumetric radar], radio relay plus television, guided missile information...Economy demands that our interests extend to the manner of compiling the information at the transmitting point, in the form of some economical modulating signal, as well as undertaking to transmit it. The corresponding reconversion of the received signal into intelligible presentable form is also an essential part of the overall relay job.[98]

In other words, an image alone might assuage the curiosity of higher authorities, but its effectiveness as a means of control depended on the logic of the image on display.

According to its study plan, the relay lab had greater ambitions: to "compress" what it called "high density information" in order to construct a total representation of the air-battle environment, presumably at a centralized location. The choice of language reflected an interest shifting from analogue multiplexing to alternative coding systems. Apparently, Samson had been unfamiliar with digital circuits until another engineer in his lab alerted him to a possible similarity between synchronizing coordinate readings from a scope and discretizing mechanisms in automatic telegraphy.[99] While existing teletype circuits operated much too slowly for direct application, they could be conceivably adapted to achieve the higher speeds necessary for relaying radar data digitally, at least after scrubbing the input signal of uninteresting features such as noise, clutter, and intermediate values.[100]

Samson's second report to the CFS steering committee expressed considerable enthusiasm for digital relay, though the research would remain largely confined to paper, as

98. "High Density Transmission Project," July 10, 1947, exhibit in *History of the Cambridge Field Station, Jul.–Dec. 1946*, AFHRA, 1.

99. This is unsurprising in light of the fact that, since teletypewriters were commercial equipment, the Radiation Laboratory never assumed an engineering task pertaining to radio or wire-line signaling, as the military had already become accustomed to taking such needs directly to Bell Laboratories: Fagen, *National Service in War and Peace*, chap. 5. On methods of automatic telegraphy in use at midcentury, see, for example, Arthur Lemuel Albert, *Electrical Communication*, 3rd ed. (1934; New York: John Wiley & Sons, 1950), chap. 9.

100. "High Density Transmission Project," July 10, 1947, exhibit in *History of the Cambridge Field Station, Jul.–Dec. 1946*, AFHRA, 2–4.

personnel shortages persisted throughout 1947 and into 1948. In response to a request from the Joint Research and Development Board, which was preparing to advise the secretaries of War and Navy on the potential “radar fence,” John Marchetti indicated that the Relay Systems Laboratory had devised a tentative coding–decoding mechanism as early as April 1947. The three millisecond interval between consecutive radar pulses could be divided into six 500-microsecond intervals, during which a rotating magnetic drum would record the signal from the detector. A second drum-head would then register a voltage representing the strength of the reflection, indicating range, and transmit it during the first interval; the drum’s synchromotor would then read off the azimuth in a binary sequence over the remaining five intervals.[101]

The capability of distinguishing between 32 different azimuthal positions over a standard telephone line represented a four-fold improvement in resolution per-unit-time. It bears reminding, however, that while Samson’s team was continuing with Division 14’s radar-relay research on independent initiative, and not in connection with an AAF procurement program, their thinking did not evolve in isolation from other ideas then circulating within the organization. Although their historians retained only scattered documentation, the similarity the problems selected and solutions considered between the two laboratories implies that engineers at the Cambridge Field Station were at least conscious of, and likely in regular contact with, a study group at Red Bank with even more rarefied objectives.

Engineers at Watson Laboratories, as well as its predecessor, the Eatontown Signal Laboratory, possessed greater experience with the conduct of air-defense operations, beyond problems of tracking and identification, than did Division 14. In April 1944, for instance, the AAF requested a design for an automatic plotting board, which led to a number of items, none of them entirely satisfactory, that attempted to represent signals received directly

101. Radar Systems Laboratory, Cambridge Field Station, “Commentary Regarding Relay for Radar Fence,” addendum C to William J. Smith, Robert M. Barrett, Frederick Kline, and Lawrence C. Mansur, “Proposed ‘Fence’ System for Air Surveillance of Continental United States,” Cambridge Field Station Report No. 1-34, May 12, 1947, exhibit in *History of the Cambridge Field Station, Jan.–Mar. 1947*, AFHRA, 9–10.

from the detector with CCTV, time-lapse photography, indicator lamps, and mechanical semaphores.[102] By the summer of 1945, this work to improve existing equipment and methods incrementally led Watson's engineers to consider holistic "program planning" for the future of air defense.

The effort was evidently small, probably limited to some occasional meetings between technicians generally occupied by other projects, but since it predates the bombing of Hiroshima, its motivation clearly derived from the V-1 and the V-2, rather than the atomic bomb *per se*. More sketch than plan, the Watson investigation did not receive a title or an assignment on the lab's list of "active engineering items" until the first quarter of 1946, when it was classified as "Item No. 178: Air Defense Central." Its specificities—to the extent they can be called such—are mostly redundant with those of other proposals described above. Nevertheless, it does represent a rare insight into the ideas circulating about the future of air warfare in the time after the operational deployment of guided missiles, but before the revelation of the atomic bomb, let alone the genesis of the Cold War. Like the DuBridge–Purcell–Valley report, the Watson plan did not really distinguish between the electronic infrastructure for offensive and defensive operations: the two would be controlled by the same means and under the same command.[103]

More ambitiously, though, the "air defense central" program focused on the long-term threat of guided missiles almost to the exclusion of piloted aircraft. Not yet anticipating the precision that would ultimately be achieved with internal guidance mechanisms, Watson's engineers seemed primarily concerned with the problem of remote control and radio navigation over extreme distances, both as a means of guiding friendly missiles as well as confusing, destroying, or even "hijacking" the enemy's. "As the first step in the accomplishment of the program," the lab's historian summarized, "detection stations are to be

102. *Watson Laboratories Quarterly Historical Report, Jul.–Sep. 1945*, AFHRA, 46–50 (see also the list of "active engineering items" on 60–75); *Watson Laboratories Quarterly Historical Report for 1 October–31 December 1945* (Red Bank, NJ: Watson Laboratories, Air Technical Services Command, n.d. [1946?]), AFHRA (0143984), 46–49.

103. *Watson Laboratories Quarterly Historical Report for 1 January–31 March 1946* (Red Bank, NJ: Watson Laboratories, Air Materiel Command, n.d. [1946?]), AFHRA (0143985), 82–87.

established to cover all approaches to the United States and its its possessions." The range of these stations would be gradually extended as over-the-horizon radar became available after 1950, according to the projections of the team, who further guessed that a 15,000-mile radius could be realized by 1965.[104]

Furthermore, "the data gathered by the detection system will be relayed to a central point, consolidated, filtered, and displayed on a master presentation unit":

> It is anticipated that ancillary equipment required at the master control central will include some of the following: data presentation units showing instantaneously, to scale, three-dimensional pictures of all activity within the surveillance of the detection stations; discriminators capable of depicting the speed of any plane or missile; automatic following units providing information on rate of speed, course, and present location of a selected target, and computers that will obtain data from the automatic following units and provide control information for any or all jamming stations so that their beams may be electronically aimed at the missile.[105]

At the time, Watson engineers had few practical suggestions for how such measures would be achieved; a progress report filed six months later offered that "new principles have been proposed" and "extension of all known techniques is also in progress," giving the impression that the project was still just a platform for discussion between the laboratory and other military-industrial-academic stakeholders.[106]

Although some elements of this vision of centralized global warfare would soon fall away—mainly those concerning radio navigation and remote control—the pattern first laid down in mid-to-late 1945 remained essentially unchanged for more than a decade. No one knew as yet how it would be done, but scientists, engineers, and a few military officials had nonetheless convinced themselves that it *could* be done, encouraging them to continue taking steps, no matter how tentative, toward to its ultimate fulfillment. "A number of actions will be required to accomplish the development of the air defense central," noted the 1946 proposal:

104. *Watson Laboratories Quarterly Historical Report, Jul.–Sep. 1945*, AFHRA, 52.

105. *Watson Laboratories Quarterly Historical Report, Jul.–Sep. 1945*, AFHRA, 54–55.

106. *Watson Laboratories Quarterly Historical Report, Jan.–Mar. 1946*, AFHRA, 84.

> An investigation will have to be conducted into consulting and computing services of major universities for research and development of basic data required for effective siting; and for studying trial targets and related problems affecting the selection and employment of electronic equipment; problems resulting from the location and operation of equipments to be located in the control central underground at great depth will have to be investigated; monitoring stations for operation with the control central will have to be developed; the development of guided-missile electronic controls and computers will have to be studied preparatory to contractual action; and acquisition of additional models of any developed equipments resulting from other projects and development, design and construction of additional devices required for integration of such equipments in the control central will have to be assured.[107]

In short, the total "system" was already understood to require the construction of a vast network of radar observation posts, remote conveyance of radar data to the centers of control, and a highly automated, most probably digital method of processing, analyzing, and presenting that information in a form intelligible to human commanders—all while respecting an as-yet aspirational notion of "integration."

Neither was this understanding isolated to the blackboard musings of a few low-ranking civil servants. In June 1946, General William L. Richardson, the AAF's director of guided missile programs, approved a set of "military characteristics" for "an Air Defense System...which will closely approach, if not actually attain, 100% efficiency in the defense of this Nation and its territories...visualized as an integrated fixed system with a Master Control Center and a minimum number of operations centers" that would incorporate "automatic search and analysis of all radio and radar activity" as well as a "centralized means for display, evaluation, communications, and target designation" in three dimensions.[108] But even as early as April 1945, AAF headquarters had begun instructing air-defense commanders in the continental United States to account for a "remote data transmission system" compatible with the AN/CPS-1 and AN/CPS-6 (both radars derived from the MEW program) in their

107. *Watson Laboratories Quarterly Historical Report, Jan.–Mar. 1946*, AFHRA, 82.

108. Memo, Brig. Gen. William L. Richardson, Chief, Guided Missiles Division, Office of Assistant Chief of Air Staff-3 to Assistant Chief of Air Staff-4, "Military Characteristics for an Air Defense System," June 24, 1946, exhibit 15 in Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol 2, Supporting Documents 1–109 (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474352).

postwar planning.[109]

However, the Continental Air Forces responded in July that it considered the AAF's request beyond its jurisdiction. Since the next war would be fought mainly with guided missiles, it presumed, a state-of-the-art radar network should be pursued only insofar as it benefited the domestic airways, and not as a defense against a persistent stream of single-aircraft attacks, like the ones launched against London and Antwerp. Instead, CAF proposed a conference to work out a multilateral bargain among all the agencies with an organizational interest in the postwar radar network, but its offer to host the conference was apparently never taken up.[110]

Planners at Air Defense Command headquarters likewise perceived scientific research and development as their only hope against the projected infeasibility of a continental defense founded on existing practices and equipment. ADC's quixotic long-term plan, completed in April 1947, remarked that "if development of certain additional materiel could be obtained or accelerated, large savings in materiel, money, and manpower (both military and civilian) could be obtained and the effectiveness of the air defense system could be considerably increased." In particular, the system "should incorporate the maximum amount of automatic operation and three dimensional presentation of radar information at points which are remotely located from the radar set itself," which would furthermore achieve "greater accuracy due to fewer operations in handling of the information."

ADC planners also desired "the televised presentation, in two dimensional form, in each wing control room of the operations of each adjacent wing" and other centralizing technologies to facilitate an increasingly centralized theory of operation:

109. "Descriptions of capabilities of newer types of aircraft warning equipment," enclosure to memo, Brig. Gen. William F. McKee, Deputy Assistant Chief of Air Staff, Operations, Commitments, and Requirements (OC&R) to Commanding General, Fourth Air Force (copy to Commanding General, First Air Force), "Aircraft Control and Warning System," April 4, 1945, exhibit 1 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

110. Commanding General, Continental Air Forces to Commanding General, Army Air Forces, "Defensive Communications and Electronics in the Postwar Period," July 21, 1945, exhibit 4 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

> The presentation in the wing control rooms must be televised to the air defense division control rooms and to the air forces, and the air forces presentation to the air defense command control room. This system of automatic presentation will eliminate the expense, time, money, and personnel associated with World War II manually operated control rooms and permit the instantaneous exchange of information necessary for the close coordination required.[111]

In the future, economy, effectiveness, automation, and organization would have to come all of a piece.

4 Conclusion: Research for command-and-control

There is no demonstrable genealogical relationship between the concepts of continental defense that emerged almost simultaneously at the headquarters of the Army Air Forces, the Air Defense Command, and within the laboratory system administered by the Air Materiel Command, namely, Watson Laboratories and its Cambridge field station. It is most probable that they evolved semi-independently, which is to say, that they all drew upon a common set of experiences and ideas, connected through informal circulation, but developed differently in order to suit the often divergent concerns of the relevant domain, whether national-security politics, operational planning, or engineering research. While a common origin seems obvious, it cannot be said to be "causal" according to the logic of bureaucracy, in which the authority is supposed to monitor its subordinates and steer their actions toward a calculated end.[112] Quite the contrary, the Department of the Air Force most definitely lacked the mechanisms for hierarchical reporting and control with respect to research and development at the time it came into existence in September 1947—a deficiency that would

111. United States Air Force, Air Defense Command, "Air Defense Plan: Long Term," April 4, 1947, annex #5 to OPD file no. 373.24 (3 May 1946) Sec. 1 (oversize), NARA, RG 341, NM-15 335-A, box 308, app. H, 4.

112. Strong determination is not a necessary feature of Weberian bureaucracy, though it is endemic in "prescriptive" theories in the tradition of Henri Fayol, *General and Industrial Management,* trans. Constance Storrs (1919; London: Pitman, 1949). Nevertheless, even classics with more humanistic or cybernetic sympathies, such as Chester I. Barnard, *The Functions of the Executive* (Cambridge: Harvard University Press, 1938) or Herbert A. Simon, *Administrative Behavior* (New York: Macmillan, 1947), tend to present causal outcomes as the ideal toward which leadership figures continually strive.

dominate its administrative development for more than a decade.[113]

For instance, the only document that could have received sufficient exposure in the Pentagon, at Wright Field, Mitchel Field, Red Bank, and Cambridge would have been the report written in early 1946 by DuBridge, Purcell, and Valley, whose influences were already diffuse in themselves, and too obtuse on the point of air defense to account for the loose consensus that arose regarding the means of implementing the radar fence.[114] They may as well have achieved the same collective realization by reading *Life* magazine. By 1948, at the very latest, it had already been widely accepted that hemispheric surveillance and control hinged critically on the development of a system for automatically relaying radar data—most probably as digital codes—and processing and displaying that data in centralized locations, which implied the application of complex digital circuits, or more precisely, digital computers. Thus, rather than staging a revolution, elite science advisors later provided a political-bureaucratic pretext for gathering pieces and fitting them into place.

What should be emphasized, however, is that the preconditions existed at the time of the USAF's foundation for a deleterious split in its scientific-technical efforts pertaining to continental defense. Watson Laboratories recognized itself as the agency responsible for directing the overall system under its exploratory Air Defense Central program, a responsibility it understood the Air Materiel Command to have exclusively granted it. While not officially incorporated into the program *per se*, Samson's work on digital relays continued nominally under Watson's supervision until December 1947, when the Cambridge lab began

113. Although some of these sources are cited elsewhere in more specific contexts, the major management studies include Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington: Air Force History and Museums Program, 2002); John Clayton Lonnquest, "The Face of Atlas: General Bernard Schriever and Development of the Atlas Intercontinental Ballistic Missile, 1953–1960," (PhD diss., Duke University, 1996), ProQuest (9707766); Michael H. Gorn, *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition, 1950–1985*, 2 vols. (repr., Andrews AFB, MD: Office of History, Headquarters, Air Force Systems Command, 1989); Robert Sigethy, "The Air Force Organization for Basic Research, 1945–1970: A Study in Change," (PhD diss., American University, 1980), ProQuest (8107687); Dennis J. Stanley, John J. Weaver, and Minnie L. Disch, *An Air Force Command for R & D, 1949–1976: The History of ARDC/AFSC* (Andrews AFB, MD: Office of History, Headquarters, Air Force Systems Command, 1977), OCLC (3479092); and Donald Ralph Baucom, "Air Force Images of Research and Development and Their Reflections in Organizational Structure and Management Policies," (PhD diss., University of Oklahoma, 1976), ProQuest (7624356).

114. On the reception and circulation of the report: Gorn, *Harnessing the Genie*, 40–42.

reporting directly to Wright Field instead of Red Bank. The separation was intended to last only until both installations could be consolidated on the site of Griffiss Air Force Base in Rome, New York, but for reasons to be explained later, the planned reunion never took place.[115]

Instead, research into electronic equipment for the purpose of continental defense effectively split between the successor to the Watson Laboratories—an agency called the Rome Air Development Center, or RADC—and an expanded Cambridge Field Station, which became the Air Force Cambridge Research Laboratories (AFCRL). As the Rome lab rapidly assimilated into the Air Force's evolving research-and-development organization, the Cambridge lab, more loosely administered from the start, began to occupy an uncomfortable position between military bureaucrats and their civilian staff, the latter of whom generally retained their sympathies to MIT and its own heir to the Rad Lab lineage: the Research Laboratory in Electronics. AFCRL's focus may have indeed been closer to the lab bench and the testing site than the more audacious plans to which RADC remained a primary party, but by seizing upon digital relay—a critical piece in the air-defense puzzle—it unwittingly offered itself as a useful proxy for the competitive research-and-development program favored by MIT's academic elite.

115. The elemental facts of organizational change are chronologized in Liebowitz, *From the Cambridge Field Station to the Air Force Geophysics Laboratory* and John Q. Smith, *Forty Years of Research and Development at Griffiss Air Force Base, June 1951–June 1991*, RL-TR-92-45 (Griffiss AFB, NY: Rome Laboratory, June 1991), DTIC (ADA250435). These sources are useful mostly for cross-referencing dates with the periods of corresponding official histories.

Chapter 5

“The Maginot Line Boys from MIT”

Air-Defense Automation and the Rise of the Cambridge Lobby

> Behind this carefully worded exchange [between Lloyd Berkner and Vannevar Bush] lies an extraordinarily meaningful story. It is the story of a rebellion of American scientists against the assumption that there is no real defense against nuclear weapons in Soviet hands... For at this point the scientists [participating in MIT summer studies] put the problem of our defense under a microscope. They took the whole problem apart and viewed it anew in the light of the technological advances of which Berkner spoke. When they had put it together again, they had devised, in theory, a new and “enormously more effective” kind of air defense.[1]
>
> Ralph E. Lapp and Stewart Alsop, *Saturday Evening Post*, 1953

Nearly five years after writing “Defense Against the Atomic Bomb,” his brief addendum to *Toward New Horizons*, George E. Valley took up the subject again as the chair of the Air Defense Systems Engineering Committee, or ADSEC. Its final report, signed on October 24, 1950, is a curious document. While the interim report, dated the previous May, displayed evidence of the committee grappling with recondite topics in radio physics and electrical engineering, the object of the final report more closely resembled a philosophy of technology than an application of it.[2] “What follows is a rationalization of various ideas on Air Defense

1. Ralph E. Lapp and Stewart Alsop, “We Can Smash the Red A-Bombers,” *Saturday Evening Post*, March 21, 1953, EBSCO (18941395).

2. Air Force Scientific Advisory Board to the Chief of Staff, United States Air Force, “Progress Report on the Air Defense Systems Engineering Committee,” May 1, 1950, MIT Lincoln Laboratory Archives, digitized copy,

gotten from many sources," began the main body. "A.D.S.E.C. did not, of course, commence its studies by inquiring 'What is a system?' But its thoughts to date shall be collected here as though it had done so, because that makes a suitable frame on which to exhibit its various tentative conclusions."[3]

The authors had apparently tripped over how to interpret its own title, dedicating ten pages of the report's 35 pages to a extended meditation on the semantics of *system*. "The word itself is very general," they mused:

> Webster's gives fifteen different meanings for "system." There are, for instance: the "solar system" and the "nervous system," in which the word pertains to special arrangements of matter; there are also systems of philosophy, systems for winning with horses, and political systems; there are the isolated systems of thermodynamics, the New York Central System and various sociological systems.
>
> The Air Defense System has points in common with many of these different kinds of systems. But it is also a number of a particular category of systems: the category of organisms. This word, still according to Webster, means "a structure composed of distinct parts so constituted that the functioning of the parts and their relation to one another is governed by their relation to the whole." The stress is not only on pattern and arrangement, but on these also as determined by function, an attribute desired in the Air Defense System.[4]

Having decided that its subject was most like an "organic system," ADSEC then proceeded with a discourse on the nature of organisms.

Implicitly, the Valley committee was invoking *organism* as a metaphor for *organization*: "groups of animals, including men," as well as "partly animate organisms which involve animals together with inanimate devices such as is the Air Defense System." All organisms

Internet Archive, https://archive.org/details/ADSECProgressReport1May1950 . Besides Valley, the committee membership included four additional member of the MIT faculty: Charles Stark Draper, H. Guyford Stever, Henry G. Houghton, and William R. Hawthorne; two former Rad Lab engineers: George C. Comstock and Arthur C. Donovan; and John W. Marchetti from AFCRL.

3. "Air Defense System," final report of the Air Defense Systems Engineering Committee, Air Force Scientific Advisory Board, October 24, 1950, MIT Lincoln Laboratory Archives, digitized copy, Internet Archive, https://archive.org/details/ADSECFinalReport24October1950 , 1. The ADSEC report is formative to the narrative received from Redmond and Smith as discussed in the introduction; in its final form: Kent C. Redmond and Thomas M. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge: MIT Press, 2000), 21–29.

4. ADSEC Final Report, Internet Archive, 2–3.

have "the power of development of growth and the possibility of decay and death," and "nearly all organisms can sense not only the outside world, but also their own activities." Moreover, "it is often the case that some of the component parts of a complicated organism are themselves complete organisms." Collectively, they used their common faculties—"sensory components, communication facilities, data analyzing devices, centers of judgement, directors of action, and effectors, or executing agencies"—in order to "interact with and alter the activities of other organisms, generally to achieve some defined purpose."

As one example of an multi-human organism, ostensibly with "no machines at all," ADSEC offered the case of "Caesar's Army":

> Men saw and heard what was going on in battle, they were the sensory organs. Other men ran in relays back to Caesar and told him about it, they were the communication facility. Caesar's staff put all the stories together and filtered out the nonsense, they were the analyzing device. Caesar himself decided what to do or what not do, he was the center of judgement. Caesar's lieutenants gave the orders, they were the directors of action. Finally the orders were executed by the army. Perhaps sometimes Caesar not only judged but also analyzed and directed; but then he had only a small job to do, and much time to do it in.[5]

The authors further claimed that "many contemporary organisms are composed almost entirely of men" but that "a survey of the organisms which men have put together, indicates that the relative magnitudes and degree of mechanization of their functional parts vary greatly according to their purpose, and to the prejudices of their particular creators." More precisely:

> Although there is usually but one center of judgement, such as the board of directors of a company, there can be many different kinds of sensory agents, many different

5. ADSEC Final Report, Internet Archive, 3–4. Organismic descriptions of military operations long predate the formalization of cybernetic theory, particularly with respect to the *Preußen Generalstab* tradition, as in Spenser Wilkinson, *The Brain of an Army: A Popular Account of the German General Staff*, 2nd ed. (1891; London: A. Constable and Co., 1895); see also J. D. Hittle, *The Military Staff: Its History and Development* (Harrisburg: Military Service Publishing, 1944). It is unclear how much the membership of ADSEC committee overlapped with cybernetic circles; none of its members participated in any of the Macy Conferences, but the reference to Shannon below indicates at least some familiarity with their activities. Cf. Ronald R. Kline, *The Cybernetics Moment, or Why We Call Our Age the Information Age* (Baltimore: Johns Hopkins University Press, 2015); David Mindell, Jérôme Segal, and Slava Gerovitch, "From Communications Engineering to Communications Science: Cybernetics and Information Theory in the United States, France, and the Soviet Union," in *Science and Ideology: A Comparative History*, ed. Mark Walker (London: Routledge, 2003), 66–96.

> analyzing agencies, directors and effectors. Nor is there any fixed pattern in which all these functional parts are tied together or communicate with one another.

They then considered the arrangement of "functional components" in the nation's existing air-defense "organism" before offering suggestions for improving it.

According to its own vernacular, ADSEC then criticized the air-defense system's "sensors," "communication," "data analyzers," "directors," and "effectors" as overly dependent on human faculties. "It will be evident that, in analogy with a man, A.D.S.E.C. considers the contemporary Air Defense System to be lame, purblind, and idiot-like. Of these comparatives, idiotic is the strongest. It makes little sense for us to strength the muscles if there is no brain; and given a brain, it needs good eyesight."[6]

In the near future, mechanization promised solutions to flagrant deficiencies in functional components throughout the system, though with respect to its "centers of judgement," the committee uncharacteristically demurred:

> It cannot be said definitely that the required judgements cannot in principle be made speedily and accurately enough by men; however such judgements cannot in fact be made now. The judgements are: should the aircraft be attacked?; from which air base should interceptors be sent and how many? The present Control Centers function more as inspectors than commanders. At the present time it is not clear that they really function at all; consequently it can be question whether there really is an Air Defense System or whether what we have now is a collection of uncoordinated radars and fighter squadrons.[7]

While speculating that "eventually one could do practically all the work of the A.D.C.C. [Air Defense Control Center] by machine according to the chess-playing ideas of Shannon…A.D.S.E.C. does not propose that this idea be tried immediately, however." Instead, they suggested that "in the initial operations of this system and possibly always, these judgements will be formed by men."[8]

6. ADSEC Final Report, Internet Archive, 9–10.

7. ADSEC Final Report, Internet Archive, 15–16.

8. ADSEC Final Report, Internet Archive, 29–30. The invocation of algorithmic chess is a clear reference to Claude E. Shannon, "Programming a Computer for Playing Chess," in *Claude Elwood Shannon: Collected Papers*, ed. N. J. A. Sloane and Aaron D. Wyner (New York: IEEE Press, 1993), 637–656, a paper first presented at the national convention of the Institute of Radio Engineers in March 1949 and published a year later in

In other words, the committee intentionally restricted its ambit to the application of automatic methods to "sensation," "analysis," "direction," and "effectuation" in order to perfect the irreducibly human act of "judgement." Without immediate technological improvement, *command*—the exercise of bureaucratic authority—would soon be rendered irrelevant in the case of a nuclear war.

1 The national-security science labyrinth

Previous scholarship has identified the ADSEC report as a genetic statement in the reinvention of continental air-defense, the point at which the military problems of nuclear warfare became irreversibly linked to the advancement of the digital electronic computer. Indeed, the impression left by the literature is that ADSEC's conclusions led to SAGE via Project CHARLES and Project LINCOLN, which became Lincoln Laboratory, in a natural, lineal descent. It should be remembered, however, that the historiography has relied heavily on accounts of Project Whirlwind, as told by the scientists and engineers who followed the computer from MIT to Lincoln Laboratory and the MITRE Corporation, among other organizations associated with its research, development, and production effort.[9]

Despite of the scope and significance of the air-defense computer to the community that built it, it remained only one constituent in an international effort to construct, operate, and maintain a military aircraft control and warning (AC&W) system across the North American continent. What has been widely overlooked is that the critical years in the history of Project Whirlwind were also the years during which the core of the North America air-surveillance

Philosophical Magazine. Although Shannon's role in the early history of artificial intelligence is beyond the scope of the present discussion, see briefly Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996), 199-205; Jimmy Soni and Rob Goodman, *A Mind at Play: How Claude Shannon Invented the Information Age* (New York: Simon & Schuster, 2017), 210–216.

9. Recall from the introduction the evolution of Thomas M. Smith's contract studies in the 1950s into Kent C. Redmond and Thomas M. Smith, *Project Whirlwind: The History of a Pioneer Computer* (Bedford, MA: Digital Press, 1980) and Redmond and Smith, *From Whirlwind to MITRE*; the special issue of the *Annals in the History of Computing* in 1985; and their subsequent influence on Edwards, *The Closed World*; Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects That Changed the World* (1998; repr., New York: Vintage, 2000); among other secondary sources.

system was actually built. As a previous chapter explained, this project began in earnest late in 1948 before the deterioration of the military situation on the Korean Peninsula prompted further acceleration in the fall of 1950.[10] Continental air-defense already carried its own momentum, and so it would be more precise to say that Whirlwind drafted off the same motion, even going so far as to assimilate the discourse already attached to that system, especially its opportunistic distinctions between "evolutionary" and "revolutionary" technology.

Meanwhile, the circumstances surrounding the creation of ADSEC have never been interrogated from the perspective of the Air Force's vast and complex administration. Although the narrative is simple when framed as an expertly formulated solution to a self-evident problem, it is much more difficult to situate ADSEC within the workings of a large organization. The committee existed, for the brief time that it did, essentially to circumvent the vagaries of a military bureaucracy that appeared certainly obtuse, and perhaps even inscrutable, to the civilians charged with monitoring, directing, and cultivating it.

Viewed in this light, the peculiarities of its final report are more readily appreciated. Valley's task was not "systems engineering" so much as fact-finding, rationalizing, and justifying, logically and politically, one particular synthesis with which he was confronted: the application of digital electronics to the problem of continental air-defense. Nevertheless, questions of how it should fit into the larger program was an issue that would not begin to be settled until 1955; it was unclear whether the project would fit at all even as late as mid-1953.[11]

10. As a brief gesture toward the greater diplomatic and military history of the Korean conflict, Bruce Cumings, *The Korean War: A History* (New York: Modern Library, 2010) is a concise but wide-ranging account by one of the longest studied scholars of the topics. The armed forces have produced their own histories as well, which are useful insofar as they reveal the concerns most salient to the military: Robert Frank Futrell, *The United States Air Force in Korea, 1950–1953*, rev. ed. (1961; Washington: Office of Air Force History, 1983) is the Air Force's own organizational study, which shows numerous signs of its development from a manuscript first circulated internally in 1953.

11. The narrative presented in Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington: Air Force History and Museums Program, 2002), 144-164 pushes the SAGE program beyond 1953 and into the mid-to-late fifties, a period either elided or ignored by the rest of the literature, which is curious, considering that even the title, "SAGE," dates to 1955. Rebecca Slayton, *Arguments That Count:*

The purpose and conviction with which the Whirlwind community told its story evolved into a teleological conflation of the computer with the entirety of the system itself, reducing all other components, both technological and organizational, to the machine's inputs and outputs. The political weight behind ADSEC did indeed push the Air Force toward the outcome that eventually became known as SAGE, and yet it was likewise appropriated into other developments with similar motivation but no genealogical relationship to the events in Cambridge.

As the first section shows, by 1949, the problem of continental air-defense had become the primary battleground for a political proxy-war concerning the future of technology management within the United States government. Though certain correlations prevail, the lines cannot be drawn simply between civilians and military officers, private citizens and public officials, or academics and industrialists. Neither were each faction's motives so definitely located on the poles between professional or individual self-interest and genuine public-mindedness. Indeed, it is the very nature of "military-industrial complex" to confuse, combine, and reconfigure all of these: rather than monolithic, its institutions are fluid, its alliances coalescent, its interests both convenient and convergent. For all its moral poignancy, this is not a normative world but a purely existential domain where the distinction between *is* and *ought* disappears into the gap between rational bureaucracy—the impossible ideal—and the necessary drive to achieve it.[12]

Physics, Computing, and Missile Defense, 1949–2012 (Cambridge: MIT Press, 2013), 28–39 is an exception to this, though its scope is confined mostly to the computer-programming effort. Redmond and Smith, *From Whirlwind to MITRE* also forges ahead, but as the final articulation of a manuscript originally concerned with the years from 1945 to 1950, the post-1953 period is relatively less developed.

12. On the institutional fluidity of academia, industry, and government during the Cold War, and earlier, consider Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008) in addition to the relevant passages in Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge: Harvard University Press, 1995); Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993). Sarah Bridger, *Scientists at War: The Ethics of Cold War Weapons Research* (Cambridge: Harvard University Press, 2015) also advances an interesting argument about the intergenerational dynamics of Cold War science as they figured in relationships between institutional stakeholders; see also Zuoyue Wang, *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America* (New Brunswick: Rutgers University Press, 2008); Gregg Herken, *Cardinal Choices: Presidential Science Advising From the Atomic Bomb to SDI*, rev. ed. (Stanford: Stanford University Press, 2000); Gregg Herken, *Counsels of War*, rev. ed. (Oxford:

The root of the conflict lay in the dismantlement of the wartime emergency-state and subsequent political hand-wringing over the structure with which the federal government would cultivate, guide, and usurp the course of scientific research and industrial production in the postwar United States.[13] As is often the case with public administration, the dispute can be reduced to one concerning the allocation of resources—dollars, in the baldest possible terms. However, as is also often the case with public administration, a fight over dollars sublimated into a more rarefied deliberation about structures and systems for dispensing those dollars fairly, reasonably, and efficiently, or, in short, about organization.[14] In its pursuit of victory by almost every possible method, the war state had committed resources in such vast quantities that these questions never took on the agonistic, virtually zero-sum quality that has characterized them ever since.

By Fiscal Year 1950, however, the federal government had served itself and its clients to five consecutive budgets of relative austerity while still deferring a decision on how best to promote science and technology in the public interest, which, at the time, overwhelmingly implied its interest in national security. Whether causally or by some resounding consonance—and it is almost certainly impossible to say which—the ascendancy of continental defense coincided almost perfectly with a crest of dissatisfaction concerning the future of science and technology in the service of the state.

With the "rational" foundation of the National Security Act too porous to bear the load, the United States Air Force rushed to fill the holes in the legislation, most notably, its flawed

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Oxford University Press, 1987).

13. The classic monograph here is David M. Hart, *Forged Consensus: Science, Technology, and Economic Policy in the United States, 1921–1953* (Princeton: Princeton University Press, 1998); portions of Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War* (Chapel Hill: University of North Carolina Press, 1999) are also relevant.

14. Although there have been a staggering number of organization studies concerning the budget process in various forms of administration, respecting an entire constellation of methodological commitments, Elias Huzar, *The Purse and the Sword: Control of the Army by Congress Through Military Appropriations, 1933–1950* (Ithaca: Cornell University Press, 1950) and Frederick C. Mosher, *Program Budgeting: Theory and Practice, With Particular Reference to the U.S. Department of the Army* (Chicago: Public Administration Service, 1954) are still useful as reflections of the concerns of the era of American national-security politics in which they were written.

construction of the Research and Development Board. The second section mainly concerns the Air Force's restructuring of its own R&D organization, which, though not exclusively motivated by air defense, likewise exploited the issue as a convenient playing field for a contest between competing bureaucratic forces.

In fact, as a consequence of the events explored in the preceding chapter, air defense provided an especially advantageous lever with which to move the Air Force's military leadership, owing to the unique relationship between the service and experts in radio electronics, formerly of Division 14, and still concentrated near MIT and the adjoining Cambridge Research Laboratories. The irony was not lost on some that the only branch of the United States military entirely dedicated to flight would hand the keys to its science-and-technology administration over to electrical, rather than aeronautical, engineers. Nevertheless, a formative "Cambridge lobby" positioned itself to do just that—to secure preferences for the organizational descendants of Division 14, who specialized in the research of ground electronics of singular importance to the growing continental-defense net.

This network was no longer confined to the pages of discarded planning documents. By December 1950, the first 24 stations in the so-called "permanent system" had achieved beneficial occupancy, with another 58 under construction and contracting scheduled on the final 15. More than 11,000 troops had already been assigned to them.[15] Furthermore, the Air Defense Command had been reinstated in , once again promoting the continental-defense mission within the Air Force field organization to the level of a "major command." Officials responsible for ADC's ground-electronics program, however, could not easily penetrate the irregular, and frankly quite insular, channel between Washington and Cambridge, preferring

15. More precisely, construction at 24 sites had advanced to the stage where the Air Force could begin installing equipment and training personnel, though no station had as yet entered operation. Altogether, 75 direction centers were to be built in the continental United States, plus an additional 10 control centers; the remaining 12 sites were scheduled for deployment in Alaska. Memo, "Progress of Permanent Radar Net," Lt. Col. Charles E. Fulton, Executive, Program Standards and Cost Control, Office of the Deputy Chief of Staff, Comptroller, Headquarters, United States Air Force, December 26, 1950, exhibit 393 in Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol. 4, Supporting Documents 214–393 (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474354).

instead to work with Watson Laboratories and, its successor, the Rome Air Development Center. But whereas the Cambridge lab most often turned to MIT for contractual support, the Rome lab established ties with Columbia and the University of Michigan.

The surge in military spending that accompanied the outbreak of the Korean War did much to ease the pressure mounting between these two competing pipelines for military-academic, public-private science and engineering.[16] Nevertheless, by 1952, the preconditions for their eventual collision had already been fulfilled. A continent-spanning network of functioning radar-observation stations still required billions of dollars in augmentation and improvement to its message-handling and information-processing capabilities, and efficiency-minded leaders could tolerate only as much apparent duplication as Congress's fickle budget priorities would allow. As the third section illustrates, the Cambridge lobby had already anticipated the conflict and had begun to mobilize even before it escalated, as it did indeed during the draw-down from Korea in 1953.

Although this chapter begins to enter territory generally familiar from other sources, here, its framing breaks from prior narratives. As a result of the aforementioned reliance on the Cambridge lobby's acts of self-interpretation, these narratives exhibit a topical uniformity uncharacteristic of their wild differences in tone, which range from laudatory to derogatory.[17] Some elements of the presentation, which include excursions into logistics, organizational behavior, and radar theory, among others, do not readily lend themselves to

16. Congress was in the process of authorizing about $13 billion in military spending for Fiscal Year 1951—the same sum it had approved during the previous cycle—just as hostilities began. A series of four supplemental appropriations quickly boosted the total to $48 billion, followed by a $60 billion package for Fiscal Year 1952. Overall, this represented a nearly five-fold increase in military spending over the austerity budgets recorded during 1946–1950. Doris M. Condit, *The Test of War, 1950–1953*, vol. 2 of *History of the Office of the Secretary of Defense*, ed. Alfred L. Goldberg (Washington: Historical Office, Office of the Secretary of Defense, 1988), chaps. 12–13.

17. Most sources previously discussed share a discernible fondness, or at least respect, for progressive management, and vary mainly by the degree to which they critique the prevailing political context, to the extent they do so at all. B. Bruce–Briggs., *The Shield of Faith: A Chronicle of Strategic Defense From Zeppelins to Star Wars* (New York: Simon & Schuster, 1988) is one commonly cited work which defies this characterization due to its acerbic, right-leaning skepticism of technocrats and New Deal politics alike. Since its methods were journalistic, however, and its concern primarily with ballistic-missile defense, its relevance here is rather limited.

neat synopsis, because they evoke a mood not of order, but of "normative chaos."[18]

And it is this message, even more than the ones communicated explicitly, that represents the thoughline of this chapter, and indeed, this dissertation. The continental defense program was an object too big, too complicated, too enmeshed in discordant and contrary bureaucratic processes, to be truly apprehended by anyone, regardless of how much effort the Air Force expended in trying to do so. To suppose that we could see further or clearer through our historical reconstructions would betray an intellectual arrogance as profound as the participants'. Rather, the advantage of retrospection in this case is the possibility of self-awareness, the acknowledgment and acceptance of our epistemic limitations, an attitude that, if it had been more common among the actors themselves, might have led toward outcomes entirely different, and perhaps more benign, from the ones expounded in the pages that follow.[19]

2 Air defense as bureaucratic proxy war

The decade following World War II marked the peak of interservice rivalry between the independent branches of the United States military. Some of the most important causal factors include the contested restructuring under the National Security Act, overextension of American military force as the nation rapidly expanded its stature as a global superpower, and the stagnation of federal spending as domestic politics recoiled from the era of New

18. This is a direct allusion to the concept of "normative uncertainty" in industrial research, as expounded in Shapin, *The Scientific Life*, chap. 5. The notion derives from an attitude promoted—at least in the literature—by prominent industrial managers, who claimed that decisions about research are inherently ambiguous, and therefore, should be optimized rather than pathologized.

19. This is a theme central to James G. March, *The Ambiguities of Experience* (Ithaca: Cornell University Press, 2010); and indeed, the author's entire mid-to-late career. As with Shapin's "normative chaos," described above, it also resonates with the well-known argument of Charles Perrow, *Normal Accidents: Living With High-Risk Technologies* (New York: Basic Books, 1984), which decried the dangers of indulging in professionalized "risk assessment" at the expense of more inclusive conversations about how much risk a technological society is willing to tolerate. See also Ulrich Beck, *Risk Society: Towards a New Modernity*, trans. Mark Ritter (Newbury Park, CA: Sage, 1992).

Deal reforms.[20] Granted remarkable slack and autonomy, and absent many opportunities for positive intermingling, the departments of the Army, Navy, and Air Force each clawed sharply for any advantage they could seize from their bureaucratic opponents.

Research and development presented an especially profitable domain for investments calculated to grow each service's stature with respect to the others. National-security science had attained considerable prestige, particularly as a result of the Manhattan Project, and unlike raising troops or mobilizing a war-economy, it was relatively inexpensive as well. To be clear, the sums appeared enormous to their recipients, but laboratory activities did not cost the military departments much in comparison to their industrial procurement programs. At the same time, however, even scattered experiments in aerodynamics, rocketry, telecommunication, and electronic control projected an image of a modern, progressive military institution proactively meeting the uncertain future of the nation's defense.[21]

As the agency charged with the primary continental defense mission, then, research into search radar, ground electronics, and information processing, and high-speed, all-weather aircraft very much favored the Air Force. Securing priority for these projects itself opened another front in the confrontation between the three armed forces, one whose importance increased greatly following the observation of the first Soviet atomic test in August 1949. Of course, the Air Force itself could hardly be described as having one mind

20. For background and theory on interservice rivalries, review the notes to the conclusion to chapter 2, as well as Carl H. Builder, *The Masks of War: American Military Styles in Strategy and Analysis,* A RAND Corporation Research Study (Baltimore: Johns Hopkins University Press, 1989) and Peter D. Feaver, *Armed Servants: Agency, Oversight, and Civil-Military Relations* (Cambridge: Harvard University Press, 2003). On the backlash against the administrative state, see Alan Brinkley, *The End of Reform: New Deal Liberalism in Recession and War* (New York: Knopf, 1995); also Ellen Schrecker, *Many Are the Crimes: McCarthyism in America* (Boston: Little, Brown, 1998).

21. To attempt to balance somewhat the emphasis on studies of the United States Air Force, Richard G. Hewlett and Francis Duncan, *Nuclear Navy, 1946–1962* (Chicago: University of Chicago Press, 1974) examines one important aspect of the United States Navy's pursuit of technological legitimacy in the postwar era. While scattered information also exists concerning similar programs and institutions of the United States Army, such as the advancement of rocketry at White Sands and the Redstone Arsenal, and the development of digital computers at the Ballistic Research Laboratories, a concise monographic account remains to be written. For a sense of the scale of the nation's production base compared to the military's research activities, however, see Philip Shiman, *Forging the Sword: Defense Production During the Cold War,* USACERL Special Report 97/77 (Champaign, IL: US Army Construction Engineering Research Laboratory, July 1997).

with respect to its ramified research agenda, but the weak central administration provided by the National Security Act lacked the means to prevent duplicative or contradictory programs either within or among the armed services, to say nothing of encouraging cooperation on problems, such as continental defense, that would have greatly benefited from a combined effort.

Automatic control: Precedents and prior considerations

Although the ADSEC report offered a number of general recommendations regarding radar and other electronic equipment, as well as aircraft and guided missiles, it specifically connected the digital radar-relay (DRR) program at the Air Force Cambridge Research Laboratories with the digital electronic computer; or rather, one in particular: the machine called "Whirlwind," then being assembled in Jay Forrester's lab at MIT, just a few blocks from AFCRL.[22] Apart from its specificities, however, the conclusion was not new. In January 1948, the Air Communications Group at USAF headquarters acknowledged, after consulting with service laboratories, that "the delay introduced into air surveillance and control systems by human operators is well known," such that "there is serious doubt that successful interceptions of modern high speed attacking airborne objects can ever be made by other than fully automatic means."[23]

Consequently, Colonel Wendell W. Bowman, the deputy chief of the communications office, recommended that "a project should be initiated initiated forthwith to conduct a thorough investigation" of a proposal in which "automatic computing machines…are the

22. The early history of Project Whirlwind is amply covered in Redmond and Smith, *Project Whirlwind* and usefully reconsidered in Atsushi Akera, *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S. Cold War Research* (Cambridge: MIT Press, 2007), chap. 5. Bernd Ulmann, *AN/FSQ-7: The Computer That Shaped the Cold War* (Berlin: De Gruyter Oldenbourg, 2014), 21–67 is more of a technical document than an historical study, but the author's tireless excavation should satisfy the curious.

23. Air Staff Routing and Record Sheet, Col. Wendell W. Bowman, Deputy Chief, Air Communications Group to Electronics and Atmospheric Branch, Directorate of Research and Development, Deputy Chief of Staff, Materiel, "Proposed Fully Automatic Radar Air Defense System," January 16, 1948, exhibit 66 in Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol 2, Supporting Documents 1–109 (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474352).

'heart' of the system." Since the Air Force was already collaborating with the Census Bureau and the National Bureau of Standards on two unrelated computers (UNIVAC and SEAC, respectively), while the Naval Research Laboratory had similar projects as well, Bowman suggested "the establishment of a joint research program...in fields where all the services and some civilian agencies are interested." Ultimately, he believed the Standards Bureau would serve the Air Force best as the federal government's lead agent for digital computer development.[24]

Recently, Air Force headquarters had been deploying similar arguments *against* the immediate build-up of a large ground-based air-defense network. If existing methods and equipment had already been rendered obsolete—the logic went—and new ones could not be expected for another five-to-ten years, then it would be counterproductive in the near-term to divert funding from the cultivation of offensive weapons. The Air Communications Office had hewed the same angle for years, but its thinking had begun to change.[25] In response to a statement from Wright Field, which claimed that "computer techniques required for an automatic air defense system can be developed more readily than some of the other components," Colonel A. T. Wilson, Chief of Electronic Systems, cautioned that "literature in this field seems to indicate the reverse." Nevertheless, he further promoted Bowman's suggestion that "an investigation of the computer problem should be begun immediately, concurrently with the other systems and components studies, and we recommend the Bureau of Standards as the most qualified laboratory for undertaking these studies."[26]

24. The Air Force's stake in these programs is briefly characterized in the conclusion to chapter 3. Further information on in-house and contracted computer development at the Census and Standards bureaus can be found in Arthur L. Norberg, *Computers and Commerce: A Study of Technology and Management at the Eckert–Mauchly Computer Company, Engineering Research Associates, and Remington Rand, 1946–1957* (Cambridge: MIT Press, 2005) and United States Department of Commerce, *Computer Development (SEAC and DYSEAC) at the National Bureau of Standards*, NBS Circular 551 (Washington: GPO, January 25, 1955).

25. Recall the position of F. L. Ankenbrandt, the Air Communications Officer, in the deliberations that culminated with Plan SUPREMACY in 1947.

26. Air Staff Routing and Record Sheet, Col. A. T. Wilson, Jr., Chief, Electronic Systems Division, Directorate of Communications to Electronics and Atmospheric Branch, Directorate of Research and Development, Deputy Chief of Staff, Materiel, "Proposed Fully Automatic Radar Air Defense System," March 16, 1948, exhibit 81 in Bagwell and Miller, *Case History of the AC&W System*, vol. 2, Supporting Documents 1–109, AFHRA.

According to the same correspondence, Wilson's office thought the air-defense problem required the application of not one kind of computer but two, "one basically new and the other an extension of known fire direction type computers." The latter, for controlling interceptors in flight, would incorporate the same electromechanical circuitry as an antiaircraft-gun director, since the trigonometry of air-to-air interception is basically identical to that of indirect artillery fire.[27] On the other hand, a digital computer for tracking and plotting radar data remained a significant challenge, albeit a surmountable one, presuming all parties could agree on exactly what they needed. "In view of the importance and complexity of automatic GCI systems development," Wilson reiterated, "it appears that a steering committee…would be most useful. The difference of opinion…could probably be resolved there to everyone's satisfaction."

Nothing came of the proposal, probably because the procurement planning required for Plan SUPREMACY, and—following its abandonment—the incremental "lash-up" and "permanent" systems, overwhelmed the relatively few officers managing the Air Force's ground-electronics program. Neither did the federal government, the armed forces, or even the USAF itself settle on a single agent, such as the Standards Bureau, to concentrate research and development on digital electronics of common military or civilian interest. In fact, enthusiasm for radically novel solutions appeared to subside as experience with the LASHUP network revealed far more pressing deficiencies in radar coverage, aircraft performance, crew training, and command organization.[28]

In February 1949, Air Force headquarters again expressed interest in an "Automatic Interceptor Director System" that would eliminate "the delays and inaccuracies inherent in the human computation of interception courses," such as the analogue fire-control-like

27. For instance, Paul P. Hanson, *Military Applications of Mathematics* (New York: McGraw–Hill, 1944), a text commonly used in late high-school to early-college military education, developed both topics in consequent chapters.

28. On the field management of these programs: Thomas A. Sturm et al., *The Air Defense of the United States: A Study of the Work of the Air Defense Command and Its Predecessors Through June 1951* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, February 1952), 75–115, OCLC (818296057).

device suggested a year earlier. However, it considered a digital "Automatic Controller Computer" to be "the least urgent" development with respect to air defense, surpassed by radar modernization, all-weather aircraft, and IFF beacons, "although it is an absolute must in guided missile operations when the delay introduced by human controllers can no longer be tolerated." But since aircraft remained the primary threat for the foreseeable future, the Air Staff could only recommend that "this program should be undertaken on a study basis immediately with development leading to a prototype completed in about 4 years."[29]

In the field, one commander questioned whether "air defense must be automatic any more so than other military operations," asserting, rather ambiguously, that "the only portions of the systems which should be permitted to become automatic are the individual highly technical pieces of equipment with which the system operates."[30] In context, the remarks speak more to a preoccupation with immediate operational problems weighed against the improbability of a concentrated air-attack against the continental United States, at least in the near term. Air-defense commanders as yet remained too conscious of their own state of disorganization to express great enthusiasm for radically new technologies that might confuse it even further.[31] "At this time it appears that our concepts will change very little before 1955 or 1956," Lieutenant Colonel Edwin F. Carey, a planner at Air Defense Command headquarters, told the class at the Air Command and Staff School in March 1949. "Beyond that period," however, "we are not prepared to state categorically that things will

29. Maj. Gen. E. M. Powers, Assistant Deputy Chief of Staff, Materiel to Commanding General, Air Materiel Command, "Development Program for Air Defense Ground Electronic Systems and Equipment," February 8, 1949, exhibit 145 in Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol. 3, Supporting Documents 110–213 (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474353).

30. Brig. Gen. Hugo P. Rush, Commander, Western Air Defense Force, December 20, 1949, second endorsement in Col. Joseph A. Bulger, Inspector General, Second Region to the Inspector General, United States Air Force, "Special Report of Observation on Exercise 'Drummer Boy' (Former Title 'Overgreasy')," December 2, 1949, exhibit in Thomas A. Sturm, *History of the Continental Air Command, 1 December 1948–31 December 1949*, vol. 3, pt. 2, Operations and Training (Mitchel AFB, NY: Directorate of Historical Services, Headquarters, Continental Air Command, n.d. [1950?]), AFHRA (0198810).

31. Sturm et al., *The Air Defense of the United States*, 407–435 gives a sense of the compromise between the stability of inferior yet familiar equipment and the potential disruptiveness of adapting to superior replacements; it also demonstrates a tempered enthusiasm for more radical change.

remains as we now see them. Obviously we will at that time begin our transition into what so many people have called the 'push button era.'"[32] In other words, ADC did perceive drastic change as inevitable, just not especially relevant to a war of piloted aircraft.

Once the threat of guided missiles became real, though, "our system must be moved outward in time and space":

> The technical portion of the system itself will be composed of automatic devices. Our present radar equipments are capable of being modified and moved forward at early warning radars or acquisition radars for guided missiles [*sic*]. The interceptor aircraft will also be almost completely automatic. The interception itself will be accomplished by mechanical means and will probably employ surface-to-air guided missiles.

Carey claimed before his audience that this future was not a "pipe-smoker's dream" because "we have today the capability of completely automatic flight" as well as "computing and directing equipments which are capable of solving any problem and directing machinery," so that "no great technical discoveries are necessary…it is only a matter of assembling all the necessary components which now exist." The statement may have been true in the most general sense, but it elided the many as-yet unrealized difficulties of the "assembly" phase.[33]

Reaction to the Soviet atomic bomb

Counterintuitively, ADC–ConAC's plans and operations changed relatively little in direct response to the news of the Soviet Union's successful test of an atomic weapon on August 29, 1949. On the ground, the Air Force's continental-defense program had essentially persisted

32. Lt. Col. Edwin F. Carey, transcript of address to the the Air Command and Staff College, Maxwell AFB, AL, March 25, 1949, excerpted in Denys Volan, *The Development of an Air Defense System in Being*, vol. 3 of *History of the Continental Air Command for 1 January–30 June 1950* (Mitchel AFB, NY: Directorate of Historical Services, Headquarters, Continental Air Command, n.d. [1950?]), AFHRA (0198819), 69.

33. In addition to primitive gyroscopic autopilots commonly equipped by both piloted and drone aircraft since the 1930s, it is probable that Carey had in mind various active projects for radio-guided or radio-assisted autonomous control. For instance, by mid-1946, Watson Laboratories had at some phase of design, construction, or testing several aircraft-control sets that could follow directions remotely, as well as respond programatically to signals from beacons, whether fixed or carried aboard another aircraft (or more than one, in the case of hyperbolic navigation). While the experiment was intended ultimately for long-range missile guidance, a network of gun-laying radars installed at the White Sands Proving Ground was already being used to steer unpiloted drones with microwave beams. *Watson Laboratories Quarterly Historical Report for 1 April–30 June 1946* (Red Bank, NJ: Watson Laboratories, Air Materiel Command, n.d. [1946?]), AFHRA (0143986), 66–72.

through a continuous mobilization crisis ever since Hanford emergency in March–April 1948 and lacked the organizational surplus to augment what it was already straining to accomplish anyway. In Washington, however, President Truman's announcement provoked responses ranging from anxiousness and surprise, in the low register, to political histrionics bordering on the apocalyptic.[34]

From its headquarters in the Pentagon, the Air Staff regularly injected official channels with heavy doses of air-defense alarmism, beginning with JCS 2048, a November 16 memorandum to the Joint Chiefs from General Hoyt S. Vandenberg, the Air Force's Chief of Staff.[35] "For the foreseeable future," Vandenberg acknowledged, "intercontinental bombing with TNT presents no grave threat to the maintenance of our war-making capacity, much less to the survival of our country"—despite the fact that his predecessor had previously declared an air-defense emergency on precisely the same pretext. "This is not true, however, of a one-blow atomic offensive against our major cities and our retaliatory forces with an adequate number of A-bombs."[36]

Since Joe I was only the first atomic explosion to have been positively detected, Vandenberg raised the possibility that the Soviet Union might have begun stockpiling atomic

34. David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939–1956* (New Haven: Yale University Press, 1994) is the standard reference on the Soviet atomic-bomb program, though Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1995) also covers similar ground while covering the path to thermonuclear weapons. Michael D. Gordin, *Red Cloud at Dawn: Truman, Stalin, and the End of the Atomic Monopoly* (New York: Farrar, Straus, and Giroux, 2009) discusses American efforts to detect the first Russian atomic test and the administration's reaction to it.

35. Kenneth W. Condit, *The Joint Chiefs of Staff and National Policy, 1947–1949*, vol. 2 of *The History of the Joint Chiefs of Staff* (Washington: Historical Division, Joint Chiefs of Staff, 1996), chap. 15 offers a fuller account of the military-political response to the first Soviet atomic test. Absent from the official account, however, is an explanation of the pathologies of the American military-political system at the time; while a contemporary, monographic critique remains to be written, Lawrence J. Korb, *The Joint Chiefs of Staff: The First Twenty-Five Years* (Bloomington: Indiana University Press, 1976) and Paul Y. Hammond, *Organizing for Defense: The American Military Establishment in the Twentieth Century* (Princeton: Princeton University Press, 1961) supply some of the institutional context. Steven L. Rearden, *Council of War: A History of the Joint Chiefs of Staff, 1942–1991* (Washington: National Defense University Press, 2012) is more recent, though as an official chronicle, its outstanding contribution is bibliographic.

36. JCS 2084, "Air Defense of the United States," memorandum by the Chief of Staff, U.S. Air Force for the Joint Chiefs of Staff, November 16, 1949, in Randolph Boehm and Paul Kesaris, eds., *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States* (Washington: University Publications of America, 1980), microfilm, reel 2, 2–3, OCLC (7108262).

weapons as early 1947, when the Russian government had first boasted about a successful test. Because the first two world wars had demonstrated that the United States and its allies would eventually win a conventional war waged on the European continent, "nothing could be more logical than for the Soviet leaders to draw upon their great store of information concerning the vulnerability of the United States and calculate the number of atomic bombs required to reduce the United States to chaos and military impotence in one blow. In my opinion, such a calculation would establish a finite number of bombs which the USSR can be expected to attain very soon now, quite possibly within the next five years. On the basis of these possibilities we have very little time." To argue around the USSR's lack of forward airfields or sufficiently long-ranged bombers, Vandenberg again invoked the menace of a hypothetical one-way attack by "an unscrupulous aggressor" who "might consider it immaterial whether the attacking aircraft returned home, since their re-use need not be contemplated."

Here it is difficult to separate political opportunism from a professional assessment of the military threat. Atomic peril certainly served the interests of the Department of the Air Force, whose leaders still felt the need to justify the existence of their organization, since air-power theory, as expressed through strategic-bombing doctrine, had failed to deliver a swift and incontrovertible victory in World War II.[37] Their preference for offensive forces notwithstanding, they nonetheless perceived continental air-defense as an effective means

37. Initially, AAF leaders tried to downplay the significance of the atomic bomb, since, as the product of Army management, they feared it might detract from their share of the credit for victory in the Pacific: Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force*, vol. 1 of (1971; repr., Maxwell AFB, AL: Air University Press, 1989), 83–90; Carl H. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force* (1994; repr., London: Routledge, 2017), 105–110. On the strategic bombing of Japan, see Gian P. Gentile, *How Effective Is Strategic Bombing? Lessons Learned From World War II to Kosovo* (New York: New York University Press, 2001), which, in addition to Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914–1945* (Princeton: Princeton University Press, 2002) and the classic Michael S. Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven: Yale University Press, 1987), seek to critique, or at least complicate, more orthodox interpretations, such as David MacIsaac, *Strategic Bombing in World War II: The Story of the United States Strategic Bombing Survey* (New York: Garland, 1976), or the officially sanctioned Wesley Frank Craven and James Lea Cate, eds., *The Pacific: Matterhorn to Nagasaki, January 1944 to August 1945*, vol. 5 of *The Army Air Forces in World War II* (1953; repr., Washington: Office of Air Force History, 1983).

to promote air-power as a public issue, increasing pressure on elected officials to support their programs. Moreover, the fiscal policy of the late-forties had essentially resulted in a series of budgetary stalemates between the three armed forces—and an especially caustic acrimony between the Air Force and the Navy—with no one service's agenda attaining supremacy over the others.[38]

Thus, in a subsequent memo, Admiral Forrest P. Sherman, Chief of Naval Operations, gladly redeployed some of Vandenberg's own arguments against him. While expressing his "support [for] the Chief of Staff, U.S. Air Force in carrying out his assigned responsibility for the air defense of the United States which has become more grave because of the probable Soviet possession of atomic bombs," Sherman noted that "the situation is not entirely new" because "it has been in prospect since Hiroshima." Instead, "the situation requires thorough analytical consideration of the air defense problem, because it would be possible to expend almost unlimited sums of money unless careful balance is preserved."

The admiral's response objected to certain unilateral actions that Vandenberg had declared on November 19 and called rather for a two-phase, tri-service program that would separate "the immediate problem of doing the best we can with what we have" from "the longer range problem of optimum air defense." Since "it is axiomatic that one hundred percent protection from determined air attack...cannot reasonably be expected," Sherman wrote that "a carefully calculated risk must be accepted," lest "the amount of effort devoted to air defense rises so sharply as to rapidly encounter the law of diminishing returns."[39] The sparring continued throughout the Joint Staff organization; the following April, for instance,

38. Recall preceding references to Michael J. Hogan, *A Cross of Iron: Harry S. Truman and the Origins of the National Security State, 1945–1954* (Cambridge University Press: Cambridge, 1998); Keith D. McFarland and David L. Roll, *Louis Johnson and the Arming of America: The Roosevelt and Truman Years* (Bloomington: Indiana University Press, 2005); and Steven L. Rearden, *The Formative Years, 1947–1950*, vol. 1 of *History of the Office of the Secretary of Defense*, ed. Alfred L. Goldberg (Washington: Historical Office, Office of the Secretary of Defense, 1984); or, for finely grained insight: Walter Millis and E. S. Duffield, eds., *The Forrestal Diaries* (New York: Viking, 1951).

39. JCS 2084/1, "Air Defense of the United States," memorandum by the Chief of Naval Operations for the Joint Chiefs of Staff, November 30, 1949, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 9–10.

the Joint Intelligence Committee failed to reach a consensus on Soviet bombing capabilities because the Navy rejected the Air Force's stubborn insistence on always evaluating the worst possible cases.[40]

Still, even as yet positioned on the remotest edge of conceivability, JCS 2048 warned against a scenario that could kill more than just American citizens, whose deaths it merely implied. Now, atomic weapons had now placed the survival of the American state *itself* in jeopardy:

> It is easy to imagine a situation that would exist if only Washington, D.C., the center of Government, and New York City, the financial center of our country, were simultaneously destroyed. If to this should be added the destruction of, say, some fifty such cities as Pittsburgh, Detroit, Chicago, Philadelphia, St. Louis, San Francisco, Los Angeles...I doubt that the United States would be able to gather itself together to fight for a period of years...Quite conceivably conceivably, civilization as we know it, and the United States as a country, would then cease to exist.[41]

Vandenberg indicated that he would order the Air Staff to conduct a study to dress his dim prognostication with dates and figures.

The findings, presented to the Joint Chiefs in March, projected that the Soviet Union would possess a stockpile of 45–90 atomic weapons by mid-1952, as well as 1,200 Tu-4 Bulls—a bomber reverse-engineered from B-29s forced down over Russian territory during the war—capable of reaching "any important target in the U.S." by "one of a number of means" such refueling in-flight or attacking one-way.[42] Only "fifty bombs on target in the United States

40. JIC 513/2, "USSR Long-Range Bombing Capabilities," memorandum by the Joint Intelligence Committee for the Director, Weapons System Evaluation Group, April 17, 1950 in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2.

41. JCS 2084, "Air Defense of the United States," memorandum by the Chief of Staff, U.S. Air Force for the Joint Chiefs of Staff, November 16, 1949, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 4. The comment is significant in light of its defiance of the dominant paradigm of total war as a competition of national industrial economies. Even the introduction of atomic weapons did not radically alter the widespread belief that World War III would look much like World War II, when an extended mobilization had followed a fast-paced initial confrontation of intermediate scale, and preceded the decisive engagement between mass concentrations of conventional forces. The destruction caused by atomic bombardment would prolong the mobilization phase, but after the contestants had expended their stockpiles, atomic weapons would likely not be seen again until the very end of the conflict, once the capacity to manufacture them had been rebuilt. See Steven T. Ross, *American War Plans, 1945–1950* (New York: Garland, 1988).

42. Evidently, the Tu-4's sudden appearance at the Tushino air show in August 1947 induced paroxysms among

could produce nearly 2 million American casualties" and also "destroy our governmental machinery in Washington and very seriously disrupt our entire communications complex":

> Yet the foregoing is but a small percentage of the damage that could be inflicted by 50 bombs on target for, in addition, these bombs could destroy a large percentage of the industrial capacity required to put arms into the hands of the U.S. Armed Forces after they are mobilized. If selectively placed, 50 bombs could simultaneously destroy 70% of U.S. industry designated in our mobilization plan to produce tanks, artillery and small arms. They could completely destroy our atomic energy industry, 30% of our special steel forgings industry and 85% of facilities to produce marine boilers. Sea communications will determine whether we can sustain allies overseas, and deploy and maintain our own forces overseas. A-bomb attacks on our major ports, the Navy's mothball fleet and major Navy yards could conceivably deny us this ability.[43]

Or, "in short, 50 bombs on target might make it impossible for the United States ever to mobilize and fight back."

The authors expressed no doubt "that the Soviets have sufficient intelligence of U.S. industry to enable them to select these targets," whose locations must already be known "down to seconds of latitude and longitude." Rather, in their estimation, the "available intelligence indicates the Soviets will have the capability for such an attack against the United States by 1 July 1952. Henceforth, this date is treated as critical. It is the time by which we *must have* an effective, operational air defense system in being." The balance of the Air Staff report points up the dearth of feasible options, given that the self-imposed deadline was barely two years away. In the near term, it could suggest little more than dispersing interceptor squadrons, prodding the Canadian government to accelerate its own air-defense initiative under American auspices, and supplementing the so-called "permanent system," which was already under construction, with a few more stations positioned near SAC bases

American military analysts, from which they never fully recovered. Despite the fact that the Bull was a rivet-for-rivet copy of the B-29—which first flew in 1942—intelligence agencies continued to presume that Russia's long-range bombing fleet must be on the verge of surpassing of the USAF's in both size and technological sophistication. John Prados, *The Soviet Estimate: U.S. Intelligence Analysis and Soviet Strategic Forces* (1982; repr., Princeton: Princeton University Press, 1986), 39–41.

43. "Attainment and Maintenance of an Operational Air Defense System in the Continental United States and Alaska," USAF presentation to the Joint Chiefs of Staff, enclosure to JCS 2084/3, "Air Defense of the United States and Alaska," March 2, 1950, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 3, all emphasis in original.

in order to protect the nation's retaliatory force.

Likely already aware of what the March report would say, Vandenberg exclaimed, in JCS 2048, that "this is not enough":

> I feel that this matter is so urgent and so vital to the security of the nation for the foreseeable future that I would be remiss in my duty as responsible executive agent for the air defense of the United States if I did not call this situation forcibly to the attention of the Joint Chiefs of Staff. I recommend strongly that drastic action be taken jointly to reduce this peril.

The list of such "drastic actions" included a recommendation that "the Joint Strategic Survey Committee, in collaboration with the Research and Development Board, determine the best method for setting up a project *with the emphasis and priority of the Manhattan Project* to improve the technological capabilities of air defense" as well as "to determine the minimum acceptable air defense system for the United States and Alaska under present technological limitations."[44]

The Joint Chiefs achieved consensus on only the final point. When they forwarded his memo to Louis A. Johnson, Secretary of Defense, they also attached a brief note affirming that they had indeed directed the Joint Strategic Survey Committee "to undertake a study to determine how best to set up a project with the urgency of the Manhattan Project," because "the level of technological development in the field of air defense is insufficient to permit adequate air defense of the United States, either now or in the future." They likewise requested that Johnson similarly instruct "the Research and Development Board to collaborate...in this study."[45]

The Air Staff agreed that "in the Research and Development Board we have an established, joint agency which has suitable personnel or knowledge of suitable personnel, to initiate the required work. Therefore, we believe an ad hoc committee of the Research

44. JCS 2084, "Air Defense of the United States," memorandum by the Chief of Staff, U.S. Air Force for the Joint Chiefs of Staff, November 16, 1949, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 6 (emphasis mine).

45. Memorandum for the Secretary of Defense, enclosure to JCS 2084, "Air Defense of the United States," memorandum by the Chief of Staff, U.S. Air Force for the Joint Chiefs of Staff, November 16, 1949, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 8.

and Development Board, already conversant with our present air defense and the planned development of this system, would best be fitted to recommend the future scope and pattern of air defense research and development."[46] After the air-intelligence briefing on March 2, the JCS again resolved to "request the Research and Development Board, as a matter of priority...determine and advise the Joint Chiefs of Staff on all new actions possible to improve the technology of air defense."[47]

By comparison, the response, received on April 3, struck a markedly subdued tone. While noting that "the Weapons Systems Evaluation Group...has recently started an over-all operational evaluation of air defense," R. F. Rinehart, the RDB's executive secretary, coolly stated that "most of the effort in research and development in air defense will of necessity continue to be directed primarily toward improving existing equipment and techniques," and that any "increased emphasis accorded the air defense effort as a whole...is more likely to result in earlier availability of end items than in revolutionary developments."[48]

Failure by design: The Research and Development Board

Much to the alarm of its proponents, the Office of Scientific Research and Development had dissolved with no organizational successor in 1946. With the *Endless Frontier*, OSRD's leadership had outlined its consensus proposal for a single, civilian agency that would administer most of the government's resources dedicated to science, medicine, and engineering, for

46. "Attainment and Maintenance of an Operational Air Defense System in the Continental United States and Alaska," USAF presentation to the Joint Chiefs of Staff, enclosure to JCS 2084/3, "Air Defense of the United States and Alaska," March 2, 1950, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 3.

47. Memorandum for the Chairman, Research and Development Board, "Attainment and Maintenance of an Operational Air Defense System System in the Continental United States and Alaska," enclosure to JCS 2084/5, "Acceleration of Research and Development for Effective Air Defense Means," memorandum by the Chief of Staff, U.S. Air Force for the Joint Chiefs of Staff, March 6, 1950, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 16.

48. R. F. Rinehart, Executive Secretary, Research and Development Board, memorandum for the Joint Chiefs of Staff, enclosure to JCS 2084/7, "Attainment and Maintenance of an Operational Air Defense System System in the Continental United States and Alaska," April 5, 1950, in Boehm and Kesaris, *Records of the Joint Chiefs of Staff, Part II: 1946–1953—The United States*, reel 2, 19.

both military and nonmilitary purposes. While leading eventually to the establishment of the National Science Foundation in 1950, the outcome only dimly reflected the ambitions of its chief advocate, Vannevar Bush, along with the senior generation of OSRD/NDRC elites, such as Karl T. Compton, James B. Conant, and Frank B. Jewett.[49]

As Congress punted on the issue, control over the vast majority of "government science" returned to the armed forces essentially by default. Uncertainty and disputation persisted within each service as to the distribution of resources between in-house laboratories and academic–industrial contractors, but the Department of the Navy became the first to capitalize on the void left by OSRD with the creation of the Office of Naval Research in October 1946. Through ONR, the Navy took up the active management of private contracts to further its scientific interests on a scale never before attempted in peacetime.[50]

Likewise, the Army and the Air Force also turned increasingly to outside contracting to remobilize some of the sources of extra-governmental research that had disbanded after the war. On February 19, 1948, President Truman signed the Armed Services Procurement Act, one of the most significant and unappreciated legislative movements of the postwar period, which granted the secretary of each of the armed forces—and, by extension, its military bureaucracy—broad discretionary powers to contract with private parties for the research and development of speculative, high-risk technologies of even the most tenuous relevance to national security.[51]

Although the power to contract for research devolved to the military departments, the

49. Some brief background appears in the front matter to the NSF's "anniversary edition," published as Vannevar Bush, *Science, the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (1945; repr., Washington: National Science Foundation, 1960); otherwise, see the note at the beginning of this chapter referencing Hart, *Forged Consensus*, among others.

50. Cf. Harvey M. Sapolsky, *Science and the Navy: The History of the Office of Naval Research* (Princeton: Princeton University Press, 1990). Also of interest is Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A&M University Press, 2001).

51. James F. Nagle, *A History of Government Contracting*, 2nd ed. (Washington: George Washington University Law School, 1999), chap. 21; Elliot V. Converse III, *Rearming for the Cold War, 1945–1960*, vol. 1 of *History of Acquisition in the Department of Defense* (Washington: Historical Office, Office of the Secretary of Defense, 2012), 41–46; or, the insatiably curious may also find interest in the papers collected in Albert C. Lazure and Andrew P. Murphy Jr., eds., *Research and Development Procurement Law* (Washington: Federal Bar Journal, 1957).

National Security Act did provide one mechanism to guide, coordinate, and reconcile their discrepant programs under expert, primarily civilian supervision: the Research and Development Board (RDB). Here it will be instructive to briefly review the intent of the National Security Act, as it passed in 1947, with its implementation and first legislative amendment, because just as the "radar fence" proposal had tested the law's budget procedures in 1948, the continental air-defense program again tried its provisions for technology management. In particular, the master structure created by the National Security Act of 1947 was *not* the modern Department of Defense, but an organizational scheme awkwardly called the National Military Establishment (NME).[52]

The distinction is less importantly semantically than conceptually; rather than a classic hierarchy, the NME codified and elaborated the rather byzantine, and almost completely *ad hoc* ordering of civil-military affairs that had existed during World War II, and as such, it more closely resembled the prewar configuration of the departments of War and the Navy than the top-heavy Pentagon of today. As originally drafted, the National Security Act provided separately for the departments of the Army, Air Force, and Navy as independent, cabinet-level agencies. What it added that had not existed before the war—and only provisionally then—was a system of interlocking boards and councils in order to effect, in the military's preferred parlance, a measure of "jointness" between the three armed forces. Only one provision departed significantly from wartime precedents, which was, not coincidentally, its most controversial feature: the Secretary of Defense and the nature of the office organized beneath him.[53]

52. The following passage is a textbook-grade explanation treated amply in Douglas T. Stuart, *Creating the National Security State: A History of the Law That Transformed America* (Princeton University Press: Princeton, 2008); Hammond, *Organizing for Defense*; and Rearden, *The Formative Years*; with support from Alice C. Cole et al., eds., *The Department of Defense: Documents on Establishment and Organization, 1944–1978* (Washington: Office of the Secretary of Defense, Historical Office, 1978). However, Amy B. Zegart, *Flawed by Design: The Evolution of the CIA, JCS, and NSC* (Stanford: Stanford University Press, 1999), to which the title of this subsection alludes, provides the key framework for the discussion that follows, even though it is a study in the theory of "agency design" rather than the historical development of those agencies *per se*.

53. Although the debate over the necessity for a Secretary of Defense is covered by most of the citations above, the literature on the office's first occupant, James V. Forrestal, tend to examine it more thoroughly; for instance, the excellent Jeffery M. Dorwart, *Eberstadt and Forrestal: A National Security Partnership, 1909–1949*

The existence of a cabinet secretary without control over a corresponding executive agency impressed some legislators and senior officials as a malfunction of organizational design. To others—including, ironically enough, James V. Forrestal, Secretary of the Navy, and the first man appointed as Secretary of Defense—the position seemed superfluous, or potentially even malign, since the war state had performed well enough without an analogous official. Consequently, the original act left the powers of the office vague apart from a statutory responsibility to chair or sit on several of the aforementioned joint committees while further confusing the obligation of the Joint Chiefs to advise both the president and the secretary, albeit under the latter's unspecified supervision.[54]

The argument from compromise cast the Secretary of Defense not as an executive but as the president's representative to the National Military Establishment, an *alter ego* to receive counsel and speak for a White House that would have to divide its attention more equitably between foreign, domestic, and military affairs in times of peace than in times of war. In other circumstances, the system might have worked again, as it had largely worked before, and yet it could not withstand the intense rivalry between the armed forces, a consequence of ambition constrained by fiscal austerity. Instead, on August 10, 1949, President Truman signed an amendment to the National Security Act which abolished the National Military Establishment, removing the three service secretaries from his Cabinet and subordinating their agencies to the new Department of Defense, formed from the nucleus of the Office of the Secretary of Defense. This legislative action empowered the secretary as an administrator and curtailed future challenges to his authority, such as the so-called "revolt of the admirals," in which the Department of the Navy, in a distressing act

(College Station: Texas A&M University Press, 1991).

54. It could be argued that Admiral William D. Leahy, whom President Roosevelt appointed as his "special military adviser" in 1942, performed an analogous function during World War II. However, since Leahy was a uniformed officer who also sat with the Joint Chiefs, his informal posting was considered precedent for the Chairman of the Joint Chiefs of Staff, an office created in 1949, rather than a civilian defense secretary. Vernon E. Davis, *Origin of the Joint and Combined Chiefs of Staff*, vol. 1 of *The History of the Joint Chiefs of Staff in World War II: Organizational Development* (Washington: Historical Division, Joint Secretariat, Joint Chiefs of Staff, 1972), 256–261, OCLC (1988050); Ronald H. Cole et al., *The Chairmanship of the Joint Chiefs of Staff* (Washington: Joint History Office, Office of the Chairman of the Joint Chiefs of Staff, 1995), 4–14.

of high-level insubordination, conspired to reverse the cancellation of its prestigious "supercarrier" project, the USS *United States*, by undermining the Air Force's transcontinental-range bomber program.[55]

It was in this environment of apprehension and hostility that the Joint Chiefs of Staff requested that the Chairman of the Research and Development Board to initiate a comprehensive study of the continental-defense problem and provide the Secretary of Defense with a technological remedy. This was precisely the kind of task for which the RDB had been created—uniting the administrations of the Army, Air Force, and Navy into a "joint" effort to better guard the nation with radically new land-, air-, and sea-based defenses—and yet the structure proved wholly incapable of supporting it. Though organized like the now-defunct National Defense Research Committee, the RDB lacked any of the decision-making or spending powers that OSRD's promoters had considered so critical to its success and argued so tenaciously to secure. Instead, the board served a purely advisory function, ideally reviewing the research programs of the three armed forces, pointing out their duplicities, admonishing their dead ends, and suggesting potentially fruitful investments for the future, all drawn from its expert membership's knowledge of the latest advances in their respective fields.[56]

55. The argument in this passage hews fairly close to the perspective offered in John C. Ries, *The Management of Defense: Organization and Control of the U.S. Armed Services* (Baltimore: Johns Hopkins University Press, 1964). For more on the USS *United States* debacle than is present in sources cited elsewhere about American interservice rivalry in general, see Vincent Davis, *The Admirals' Lobby* (Chapel Hill: University of North Carolina Press, 1967) or Jeffrey G. Barlow, *Revolt of the Admirals: The Fight for Naval Aviation, 1945–1950* (Washington: Naval Historical Center, Department of the Navy, 1994).

56. Early in its existence, the RDB circulated a number of publications, such as *Research and Development Board, History and Functions* (Washington: Research and Development Board, National Military Establishment, June 1, 1948), OCLC (22478948), intended to explain its responsibilities and panel structure, presumably to an audience in industry and academia. who found its workings difficult to understand. Deficiencies resulting from perceived weaknesses in its statutory basis received attention and excoriation in United States Commission on Organization of the Executive Branch of the Government, Committee on the National Security Organization, *National Security Organization: A Report With Recommendations*, Task Force Reports, Appendix G (Washington: GPO, January 1949), OCLC (976532171), one of the 18 special studies produced by the "First Hoover Commission," so called for its chair, the former president—and still-powerful Republican party-boss—Herbert Hoover. Joanna L. Grisinger, *The Unwieldy American State: Administrative Politics Since the New Deal* (Cambridge: Cambridge University Press, 2012), chap. 4 situates this extraordinary enterprise, an early example of what is now commonly referred to as a presidential "blue ribbon" commission.

At its peak, about 200 advisers from industry and academia filled part-time positions on its network of committees and specialty panels, supported by a small secretariat. Vannevar Bush chaired the board at the time of its first meeting in December 1947, continuing his presidence over its predecessor, the Joint Research and Development Board, which had been set up on an interim basis in June 1946. Though optimistic at first, Bush later complained that his chairmanship had become "his own personal war" and a dispiriting game of "shadow boxing" in which he could exercise "no authority whatsoever over anything."[57]

The outcome was unsurprising given the board's limited powers and, moreover, the stifling number of projects with which it was tasked with monitoring: as many as 18,000, according to one accounting.[58] As Bush grew frustrated with his marginal role, he increasingly blamed his poor health and ill temper on his participation with the RDB, resigning a year later. His successor, Karl T. Compton, the former president of MIT, fared little better and resigned after less than 18 months in the chairman's seat, likewise citing concerns over his health and personal wellbeing. Although the RDB trucked on for three years following Compton's departure in March 1950, OSRD elites had already abandoned it as a means to control military research and development. Bush, per his wont, spent most of the next five years—and indeed, the remainder of his entire career—denouncing the government's failure to rationalize scientific research and development under civilian supervision.[59]

A review of the RDB's files confirms that its practical irrelevance to the continental-defense program. Most panel work and committee papers merely churned through cases presented individually by the armed forces, drawn from an overwhelming variety of disconnected projects and studies, which provided scant opportunity to assess their relative significance, let alone construct any sort of policy resembling a unified research-and-devel-

57. Vannevar Bush to James V. Forrestal, July 23, 1948; Vannevar Bush to Frank B. Jewett, August 3, 1948; both quoted in G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (1997; repr., Cambridge: MIT Press, 1999), 341.

58. Converse, *Rearming for the Cold War*, 31.

59. This point became something of a hobbyhorse in the writings and public addresses of Vannevar Bush, according to Zachary, *Endless Frontier*.

opment plan. Essentially, the process of surveying the military's disparate programs had itself inundated the rank-and-file membership and failed to generate any definite action from the board beyond a few reaffirmations to continue to study the problem.[60]

In 1951, for instance, the secretary of the RDB's Fire Control Panel noted that "recent presentations…have indicated that several groups and organizations are working on the air defense program," raising a question "as to whether the resulting air defense system will be a well integrated system."[61] The panel deferred action on the agenda item for three consecutive meetings before finally concluding the issue more properly belonged to the Electronics Panel. The Electronics Panel, meanwhile, expressed a perpetual reluctance to challenge the Air Force's unilateral decisions to move forward with various aspects of its air-defense research-and-development program.

In May 1949, the panel voted that "the Department of the Air Force be allocated responsibility for research and development…for all equipment specifically required for Information Centers and Nets for Air Defense Systems [*sic*] of land areas," albeit in coordination with "Canadian authorities, with Civil Defense organizations in the United States, and with the Department of the Navy for integration with pertinent naval facilities; with the Department of the Army for communication facilities and for the integration of anti-aircraft systems, and with the Air Navigation Development Board for the integration of common systems of traffic control and navigation."[62] The assumption never changed, and, likely

60. The description here is a general impression based on a review of hundreds of brief documents that would be infeasible to cite individually. The National Archives preserves what remains of the Board's official records under RG 330, NM-12 341—a collection of over 600 boxes, typically subdivided by fiscal year, then again by panel, and often again by document type (agendas, minutes, memos, and so on), though these patterns are inconsistent and partially overlapping. Thus, papers related to air-defense work are scattered across many boxes, as they were likewise spread across multiple committees and panels, each of which typically contain only a small number of relevant documents. There is, however, a cursory topical index available to researchers, though many papers had to be located by means of cross-reference slips inserted into the files themselves.

61. Research and Development Board, Committee on Ordnance, "The Air Defense Problem," item 3 on the agenda of the 23rd Meeting of the Panel on Fire Control, OFC 202/3, August 20, 1949, NARA, RG 330, NM-12 341, box 289, folder 5.

62. Memo, Donald A. Quarles, Chairman, Committee on Electronics to Executive Secretary, Research and Development Board, "Recommendation for Allocation of Responsibility," RDB 222/1, May 16, 1949, NARA, RG

recognizing its own impotence regarding the matter, the panel seemed almost relieved at the news in 1950 that a USAF-contracted study called "Project CHARLES" would pick up where ADSEC had left off.

Due to perceived ineffectiveness, President Eisenhower abolished the Research and Development Board in June 1953, invoking a provision in the original National Security Act that granted the chief executive some discretion to reorganize the National Military Establishment (now the Department of Defense) so long as Congress declined to object. Not coincidentally, this was also the time that serious choices had to be made concerning the appropriation of *billions* of dollars for development and production of equipment related to continental defense—to say nothing of guided missiles—as opposed to the comparatively paltry sums spent previously on preliminary research and design. As such, multiple secretaries of defense never received the comprehensive assessment on a potentially "joint" technology program that the RDB had been intended—and even explicitly instructed—to provide them.[63]

Indeed, it can be argued that the Research and Development Board represented an organizational "failure by design," as was the case with several other elements of the National Military Establishment that did not long survive passage of the National Security Act in 1947. Though ostensibly a rational compromise, the civilian-advising structure had been strategically weakened in order to ensure a *de facto* maintenance of the prewar *status quo*, in which the military department retained virtual autonomy over their internal priorities and programs.[64] As one observer noted:

330, NM-12 341, box 289, folder 5.

63. It is indeed unfortunate that except for Converse, *Rearming for the Cold War*, 26–41, very little has been written about the RDB. Although it existed for only a brief time, the prominence, quantity, and enthusiasm of its early participants signal a path not followed in the conduct of American science policy, especially with respect to military applications. Many reforms pursued in the time since the Board broke down can be construed as attempts—though ultimately futile ones, as some would argue—to invent an organizational apparatus of similar scope of motivation. Cf. J. Ronald Fox, *Defense Acquisition Reform, 1960–2009: An Elusive Goal*, CMH Pub 51-3-1 (Washington: US Army Center of Military History, 2011).

64. As mentioned previously, this alludes to Zegart, *Flawed by Design*, which argues that national-security agencies are unique do to their secrecy, obscurity, unaccountability, and so on, and thus, were never intended to

> At [panel] meetings, the civilians usually assume the role of jurists. The military representatives play dual roles: first, as lawyers to argue for their cases, and then to sit with the judges to decide on the cases. Intentionally or otherwise, the civilians withdraw from decisions contrary to the arguments of the military representatives. Most men trained in scientific and technical fields prefer not to argue against someone with fuller, more detailed information.[65]

Likewise, each service appointed two general officers to the board's executive committee, who in practice functioned "in a triple capacity of witnesses, attorneys for the defense, and judges with regard to research and development matters. In the first two capacities they are in many instances bound by the policies of their departments. Consequently in the role of judges they are not in a position to place weight on any evidence other than their own."[66]

Although the RDB presented the Air Force with a purely notional threat to its hegemony over the research and development of equipment related to continental defense, neither could it provide the means for hobbling the continental-defense programs of the other two services. While this latter point will prove significant later, the conflict that follows is the Air Force's own, almost completely unforced by the imposition of extra-departmental demands and constraints, at least apart from the process of securing its annual appropriation from Congress.

3 Breaking the political stalemate

Chroniclers of the reorganization of the Air Force's technology program have generally characterized it as a necessary rationalization and a critical moment in the progression of

serve an articulable "national interest," but rather, to provide ready battlegrounds for factionalized incumbents. As such, they are deliberately kept weak in order to prevent them from developing objectives independent of the desultory thrashings of their competing participants.

65. Memo, Richard M. Emberson, Assistant Executive Secretary, Research and Development Board for Dr. R. F. Rinehart, Executive Secretary, Research and Development Board, "Executive Directors' Comments on Limitations of Committee Actions, as Developed during Recent Discussions Concerning Proposed Regulations for the Control of R&D Obligations," March 21, 1949, quoted in Converse, *Rearming for the Cold War*, 34.

66. Memo, Dr. R. F. Rinehart, Executive Secretary, Research and Development Board for Dr. Karl T. Compton, Chairman, Research and Development Board, "Further Comments by Executive Directors on Limitations of Committee Actions," March 22, 1949, quoted in Converse, *Rearming for the Cold War*, 31.

"systems thinking" toward total "systems management": the dominant pattern by which the most ambitious projects in defense, aerospace, electronics, infrastructure, and other major applications, have since been achieved.[67] Advocates of "progressive" R&D within the Air Force expressed a tangible enthusiasm for organization as a tool to promote planning and rational forward-thinking: an administration that could map a future that met abstract military necessities and then efficiently deploy the private resources needed to realize it. Put simply, their intentions and methods paralleled the grand vision that Vannevar Bush and fellow OSRD elites espoused at the end of World War II.

If that goal can be restated as crudely as the redirection of public money to outside contractors for the purpose of executing research programs as optimistic as they were unrestrained, then the Air Force, like the Army and the Navy, remained better positioned to achieve it than other federal agencies, due to both the size of its annual appropriation and the insufficient oversight of its disbursement.[68] Although work performed directly under government control kept pace for some time at non-defense agencies such as the Census and Standards, the mobilization for the Korean War, and subsequent lack of demobilization, pushed the military departments, along with their closest academic and industrial partners,

67. As noted elsewhere, the literature on this topic is well represented by Converse, *Rearming for the Cold War*; Thomas C. Lassman, *Sources of Weapon Systems Innovation in the Department of Defense: The Role of Research and Development, 1945–2000*, CMH Pub 51-2-1 (Washington: US Army Center of Military History, 2008); Johnson, *United States Air Force and the Culture of Innovation*; Hughes, *Rescuing Prometheus*; and Michael H. Gorn, *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition, 1950–1985*, 2 vols. (repr., Andrews AFB, MD: Office of History, Headquarters, Air Force Systems Command, 1989).

68. Huzar, *The Purse and the Sword* made clear the impracticality of managing the defense establishment through legislative fiscal-policy; as Mosher, *Program Budgeting* likewise demonstrated, even the armed forces struggled to improve their capability to direct approved spending toward beneficial ends. Perversely, the same management-control reforms implemented separately by the military departments during the 1950s became the leading source of military-political tension in the next decade, when Robert McNamara, motivated by such studies as Charles J. Hitch and Roland N. McKean, *The Economics of Defense in the Nuclear Age*, Project RAND, R-346 (Cambridge: Harvard University Press, 1960), fought to centralize them in the Office of the Secretary of Defense. Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program, 1961–1969* (New York: Harper & Row, 1971), though partisan in favor of McNamara, is considered the canonical account since the normalization of integrated budget; the critical accounts are also legion, but for a starting point on the contemporaneous pushback, see Lawrence S. Kaplan, Ronald D. Landa, and Edward J. Drea, *The McNamara Ascendancy, 1961–1965*, vol. 5 of *History of the Office of the Secretary of Defense*, ed. Alfred L. Goldberg (Washington: Historical Office, Office of the Secretary of Defense, 2006), especially chap. 5.

to the forefront of government science.[69] Nevertheless, even copious funding and the autonomy to exploit it did not guarantee rationally efficient outcomes, seemingly regardless of organizational design.

Indeed, the Air Force's technology management experienced much of the same factionalization, confusion, and subordination to external interests as the toothless boards and panels of the National Military Establishment, except with real dollars at stake. Despite repeated reform measures, bureaucratic instability prevailed throughout the 1950s, failing to reach anything resembling a "steady state," however imperfect, until the next decade.[70] Apropos, the previous chapter introduced the twin threads of both the Rome and Cambridge laboratories, an intertwining that will be taken up again here. The R&D reorganization was itself engineered with the help of old hands from Division 14, which naturally continued to push the Air Force to expand its investment in former Rad Lab elements clustered around the Boston area. While influential, they also realized their goal required maneuvering around the overwhelming power of logistics, the bureaucratic predominance of which should not be understated.

69. At the start of World War II, the Census Bureau possessed such a high concentration of mechanized accounting equipment that it provided rush services to federal agencies in urgent need of war-related tabulations. For instance, one job of which the author of manuscript [anon.], "Census Bureau War History," n.d. [1946]?, in *Administrative Histories of World War II Civilian Agencies of the Federal Government* (New Haven: Research Publications, 1979), microfilm, OCLC (223791959), reel 9, doc. 84 seemed especially proud was the identification of the vast majority of immigrants, residents, and citizens of Japanese ancestry within just three weeks of the attack on Pearl Harbor. A more benign application was the compilation of industrial statistics for the War Production Board: Cf. Leon E. Truesdell, *The Development of Punch Card Tabulation in the Bureau of the Census* (Washington: GPO, 1965); Joseph W. Duncan and William C. Shelton, *Revolution in United States Government Statistics, 1926–1976* (Washington: GPO, 1978). By 1961, however, the Commerce Department had only four digital computers operating at the Census Bureau and six at the Standards Bureau. Meanwhile, defense, nuclear, and aerospace agencies accounted for 80% of all federal spending on automated data-processing—both digital and electromechanical—compared to 1.8% for the entire Department of Commerce. United States Bureau of the Budget, *Inventory of Automated Data Processing (ADP) Equipment in the Federal Government, Including Costs, Categories of Use, and Personnel Utilization* (Washington: GPO, October 1962), OCLC (760366657).

70. To supplement the many other sources that focus on the 1950s, note also Walter S. Poole, *Adapting to Flexible Response, 1960–1968*, vol. 2 of *History of Acquisition in the Department of Defense* (Washington: Historical Office, Office of the Secretary of Defense, 2013).

Defying the hegemony of Air Force logistics

Paradoxically, for an institution that had always staked it fortune more on the promise of technology in the future than its capabilities in the present, the United States Air Force lagged behind the other services in implementing an administration for managing research and development.[71] While no single cause stands above the rest, the predominance of Wright Field—or Wright–Patterson Air Force Base, as it became officially in 1948—is among the most salient. Home to the Air Materiel Command (AMC), Wright Field anchored one of the largest maintenance and logistics networks in the entire world, a global complex of depots, warehouses, stockpiles, laboratories, workshops, and training centers clustered around eight regional "air materiel areas," whose daily operations rivaled and perhaps even exceeded the scope and pace of actual flying activities.[72]

Built up during the war as the Air Technical Services Command, AMC had expanded through a nearly single-minded drive to move aircraft, munitions equipment, and supplies out of the factories and into the field, then keeping it all running once they did.[73] In

71. The disconnectedness between the early enthusiasm for military and its technical capabilities is a theme common in the air-power literature; for instance, Stephen L. McFarland, *America's Pursuit of Precision Bombing, 1910–1945* (Washington: Smithsonian Institution Press, 1995).

72. Cf. Lois E. Walker and Shelby E. Wickam, *From Huffman Prairie to the Moon: The History of Wright–Patterson Air Force Base* (Wright–Patterson AFB, OH: Office of History, 2750th Air Base Wing, Air Force Logistics Command, 1987), OCLC (916076855). In addition to Wright–Patterson Air Force Base in Dayton, Ohio, the major air-material areas at the time were located in Middletown, Pennsylvania; Mobile, Alabama; Ogden, Utah; Oklahoma City, Oklahoma; Sacramento, California; San Antonio, Texas; and Warner Robins, Georgia. Another opened later in Rome, New York, and satellite facilities existed overseas in France, Japan, Guam, and the Philippines: *Report of the Secretary of the Air Force to the Secretary of Defense for Fiscal Year 1948 (1 July 1947–30 June 1948)* (Washington: GPO, 1948), 187–207, OCLC (743492439). Although there appears to have been an early preference for retaining the diacritic in the official title, "Air Matériel Command," American typewriters lacked this character, so it appears inconsistently in contemporaneous sources, while retrospective ones tend to drop it entirely, likely respecting the convention adopted by its successor organization, the Air Force Materiel Command. The latter styling will be used here.

73. Wesley Frank Craven and James Lea Cate, eds., *Men and Planes*, vol. 6 of *The Army Air Forces in World War II* (1954; repr., Washington: Office of Air Force History, 1983), chap. 11. On the general under-appreciation of industrial logistics in the military history of the period generally, see Alan Gropman, ed., *The Big 'L': American Logistics in World War II* (Washington: National Defense University Press, 1997). Consequently, little has been published on ATSC/AMC that has not originated in the historical offices of one of its successor agencies, e.g. David C. Rutenberg and Jane S. Allen, eds., *The Logistics of Waging War: American Logistics 1774–1985—Emphasizing the Development of Airpower* (Gunter AFS, AL: Air Force Logistics Management Center, 1996), OCLC (607836582); Bernard J. Termena, Layne B. Peiffer, and H. P. Carlin, *Logistics: An Illustrated History of AFLC and Its Antecedents, 1921–1981* (Wright–Patterson AFB, OH: Office of History, Headquarters, Air Force

practice, AMC headquarters exercised as much influence over the service's direction as USAF headquarters itself; as the Air Force's primary agent for procurement and construction, for instance, it controlled 99% of its purchasing and over 75% of the entire budget—and even the budgeting process itself.[74] In other words, AMC's actions could determine whether a plan or a policy handed down from Washington ever reached the ground, let alone the skies. The Air Force may have dreamed of wings, but its home lay beneath the clouds, in Dayton as much as in the nation's capital, and the Air Materiel Command had the bureaucracy to prove it. In 1948, 15,561 military and civilian personnel worked for AMC headquarters at Wright–Patterson, with another 6,605 supporting the base, compared to 4,339 in the Pentagon.[75]

Logistics Command, 1981), OCLC (10985861); H. P. Carlin, *Building a New Foundation: Plans and Preparations for Establishing the Air Force Materiel Command* (Wright–Patterson AFB, OH: Office of the Command Historian, Air Force Materiel Command, 1992), OCLC (33807504); Frederick A. Alling et al., *Air Force Logistics Command, 1917–1976*, 7th ed. (Wright–Patterson AFB, OH: Office of History, Air Force Logistics Command, 1977), OCLC (41022017). Given the decentralized nature of the Air Force's depot system (or "air materiel areas," as they were called for most of the Cold War), the output of field-level agencies is also relevant: Helen Rice, *History of Hill Air Force Base* (Hill AFB, UT: History Office, Ogden Air Logistics Center, Air Fore Logistics Command, 1981), OCLC (8403391); James L. Crowder, *Tinker Air Force Base: Sixty Years of History, 1942–2002* (Tinker AFB, OK: Office of History, Oklahoma City Air Logistics Center, Air Force Logistics Command, 2002), OCLC (51514415); Ann Krueger Hussey, *A Heritage of Service: Seventy-Five Years of Military Aviation at Kelly Air Force Base, 1916–1991* (Kelly AFB, TX: Office of History, San Antonio Air Logistics Center, Air Force Logistics Command, 1992), OCLC (645697966); and Charles W. Grindstaff, *War Baby of the South, 1940-1945* (Robins AFB, GA: Office of History, Warner Robins Air Logistics Center, Air Force Logistics Command, 1991), OCLC (24207046) is sample among the largest of these. None of these sources is particularly well historicized, with many pages dedicated to chronologies, tables, charts, and photographs, but together they produce a composite sketch of the scope and importance of a topic that can otherwise only be grasped through an exhausting review of the annual historical reports of each of these agencies separately, in addition to parsing the professional literature on military logistics.

74. United States Department of the Air Force, Air Staff, Director of Statistical Services, Office of the Air Comptroller, *United States Air Force Statistical Digest, Fiscal Year 1948*, 3rd ed. (Washington: Headquarters, United States Air Force, 1949), tables 194–196, https://media.defense.gov/2011/Apr/04/2001329918/-1/-1/0/AFD-110404-032.pdf . United States Department of the Air Force, *Programming Procedures*, Air Force Manual (AFM) 27-1 (Washington: GPO, April 1, 1954), Authority Collection, Muir S. Fairchild Research Center, Air University, Maxwell AFB, Montgomery, AL, the first published documentation of the Air Force's integrated budget system, emphasized the role of central headquarters, but Mosher, *Program Budgeting*, 71–77, 127–132, 178–179 observed that, in practice, the Air Materiel Command prepared most of the service's annual budget. The author actually considered the *de facto* concentration of budgeting authority a net positive compared to the Army's tradition of branch autonomy, while still acknowledging the concern about the accumulation of administrative power in a single operating agency.

75. Figures from *Report of the Secretary of the Air Force to the Secretary of Defense for Fiscal Year 1948 (1 July 1947–30 June 1948)*, 189; George M. Watson, Jr., *The Office of the Secretary of the Air Force, 1947–1965* (Washington: Center for Air Force History, 1993), 281. For this accounting, "USAF headquarters" is defined as the Office of the Secretary of the Air Force plus the Air Staff, or what is, legally speaking, the Department of the Air Force. According to 65 Stat. 326, Pub. L. 82-150, also known as the "Air Force Organization Act," the *United States*

Other factors spoiling the cultivation of research and development in the United States Air Force include the slackening interest of senior leadership, lower levels of educational attainment among its officers relative to the other services, and the general organizational instability that prevailed following the dissolution of the War Department, but the one given most frequently by critics at the time was the institutional hegemony of logistics over science and technology. The claim is difficult to assess; on the one hand, Wright Field had decades to mature a large and sophisticated administration for development, test, maintenance, and industrial engineering. It is not inconceivable that a robust system for managing laboratories and contract research might have grown within the same institutional framework that had presided over advances in airframes, propulsion, and airborne electronics since the First World War. AMC did indeed reorganize to intervene in postwar science like the other military departments, establishing in 1948, for instance, the Office of Air Research on the same premise as the Office of Naval Research.[76]

Instead, the division formed less along the lines of technical competence or organizational capacity *per se*, but rather, personalities and professional culture. Career logisticians dominated the staff at AMC headquarters, which had spent the war mobilizing the American aircraft industry and the years afterward disposing of its surplus. Their interests and experience lay in purchasing, mass production, and preparing operational end-items for

Air Force is the uniformed service that intersects with the executive *Department of the Air Force*, the latter of which also includes the civilian office of the secretary: Richard I. Wolf, ed., *The United States Air Force: Basic Documents on Roles and Missions* (Washington: Office of Air Force History, 1987), 223-236; see also Futrell, *Ideas, Concepts, Doctrine*, 158–160. Also in 1948, the Air Force had an additional 6,694 military and 793 civilian personnel stationed at Bolling Field in southwestern Washington, DC in order to support its activities at the Pentagon and throughout the National Capital Region: *United States Air Force Statistical Digest, Fiscal Year 1948*, tables 24 and 73.

76. Nick A. Komons, *Science and the Air Force: A History of the Air Force Office of Scientific Research* (Arlington, VA: Historical Division, Office of Information, Office of Aerosapce Resesarch, 1966). One legitimate strike against the Air Materiel Command was that, in the absence of an established "arsenal system" like the US Army's (see previous chapter), it had historically relied heavily upon the National Advisory Committee for Aeronautics (NACA, the predecessor to NASA) for basic flight research and experiments. For instance, despite the modern airplane's origins in the United States, the size of the American aircraft industry, as well as the sophistication of its products, lagged substantially behind the European powers until the end of World War II. Cf. Michael H. Gorn, *Expanding the Envelope: Flight Research at NACA and NASA* (Lexington: University Press of Kentucky, 2001); also James R. Hansen, *The Bird Is on the Wing: Aerodynamics and the Progress of the American Airplane* (College Station: Texas A&M University Press, 2004).

the field. Research and development, on the other hand, too often lacked relevance to the immediate concerns of manufacturing and equipment.

Moreover, the resources required for so-called "basic science" appeared practically negligible compared to the megabucks sloshing through the Air Force's major industrial programs. In Fiscal Year 1950, for example, the Air Materiel Command expended $23 million on contracts with budget code 610—Basic Research—but $1.8 *billion* in contract purchases overall.[77] In a bureaucracy accustomed to working on an industrial scale, projects of such meager proportions seemed relatively unimportant and often failed to command attention commensurate with their potential, even as they proliferated.

At Air Force headquarters, meanwhile, the Director of Research and Development (D/R&D) reported to the Deputy Chief of Staff, Materiel (DCS/M), head of the USAF's logistics, maintenance and industrial program, and one of the four senior-most positions beneath the Chief of Staff (the other three deputy chiefs, as of mid-1949, were Operations, Personnel, and the Comptroller). The subordination of science-and-technology policy—notionally, the primary responsibility of the D/R&D—to the office of the DCS/M exemplified the two philosophies in contest among the Air Force's professional military leadership, a debate concerning the organization's essential mission in the postwar era. Although both camps agreed that America must have the technological advantage in a future war, as one of the state's arms of combat, they disagreed about their own responsibility to achieve it.[78]

The prevailing view held closer to the Air Corps' prewar assumption that private industry and government bodies such as the National Advisory Committee for Aeronautics (or NACA, the antecedent to NASA) would drive the engines of aviation progress. While the Air Force should closely monitor these developments and continually evaluate their implications for

77. United States Department of the Air Force, Air Staff, Director of Statistical Services, Deputy Chief of Staff, Comptroller, *United States Air Force Statistical Digest, January 1949–June 1950*, 5th ed. (Washington: Headquarters, United States Air Force, April 25, 1951), tables 140, 151, https://media.defense.gov/2011/Apr/05/2001329940/-1/-1/0/AFD-110405-027.pdf . Total spending from "P600" (program code 600) accounts amounted to $189 million via AMC and $202 million service-wide, though the vast majority funded pre-production work on a small number of major aircraft procurements.

78. The following passage draws mainly from Gorn, *Vulcan's Forge*, vol. 1, 1–49.

its present capabilities, shaping the future lay ultimately beyond the power—or, at least the propriety—of a traditional military institution. Opponents doubted whether this attitude could actually work in practice; the Air Force would be constantly reacting, they argued, always behind the times, and unable to steer government, industry, and academia in the direction best suiting the interests of American air-power.

Research and development policy changed behind a coalition of younger Air Force officers, former OSRD elites, and a sympathetic faction within the old guard of American military aviation. Official histories have identified Brigadier General Donald L. Putt as the leader of a vanguard that included, most notably, a colonel named Bernard A. Schriever—future boss of the Air Force ballistic-missile program—but also Peter J. Schenk, a figure who will reappear in the air-defense discourse multiple times, both as an officer and a civilian. Collectively, Putt's coterie became known at headquarters as the "Young Turks," a tired expression which nonetheless communicated their ambitiousness as well as its perceived cultural-generational motivation. Characteristically, they were career officers with university training as engineers who came of age professionally during World War II, where they served the Army Air Forces most prominently as technical and industrial managers.[79]

In September 1948, Putt was appointed D/R&D in Washington, which also carried with it the responsibility of supervising the Air Force Scientific Advisory Board (SAB), a consulting organ set up to codify the wartime Scientific Advisory Group, or the aforementioned "von Kármán committee." Despite General Arnold's attempt to systematize the pipeline feeding the Office of the Chief of Staff from outside sources of academic-industrial expertise, Air Force headquarters had never seriously moved to incorporate the board's activities, infrequent and unfocused as they may have been, into its deliberative process. By 1949,

79. Donald Ralph Baucom, "Air Force Images of Research and Development and Their Reflections in Organizational Structure and Management Policies," (PhD diss., University of Oklahoma, 1976), ProQuest (7624356) best characterizes the postwar competition between factions within the USAF about the future of research-and-development policy.

key members were losing interest in their seemingly perfunctory work and turned their attention to reforming the Air Force's technology program altogether. After the Young Turks failed in their own effort to unshackle the administration of research and development from the Air Materiel Command, Putt enrolled the SAB in his goal of convincing senior leadership to establish an independent authority for science-and-technology affairs.[80]

Together with Theodore von Kármán, who still chaired the board, Putt arranged for General Muir S. Fairchild, Vice Chief of Staff, to officially charge the SAB with an assignment it had devised for itself: a sweeping study of the Air Force technology bureaucracy for the purpose of recommending its potential reorganization. The board appointed Louis N. Ridenour, formerly of Division 14, to lead the committee, which included other name brands such as Carl F. J. Overhage, Ralph A. Sawyer, George P. Baker, and the then-retired general James H. Doolittle, commander of the famous "Doolittle raid," but also a trained aeronautical engineer with postgraduate degrees from MIT. The weight of the committee's prestige proved sufficient to persuade Chief of Staff Vandenberg to approve most of their suggestions, though not without a chummy intervention from Jimmy Doolittle through one of the choicest pleasures Washington's polite society: the Chesapeakian duck hunt.[81]

Although many details remained to be negotiated regarding the transfer of offices, duties, and personnel over the following year, the Ridenour committee outlined the structure of R&D management in the United States Air Force that would stand for the next decade. Briefly, the report, rendered in September 1949, recommended the establishment of a separate "research and development command" at the same level of organization as the Air Materiel Command, which is to say, a "major command" reporting directly to Washington. At Air Force headquarters, the Directorate of Research and Development would be removed

80. Cf. Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944–1986* (Washington: Air Force History and Museums Program, 1988); Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944–1964* (1967; repr., Washington: Air Force History and Museums Program, 1986).

81. Although this minor detail seems to have appeared first in Gorn, *Vulcan's Forge*, vol. 1, it adds a sufficient degree of personality to an otherwise obtuse story of organizational policy that it has been reproduced in virtually every published account to follow.

from the Office of the Deputy Chief of Staff, Materiel and elevated to deputy-chief status as well.[82]

The committee's observation that military officers lacked incentives to pursue careers in science and engineering, as opposed to "operations"—which is to say, assignments related to combat, intelligence, and strategic planning—probably came closer to identifying the systemic cause of the Air Force's perceived delinquency. Nevertheless, changes to organizational policy were immediately actionable, whereas personnel policy presented a longer term, and potentially even more contentious problem.[83]

By January 1950, Vandenberg had appointed Major General Gordon P. Saville to the new position of Deputy Chief of Staff, Development (DCS/D) and signed the paperwork that authorized the creation of the Air Research and Development Command (ARDC). After an initial skirmish over access to facilities at Wright–Patterson, the still-incipient Headquarters ARDC began relocating to Baltimore in mid-1951 with the intention of literally distancing itself from AMC, whose influence and resources still towered by comparison.[84]

The Cambridge lobby

One case of special relevance is the appointment of a "chief scientist" at Air Force headquarters, a position that had not been explicitly recommended by the Ridenour committee but which Vandenberg asked Ridenour himself to take up. Controversy mired the appointment from the start; Ridenour, in particular, had for years rankled the military, the AEC, and

82. While finding its way into numerous archival collections, the text of the "Ridenour report" has never been reprinted in a published source. It is most commonly referenced as L. N. Ridenour, G. P. Baker, J. F. Doolittle, J. B. Fisk, C. F. Overhage, R. A. Sawyer, F. Wattendorf, J. M. Wild, and R. J. Woodrow, "Research and Development in the United States Air Force," Report of the Special Committee of the Scientific Advisory Board to the Chief of Staff, United States Air Force, September 21, 1949, AFHRA (0122571).

83. In addition to Gorn, Robert Sigethy, "The Air Force Organization for Basic Research, 1945–1970: A Study in Change," (PhD diss., American University, 1980), 21–61, ProQuest (8107687) covers much of the same ground, but with reference to a specific, albeit dated, model of organizational systems.

84. To the sources above, the insatiable may add Dennis J. Stanley, John J. Weaver, and Minnie L. Disch, *An Air Force Command for R & D, 1949–1976: The History of ARDC/AFSC* (Andrews AFB, MD: Office of History, Headquarters, Air Force Systems Command, 1977), OCLC (3479092).

the FBI by joining a number of prominent scientists who criticized the regime of secrecy that shrouded government and government-funded research after the fulfillment of the Manhattan Project.[85]

Antipathized as a potential communist, the 39-year-old professor of physics at the University of Illinois could not be guaranteed the clearance necessary to fill a position that required access to restricted information. In the interim, Ivan A. Getting, who had formerly worked with Ridenour at the Rad Lab before joining the faculty at MIT, was brought in to perform the role intended for Ridenour as General Saville's "special assistant for evaluation"—a move conceived so poorly that no one seemed to realize that Colonel Schriever, an integral member of Saville's staff, had already been acting under the same title for some time.[86]

When Ridenour finally did report to Air Force headquarters in mid-1950, the questions of whom he worked for, and what he was supposed to do, remained unresolved; as a civilian, many officers felt the Chief Scientist should advise the Secretary of Air Force rather than the Chief of Staff, which would further dilute the influence of the chairman of the Scientific Advisory Board as well. In October, von Kármán complained to General Putt about "the wholesale invasion of high power radiation men into the R and D organization" who suffered from "a superiority complex similar to that of the Nuclear Clan" and "a messianic attitude and approach to relatively simple problems...After all, you are the Air Force," needled the

85. In particular, Ridenour supported the international control of atomic energy, opposed the military-friendly May–Johnson draft of the Atomic Energy Act, and contributed to Dexter Masters and Katharine Way, eds., *One World or None* (New York: McGraw–Hill, 1946), a key tract for the postwar "Scientists' Movement," in which he participated through the Federation of Atomic Scientists: Chrystyna Dail, *Stage for Action: U.S. Social Activist Theatre in the 1940s* (Carbondale: Southern Illinois University Press, 2016), 126–129. Generally, however, little has been written on Ridenour, as a public figure or otherwise; the main sources of information about his career remain his professional obituaries: F. W. Loomis, "Louis Nicot Ridenour, Jr., 1911-–1959," *Physics Today* 12, no. 9 (September 1959): 18, doi:10.1063/1.3060961 and Frederick Seitz and A. H. Taub, "Louis N. Ridenour, Physicist and Administrator," *Science* 131, no. 3392 (January 1, 1960): 20–21, doi:10.1126/science.131.3392.20; though he does appear frequently in the memoir, Ivan A. Getting, *All in a Lifetime: Science in the Defense of Democracy* (New York: Vantage Press, 1989), from which some details in the following passage have been selected.

86. The following passage borrows from Dwayne A. Day, *Lightning Rod: A History of the Air Force Chief Scientist's Office* (Washington: Chief Scientist's Office, United States Air Force, 2000), 21–45, including a number of its primary sources, which, for the purpose at hand, need not be cited separately.

aerodynamicist, "and some airplanes still fly in the air and not only in the electro-magnetic field."[87]

Anxious of his diminishing suasion, the Hungarian émigré continued that "the messianic attitude combined with the hazy imagination of some generals (not handicapped by too much logics [*sic*] and technical knowledge) and the well-meaning but unbalanced zeal of younger officers...may produce a first-class mess," a "system of everybody working for everybody...I cannot figure out how we came to this result, but it looks to me that the steering wheel got into the hands of a composite group of technically untrained military personnel and unilaterally trained civilian scientists."[88]

Although Ridenour was ostensibly responsible to the Chief of Staff, his placement within the offices of the Deputy Chief of Staff, Development meant he would serve as General Saville's *de facto* adviser by dint of physical proximity. Saville remarked later, however, that while he consulted frequently with the new Chief Scientist, he never entirely trusted his motivations. The DCS/D suspected that Ridenour regarded himself as an advocate for the interests of the institutions of American science, rather than a public official advancing the goals of the agency he served, a view consistent with ideals Ridenour had previously expressed in print and other communications.[89]

87. Letter, Theodore von Kármán to Maj. Gen. Donald L. Putt, D/R&D, HQ USAF, October 9, 1950, quoted in Day, *Lightning Rod*, 35.

88. The standard scientific biography here is Michael H. Gorn, *The Universal Man: Theodore Von Kármán's Life in Aeronautics* (Washington: Smithsonian Institution Press, 1992).

89. In addition to the personal and professional associations documented in his FBI file, publications likely to have distressed his uniformed coworkers include: Louis N. Ridenour, "Military Security and the Atomic Bomb," *Fortune* 32, no. 5 (November 1945): 170–171, EBSCO (112418942); Louis N. Ridenour, "Pilot Lights of the Apocalypse," *Fortune* 33, no. 1 (January 1946): 116, EBSCO (59310231); Louis N. Ridenour, "Science and Secrecy," *The American Scholar* 15, no. 2 (Spring 1946): 147–153, JSTOR (41204774); Louis N. Ridenour, "Should the Scientists Resist Military Intrusion?" *The American Scholar* 16, no. 2 (Spring 1947): 213–218, JSTOR (41206611); Louis N. Ridenour, "Military Support of American Science, a Danger?" *Bulletin of the Atomic Scientists* 3, no. 8 (August 1947): 221–223, doi:10.1080/00963402.1947.11459095. His "Pilot Lights of the Apocalypse," a playlet with a hand too heavy for its satirical mood, was subsequently expanded into Robert Adler, George Bellak, and Louis N. Ridenour, *Open Secret: A One-Act Play* (New York: Samuel French, 1947), OCLC (7080302). Nevertheless, Ridenour's criticism of the British "scientific left," particularly P. M. S. Blackett and J. B. S. Haldane, suggests he was no radical, or else an implausibly canny one: Louis N. Ridenour, "Science With a Marxist Moral," *New York Times*, August 18, 1945, ProQuest (107820407); Louis N. Ridenour, "A U.S. Physicist's Reply to Professor Blackett," *Scientific American* 180, no. 3 (August 1947): 16–19, doi:10.1038/scientificamerican0349-16.

The practical significance of these events was the esconcement of a peculiar lobby at an unusually high level of the Air Force's central administration. While Theodore von Kármán likely feared for his stature as chairman of the Scientific Advisory Board when he objected to the "invasion" of "high power radiation men," his griping nonetheless highlighted the curiosity that the Air Staff should continue to favor electronics specialists, with current or former ties to MIT, in selecting its most influential advisers. Other recent events probably reinforced the impression that the Air Force's technology interests might already have become ensorcelled by a Cambridge lobby consisting of current and former members of Division 14, whose institutional loyalties lay primarily with the complex of academic and governmental laboratories situated in the Boston area.

In mid-1948, for instance, the Air Materiel Command tried yet again to implement its plan to consolidate an electronics-research organization at Griffiss Air Force Base. As Watson Laboratories began the two-year process of decamping from its facilities in New Jersey, staff at the Cambridge Field Station revolted against the proposed move to a semi-rural area of upstate New York. The lab's employees enjoined the City of Cambridge and the district's powerful representative, House Majority Leader John W. McCormack, to pressure Eugene M. Zuckert, Assistant Secretary of the Air Force, who maintained close relations with Harvard Business School, to cancel AMC's rebasing plan.[90]

On June 1, 1949, Zuckert himself toured the facility and announced that the move, schedule to commence on July 30, would be "postponed indefinitely," albeit "pending a survey of the research program in electronics conducted at the station."[91] However, the review committee could scarcely have been assembled more favorably, as Zuckert reportedly assured the lab's impassioned personnel that the site would eventually be made permanent. CFS was even granted a less-provisional title, the Air Force Cambridge Research Laboratories (AFCRL), on July 5—more than a month before the committee returned its evaluation.

90. Julius King, Jr., *History of Air Force Cambridge Research Center, 20 September 1945–30 June 1959* (Bedford, MA: Air Force Cambridge Research Center, n.d. [1959?]), 1–15, AFHRA (0476953)

91. "Air Force Halts Transfer of Cambridge Labs," *Boston Globe*, June 2, 1949, ProQuest (822223779).

The "Ad Hoc Board on the Air Force Cambridge Research Laboratories" consisted of six members, three of whom directed laboratories at AFCRL, including John W. Marchetti, its first administrator and later chief of research. F. Wheeler Loomis, the Rad Lab's former associate director; and Julius A. Stratton, who took leadership over the Research Laboratory in Electronics, or RLE—MIT's stake in the husk of Division 14—occupied two of the remaining positions; leaving only Colonel Gordon A. Blake, from the Electronics Subdivision of the Air Materiel Command, as the sole out-member of the radio-physics community in Cambridge. Assisting as a special "task group" were Albert G. Hill and Jerome B. Wiesner, both MIT faculty who had proceeded from the Rad Lab to the RLE.[92]

By the time the body delivered its report, however, Washington had already mooted the purpose for which it convened. "The Board understands that a decision has been made to maintain an Air Force electronics research establishment in the Boston area and that consequently the location of the Laboratories is not a subject for Board recommendations." So instead of informing the decision as originally declared, they set about to justify it. Though never stated so bluntly, Stratton's group had to argue for the inherent uniqueness of the work at AFCRL, because "a major aspect of its assigned task has been that of determining the extent to which the present Cambridge program is of a developmental character rather than research," which would be more beneficially relocated to a larger, better equipped facility such as the one then being established at Rome.[93]

Their reasons closely mirrored those deployed years previously, when the Army Air Forces first considered claiming a piece of the dissolving Rad Lab: most importantly, that Boston, Cambridge, and their adjoining communities had already accumulated a favorable concentration of young engineering professionals who enjoyed the area's education-rich

92. For more on how on Stratton, Loomis, Hill, and Wiesner and their key roles in shaping MIT's political and institutional development both during and after the war, see David Kaiser, ed., *Becoming MIT: Moments of Decision* (Cambridge: MIT Press, 2010); Leslie, *The Cold War and American Science*; Redmond and Smith, *From Whirlwind to MITRE*; and Dorothy Nelkin, *The University and Military Research: Moral Politics at M.I.T.* (Ithaca: Cornell University Press, 1972).

93. Report of the Ad Hoc Board on the Air Force Cambridge Research Laboratories, August 4, 1949, Papers of Albert Gordon Hill, MIT, MC.0365, series 2, box 28, folder 4, 2, 4.

environment, and its comfortable living, too much to consider uprooting their growing families purely out of loyalty to the federal government—especially not when private industry was bursting with better opportunities in terms of salary and suburban repose. Taking advantage of the rather artificial distinction between "research" and "development," the final report countered that "several projects that at first glance might appear to be development are in fact essential parts of the complete research program" of Marchetti's Radio Physics Directorate, "a well-organized, well-knit group of laboratories whose functions are closely interrelated...[and] conducting first-class, imaginative research."[94] The relationship between volumetric radar, digital relay, and IFF transponders received special praise as an example of the directorate's integrated program, because "the rate at which these volumetric radars generate information is so great that human operators would have extreme difficulty in handling the data without the assistance of automatic equipment," though the review presented no evidence that the engineering teams were genuinely working together.[95]

A lengthy appendix to the six-page report showed that Hill and Wiesner performed most of the actual investigation of AFCRL, interviewing the staff, observing work in the laboratories, and comparing its activities with their rational ideal. The two claimed that "no criticism by the military of the civilian-controlled operations was heard" but guessed that "a principle complaint of the military would probably be that the civilian hierarchy is never satisfied and is always complaining about administrative procedures." Indeed, the majority of their contribution had been just that: a ledger of remonstrations against the constraints imposed on the laboratory staff by technically under-qualified yet overly

94. With the separation of ARDC from AMC, the contestable point at which "research" ended and "development" began became a problem of organizational jurisdiction as well, especially since AMC controlled a far greater number of engineering funds than did ARDC. The problem of divided responsibility contributed to the creation of the first "joint project offices," which combined representation from the two agencies, with working-level agreements about handing off duties from one to the other. Converse, *Rearming for the Cold War*, 235–247, 472–479; Johnson, *United States Air Force and the Culture of Innovation*, 46–54.

95. A. G. Hill and J. B. Wiesner, "A Report to the Stratton Board by a Fact-Finding Group, Composed of Dr. A. G. Hill and Professor J. B. Wiesner, Based on Observations Made at the Air Force Cambridge Research Laboratories during the Period from 1 July to 29 July, 1949," n.d., 3, in Report of the Ad Hoc Board on AFCRL, August 4, 1949, MIT.

regulations-minded military administrators. "This lack of satisfaction is indicative of a virile and forceful group of research workers," asserted Hill and Wiesner, wary of the lab's (likely earned) reputation for obstreperousness.[96]

Unsurprisingly, the board ultimately recommended that "plans for movement of the Radio Physics portion of Air Force Cambridge Research Laboratories to Griffiss Air Force Base be definitively canceled" under the assumption that a similarly talented group of civilian scientists and engineers could not be assembled elsewhere.[97] About the Geophysics Directorate, on the other hand, the Stratton group said nothing, and even implied it could be a potential target for cutbacks if the Air Materiel Command remained concerned about the cost of operating both the Rome and Cambridge labs concurrently. But its characterization of uninhibited science as rationally efficient recalled the Rad Lab's own narrative for its self-motivated successes and revived the apprehension surrounding the establishment of the Cambridge Field Station in 1945.

The overwhelming difference between the two situations, however, was that the loss of the war's urgency and, more importantly, its concomitant *largesse* accompanied a re-assertion of regular bureaucratic controls. What the Cambridge lobby sought most of all was normalization of OSRD's wartime practice, in which civilians partnered with military officials, on at least equal terms, in a state of total mobilization. A loose network formed around the Air Force's electronics program during the years 1949–1950 capable of promoting and eventually implementing this ideal, though it still required the outbreak of the Korean War to unleash the lavish spending needed to sufficiently loosen the restraints.[98] When the

96. Hill and Wiesner, "Report to the Stratton Board," 2, in Report of the Ad Hoc Board on AFCRL, August 4, 1949, MIT.

97. Report of the Ad Hoc Board on AFCRL, August 4, 1949, MIT, 5.

98. Probably as a result of the coincidence between the outbreak of the Korean War in June 1950 and the establishment of ARDC three months later, United States Department of the Air Force, Air Staff, Director of Statistical Services, Deputy Chief of Staff, Comptroller, *United States Air Force Statistical Digest, Fiscal Year 1951*, 6th ed. (Washington: Headquarters, United States Air Force, November 18, 1952), https://media.defense.gov/2011/Apr/05/2001329929/-1/-1/0/AFD-110405-028.pdf was the first such digest to specifically break out facts about the service's research-and-development program. United States Department of the Air Force, Air Staff, Director of Statistical Services, Deputy Chief of Staff, Comptroller, *United States Air Force Statistical*

floodgates finally opened, civilians had already dug a channel between the Chief Scientist and Scientific Advisory Board, the Office of the Secretary of the Air Force, the Air Force Cambridge Research Laboratories, and the Massachusetts Institute of Technology that was deep enough to shunt a significant volume of resources away from the dams and levies at Wright–Patterson and into the pools of science in the public interest.[99]

While all the military departments experienced similar shifts during the same period, the United States Air Force, by far the youngest of the three armed forces, possessed the weakest legacy of technological development, and therefore, the most flexible. Likewise, agencies throughout the federal government funded projects related to radio, communications electronics, and digital computing, but the Air Force's para-organization for air-defense electronics, which short-circuited the formal structures for research into general electronics, resulted from an accident of personalities.

The Navy, for instance, had been just an active participant as the Army Air Forces in the activities of Division 14 and similarly eager to retain the services of civilian scientists and outside experts, as had the military establishment as a whole.[100] Although they too accumulated their own lobbies clustered around persons, places, and research programs, the tight connection between the Air Force, ground electronics, and scientific–technical

Digest, Fiscal Year 1953, 8th ed. (Washington: Headquarters, United States Air Force, October 1954), table 150, https://media.defense.gov/2011/Apr/05/2001329929/-1/-1/0/AFD-110405-030.pdf , showed the R&D budget increasing 125% between 1950 and 1953—from $232 million to $525 million—up from its postwar low of $145 million in 1948. For perspective, however, the Air Force spent $16.8 *billion* on procurement, property, maintenance, operations, and personnel during the same cycle, so science and engineering remained a relatively minor fiscal consideration compared to cost of mobilization—a mere 3% of annual spending.

99. The Air Force calculated that granting OSRD's former leadership greater influence over its internal research administration would dissuade them from agitating for the reestablishment of an external, civilian-controlled research agency along the lines of OSRD: memo, Lt. Gen. K. B. Wolfe, Deputy Chief of Staff, Materiel, "Emergency Mobilization of Scientists and Engineers for Air Force Research and Development," February 19, 1951, exhibit 5 in Kent C. Redmond and Harry C. Jordan, *Air Defense Management, 1950–1960: The Air Defense Systems Integration Division*, ARDC Historical Publication 61-31-II, vol. 2, pt. A, Supporting Documents 1–44 (Bedford, MA: Historical Branch, Office of Information, Air Force Command and Control Development Division, February 1961), AFHRA (0485178).

100. Recall the note about "systems thinking" at the beginning of this section; particularly the reference to Lassman, *Sources of Weapon Systems Innovation in the Department of Defense*, an excellent bibliographic resource as well.

institutions in the Boston area resulted from the actions and interactions of specific individuals. Consequently, a certain category of civilian expert was poised to exert unusual influence over the Air Force's technology program with respect to issues related to ground radar and air defense, almost to the exclusion of centers of bureaucratic authority that continued to function more normally in other domains, such as the procurement of jet-propulsion systems within the Air Material Command, to name one example.

It is within this context that the work of ADSEC, the Air Defense Systems Engineering Committee, needs to be understood. ADSEC's final report, as already explicated, actually demonstrated very little in terms of "systems engineering," as the admittedly imprecise term would be commonly understood. The document expressed a relatively cursory view of air-defense operations through an unfocused and strangely metaphysical meditation on the nature of system. It supported its unclear or undistinguished conclusions with only a handful of stray observations and back-of-the-envelope calculations.

And yet the study engaged a propitious set of experts at an especially tenuous moment in the history of the administration of science and technology in the federal government, with higher authority ineffectual and the Air Force's attention essentially captive. George Valley, formerly of Division 14, a member of the faculty at MIT, and a technical director in the RLE, assumed the chairmanship as an extension of his role on the SAB's Electronics Panel. John Marchetti from AFCRL also sat with the committee, as well as three other professors from MIT, including Charles Stark Draper and H. Guyford Stever. In short, ADSEC was well situated for assimilation into a rational narrative about the revitalization of a hybrid public–private research initiative with the urgency of wartime mobilization, like the Radiation Laboratory that preceded it.

To appreciate this significance chronologically, General Fairchild ordered its creation under the auspices of the Scientific Advisory Board shortly following the first Soviet atomic test and General Vandenberg's subsequent memorandum, JCS 2048, on November 16, 1949: four months after the Stratton committee helped cement the place of AFCRL; and two months after the Ridenour committee inspired a sweeping reorganization of Air Force R&D, but approximately two years before its recommendations came into effect. Acting through Ridenour, it was actually Valley himself who had drafted the letter, ultimately signed by Vandenberg, that had argued the necessity of a group like ADSEC.[101]

The final report, dated October 24, 1950, arrived near the peak of the fighting on the Korean Peninsula, just as MacArthur's forces pushed north of the 38th parallel prior to China's intervention across the Yalu River. Congress and the Truman administration were then in the midst of remobilizing the armed forces and the nation's war economy on a "partial" basis that was only partial with respect to the totality of World War II.[102] Money, manpower, and moral sanction were all multiplying rapidly with respect to the period from September 1945 to June 1950, when the United States military fed from a budget too lean to match its ravenous ambitions. For the first time since the previous war had ended, the government's resources became plentiful enough for researchers to openly claim, especially without a sufficiently mature administration in place to evaluate them.

This lingering point leads to perhaps the single most significant contingency in the development of automated air-defense. Since the Air Force Scientific Advisory Board, like the Research and Development Board, possessed no authority to issue contracts and no staff to administer them, some other body would have to be seconded for the purpose of managing ADSEC. The task in this case was trivial, limited essentially to paying out travel and *per diem* expenses for a seven-person committee that met periodically over the course of a few months. Since nearly the entire membership lived and worked in the Boston area,

101. While the story of ADSEC is common, most sources refer back to passages in Redmond and Smith, *From Whirlwind to MITRE*, 21–29 or its previous iterations: Redmond and Smith, *Project Whirlwind*, 168–178 and Kent C. Redmond and Thomas M. Smith, *Project Whirlwind: A Case Study in Contemporary Technology* (Bedford, MA: MITRE Corporation, November 1975), 10.1–10.16, Internet Archive, Bitsavers Collection, https://archive.org/details/bitsavers_mitwhirlwirlwindACaseHistoryInContemporaryTechnolo_14582082 .

102. In response to what was then being called "the Korean situation," President Truman announced on July 19, 1950 a "partial mobilization" of the national economy, selectively invoking some of the presidential war-powers still on the books after World War II. For a narrative bibliography on the topic, see Terrence J. Gough, *U.S. Army Mobilization and Logistics in the Korean War: A Research Approach*, CMH Pub 70-19 (Washington: US Army Center of Military History, 1987).

the responsibility naturally fell on AFCRL.[103]

There is no indication that this provision amounted to anything greater than a self-evident convenience; as an official activity of AFCRL, for instance, ADSEC could make use of its facilities for meeting space and other uses. However, the committee considered itself merely the first phase of an as-yet undefined effort to completely map out the continental defense system of the future. Subsequent phases would all follow the same precedent of using the Cambridge lab as the Air Force's *de facto* contract manager, despite that the fact that as a research center, and not a procurement agency, it lacked the capability to effectively monitor the increasingly large sums funneled into Project CHARLES, and more importantly, Project LINCOLN.

The effects of this bureaucratic quirk would be profound, because in essence, one of the largest military programs in United States history began and, for several years, continued without significant guidance and oversight from an office capable of coordinating effectively with stakeholders beyond the community immediately involved. To an extent, this outcome was desired; both the military and civilian officials involved intended to launch a crash program, free of regular interferences, along the lines of the Manhattan Project. What they did not anticipate, however, was the confusion, obstinacy, and incongruity that would prevail once their own effort accelerated to the point where it could no longer avoid colliding with other continental-defense initiated across the entire federal government—and even within the Air Force itself.[104]

103. The problem of contracting the entirety of Lincoln's activities through AFCRL will be documented properly in the next chapter. However, an annotation on the cover sheet to ADSEC Final Report, Internet Archive identifies it as the contracting authority for special air-defense work, even at this early stage.

104. A sensitivity to subtext is unnecessary to derive this point even from the Redmond–Smith narrative; it is entirely evident even from their selection of topics of sources. Nevertheless, they tend to treat compounding managerial crises as a succession of thoroughly tractable "growing pains," each one surmounted by the steady application of rational pragmatism. In arguing that the automated air-defense program remained fragile even after the famous showdown between MIT and the University of Michigan, the following chapter will present the evidence for reconsidering their interpretation.

4 Building the continental-defense network

Despite some overlap among the key figures involved—most notably, Gordon P. Saville—at the working level, air-defense professionals did not express much of a stake in the reorganization of Air Force R&D. Their priorities lay elsewhere; namely, in the deployment of the LASHUP network and subsequent changeover to the Permanent System. Despite its title, officials understood that even the "permanent system" was never intended to be immutable, but rather, subjected to continuous incremental change, as Saville himself had argued in 1947. True to the original concept, its radio- and communications-electronics were, in fact, augmented and upgraded, and its network expanded, throughout the next decade. Moreover, radically new air-defense weapons, such as the F-102 Delta Dagger and the Army's Nike Ajax surface-to-air missile entered operational service—not without difficulties, of course, but ones surmountable through the maturation of existing technology, rather than uncertain explorations into the limits of possibility.[105]

Improving the performance of ground control, on the other hand, proved far more problematic than merely improving its equipment, because unlike modernization programs for radar sets or fighter aircraft, changing equipment changed the environment, changing the environment changed the performance, and changing performance changed the organization. By way of contrast, ADC–ConAC had already managed multiple successive disruptions to its flying capabilities, advancing from a small contingent of war-surplus

105. As is generally the case throughout this dissertation, simple facts about America's postwar air-defenses, when merely mentioned in passing, can be assumed to be supported by Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* (Washington: Office of Air Force History, 1991); *History of Strategic Air and Ballistic Missile Defense*, 2 vols. (1972; repr., Washington: US Army Center of Military History, 2009); or C. L. Grant, *The Development of Continental Air Defense to 1 September 1954*, USAF Historical Study No. 126 (Maxwell AFB, AL: Historical Studies Division, Air University, October 1954), AFHRA (0467710). Specifically with respect to programs such as the F-102 interceptor and the Nike family of surface-to-air missiles, more recondite sources such as Richard F. McMullen, *History of Air Defense Weapons, 1946–1962*, ADC Historical Study No. 14 (Ent AFB, CO: Historical Division, Headquarters, Air Defense Command, 1962), redacted copy provided by Command History Office, US Northern Command, Peterson AFB, CO and Mary T. Cagle, *Development, Production, and Deployment of the Nike Ajax Guided Missile System, 1945–1959* (Redstone Arsenal, AL: Office of the Chief of Ordnance, Army Rocket and Guided Missile Command, June 30, 1959), declassified copy provided by History Office, Army Aviation and Missile Command, Redstone Arsenal, AL provide an abundance of information that would be excessive to detail here but could be usefully interrogated in other contexts.

"prop jobs" through several generations of jet fighters in a single decade. In these cases, transitory disturbances could be contained, mainly to the squadron, but any proposition that fundamentally altered the way ground controllers performed their duties immediately ramified to an entire region, and then from region to adjoining regions, until it implicated the whole air-defense plan for the continental United States.[106]

By 1952, the Air Defense Command realized that essential questions about its field organization—how to divide the country into sectors, where to fix their boundaries, and so on—hinged on as yet unanswered questions about automatic control. Officials looked on Cambridge with perplexity; while Project LINCOLN had already impressed several elementary demonstrations of its technology, nothing about LINCOLN appeared certain or regular. Its charter essentially circumvented the Air Force's administration, rendering the project's goals and progress unintelligible to air-defense officials. Rather, they relied on their established relationship with Watson Laboratories, which had since moved and restructured to form the Rome Air Development Center. Although Rome's technology program had serious issues of its own, the Cambridge lobby remained active in promoting Project LINCOLN and vigilant in dispelling the skepticism that drove military officers elsewhere for clarity.

The third Air Defense Command

By this point in time, the 44 stations in the LASHUP network, which had been figuratively "lashed up" from war-surplus equipment, was essentially complete. The final LASHUP site, L-50, located near Limestone, Maine, passed its calibration check in February 1951, the same month that P-1, the first station in the so-called Permanent System came online at McChord Air Force Base in Tacoma, Washington. The two networks operated in parallel for a brief period as the 75-station Permanent System phased into service in three stages between 1951 and 1953, with the last of the LASHUP sites deactivated in the summer of 1952.

106. *Air Defense Command Semi-Annual Historical Report, 1 January–30 June 1953* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, February 24, 1954), vol. 1, Narrative, AFHRA (0500343), 1–14. This will be treated more thoroughly in a later section.

In 29 cases, production delays required transferring an old LASHUP set from its temporary location to a nearby permanent one, giving brief life to a third network, the hybrid LASHUP–Permanent, or "LP" system.[107]

Before the end of 1953, though, a modernized search-radar had been installed at all 75 of the more deliberately selected sites in the Permanent System. The two primary sets in use were the S-band General Electric AN/CPS-6B, a substantial improvement over the AN/CPS-6 originally designed in collaboration between Bell Labs and the MIT Radiation Laboratory, and the Bendix AN/FPS-3, an L-band radiator-detector like the AN/CPS-5. Some sites still relied on war-vintage height-finding equipment for several years after their initial activation, but subsequent improvement programs gradually replaced these throughout the 1950s.[108]

The AN/FPS-3 likewise gave rise an entire family of variations with additional capabilities, such as Moving Target Indication, which reduced the effect of ground clutter, enhanced gain, and resistance to electronic countermeasures. Derivatives of the AN/FPS-3, particularly the higher-power FPS-7 and FPS-20 series, comprised the backbone of America's air-surveillance network until the end of the Cold War, and indeed, beyond it. A number of sites originally occupied by the Permanent System remain active today—some of them still operating their legacy radar equipment—although the Air Force has long since relinquished primary control to the Federal Aviation Administration.[109]

A parallel effort to build a permanent network of about 20 AC&W stations in territorial Alaska commenced during the same period of time, though this fell within the jurisdiction of the Alaskan Air Command, rather than the Air Defense Command. Likewise, a "seaward

107. Grant, *Development of Continental Air Defense*, AFHRA, 37–44.

108. *ADC Historical Report, 1 Jan–30 Jun 1953*, vol. 1, Narrative, AFHRA, 15–48.

109. Radar sites carried over from the military network were incorporated into the Joint Surveillance System, which has been administered by the FAA and the USAF since 1983. Control of civil and military aviation in Canada is also coordinated through NORAD, and a vestige of early-warning lines constructed during the 1950s still exists in the form of the North Warning System. Cf. Arthur Charo, *Continental Air Defense: A Neglected Dimension of Strategic Defense*, Belfer Center for Science and International Affairs, Occasional Paper No. 7 (Lanham, MD: University Press of America, 1990).

extension" of radar coverage into the Canadian maritimes, and even into Greenland, came together under the auspices of the Northeast Air Command. More notably, radar pickets advanced northward in three rows of continent-spanning electronic fences, culminating in the Distant Early Warning line, completed in 1957, with the cooperation of the Canadian, Danish, and Icelandic governments. Various schemes to deploy early-warning radar aboard aircraft, naval vessels, and even offshore platforms continued apace throughout the 1950s, but the core system of 75 AC&W stations within the continental United States remained the presumed battlefield for a defensive air-war with the Soviet Union.[110]

Obviously, the Air Force had had to abandon its early postwar designs on a comprehensive "radar fence," settling for what it instead called the "double-perimeter concept," a plan to surround the nation's major industrial centers in concentric rings of air-surveillance and control. In 1953, the first of three phases of "mobile" expansion began in order to supplement the Permanent System with over a hundred "gap-filling" radar stations. The term is somewhat of a misnomer, since the sites themselves were not mobile, but rather, equipped with modified detectors, which could be trucked in and set up without the heavy construction needed to emplace a long-range search radar like the AN/FPS-20. Stations established under the gap-filler program, which peaked in 1960 at 131 sites, operated at lower power in order to cover low-altitude blind spots in the search pattern, usually caused by terrain, and utilized only a relative handful of on-site personnel to relay scope readings to the nearest GCI. The Air Force expected it should eventually become possible to run them completely unattended.[111]

110. Thomas A. Sturm, *Air Defense of Alaska, 1940–1957,* CONAD Historical Reference Paper No. 2 (Ent AFB, CO: Directorate of Command History, Headquarters, Continental Air Defense Command, April 17, 1957), redacted copy provided by Command History Office, US Northern Command, Peterson AFB, CO; Lydus H. Buss, *Seaward Extension of Radar, 1946-1956,* CONAD/ADC Historical Study No. 10 (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, December 31, 1955), OCLC (31413851); Lydus H. Buss, *U.S. Air Defense in the Northeast, 1940–1957,* CONAD Historical Reference Paper No. 1 (Ent AFB, CO: Directorate of Command History, Headquarters, Continental Air Defense Command, April 1, 1957), redacted copy provided by Command History Office, US Northern Command, Peterson AFB, CO.

111. As mentioned previously, David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, IL: U.S. Army Construction Engineering Research Laboratories, November 1997) conveniently catalogues the continental military-radar infrastructure, with some facts about

It must be emphasized that the Air Force's defensive radar program had been conceived in the late forties, and proceeded through subsequent revisions, with long-range plans only guessing at how it would all fit together. Though beset with delays and budget issues, the manufacturing of the equipment itself, as well as the siting, construction, testing, training, and staffing of core installations, unfolded more or less as anticipated. Microwave radar had reached a state of relative maturity by 1949, and while documents express the clear stress and frustration of meeting the ambitious deployment schedule, the new models produced in the early fifties did not withhold any surprises from air-defense planners. Despite continuing refinements to their design and usage, they performed largely as expected and necessitated no fundamental changes to the overall program.[112]

The same cannot be said, however, for the system's overall method of operation, particularly with respect to communications, identification, information-handling, and display, both within and between air-defense sectors. The deficiencies had been well known and well studied since the war, but the American AC&W was built with only vaguest notions of what kind of technological improvements might ultimately prove feasible—or even more critically, *when*. As has already been demonstrated, military laboratories and government contractors were pursuing a host of possibilities, ranging from comparatively simple television and photo-reproduction gear tested at Watson Laboratories to the ambitious, yet highly uncertain, digital-relay project at AFCRL. In other words, Air Defense officials had to formulate and execute their plans with manifold uncertainties about many of the electronic components they knew would have to be incorporated into the system at some point. Whatever form of automation ultimately emerged, it could only be adapted to the AC&W network after its was essentially completed, and not anticipated from the very start.

their equipment and operational record during the mid-to-late twentieth century, though much of the raw information appears to have originated with *Historical Data of the Aerospace Defense Command, 1946–1973*, ADCHO 73-4-12 (Ent AFB, CO: Office of Command History, Headquarters, Aerospace Defense Command, April 1973), AFHRA (1006100), vol. 3, where the table on the gap-filler program, in particular, runs from pp. 47–57.

112. To the other sources cited here that can speak to the program's implementation, add *A Decade of Continental Air Defense, 1946-1956* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, July 1956), OCLC (47005625).

Of course, the phased deployment of the Permanent System and the subsequent gap-filler expansion complicated the distinction between an industrial-procurement and a research-and-development program. Detectors underwent continual modification and reconfiguration as replacement or supplementing equipment rolled off the assembly lines. Likewise, tactical and back-end communications changed constantly as circuits opened, closed, and changed courses or capabilities. The Air Materiel Command still managed the majority of these expansion and improvement programs, even after the separation of the Air Research and Development Command, since they mostly involved purchasing, construction, and industrial engineering.[113] AMC's plan to build up an "Air Force electronics center" at Griffiss Air Force Base continued despite the revolt in Cambridge, which also secured special treatment from Congress. The bill signed in September 1950 that authorized the build-up at Griffiss formally delegated the details of the reorganization to the Secretary of the Air Force, but hearings and reports made clear the relevant committees' intent to exclude AFCRL from consideration.[114]

Nevertheless, by February 1951, Watson Laboratories had finished relocating from Red Bank, New Jersey to its new site at Griffiss, where it constituted the bulk of the new Rome Air Development Center (RADC) after ARDC assumed administration of the Air Force laboratory system in April. The Pentagon, moreover, reestablished the Air Defense Command (ADC) on January 1, 1951 after two years of absorption into the Continental Air

113. Recall the numerous citations to Margaret C. Bagwell and Martin J. Miller, Jr., *Case History of the Aircraft Control and Warning System*, vol. 1, Narrative (Wright–Patterson AFB: Historical Office, Air Materiel Command, February 1952), AFHRA (0474351) and its supporting documents.

114. House Committee on Armed Services, *Full Committee Hearings on S. 3727, to Authorize Certain Construction at Griffiss Air Force Base and for Other Purposes* 81st Cong., 2nd sess., September 18, 1950, CIS (HRG-1950-ASH-0079); Senate Committee on Armed Services, *To Authorize Certain Construction at Griffiss Air Force Base (Watson Laboratories)* 81st Cong., 2nd sess., July 21, 1950, CIS (HRG-1950-ASH-0079). The testimony given at both sets of hearings further corroborates the characterization of the relationship between the Rome and Cambridge labs presented in the next session; the act itself became Pub. L. 81-838, 64 Stat. 1035 (September 26, 1950). Incidentally, the fact that Congress generated an official record of nearly 200 pages for a bill appropriating fewer than $3.1 million—while remaining virtually silent on far greater sums related to the air-defense program—is a prime example of the phenomenon of managerial "bike-shedding" observed in C. Northcote Parkinson, *Parkinson's Law, and Other Studies in Administration* (Boston: Houghton Mifflin, 1957), 24–32.

Command (ConAC), a move intended to refocus air-defense planning in an agency separated from ConAC's burden of remobilizing stateside units for the Korean War. Thereafter, direct supervision of the AC&W program fell to ADC's new headquarters in Colorado Springs, albeit in close collaboration with RADC, the Air Force's main site for the design and test of ground electronics, and AMC, still the prevailing power with respect to procurement, installations, maintenance—and indeed, virtually all large expenditures, with the exception of payroll.[115]

A review circulated at a conference held at Griffiss in July 1950, in the midst of the relocation and reorganization, demonstrated the breadth of active projects at the Rome lab pertaining to air defense, particularly methods for mechanizing the communication and display of radar information. While aware of the digital radar-relay project at AFCRL, engineers at Rome were still experimenting with other techniques, including the promising use of microwave-relay networks to multiplex high-resolution video signals together for conveyance from remote detectors to air-defense control centers. Other open investigations continued earlier attempts to develop equipment for processing various types of signals and generating real-time displays through photographic or similar means, as well as electronic control-consoles for directing interceptions.[116]

While hardly representing a unitary research agenda or a coherent vision for the future of air defense, neither was the demand for one urgent. The notion of "system" applied to the continental AC&W network since its inception stressed the malleability of components, as opposed to fixed facilities, and assumed that changes would be applied incrementally, so as not to unnecessarily disrupt operation. The Rome lab worked closely with officials from both ADC and AMC, as well major industrial firms, hosting a regular conference series with representatives from multiple stakeholders and published the *Air Defense Systems Reports*, a

115. Grant, *Development of Continental Air Defense*, AFHRA, 32–36

116. *Review of the Watson Laboratories' Development Program of Electronic Equipment and Systems for Air Defense* (Red Bank, NJ: 3151st Electronics Group, Air Materiel Command, July 3, 1950), AFHRA (0476910).

biweekly digest of events pertaining to the development of electronic equipment.[117]

Thus, by 1951, two military-industrial-academic complexes had formed around essentially the same task of improving continental defense through electronic automation. One axis ran through MIT/RLE, AFCRL, and the Deputy Chief of Staff, Development via the Chief Scientist and the Office of the Secretary of the Air Force. The second linked the University of Michigan to the Rome Air Development Center and the Air Defense Command. This latter relationship began as an extension of Project BOMARC (named for the Boeing–Michigan Aeronautical Research Center), an academic-industrial collaboration for the design of a long-range, supersonic, surface-to-air missile.

As an aeronautical program, BOMARC itself fell under the purview of the Wright Air Development Center—ARDC's new laboratory at Wright–Patterson Air Force Base—but the problem of developing a suitable ground-based fire-control system raised many of the same concerns as air defense in general: rapidly relaying and displaying information to controllers and computing and directing intercepts automatically, or at least, with mechanized assistance. Consistent with its expertise, RADC received a substantial assignment to assist with BOMARC's ground environment, which brought the engineering staff into contact frequently with personnel from Willow Run. What MIT, and the RLE in particular, provided for AFCRL—an outside source of consulting and bench-top fabrication and experimentation—the University of Michigan's Willow Run Research Center likewise became for RADC.[118]

In fact, as of late 1951, RADC contracts occupied about 50 researchers full-time at the

117. A collection of these digests would most likely be found at the Griffiss base library, if such a collection ever existed at all. Single issues do appear frequently in office records from Air Force headquarters; for instance, *Air Defense Systems Reports* 2 no. 23 (January 20, 1950), enclosure in United States Air Force, Air Staff, "Minutes of the Watson Laboratories Air Defense Systems Group Meeting Held on 16 December 1949," Directorate of Plans and Operations (D/P&O) file no. 373.24 (20 Jan 1950), NARA, RG 341, NM-15 336, box 229.

118. Donald R. McVeigh, *Development of the BOMARC Guided Missile, 1950–1953* (Wright–Paterson AFB, OH: Historical Branch, Office of Information Services, Wright Air Development Center, January 1956), redacted copy provided by staff, AFHRA (0485517); Margaret C. Bagwell, *History of the BOMARC Weapon System, 1953–1957*, AMC Historical Study No. 319, vol. 1, Text (Wright–Patterson AFB: Historical Division, Office of Information Services, Air Materiel Command, February 1959), redacted copy provided by staff; though some information on BOMARC specifically in relation to fire-control systems appeared in McMullen, *History of Air Defense Weapons*.

University of Michigan, which, combined with another 25 at Columbia University, rivaled the number of technicians the laboratory itself employed on projects related to its air-defense program.[119] The Cambridge lab, on the other hand, while better equipped for so-called "basic research" than development engineering, it also remained relatively distant from the Air Force's field organization. In June 1951, it too received a new designation as the Air Force Cambridge Research Center (AFCRC) after AMC turned over its laboratories to ARDC, pursuant to the Ridenour reorganization. Nevertheless, common supervision did not seem to promote organizational clarity with respect to air-defense research. It was recognized as early as September that the tension between Rome and Cambridge had the potential not only to waste money and effort, but to inflame grievances through active interference.

Rome–Cambridge relations: The Getting review

In August 1951, Louis Ridenour relinquished his position as Chief Scientist to a close colleague, David T. Griggs, a geophysicist who had served as one of Henry Stimson's many "special assistants" during the war, an *ad hoc* position in which he fulfilled various assignments for the AAF and OSRD, mostly related to airborne radar equipment. Although Griggs had worked briefly for Project RAND, he soon joined the faculty at UCLA and thus was not a party to the reform of the Air Force's research-and-development organization, nor the air-defense studies emerging from MIT—both significant projects for his predecessor. Almost immediately after taking up his office in the Pentagon, Griggs began expressing his concern over the air-defense problem to military administrators, particularly General Earle E. Partridge, commander of the Air Research and Development and Command.[120]

119. "Air Defense Committee Report, Part I: Summary of Facts and Critiques," 1, attachment to Ivan A. Getting to Lt. Gen. E. E. Partridge, April 4, 1952, Office of the Director of Research and Development (D/R&D) file no. 319 (Air Defense Committee Report), NARA, RG 341, NM-15 160, 1952 series, box 2.

120. Grigg's tenure as Chief Scientist, which lasted from August 1951 to August 1952, is summarized in Day, *Lightning Rod*, 45–59; furthermore, a collegial memoir was published as Ivan A. Getting and John M. Christie, *David Tressell Griggs, 1911–1974*, in *Biographical Memoirs*, vol. 64 (Washington: National Academy of Sciences, 1994), OCLC (45729857). Besides his time at Air Force headquarters, Griggs' most noted political moment came in 1954, when he testified against J. Robert Oppenheimer at his infamous "security hearing": Priscilla J.

It is unclear whether Griggs himself was stymied by the current state of affairs, if he was worried about the possibility of misapprehension between major stakeholders, or both, but after first petitioning General Partridge to host a conference between representatives of the Rome and Cambridge labs—as well as officials from AMC and ADC—the new chief scientist instead moved to commission an outside review, which commenced in October. "At the present time the United States Air Force has a number of agencies and study groups working on Continental United States Air Defense problems," read the investigation's charter. "It would appear that from these development activities there have evolved at least two fundamentally different Air Defense Radar systems," both of them "complex and expensive," as well as "radically different in concept, in circuitry, and in operation." Through General Partridge's office, a committee would be invited to register its opinion on the "most logical evolution of the air defense ground environment" and whether one or both proposals could "fit the evolution either wholly or in part."[121]

Griggs asked Ivan Getting, who had only just left the Air Staff a few months earlier for a vice-presidency at Raytheon, to select and lead the group, officially titled the Ad Hoc Committee on Examination of Air Force Plans for Continental U.S. Air Defense Radar. Getting in turn approached three members of the Scientific Advisory Board; George Metcalf, an engineering director at General Electric, J. C. Street, a Harvard physicist, and Edward J. Barlow of the RAND Corporation, to join him. "It is my strong conviction that any once over followed by the preparation of a report will not be effective," he wrote. Over the past year, officials in Washington had received several voluminous studies on the subject of continental defense, each representing many man-years of labor: Edward Barlow, for instance, directing a such study for RAND, which put 32 of its researchers on the project;

McMillan, *The Ruin of J. Robert Oppenheimer, and the Birth of the Modern Arms Race* (New York: Viking, 2005), 130, 151–152, 219–220.

121. "Examination of Air Force Plans for Continental U.S. Air Defense Radar," attachment to Lt. Col. T. F. Walkowicz, Executive, Office of the Special Assistant to the Chief of Staff to Dr. Ivan A. Getting, Raytheon Manufacturing Company, October 30, 1951, tab 1 of Office of the Chief Scientist file no. 334.7 (Getting Committee), NARA, RG 341, NM-15 10, box 9.

meanwhile, the twenty-seven members of MIT's "Project CHARLES" had only just adjourned in August.[122] So according to Getting, "it would not be the function of my committee to go over this ground for the purpose of of preparing only another report, particularly since such a report could add nothing to those already available." Instead, "we are to make use of these...and other such studies as are available to the Air Force, and...arrive at conclusions and suggestions for positive constructive steps for action which we would recommend to the Commanding General ARDC and the Deputy Chief of Staff, Development."[123]

While seemingly boilerplate, this statement actually reflected considerable intuition on Getting's part: in other words, the accumulation of studies, reports, forecasts, and estimates in Washington, while illuminating the problem, was further confusing the agencies charged with pursuing the possible solutions. "I recognize the danger...of trying to operate a complicated organization like the Air Force from directive from above," he told Partridge, proposing that "in carrying out our mission the committee meet with the necessary elements of ARDC," or namely, the laboratories, "and work out with them in as much detail as necessary an over-all consistent program in the field of AC&W, and in doing this the committee act as a reviewing group providing guidance and coordination." Rather than mere fact-finding, Getting was planning to stage a managerial intervention.

On December 28, Griggs wrote to Getting about a recent meeting with John Russell, an electrical engineer at Columbia University and a member of RADC's council of scientific advisors. Since the council generally approved of the laboratory's program, Russell "wanted to be sure that I was aware of the friction between Rome and Project LINCOLN." To wit, the technical staff perceived the pending review as an inherently biased attempt to extract an

122. An abridged version of the Barlow study—which still exceeded 350 printed pages—was eventually introduced into the gray literature as Project Air Force, *Air Defense Study,* RAND Report R-227 (Abridged) (Santa Monica: RAND Corporation, November 15, 1951), DTIC (ADA41260). MIT distributed the findings of its classic "summer study" in the cumbersome *Problems of Air Defense: Final Report of Project CHARLES*, 3 vols. (Cambridge: Massachusetts Institute of Technology, August 1, 1951), OCLC (2529755), a document that will be examined more closely soon.

123. Ivan A. Getting, Vice President of Engineering and Research, Raytheon Manufacturing Company to Dr. David T. Griggs, Office of the Special Assistant to the Special Assistant to the Chief of Staff, December 21, 1951, tab 4 of USAF Chief Scientist file no. 334.7 (Getting Committee), RG 341.

ostensibly "objective" comparison between Rome and Cambridge, a suspicion evidently confirmed by the presence of Getting, who had been connected to MIT ever since he enrolled as an undergraduate in 1929.[124] Griggs tried to reassure Russell, who "volunteered to do so missionary work at Rome in persuading them that your committee would be impartial and constructive." The Chief Scientist nonetheless encouraged Getting to act quickly in order to dispel the impression that his group was being airlifted in to cover for Project LINCOLN at the expense of Rome's own air-defense program.[125]

Cambridge, for its part, had already signaled its awareness of how badly a strong recommendation in its favor could appear in light of the highly partisan circumstances. While first enticing Getting to accept the job in September, Griggs mentioned that General Donald N. Yates, the Director of Research and Development, would "sound out [George] Valley on the subject" on an official visit to Cambridge. "Valley is being suitably coy," he wrote, "but I'm sure just wants to be free of suspicion of having instigated this coup d'etat." Despite the heavy weight behind ADSEC and its follow-on projects, the possibility remained that their proponents might push too hard.[126]

The report itself, rendered in April 1952, attempted to walk a fine line between the two competing interests, though the result badly wanted for delicateness and finesse. Although the Getting Committee praised the scientific and engineering talent at both Rome and Cambridge, and even considered both their respective air-defense programs worth continuing,

124. Unfortunately, to date the only major account of Getting's life and work is his own: Getting, *All in a Lifetime*. He did grant numerous oral history interviews, including the roundtable discussion recorded in Jacob Neufeld, ed., *Reflections on Research and Development in the United States Air Force: An Interview With General Bernard A. Schriever, and Generals Samuel C. Phillips, Robert T. Marsh, and James H. Doolittle, and Dr. Ivan A. Getting* (Washington: Center for Air Force History, 1993).

125. David T. Griggs to Dr. Ivan A. Getting, Raytheon Manufacturing Company, December 28, 1951, tab 5 of USAF Chief Scientist file no. 334.7 (Getting Committee), RG 341.

126. David T. Griggs, Office of the Special Assistant to the Chief of Staff to Dr. Ivan A. Getting, Vice President of Research and Engineering, Raytheon Manufacturing Company, September 21, 1951, tab 54 of Office of the Chief Scientist file no. 360.1 (Air Defense—General), NARA, RG 341, NM-15 10, box 9. A handwritten annotation on this copy reads, "Dave—pls. discuss with ARDC air defense & electronics people and settle who and how to do this? all SAB, say when & we'll pull the string—W." The note was likely left by Griggs' military assistant, Theodore F. Walkowicz, one of Saville's "young turks," to indicate that other members of the Scientific Advisory Board, on which Valley sat, were also willing to join the low-key charm offensive.

it recommended closing the Rome lab and relocating its personnel to Hanscom Field in Bedford, Massachusetts, where the Air Force had recently begun expanding facilities for Project LINCOLN. On April 4, Getting notified General Partidge of his group's "unanimous conclusion" that the problem "could be best met by a full integration of the two establishments," which was in "no way...to be interpreted as a belittlement of the personnel at either RADC or AFCRC," but "to the contrary," represented "the conviction...that the technical members at both places are of superior quality."[127]

Nevertheless, the committee recognized that Rome and Cambridge suffered from a "particularly unsatisfactory relationship" that "cannot be markedly improved by simple directive measures...The reasons for this lies in the nature of the two organizations," the summary continued. "The RADC was artificially established in its present location essentially on one argument—the existence at Griffiss Air Force Base of a certain amount of real estate." Because the Air Materiel Command operated Griffiss primarily as a depot, "the continued existence of the Development Center there is dependent upon by the retention by that station of an end-item mission," which was to say, a focus on benchtop projects geared for immediate production. Moreover, "the situation is further aggravated by the preponderant warehousing activities...to the extent that there is a continuing encroachment on the activities of the engineering group." Or, in fewer words, "the environment at Rome is not conducive to the build-up of a strong intellectual engineering center."[128]

On that score, the Getting Committee found AFCRC much likelier to succeed, though not without additional support. Although the center's "Radio Physics Laboratory has maintained a vigorous program in spite of not having an end-item mission...the prevention of any true research at Cambridge by lack of adequate personnel and by the restrictions on their mission on components has brought the personnel of AFCRC into a dilemma." The nature of this

127. Ivan A. Getting to Lt. Gen. E. E. Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341.

128. "Air Defense Committee Report: Recommend Administrative Actions Within USAF," 1, attachment to Getting to Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341.

dilemma will be more fully explained shortly, but in brief, AFCRC's already limited resources were being increasingly split between its formal responsibility to the USAF and its informal assistance to MIT. To the committee, "this raises the question whether the Radio Physics section of AFCRC, though in a fine environment, can continue to operate with the artificial restrictions placed upon it."

Therefore, "any analysis of the personnel at Rome at Cambridge will show that to a large extent the engineering personnel are very similar emotionally, temperamentally, and in training...a solution should be sought for the integration of these two establishments in a way which would not aggravate any personal embitterment existing between the people of the two establishments—and which would not jeopardize the cooperation of Project Lincoln with the Air Force." It was on these grounds that Getting recommended that "a new air force development center be established based on the facilities now programmed at Hanscom Air Field" comprised of the conflicting elements of the two centers "as rapidly as possible with such transfer of authorizations and appropriations from the RADC as are legally possible."[129]

The precise language of the report suggests that the review group was as much if not more concerned about the laboratories' morale as their administrative efficiency. Indeed, stabilizing the relationship between RADC and AFCRC was probably just incidental to the committee's implicit goal of reassuring MIT about its air-defense contract. To start, the cover letter attached with the report included a two-page statement Getting had designed to address the "considerable confusion within the Air Force on the role of Project Lincoln in the overall development set-up," in which "sight is continually being lost of the fact that Project Lincoln was established by the top levels of the Air Force with the express purpose of bringing to bear on the problem of Air Defenses...technical talent *not otherwise* available."[130]

While acknowledging that "the responsibility for Air Defense...must remain in its

129. "Air Defense Committee Report: Recommend Administrative Actions Within USAF," 2, attachment to Getting to Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341.

130. Getting to Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341, emphasis in original.

normal channels," Getting simultaneously offered the incongruous assertion that "it must be recognized that Project Lincoln is a responsible organization on which the Air Force can place a high degree of reliance," in spite, or even *because* of its affront to these "normal channels," which he seemed to admire. "Too often it is remarked by Air Force officers, 'The Air Force cannot count on Project Lincoln because we cannot tell them what to do.' This attitude must be dispelled," specifically by circulating Getting's statement, which merely paraphrased the official charter.[131]

Perhaps the chief reason for handling MIT's concerns with such tenderness was the fact that "the number of professional people generally available within Project Lincoln is equal to that roughly of the entire remaining effort in the Air Force"—"a very capable staff," in Getting's opinion, which "could not become available to the Air Force in any other type of organization":

> Because of the lack of red tape and other restrictions which are necessary to operations within establishments of the Government, and because Project Lincoln contains within itself to a large degree the necessary intellectual capacity to do an integrated effort, it is anticipated that the Lincoln project will be extremely productive as regards both quality and time.[132]

Effectively, the committee was arguing that MIT already had the capability to solve the "integration" problem, and thus, it should be granted the administrative forbearance necessary to accomplish the task itself, with apparently little regard for where the legal responsibility for air-defense planning ultimately lay.

In fact, the only "critique" the report saw fit to level on Project LINCOLN was a cursory admission that "it does represent somewhat of a free wheeling operation," so "it will be necessary from time to time to get definite fixes on the program," though how this should be accomplished, or what to do if the program's direction wandered, or its progress faltered, remained unspecified. The outcome seemed all but certain, though, because "it is clear that

131. Getting to Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341.

132. "Air Defense Committee Report, Part I: Summary of Facts and Critiques," 13–14, attachment to Getting to Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341.

a large amount of the thinking, which in the RADC is in the future and therefore somewhat vague, has already taken concrete form at Lincoln." Whatever issues still lingered between RADC and AFCRC should be resolved with an eye toward supporting the program at MIT, or at the very least, retaining its cooperation, which could not yet be taken for granted.[133]

There is no evidence that the Air Force took any action on the committee's recommendations. Although Getting reported directly to General Partridge, the arrangement was motivated only by administrative convenience; Griggs had always intended to target the review for Washington as much as Baltimore. Whatever discussion may have taken place at ARDC headquarters, however, no further correspondence regarding the Getting Committee appears in the records kept by the offices of the Chief Scientist or the Deputy Chief of Staff, Development.[134]

On the other hand, it is quite likely that the group's suggestion of consolidating RADC and AFCRC at Hanscom Field was quickly dismissed as specious. In addition for calling for the exact reverse of a scenario still contemplated as recently as 1951—relocating the Cambridge lab to Rome—the facility at Griffiss had been established by legislation that could not easily be changed. The idea carried a certain rationalist appeal, but it neglected political and bureaucratic reality, and to the extent that the report circulated at all, its findings would have reinforced the impression, which it well noted, that a band of civilian dilettantes wanted more from the Air Force than just a research contract, but leverage over policy and planning as well.

133. "Air Defense Committee Report, Part I: Summary of Facts and Critiques," 14, attachment to Getting to Partridge, April 4, 1952, D/R&D file no. 319 (Air Defense Committee Report), RG 341.

134. Most of the correspondence was compiled, with some duplication, in USAF Chief Scientist file no. 334.7 (Getting Committee), RG 341; USAF Chief Scientist file no. 360.1 (Air Defense—General), RG 341; and D/R&D file no. 319 (Air Defense Committee Report), RG 341.

5 Conclusion: Selling command-and-control

Tensions escalated over the following year as scientists involved Project LINCOLN were suspected of leaking overly optimistic prognostications about the future of air defense to the press in order to pressure the Air Force to adopt the conclusion of several other studies MIT conducted in 1952.[135] (One leak was eventually traced back to Lloyd V. Berkner, who had apparently disclosed too much while drinking casually with colleagues in England.)[136] Rumors of the so-called "ZORC conspiracy"—supposedly the secret effort of Jerrold Zaccharias, Robert Oppenheimer, I. I. Rabi, and Charles Lauritsen to discredit the Air Force, and the hydrogen-bomb project more generally, by proposing an alternative based on atomic defense—aggravated officials already sweating under the McCarthyist fever.[137]

In a private letter dated December 14, 1953, General Thomas D. White, Vice Chief of Staff, grumbled to the now-retired general Ennis C. Whitehead that "the Maginot Line boys from MIT" had effectively sold the public on a problematic "Great Wall of China concept" at the expense of other programs.[138] Years later, Gordon P. Saville, who had himself retired

135. Richard F. McMullen, *Air Defense and National Policy, 1951–1957*, ADC Historical Study No. 24 (Ent AFB, CO: Headquarters, Air Defense Command, 1964), OCLC (47033171); Schaffel, *The Emerging Shield*, 172–191; Allan A. Needell, *Science, Cold War and the American State: Lloyd V. Berkner and the Balance of Professional Ideals* (2000; repr., London: Routledge, 2012), 223–257. The act that truly enraged the Air Force leadership was the publication of Lapp and Alsop, "We Can Smash the Red A-Bombers", which it viewed as an illegal disclosure of classified information, as well as a violation of the standard press practices at the time, wherein major media outlets acted as a "voluntary propagandists," allowing government agencies to control the coverage of their own affairs for reasons both ideological and opportunistic: cf. Nancy E. Bernhard, *U.S. Television News and Cold War Propaganda, 1947–1960* (Cambridge: Cambridge University Press, 1999).

136. Maj. Gen. Joseph F. Carroll, Deputy Inspector General, United States Air Force, "Lincoln Summer Study Group," Air Staff Summary Sheet, October 8, 1953, enclosed in Office of the Secretary of the Air Force (OSAF) file no. 000.8 Massachusetts Institute of Technology (7 Dec 1950), vol. 4, NARA, RG 340, A1 1-B, box 1391. The Air Force blamed Berkner for the Alsop article and raised the possibility of terminating his clearance, though this action was never taken, instead leveraging it against a larger but more vulnerable target (see below).

137. The fires were stoked by "The Hidden Struggle for the H-Bomb," *Forbes*, May 1953, EBSCO (112397680), a spurious article engineered by Colonel Theodore Wolkowicz, whose name appears in prior footnotes as the military assistant to Louis Ridenour and David Griggs in the Office of the Chief Scientist, a positioned he retained for some time afterward, despite the fact that the Air Staff declined to replace Griggs for over a year. The disinformation was probably intended as retaliation for the Alsop piece and accelerated the push to revoke Oppenheimer's security clearance; Griggs himself testified to the existence of a "ZORC conspiracy," though without corroboration: McMillan, *The Ruin of J. Robert Oppenheimer*, 163, 219–220.

138. Quoted in Schaffel, *The Emerging Shield*, 179.

in mid-1951 after most recently serving as DCS/D, later recalled the time "after I got out of the business when the air defense of the United States was basically determined by MIT." Though certainly hyperbolic, and more than a little astringent, Saville's remarks did speak to the singularity of the historical moment, when even the Air Force's senior-most leaders felt constrained by a contract whose political stakes had been elevated to a degree grossly disproportionate to its dollar value.[139]

If they sensed that the Cambridge lobby was already moving to corner the issue, however, it was an outcome for which the Air Force itself bore primary responsibility. Since the late forties, USAF officials had leveraged expert legitimacy as much as public support in its push for favorable budgetary actions. In doing so, it had also raised the stakes to impossibly high levels. For instance, a remarkable feature of JCS 2048, Chief of Staff Vandenberg's response to the Soviet atomic test, was its observation that nuclear weapons could be used not only as weapons of nation-killing, but of *state*-killing.[140]

The total consequences of Vandenberg's proposition would not be examined more fully for another decade, when ballistic missiles rendered the possibility of destruction as instantaneous as it was absolute. It was nonetheless recognized from the moment the United States first confronted a nuclear-armed adversary that to defend the nation, which is to say, the lives of its citizens, is also to defend the state, an idealized instrument of order and reason. In 1960, it had become possible to calculate that just nine ICBMs, directed against four key targets in the Chesapeake region, would almost certainly terminate the political existence of the United States.[141]

139. Interview, Maj. Gen. Gordon P. Saville, United States Air Force (Retired), with Thomas A. Sturm, Office of Air Force History, Sun City, AZ, August 27, 1988, AFHRA (1085564).

140. This grim reality is especially clear from the work of Paul Bracken, who wrote that "nuclear weapons are not like other weapons, because no other weapons can precipitously attack the institutions of law and government that define the modern nation state." Paul Bracken, "Delegation of Nuclear Command Authority," in *Managing Nuclear Operations,* ed. Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket (Washington: Brookings Institution, 1987), 353.

141. Multiple extended passages were reproduced verbatim in L. Wainstein et al., *The Evolution of U.S. Strategic Command and Control and Warning, 1945–1972,* IDA Study S-467 (Alexandria, VA: Institute for Defense Analyses, International and Social Studies Division, June 1975), declassified copy, 239–248, DTIC (ADA331702); but see

ADSEC had not been so explicit, but it did further extend the theme, already well developed by that point in time, that preserving "human judgment"—the rational legitimacy of the state—needed to protected and amplified through radical technology. In contradiction, however, it also supposed that such "revolutionary" ends could be achieved by purely "evolutionary" means: to sink the ship, but without rocking the boat. This conceptual rivalry, the revolutionary against the evolutionary, basically encapsulates the entire dialectic concerning automated air-defense as it developed into nuclear command-and-control.[142]

also John Ponturo, *Analytical Support for the Joint Chiefs of Staff: The WSEG Experience, 1948–1976*, IDA Study S-507 (Alexandria, VA: Institute for Defense Analyses, International and Social Studies Division, July 1979), declassified copy, 129–151, DTIC (ADA090946) for the context of the report, which motivated a long-term study contract on the topic of nuclear command-and-control between the Weapons Systems Evaluation Group, acting on behalf of the Office of the Secretary of Defense, and the Institute for Defense Analyses.

142. David E. Pearson, *The World Wide Military Command and Control System: Evolution and Effectiveness* (Maxwell AFB, AL: Air University Press, 2000), 343–358 identifies the same tension, though the author's framework of "evolutionary" and "revolutionary" forms of organizational technology varies considerably from the one presented here.

Chapter 6

Crisis in Command

Computer Automation and the Maximization of Choice

> Missiles and satellites, moving at almost incomprehensible velocities, have provoked a "crisis in command" with which we cannot begin to cope save electronically. There was, and is, much still to be done in the missile and satellite fields, but it is now fair to say that electronics has become the key to our current technological situation and that our military future depends on our learning, in time, the conceptual and organizational lessons that the computer would teach.[1]
>
> Howard R. Murphy, Electronic Systems Division, 1966

For three gloomy days in October 1960, nearly 300 distinguished representatives of science, government, and industry convened at a small New England airfield. The assembly welcomed experts from across the spectrum of technical-scientific specialties, together with Pentagon heavyweights in suit and uniform alike. A conspicuous number of acting field commanders also joined the usual military-industrial elite, including officers from SAC, NORAD, PACOM, and even NATO. The occasion was the 28th semiannual general meeting of the Air Force Scientific Advisory Board, which, according to custom, called for discussion of an issue of special concern to the Air Force of the future.[2] Recent general meetings

1. Howard R. Murphy, *Prologue to the Hanscom Complex,* vol. 1 of *History of the Air Force Command and Control Development Division,* AFSC Historical Publication 64-32-I (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485180), 29.

2. The printed proceedings included a list of attendees as well as an agenda: United States Department of the Air Force, Scientific Advisory Board, *Report of the Scientific Advisory Board Meeting at L. G. Hanscom Field,*

had mostly revisited the staple themes of postwar research and development: propulsion, guidance, technology management, and so on. This meeting would be the first of its kind, a source of anticipation in its own right.[3]

That fall, the Air Defense Command would activate the eighteenth of 36 installations scheduled for the Semiautomatic Ground Environment. Barely ten years removed from the Whirlwind schematics in an MIT laboratory, the AN/FSQ-7 was now mission-critical equipment at the midpoint of its deployment schedule. The feat had the ironic property of exceeding hopes while defeating expectations; whereas ADC had once planned to roll out 46 installations by January 1961, the most recent schedule extended construction until December 1963.[4] The refinement of the long-range ballistic-missile, combined with the imminent, highly competitive presidential election, in which an alleged "missile gap" had emerged as a major issue, threatened even these deflated ambitions.[5] The half-built computer network, as yet unready to repel Russian bombers, was already facing further curtailment amid claims of functional obsolescence. IBM had proposed a transistorized successor as early as 1958, but strategic politics continued to turn against mass air-defenses faster than the military-industrial-academic complex could implement them.[6]

Bedford, Massachusetts, 24–26 October 1960 (Washington: Office of the Chief of Staff, Headquarters, United States Air Force, December 1960), redacted copy provided by staff, AFHRA (0473042).

3. The conduct and intention of these general meetings are characterized in Thomas A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944–1964* (1967; repr., Washington: Air Force History and Museums Program, 1986), 27–28. A list of special topics considered during the postwar period also appears in Appendix H of the same volume.

4. For a brief summary of SAGE's deployment program, see Thomas A. Sturm, *Command and Control for North American Air Defense, 1959–1963* (Washington: USAF Historical Division Liaison Office, January 1965), 10–15, https://media.defense.gov/2016/Apr/22/2001521098/-1/-1/0/AFD-160422-409-002.pdf .

5. Cf. Gary A. Donaldson, *The First Modern Campaign: Kennedy, Nixon, and the Election of 1960* (Lanham, MD: Rowman & Littlefield, 2007).

6. Richard F. McMullen, *Command and Control Planning, 1958–1965*, ADC Historical Study No. 35, vol. 1, Narrative (Ent AFB, CO: Headquarters, Air Defense Command, December 1965), AFHRA (0500706) discusses various schemes for enhancing or otherwise extending the SAGE program, as well as its eventual termination in 1962. While *Sputnik*, the "missile gap," and anti-ballistic missile defense are interrelated topics with an established literature, Richard F. McMullen, *Air Defense and National Policy, 1958–1964*, ADC Historical Study No. 26 (Ent AFB, CO: Headquarters, Air Defense Command, 1964), OCLC (47033168) narrates the concomitant decline of "anti-bomber" air defense as a public issue during the 1960s.

The plight of the SAGE program alone was enough to inspire urgency, but it was alone no longer. The 28th general meeting of the Air Force Scientific Advisory Board would consider the final report of a prestigious study—representing nine months of work by about 150 participants—on 18 subsequent computer-automation projects, most of them initiated within the last two years. Beyond a general inclination toward computerization, however, experts found no greater consistency between them than an arbitrary suffix in their management codes: 425L, the NORAD Combat Operations Center (COC); 438L, the Intelligence Data Handling System (IDHS); 465L, the Strategic Air Command Control System (SACCS); 474L, the Ballistic Missile Early Warning System (BMEWS), to name only a few. To fit the pattern, SAGE itself received a reclassification as Project 416L, an upgrade from its previous enumeration, a mere 216L.[7]

Each of these "Big L" systems, as they were called, applied digital computing technology to vastly different problems that arose in independent organizational contexts. No one could yet definitely say how these state-of-the-art information systems should work together to further national strategic objectives as a whole, nor even how much they would cost. The thirteen-volume report of the Winter Study Group, debuted at the New England meeting, was to be the first collective assessment of the entire Air Force program.[8]

7. The study considered 17 "Big L" systems, which it categorized as *command systems* (of which it counted three), *intelligence systems* (also three), *warning systems* (four), *control systems* (three), and *support systems* (four); moreover, it added two projects that did not fall completely under Air Force management: the Atomic Strike Recording System (codenamed OSR-62) and the Bomb Alarm System (OSR-290). Winter Study Group, *Final Report*, WSR-7, September 16, 1960, in OSAF file no. 165-60 (Winter Study Group, oversize), NARA, RG 340, A1 1-F, box 461, 4–5. Declassified OSAF files also contain about half the panel reports, but another copy of the summary report is located in MIT, MC365, ser. 2, box 49, folder 5. Additional subreports were obtained from the Air Force Electronic Systems Center. Since that agency is now defunct, having been deactivated and absorbed into the Air Force Life Cycle Management Center in 2012, archival holdings will be preferred in all citations.

8. Howard R. Murphy and Charles J. Smith, *Foundation of the Hanscom Complex*, vol. 2 of *History of the Air Force Command and Control Development Division*, AFSC Historical Publication 64-32-II (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485181), 63–68. This two-volume narrative will be relied upon frequently, though not as often as the primary sources collected in its twelve volumes of supporting documents. While curated sources impose obvious limits on their interpretation, it is helpful that, in this case, the curators were exceedingly generous in their selection. Unfortunately, many pages of the copy available at AFHRA are difficult or impossible to read; although higher-quality photocopies were obtained from the Electronic Systems Center, see the note above regarding the general preference for citing archival holdings.

General Curtis LeMay, who then served the Air Force as its Vice Chief of Staff, addressed the convocation first. "Some day in the foreseeable future," he said, "one man may be called upon to make a decision within a few minutes that may change the path of civilization...He may only have seconds if we don't keep pace with the times. Our task is to stretch seconds into long minutes."[9] For the *paterfamilias* of the strategic air-power, apocalypticism was mere routine; LeMay's significance lay rather in his banality.[10]

"Command and control systems," he continued, "must be built to enable the human to command and control the forces...The mechanized processes of data collection, processing, evaluating, transmission and display culminate in one all-important event—the *human decision*." The words echoed many others spoken throughout the three-day conference, which again and again commended the nation's, or even the species' existence to digital electronics. Proper automation could actually magnify the exercise of individual authority, instead of usurping it, rescuing both human life and human agency from the intercontinen-

9. Air Force Scientific Advisory Board, *Report on Proceedings, October 1960*, AFHRA, 9. Although this document summarized, rather than transcribed the proceedings, the author—Peter J. Schenk—transitioned between paraphrase and quotation without clearly signaling the divisions between them. Thus, when citing the proceedings, the speaker will be attributed directly, for convenience as much as clarity.

10. A previous iteration of this dissertation dedicated an entire chapter to LeMay. Briefly, the general's self-fashioning in his notorious retirement memoir, Curtis E. LeMay and MacKinlay Kantor, *Mission With LeMay: My Story* (Garden City, NY: Doubleday, 1965), displayed his skill and commitment in shaping his reputation; indeed, his public persona and America's aggressive posturing during the Cold War (precedented by the merciless air-campaign against the Japanese home islands) are practically merged in such literature as Michael S. Sherry, *The Rise of American Air Power: The Creation of Armageddon* (New Haven: Yale University Press, 1987) and Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb* (New York: Simon & Schuster, 1995)—a linkage he himself seems to have encouraged: Trevor Albertson, "A Strategy for Victory: Curtis LeMay and His Public Relations Machine," *New England Journal of History* 72, no. 2 (Spring 2016): 33–61, EBSCO (115656292); but see also Dan T. Carter, *The Politics of Rage: George Wallace, the Origins of the New Conservatism, and the Transformation of American Politics*, 2nd ed. (Louisiana State University Press: Baton Rouge, 2000), 45–67. In trying to recover a kind of balance, however, both of his major biographies, Thomas M. Coffey, *Iron Eagle: The Turbulent Life of General Curtis LeMay* (New York: Crown, 1986) and Warren Kozak, *LeMay: The Life and Wars of General Curtis LeMay* (Washington: Regenery, 2009), lean so heavily on anecdotes illustrating his personality as to perpetuate a generic "tough but fair" archetype. His appearances in some historical biographies, such as Eric Larrabee, *Commander in Chief: Franklin Delano Roosevelt, His Lieutenants, and Their War* (New York: Simon & Schuster, 1987), 579–622, show that it is possible to soft-pedal the mythology while still admiring his operational record. What remains understudied is LeMay's role as a *manager*—as opposed to a heroic leader or cruel ideologue—a role that should not be ignored considering his centrality to the growth and complexification of American military bureaucracy. Though brief, his characterization in *The Fog of War: Eleven Lessons From the Life of Robert S. McNamara*, directed by Errol Morris, DVD (2003; Santa Monica: Sony Pictures Classics, 2009) as a sort of dark reflection of the rational efficiency that McNamara brought to the Ford Motor Company is probably the strongest illumination of this theme.

tal ballistic missile. Nuclear weapons traveled faster than the moon around the earth, but electrons traveled faster yet.

The digital electronic computer, which studies and proposals had previously promoted as the best hope for survival, was now being offered by the second highest-ranking officer in the United States Air Force as the *only* hope. Every faction represented at the proceeding, whether military or civilian, manager or practitioner, shared LeMay's basic premise. Computer automation, as these men envisioned it, would preserve, or even amplify the agency of the individual in the face of unfathomably complex, rapidly-evolving situations. But it was emphatically not supposed to replace the human being as the ultimate decision-maker.

Nevertheless, automatic control also implied an unavoidable surrender of human control. "Command and control systems," stipulated LeMay, "must be built to enable the human to command and control the forces. Over-sophistication can lead to the system commanding and controlling the forces." Unrestrained, innovation could "over-estimate and over-tax the human brain in the role of decision making...The end result might well be a situation where the decision maker is in effect faced with a third degree interrogation—pounded from all directions with facts, facts, and more facts. He could easily be overwhelmed and descend into the morass of confusion."[11]

Curiously, this hypothetical was in fact the very same problem that computer automation was intended to solve. An "electronic revolution" in communications and automated data-processing had already made raw "facts" numerous indeed, but LeMay wondered if commanders of the future might still be starved of *knowledge*—sense, or understanding, as opposed to volumes of likely irrelevant detail. Perceptible information required structure, and structure, in turn, required a thoughtful division of responsibilities between humans and machines. If this division was not sorted through in proper order, the Air Force, and indeed the entire nation, would soon suffer a irrevocable "crisis in command"—in the words

11. Air Force Scientific Advisory Board, *Report on Proceedings, October 1960*, AFHRA, 9, all emphasis original.

of the Winter Study Group—assuming it was not doing so already.[12]

1 The new dialectic of systems integration

In 1960, the stock phrase, "crisis in command" took purchase on the premises of Laurence G. Hanscom Field, the small Air Force installation that hosted the Winter Study Group, as well as that year's proceedings of the Scientific Advisory Board. Since the war, the government-leased plot in Bedford, Massachusetts had evolved from a small Army field station supporting the Radiation Laboratory, with its twisted waveguides and shaped paraboloids suspended, Calderesque, from metal gantry towers—into a *literal* military-industrial-academic complex: the site of MIT's Lincoln Laboratory, as well as its non-profit spin-off, the MITRE Corporation; the USAF's Command and Control Systems Development Division, Electronic Systems Center, Cambridge Research Laboratories, and the 3245th Air Base Wing; in addition to a dozen special-projects offices, with liaison spaces allocated to nearly a hundred private firms. By September, the Hanscom population had exceeded 7500 and was projected to approach 10,000 by mid-1964—not counting the staff of the Massachusetts Port Authority, the property's formal landlord, nor the workers at small on-site fabrication plant leased to Raytheon.[13]

This physical concentration of technical expertise had come together to confront the

12. Usage of "crisis in command" as a stock phrase accelerated with the publication of Richard A. Gabriel and Paul L. Savage, *Crisis in Command: Mismanagement in the Army* (New York: Hill & Wang, 1978), a polarizing screed that blamed the outcome of the Vietnam War on spineless commanding officers who had allowed effete civilian managers—namely, Robert S. McNamara—to domesticate their virtuous martial instincts. It seems almost certain, however, that the Winter Study first introduced the phrase, "crisis in command," into the military–political discourse, though, as we shall see, for a purpose entirely different from this later misappropriation.

13. Richard E. Maltais, *History of the AMC Electronic Systems Center, 2 November 1959–30 June 1960*, vol. 1, Narrative (Bedford, MA: Historical Office, Office of Information, Electronic Systems Center, n.d. [1961?]), AFHRA (0476827), 74–82; "Manpower Projections at Laurence G. Hanscom Field, Bedford, Massachusetts through Fiscal Year 1964," Manpower and Organization Division, DCS/Manpower and Operations, Air Force Command and control Development Division, October 27, 1960, exhibit 278 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 11, Supporting Documents 224–289 (September 1960–November 1960), AFSC Historical Publication 64-32-XI (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485190).

problem of managing the SAGE program, and it would stay together to confront the even greater problem of fitting SAGE, and other programs like it, into the Air Force's global organization. Still, after consulting with numerous commanders, managers, and experts from across the defense establishment, the Winter Study reported "a surprising consensus that present U.S. operational command capability is seriously, if not critically, deficient." Despite the radical advancements in capabilities that computers had promised, and indeed, were beginning to deliver, there was, at the time, "considerable agreement within the USAF that we are facing a crisis in operational command," causing many commanders to doubt whether their forces could execute the complex nuclear war-plans assigned to them.[14]

This final chapter will sketch the realization of a self-contradicting outcome, in which the very mechanisms intended to render US nuclear forces more responsive to "human judgment" were perceived to do the opposite. Another outcome, notable from the preceding passage, was an abstraction from the specific "integrated air-defense system"—the subject of previous chapters—to the more general "nuclear command-and-control system," a term retroactively applied to SAGE after the initiation of numerous subsequent projects that were all, in some vague sense, considered to possess "SAGE-like" qualities. Although many of these systems actually had few features in common with SAGE, they tended to share at least one: an increasing reliance on state-of-the-art digital electronics—though not necessarily on the scale of a digital-electronic computer—cementing the relationship between a newly conceived aspect of military organization, "command and control," and a particular class of electrical circuit premised on binary coding and arithmetic.

When Lincoln Laboratory proposed the "Lincoln Transition System," or LTS, in January 1953, it was not the first research center to push the Air Force toward introducing digital logic into its continental-defense organization. Rather, in September 1952, the Air Force's own Rome Air Development Center, in cooperation with the University of Michigan's Willow Run Research Center, offered to take charge of a program of its own devising called "ADIS,"

14. Winter Study Group, *Final Report*, September 1960, RG 340, 81, 88.

the Air Defense Integrated System. Previous studies have generally relegated ADIS, and its association with the University of Michigan, to a mere foil, a source of dramatic tension in the story of MIT's Project Whirlwind and its evolution into Lincoln Laboratory, and ultimately, the Semiautomatic Ground Environment.[15] However, it is worth examining exactly what kind of program Rome and Michigan were suggesting, and why, if only because the proposal sketching the architecture of the Lincoln Transition System was written directly in reaction to it.

The first section will not provide a speculative technical assessment, but rather, detail the relationship between Michigan, Rome, and the Air Defense Command in order to explain ADIS's wide appeal to the professional Air Force. In short, the preference of the rank-and-file reflected experienced caution more than stubborn conservatism, as has sometimes been claimed in accounts especially favorable to MIT, resulting primarily from greater familiarity and trust with a program administered through regular channels.[16] Although it is both impossible and unnecessary to pronounce which outcome was the most "rational"—especially since, in the framework adopted here, managerial "choice" frequently becomes rational only through retrospection—retrospection does at least afford some vindication to the skeptical. As will be seen, Lincoln's blistering criticism of ADIS eventually proved to be

15. For the purpose of this chapter, the most important "missing links" in the received story are Murphy, *Prologue to the Hanscom Complex*, AFHRA; Murphy and Smith, *Foundation of the Hanscom Complex*, AFHRA; Maltais, *History of the Electronic Systems Center, 1959–1960*, vol. 1, Narrative, AFHRA; Richard E. Maltais, *History of Headquarters, Air Materiel Command, Electronic Systems Center, 1 July 1960–31 March 1961; History of Air Force Systems Command, Electronic Systems Center as a Quasi-Organization, 1 April 1961–30 June 1961—A Summary Evaluation of the Electronic Systems Center*, AFSC Historical Publication 62-32-IV (Bedford, MA: Historical Dvision, Office of Information, Electronic Systems Division, October 1962), vol. 1, Narrative, AFHRA (0476830); as well as Kent C. Redmond and Harry C. Jordan, *Air Defense Management, 1950–1960: The Air Defense Systems Integration Division*, ARDC Historical Publication 61-31-I, vol. 1, Narrative (Bedford, MA: Historical Branch, Office of Information, Air Force Command and Control Development Division, February 1961), AFHRA (0485177)—a project in which Redmond himself participated; and the regular histories of the 4620th Air Defense Wing, AFHRA call no. K-WG-4620-HI (or on microfilm roll P0159). The familiar literature makes little to no use of these sources or their supporting documents, with the exception of Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945–1965* (Washington: Air Force History and Museums Program, 2002), though even he did not cite the Maltais volumes or the 4620th Wing histories.

16. Following from the above, this dynamic is observed most forcefully in Johnson, *United States Air Force and the Culture of Innovation*, 144–151, though it also receives some mention in most of the other major sources in the SAGE canon.

an almost uncanny prognostication of SAGE's future as well.

The second section moves on to territory more familiar to the literature: the research-and-development politics surrounding the formation and early history of MIT Lincoln Laboratory. Rather than retread the same ground, however, the goal here will be fill in a number of important gaps, particularly with respect to the burden of monitoring—or, more precisely, failing to monitor—the work contracted to MIT. While the process that led to the initiation of SAGE has been celebrated as a supreme managerial achievement from the perspective of Lincoln and MIT, their patrons recorded an experience different from the ones told by the project's insiders. The Cambridge lobby's deep connections to the Office of the Secretary of the Air Force allowed Lincoln to proceed virtually unimpeded by the vagaries of military administration: exactly the kind of profession-dominated, "privatized mobilization" OSRD elites had imagined at the end of World War II.[17]

What had worked in the laboratory, however, malfunctioned when the time came to introduce the project to the greater organization it was intended to serve. Because it had been supported primarily through bureaucratic back-channels, neither Lincoln Laboratory nor the Air Defense Command understood one another well enough to adapt smoothly to their sudden union—notwithstanding demonstrable goodwill on the part of military professionals. Moreover, Lincoln's habitual disregard for regular procedure nearly precipitated a major scandal in 1954, when a crucial negotiation to build the necessary infrastructure for the LTS failed to produce a contract with Western Electric. Although the Air Force did eventually reach terms with one of its closest important industrial partners, the embarrassment invited further scrutiny of Lincoln's apparently meddlesome role in a program that was now much larger than its own. In 1956, a searing report by the Air Force Inspector General nearly took SAGE from the hands of the Air Research and Development Command entirely, an action

17. The "privatized mobilization" phrasing properly belongs to Larry Owens, "The Counterproductive Management of Science in the Second World War: Vannevar Bush and the Office of Scientific Research and Development," *Business History Review* 68, no. 4 (Winter 1994): 451–482, doi:10.2307/3117197, which complements the critique of the OSRD generation developed throughout these latter chapters.

that invited congressional scrutiny as well.

Finally, the third section illustrates SAGE's collision with the broader defense establishment. The authority delegated to the Air Force may have been sufficient to initiate the project, as well as carry it nearly to completion, but the air-defense mission was legally still an interservice one, and as such, SAGE could not be deployed without support from the Army and Navy. When contested across lines of divided authority, however, technological behaviors became organizational problems, and organizational problems became political standoffs, as demonstrated by the conflict over SAGE and Missile Master—a fire-control computer the Army developed as part of its surface-to-air missile program.[18] Resolving the relative priority, or establishing standards and equipment for interoperation, among competing systems such as these would either require repeated, dilatory mediation by the Joint Chiefs and the Secretary of Defense, or else an entirely new method for coordinating research-and-development actions with cross-organizational implications between stakeholding entities.

A coping strategy evolved through a mix of *ad hoc* reorganization and spontaneous community-building. An idiosyncratic association formed gradually in the vicinity of Hanscom Field, beginning with the establishment of Lincoln Laboratory in 1952, before expanding rapidly around 1958, when SAGE entered full production and the Air Force added an average of one new major electronic system to its research-and-development agenda per month, until finally precipitating in 1960 as the "Hanscom Complex": a campus, a sect, or a philosophy, depending on the context. This rapidly accumulating population of scientists, engineers, officers, and managers, most of them veterans of SAGE, cultivated their own thoughts about systems integration, which distinguished what they called *technical* integration—the assur-

18. Other examples of this phenomenon, endemic to the American defense establishment—even after it became increasingly centralized in the Office of the Secretary of Defense—include guided missiles, fighter aircraft, and helicopters: Michael H. Armacost, *The Politics of Weapons Innovation: The Thor–Jupiter Controversy* (New York: Columbia University Press, 1969); Robert F. Coulam, *Illusions of Choice: The F-111 and the Problem of Weapons Acquisition Reform* (Princeton: Princeton University Press, 1976); Frederic A. Bergerson, *The Army Gets an Air Force: Tactics of Insurgent Bureaucratic Politics* (Baltimore: Johns Hopkins University Press, 1980).

ance of compatibility between components—from *functional* integration, which instead emphasized careful negotiation between parties interested in the system's technological behavior, before ingraining that behavior, perhaps irreversibly, through mechanism.[19]

Nevertheless, the Winter Study Group, which was calculated to promote the Hanscom Complex's interest in organizational technology, not to mention its stature within the defense establishment, failed to advance either objective. Indeed, by questioning the Air Force's self-determination of its own research-and-development policy, the study's architects flustered their patrons, who attempted to suppress—or at least impede—the circulation of their ideas within industry, government, and academia at large. But the concepts did spread, sooner rather than later, through the sheer number of participants and observers, who carried them across the fluid institutions of Cold War science and technology, and in the process, reduced this loose confederation of interconnected notions, commitments, and connotations to single term, inaugurating our present, continuing, bewildering era of nuclear command-and-control.

2 The Rome–Michigan proposal

At the same time that the Getting Committee was praising Project LINCOLN, where "a large amount of the thinking, which in the RADC is in the future and therefore somewhat

19. The Winter Study's primary thesis suggests a primordial consciousness of "technological momentum" among a peculiar group of scientists and engineers. While certainly archetypal "system builders," their concerns about organization extended beyond organizing themselves *as managers* to the "using organizations" (their phrasing) that would grow around the products of their development. A classic Hughesian model would identify these actors with the system's "environment" and highlight the emergence of "reverse salients" as the system evolved and adapted to its environment: Thomas P. Hughes, "The Evolution of Large Technological Systems," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch (Cambridge: MIT Press, 2012), 45–76. It should be emphasized, however, that the Winter Study dwelled less on impediments to the growth and consolidation of nuclear command-and-control systems than the construction of a Weberian "iron cage" that would constrain the freedom of human action in situations unanticipated by the bureaucratic assumptions invisibly fixed by system design. Although still recognizable as a form of momentum, the inertial body is the organization, and the potential casualty is *decision*—and with it, political authority—rather than technological progress or economic growth.

vague, has already taken concrete form," air-defense officials perceived the opposite.[20] This confusion carried more than theoretical consequences, because the construction of the core AC&W network between 1950 and 1953 also coincided with the first stage of maturity for America's air-defense organization. In 1952 ADC, began testing a new organizational scheme intended to mitigate many of the issues that had been raised by the "wing–base plan," mandated service-wide in 1948.[21]

The wing was a relatively large unit, comparable to an army regiment—a garrison large enough to sustain a mid-sized town—and the correspondence between one wing and one airbase, though benign in most cases, complicated and even confused the structure of air-defense operations, which depended critically on the geographical distribution of smaller, non-flying stations, such as radar observation posts, as well as fighter squadrons dispersed at airfields throughout the region.[22] This configuration gave rise to an unorthodox and problematic dual hierarchy split between a number of "air divisions," essentially administrative fictions for the wing, and the Eastern and Western Air Defense Forces, a pair of "para-organizational" headquarters that did not easily fit the general pattern, but which nonetheless exercised so-called "operational control" over the air-defense units, including radars, control centers, and interceptors, within their respective areas. The issue was widely recognized, and plans to mitigate it had been prepared as early as 1950, but the specifics of their implementation depended on answers to technical questions that ADC still found frustratingly elusive.[23]

20. From "Air Defense Committee Report," attachment to Ivan A. Getting to Lt. Gen. E. E. Partridge, April 4, 1952, Office of the Director of Research and Development (D/R&D) file no. 319 (Air Defense Committee Report), NARA, RG 341, NM-15 160, 1952 series, box 2, quoted at length in the previous chapter.

21. While purely didactic in tone, United States Air Force, Air Defense Command, Briefing ADC TSCO 263, May 15, 1954, annex to OPD file no. 373.24 (3 May 1946) Sec. 7 (oversize), NARA, RG 341, NM-15 335-A, box 311 recorded the agency's immediate concerns and countermeasures with the clarity of succinctness not present in the periodic histories otherwise referenced here.

22. The pattern specified by United States Department of the Air Force, *Organizational Policy and Guidance,* Air Force Manual (AFM) 20-2 (Washington: GPO, December 11, 1964), MSFRIC, noted in a previous chapter.

23. As synopsized in Thomas A. Sturm et al., *The Air Defense of the United States: A Study of the Work of the Air Defense Command and Its Predecessors Through June 1951* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, February 1952), 197–216, OCLC (818296057).

ADC reorganization of 1952

Starting in February 1952, the Air Defense Command reorganized its 31st Air Division, whose boundaries roughly encompassed the Upper Great Plains, in order to unify the chain of command. Some of the changes, particularly at airbases, mainly concerned the reporting structure. "Prior to the reorganization," wrote ADC's official historian, "neither the interceptor squadron commander nor the base unit commander on these bases had had authority over the actions of the other, a situation which 'had tended to create some friction in lack of proper administration of base responsibilities as it placed reliance on cooperation and good will rather than command control,' " quoting a report from the headquarters of the 31st Air Division.[24] During the evaluation period, ADC merged the fighter squadrons with its base support to consolidate both administrative and operational responsibilities in the air-defense group—a unit smaller than a wing—which would then, ideally, be attached directly to an air-defense division—the next unit larger than a wing.[25]

In effect, this consolidated the command chain with regional-defense activities in the division—operating the surveillance network, scrambling and directing interceptors, and so on—while delegating base-level affairs to the group. The greatest problem remaining, however, was where to place the "sector," which, in the old system, corresponded to the radiation pattern of a single long-range search radar, possibly together with a few auxiliary gap-filling or height-finding sets. Due to the limits on communicating contact reports *between* stations, most ground-intercept functions were performed on the site of the search radar itself. As the anticipated airspeed of enemy aircraft increased, ADC badly wanted to move more of the responsibility for surveillance and control away from individual radar sites, concentrate them in the division, and abolish as many wing-like intermediaries as

24. *Air Defense Command Semi-Annual Historical Report, 1 January–30 June 1953* (Ent AFB, CO: Directorate of Historical Services, Headquarters, Air Defense Command, February 24, 1954), vol. 1, Narrative, AFHRA (0500343), 2.

25. Although printed a decade later, AFM 20-1, *Organizational Policy and Guidance,* Decemeber 1964, MSFRIC recodified the structure stipulated by the regulations in force during the period in question.

possible between the division and the groups. To what extent this would be possible, and how the boundaries of each division should be drawn, ultimately reduced to a question of "span of control": the number of contacts an individual operations center could simultaneously track.[26]

After positive evaluations of the new 31st Air Division, ADC proposed a new organizational plan designed to anticipate the distributions of threats, and their targets, expected by 1955. Drawing the division boundaries depended primarily upon two factors: an intelligence estimate of likely enemy activity in the area during a mass raid, as already mentioned, and the number of tracks an air-defense operations center could handle at once. Based on system-training exercises—more so in the field than the laboratory—this number was, for planning purposes, assumed to be 100 per direction center, and 500 per control center. (Since a track could represent a multi-plane formation, as well as a single aircraft, 100 tracks could, in general, correspond to several times as many enemies.)

The figure still incorporated substantial guesswork regarding the technology forecasts from RADC, where end-items designed to increase the speed, accuracy, and display of radar data, as well as the communication of instructions to interceptors and anti-aircraft weapons, remained in a formative stage of development, despite the fact that some had already been programmed to enter service by 1955. If the 100 track-per-center target could be achieved, however, the Air Defense Command planned to increase the number of air-defense divisions from 11 to 18, while more or less eliminating its wing structure. If not, then some sectors might become too busy during a large air-battle; thus, it was thought at the time that more intermediate headquarters would need to be retained. This potential outcome was less than ideal for coordinating a so-called "double perimeter" defense around each "strategically vital" area.[27]

26. *ADC Historical Report, 1 Jan–30 Jun 1953,* vol. 1, Narrative, AFHRA, 1–14. Due to the overlapping nature of the chapters compiled in this volume, only the passages with the densest concentration of pertinent information will be called out explicitly.

27. *ADC Historical Report, 1 Jan–30 Jun 1953,* vol. 1, Narrative, AFHRA, 20–27. The concept and adoption of ADC's "double perimeter" doctrine is best explicated in Kenneth Schaffel, *The Emerging Shield: The Air Force*

According to the official historian, "at the end of 1952, Air Defense Command was counting on the University of Michigan's Willow Run Research Center (WRRC) to provide it with an electronic data display and transmission system" in order to reach its planning targets by 1955.[28] Willow Run had been working on ground-control equipment for air-defense purposes under contract with RADC since 1950, beginning with the BOMARC program, the long-range antiaircraft cruise-missile that had since received a service designation as the F-99. The scope of WRRC's efforts quickly expanded to include direction-center operations as well the F-99's fire-control system, though the expeditiousness of ADC's 1955 program severely constrained its options for equipment selection.[29]

Pressed for time, the RADC–WRRC team chose in 1952 to proceed with adapting the Comprehensive Display System (CDS)—a development of the British Royal Navy—for installation in Air Defense Direction Centers. The United States Navy was also considering adopting an "Americanized" version of the CDS, or "ACDS," for its carrier fleet, though testing as yet remained limited to a single installation at the Naval Research Laboratory. Although the Navy ultimately rejected the ACDS as too bulky and insufficiently rugged to rely on or maintain at sea, these considered mattered less for a fixed ground installation, where the requirements for space and reliability were not as rigorous.[30]

Instead, the prospect of acquiring technology already in a relatively advanced state of development weighed more heavily on the calculations of air-defense planners. Even as a prototype, the Navy's ACDS appeared to be more mature than any of the likely alternatives. Project LINCOLN, on the other hand, which by 1952 had officially spun off from MIT proper

and the Evolution of Continental Air Defense, 1945–1960 (Washington: Office of Air Force History, 1991), 152–160.

28. *ADC Historical Report, 1 Jan–30 Jun 1953*, vol. 1, Narrative, AFHRA, 7.

29. Margaret C. Bagwell, *History of the BOMARC Weapon System, 1953–1957*, AMC Historical Study No. 319, vol. 1, Text (Wright–Patterson AFB: Historical Division, Office of Information Services, Air Materiel Command, February 1959), redacted copy provided by staff, 23–31; Charles J. Smith, *SAGE: Background and Origins*, vol. 1 of *History of the Electronic Systems Division, January–June 1964*, AFSC Historical Publication 65-30-1 (Bedford, MA: Electronic Systems Division, Air Force Systems Command, Air Force Systems Command, December 1964), AFHRA (0485201), 87–91.

30. David L. Boslaugh, *When Computers Went to Sea: The Digitization of the United States Navy* (Los Alamitos, CA: IEEE Computer Society Press, 1999), 66–67.

to form Division 6 of the new Lincoln Laboratory, continued to operate primarily through extraordinary channels, leaving the rest of the Air Force's R&D administration only dimly aware of its progress and intentions.[31] ADC's historical summary reported that "there was little information available on the status of this project" at headquarters in Colorado Springs, and thus officials "presumed its completion was a much longer way off" than the Michigan system.[32]

The Comprehensive Display System

The centerpiece of the British CDS was a 96-element electronic storage array, each of which encoded the coordinates of a radar track as a pair of voltages. These values would be input manually, or "tabbed," by an operator at a PPI scope equipped with a trackball or joystick, which, in turn, controlled potentiometers attached to the selected circuit. At that point, another set of potentiometers could interpolate the voltages automatically in response to feedback from the detector signal, so long as the target did not maneuver too abruptly between successive scans or else become confused with clutter or other returns, in which case the operator would need to tab it again.[33]

Experiments suggested that a single operator might be capable of monitoring about ten tracks simultaneously under realistic conditions, a significant improvement over traditional voice-telling. Moreover, once a target had been entered into storage, it could be

31. The open literature covers the foundation of MIT Lincoln Laboratory well enough as to render further elaboration only marginally useful to the task at hand: in particular, Kent C. Redmond and Thomas M. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* (Cambridge: MIT Press, 2000), chaps. 9–13 is an adequate baseline. Primary sources introducing finer points of difference, however, will be introduced as needed.

32. *ADC Historical Report, 1 Jan–30 Jun 1953*, vol. 1, Narrative, AFHRA, 10. Incidentally, the Royal Navy viewed the CDS as dimly as the United States Navy, though some of its technique did help inspire the data-handling subsystem incorporated in the AMES Type 82 naval and air-traffic surveillance systems, which enjoyed several decades of operational use: Jack Gough, *Watching the Skies: A History of Ground Radar for the Air Defence of the United Kingdom by the Royal Air Force From 1946 to 1975* (London: HMSO, 1993), 67–71, 156–163, 274–276; Simon Lavington, *Moving Targets: Elliott–Automation and the Dawn of the Computer Age in Britain, 1947–1967* (New York: Springer, 2011), 41–43.

33. Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory*, NRL Report 8300 (Washington: Naval Research Laboratory, 1979), 379–381, DTIC (ADA084225).

electronically processed as data for the purposes of display, identification, and weapons direction, with minimal intervention. A set of simple switches associated with each storage element allowed operators to set additional parameters representing the state of the track, such its approximate altitude, number of planes, weapons assignment, and so on. As of 1952, however, the design of the necessary peripheral equipment needed to process and display the data in the electronic store remained unsettled, pending production engineering. The British CDS relied entirely on analogue signals, so it was presumed that these would ultimately resemble the fire-control circuits refined during World War II. The greatest uncertainty concerned the method by which aggregated "summary displays" should be generated for the command staff, whether by electronic, photochemical, or manual means, or possibly some combination of them all.

Although the Naval Research Laboratory and the Willow Run Research Center both adopted the premise of the British CDS, they experimented with alternative forms of electronic storage and signal processing. The version proposed to the Air Force replaced the analogue store with electroacoustic delay-lines, a digital memory-storage technique developed at the University of Pennsylvania for the EDVAC machine, completed in 1951.[34] Essentially, these were tubes of heated mercury with piezoelectric transducers at each end, one for "reading" and another for "writing." A signal generator on the writing circuit converted digital input into a waveform to be induced into the liquid storage medium as an acoustic beam, which bounced back and forth between the two ends of the cylinder until the data needed to be accessed, at which point it would be read-out and reconverted. Of course, mechanical resistance within the medium also attenuated the waveform, so it was necessary to refresh the memory element by reading out the signal, amplifying it, and

34. Although the EDSAC, built at the University of Cambridge, technically derived from the design of the EDVAC, the latter's protracted construction allowed the former to start operating first: cf. M. V. Wilkes, *Automatic Digital Computers* (London: Methuen, 1956); Nancy B. Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert–Mauchly Computers* (Bedford, MA: Digital Press, 1981); Arthur L. Norberg, *Computers and Commerce: A Study of Technology and Management at the Eckert–Mauchly Computer Company, Engineering Research Associates, and Remington Rand, 1946–1957* (Cambridge: MIT Press, 2005).

writing it back into storage after a certain number of reflections.[35]

Read and write operations, moreover, had to be carefully synchronized to the resonate frequency of the medium, and the periodic refreshing cycles introduced additional latency and circuit complexity. But despite the drawbacks, WRRC judged that the switch to digital memory provided "greater flexibility, greater accuracy, ability to handle remote data better, and a greater adaptability to pulse communication equipment."[36] The ACDS proposed for an Air Defense Direction Center would consist of two banks of eight delay lines; one for "local" storage of up to 100 contacts tracked by the direction center itself, and other for "remote" storage of up to 60 contacts relayed from other sources. According to the Michigan design, a single track required 82 bits of storage, which placed the memory capacity of each tube between 615 and 1,025 bits—an aggressive specification for a high-reliability device intended for mass production. Nevertheless, WRRC claimed that the Laboratory for Electronics, a Boston-based industrial-research firm, could have the equipment available for testing by February 1953.[37]

Despite the change in memory storage from analogue to digital technology, WRRC's plan for the American CDS still relied on analogue circuits to process them. Although the storage system could exploit either method, the project's engineers considered the digital

35. Electroacoustic (or ultrasonic) delay-lines were originally developed for analogue signal-processing applications—for instance, decluttering and noise reduction—in World War II radar systems: F. M. Smits, ed., *Electronics Technology, 1925–1975*, vol. 6 of *A History of Engineering and Science in the Bell System* (New York: Bell Telephone Laboratories, 1985), 263–266; or, more generally, Charles V. L. Smith, *Electronic Digital Computers* (New York: McGraw–Hill, 1959), 264–273.

36. University of Michigan, Willow Run Research Center, *Michigan Air Defense System Proposal*, UMM-100 (Ann Arbor: University of Michigan, September 29, 1952), response to FOIA request, 117–118, DTIC (AD0046546).

37. According to the data compiled in United States Department of the Navy, Office of Naval Research, *A Survey of Automatic Digital Computers* (Washington: Office of Technical Services, U.S. Department of Commerce, 1953), OCLC (562717590) most early computers employing ultrasonic delay-line memory stored about 360 bits-per-channel, with a smaller group clustering around 560 bits-per-channel (mercury-tube memory required a balance between capacity and speed, so acoustically "longer" lines were not necessarily better.) Only the RAYDAC, built for the Navy by Raytheon in 1952, incorporated internal memory that could meet the ADIS specification; given their geographical proximity, it is possible that the "Laboratory of Electronics" was either a spin-off or supplier of Raytheon on its contract with the Navy. Also note that the term "bit" had not yet been universally accepted, since some important digital architectures still used non-binary numerical systems (UNIVAC I, for instance).

computer too risky to recommend for operational use by 1955, even before beginning to contemplate its possible cost.[38] Nevertheless, wary of competition from Project LINCOLN, as well as perceptions that its program was insufficiently "systematic," the Rome lab worked to incorporate ACDS into a proposal for an "integrated" air-defense system more along the lines of the ambitious schemes formulated in Cambridge. The instability of the project's name reflected the incipience of its ideas; generically, it was simply called the "Michigan air-defense system," though the lab floated several cants, such as the Ground Report System, before settling finally on ADIS, the Air Defense Integrated System, in the fall of 1952.[39]

The date corresponded to the publication of University of Michigan Report UMM-100, the *Michigan Air Defense System Proposal*, by the Willow Run Research Center in late September, a document that attempted to counter the aggressively forward-looking influence of Project CHARLES with a more definite recommendation calibrated to the immediacy of the moment. Because of the prevailing confusion about what MIT was doing, and according to whose schedule, it is unclear whether RADC genuinely intended to offer ADIS as a direct competitor to the Lincoln program, as MIT interpreted.[40] Still, a blueprint-ready engineering plan UMM-100 was not—RADC–WRRC clearly meant to defer the heaviest lifting to industrial-engineering firms bidding on the request-for-proposals—yet it did specify a complete method of operation with greater coherence than any of MIT's products to date.

38. *Michigan Air Defense System Proposal*, 2–3.

39. The ADIS proposal internally referenced a prior report, UMM-50, which had apparently discussed a large-scale, distributed, computerized control system, though likely in connection to Project WIZARD, an early anti-ballistic-missile project with a development history too convoluted to recount here; though cf. *History of Strategic Air and Ballistic Missile Defense*, 2 vols. (1972; repr., Washington: US Army Center of Military History, 2009), vol. 1, 105–108. The salient feature, however, is that it gave rise to the BOMARC program, and thus, suggests that engineers at Boeing, Michigan, and possibly Columbia had been thinking independently about applications of digital-electronic computers similar to the radical solutions peddled by MIT around the same time.

40. The introductory passages to *Michigan Air Defense System Proposal* staked out the position that although Whirlwind, or something like it, would almost certainly be incorporated into the continental-defense system eventually, it was unlikely to do so before 1960. ADIS, meanwhile, could, at the very least, provide the necessary bridge to this future system, and, potentially, even complement its operation in the decade ahead.

The Air Defense Integrated System

The Willow Run team wrote UMM-100 in two main parts, one for the functions of a sector, or division-level, "control center," and the other to the "direction center" responsible for any one of the division's subsectors. (Following USAF convention, the document designated these facilities as *Air Defense Control Centers* and *Air Defense Direction Centers*—ADCCs and ADDCs, respectively—introducing such an unwieldy acronymic clutter that in every instance, the typist underscored the "C" corresponding to "control" in "ADCC," or the "D" for "direction" in "ADDC.")[41] A 100-element digital ACDS store backed operations at all subsector direction-centers, which acted as primary points of radar-data collection. The sector control center, on the other hand, depended on a rotating magnetic drum designed to record 500 tracks received automatically over as many as 16 sources of telephonic input, together with a matching set of 16 outputs, distributed between two categories: eight for connection to subsector direction centers, and the other eight reserved for a mix of neighboring control centers and Army antiaircraft batteries operating within the division's boundaries.[42]

Like ACDS, the communication system would mix digital and analogue technologies as well. Although Willow Run's engineers referenced AFCRC's digital radar-relay project, UMM-100 favored video over digital coding for transmitting signals from distant detectors, since in the ADIS proposal, direction centers merely superseded the existing, decentralized GCI stations, which meant that most high-power radar would be co-located with an ACDS installation anyway. Moreover, the problem of communicating with remote gap-filling, height-finding, or mobile sets was considerably less difficult within the continental United States, where commercial microwave-relay networks had expanded almost exponentially since the Bell System introduced the first TD-2 carrier routes in 1947.[43] Though limited

41. For clarity, the following passage will substitute "control center" for "ADCC" and "direction center" for "ADDC," as these seem to have been most common, except in formal writing.

42. *Michigan Air Defense System Proposal*, 13–17; 26–43.

43. For the AT&T monopoly, microwave-transmission technology—facilitated by the cavity magnetron—provided the greatest commercial windfall of wartime research and development; by 1980, for instance, microwave-relay networks carried nearly three-quarters of the Bell System's total traffic load: E. F. O'Neill,

to line-of-sight, a microwave beam could carry a signal fine enough to represent a high-resolution PPI image across some tens of miles, until, after passing through relay towers as necessary, it eventually reached the scope readers concentrated at the direction center. Then, after operators input contacts into the local ACDS store, a modem would automatically forward track data to the sector control center over another microwave circuit.[44]

The messages passed between direction centers and control centers would be coded digitally. The ADIS specification claimed that modems should be capable of transmitting and receiving 60 tracks-per-second, so that the total capacity of an ACDS store could be moved between sites in 1.67 seconds. Since the control centers polled their inputs and outputs serially, a network of eight direction centers could read-in and write-out in 13.4 seconds, which, after accounting for processing overhead, was supposed to synchronize the data at every site in the division in less than 15 seconds, a period significant because it corresponded to the sweep time of a 4-RPM search-radar, like the increasingly standard AN/FPS-3.[45]

However, the data frames exchanged between centers used the same 82-bit code as the ACDS storage system itself, meaning that 60 tracks-per-second corresponded to a transfer rate of nearly 5,000 bits-per-second; thus, UMM-100 dangled a conspicuous uncertainty about how such a high throughput could be achieved. Digital modulator-demodulators were still benchtop equipment in 1952, and while a 4-gigahertz microwave network like TD-2 carried a band more than wide enough to accommodate the signal rate, digital-transmission experiments had been conducted almost exclusively with conventional telephone circuits, with speeds on the order of 500 bits-per-second.[46] Willow Run's engineering team did suggest

ed., *Transmission Technology, 1925–1975*, vol. 7 of *A History of Engineering and Science in the Bell System* (New York: Bell Telephone Laboratories, 1985), 291–308; M. D. Fagen, ed., *National Service in War and Peace, 1925–1975*, vol. 2 of *A History of Engineering and Science in the Bell System* (New York: Bell Telephone Laboratories, 1978), 335–338.

44. *Michigan Air Defense System Proposal*, 177–178.

45. *Michigan Air Defense System Proposal*, 32.

46. A. W. Horton Jr. and H. E. Vaughn, "Transmission of Digital Information Over Telephone Circuits," *Bell System Technical Journal* 34, no. 3 (May 1955): 511–528, doi:10.1002/j.1538-7305.1955.tb01484.x reported on

multiplexing all 100 ACDS tracks together for parallel transmission over a microwave-relay link (at the time, TD-2 could carry up to 480 simultaneous voice channels), but such a complicated circuit would have likely proved challenging to design and manufacture.[47] Other potential solutions required research and development, and the self-imposed mandate for ADIS was, in a word, *now*.

As mentioned previously, Willow Run probably did not propose ADIS to directly compete with MIT's program. According to UMM-100, "the system shall be designed so that if implementation is started immediately, it can be placed in operation by 1955." It continued to claim that "an essentially automatic system such as that described…by Project Charles…though it might meet the technical requirements" to defend against the current fleet of Soviet bombers, "could not be implemented in time to meet the threat of this period." Thus, the assumption was that MIT must have been working on a future defense against *missiles*, rather than aircraft. To that end, what the University of Michigan did not suggest a unitary system, but a platform for components upgradeable with minimal organizational disruption:

> The proposed Michigan System has been designed so as to make maximum use of the present Air Force defense organization, the present Air Force ground system, and the equipment resulting from the present Air Force development program…The resultant system consists of a set of components which can be assembled according to the needs of a particular location. Every effort has been made to keep the design flexible so that ADC can establish operational doctrines which best fit its tactical situation.[48]

Indeed, ADIS's entire concept of "netting" mirrored the existing air-defense organization crystallizing throughout the Permanent System, which varied considerably depending on

experiments conducted "several years ago" at the time the paper was written (most likely, 1951–1952) that showed a reliable 650-bit-per-second transmission could be reliably achieved over a commercial telephone line. It is possible the experiment was conducted in connection with the Army's digital data-relay program, as described in the following note.

47. While obtuse about the link between control centers and direction centers (or adjoining control centers), the proposal includes bibliographic references, as well as certain technical features—such as an equivalent carrier frequency—implying that the authors had in mind a device like the Army's AN/TSQ-8, a digital radar-relay, like the one under development in Cambridge, for use by the Nike program. *Michigan Air Defense System Proposal*, 170–175; 177a, 177b.

48. *Michigan Air Defense System Proposal*, 2–3.

the division's tactical circumstances—its geography, topography, weather, its surveillance and communication capabilities, and so on. Nevertheless, a trend toward decentralizing data collection and aircraft control in the subsector direction centers, while concentrating the analysis of information in the sector control-center, was emerging as standard practice.[49]

Although Michigan engineers specifically avoided recommending digital computers, believing they remained too expensive and unreliable for immediate operational deployment, the digital-circuit infrastructure that supported both analogue and manual processing methods in ADIS, by design, left open the possibility of future replacement by more sophisticated equipment. In the near term, components such as displays and intercept-course computers would be improved only marginally, but the semi-automatic ACDS, combined with fully automatic digital transmission, had the potential to eliminate—except as a contingency—traditional voice-telling, which experienced showed as the greatest source of error and bottlenecking in air-defense operations. In short, UMM-100 proposed to mitigate the problem most urgent to air-defense professionals and deferred higher risk, lower priority issues to longer-term developments, such as ADSEC's solution based on the digital electronic computer.[50]

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49. As discussed in a previous chapter, the optimal site for correlating information regarding the identification of contacts, as well as ordering the scramble of interceptors, both remained active topics of study and disagreement during the operational exercises of 1949–1950. The language adopted in United States Air Force, Air Defense Command, *Organization and Functions for Air Defense*, Air Defense Command Manual (ADCM) 50-3 (Colorado Springs: Headquarters, Air Defense Command, October 25, 1951), MSFRIC, 13–21 seemed to accept the devolution of scramble authority while merely phrasing the duties of the "movement identification section" at each direction and control center in such a way as to accommodate variations adopted by division commanders. From October 1952 to May 1953, however, ADC headquarters developed its own plan for redistributing functions between stations according to their tactical, geographic, and equipment factors considered on a national scale, and in the process, affirmed the role of the control center's information-gathering activities: *ADC Historical Report, 1 Jan–30 Jun 1953*, vol. 1, Narrative, AFHRA, 20–27.

50. Indeed, in a six-page missive featuring a large of number of passages emphasized with full capitalization, the president of the University of Michigan argued that not only did ADIS offer a fill near-term gaps in the MIT program, it represented a fundamentally asymmetrical enterprise, since ADIS, in his view, was a bounded part of a larger development effort, whereas Lincoln should be properly understood as a wartime mobilization of scientific manpower with power to unilaterally explore all future possibilities. Harlan Hatcher to Gen. E. E. Partridge, Headquarters, ARDC, March 12, 1953, exhibit 7 in Kent C. Redmond and Harry C. Jordan, *Air Defense Management, 1950–1960: The Air Defense Systems Integration Division*, ARDC Historical Publication 61-31-II, vol. 2, pt. A, Supporting Documents 1–44 (Bedford, MA: Historical Branch, Office of Information, Air Force Command and Control Development Division, February 1961), AFHRA (0485178).

Certain features of Willow Run's proposal will prove relevant when it comes time to discuss Lincoln's response and subsequent counter-proposal. For now, the most remarkable feature of the Michigan report is, once again, a lack of distinction between the organizational and technological behavior described in its specification. Indeed, as a whole, the document can be read as a detailed explication on air surveillance and control as it was actually practiced at the time of its writing, and as such, represents a relatively strong familiarity with ADC doctrine, tactics, and operations on the part of Willow Run engineers.[51]

Theirs was an idealized explication, of course, which, despite an explicit acknowledgment to the contrary, did not allow much variation beyond some vague statements about how certain features would be implemented, which likely said more about the engineers' technical elisions than their intentions for operational flexibility. Because notwithstanding the proposal's relatively faithful presentation of air-defense activities in the Permanent System, the formalization of those activities through *mechanism*, as opposed to human action, would have, in itself, created a new material environment to which the organization would need to adapt.[52]

In other words, while UMM-100 depicted the replacement of humans with machines as a process as straightforward as swapping one part for another, the reality was that human labor had always supplied a critical element of informational "slack" in air-defense operations, in spite of its inherent limitations. The RAND air-defense experiments had shown as much, and the entire System Training Program relied on this fundamental premise as well.[53] None of this is to say that manual operations were entirely sufficient—either at

51. Compare to the prior discussion of the ADSEC report, which lucubrated on the systemic nature of organizations in general, and the following observations of the CHARLES report, which, insofar as it referenced existing air-defense organization at all, concerned itself mainly with how to reform it through technology.

52. The thesis of N. F. Kristy, *Man in a Large Information Processing System: His Changing Role in SAGE*, RM-3206-PR (Santa Monica: RAND Corporation, February 1963), AFHRA (0907065), as discussed in the introduction.

53. Properly, "organizational slack" refers to an internal adjustment of payments within a large economic enterprise in response to the changing availability of resources: Richard M. Cyert and James G. March, *A Behavioral Theory of the Firm*, 2nd ed. (1963; Malden, MA: Blackwell, 1992), 41–44. Its loose invocation here is more redolent of a reverse "Parkinson's law," the oft-quoted apothegm that "work expands so as to fill the time available for its completion": C. Northcote Parkinson, *Parkinson's Law, and Other Studies in Administration*

the time, or in the foreseeable future—only that in the untempered push to mitigate their flaws with automation, scientists, engineers, and even military professionals tended to overestimate the as-yet unproven capabilities of electronic remedies while underestimating human abilities to compensate.

Unfortunately, the ADIS specification itself did not propose any explicit parameters for arbitrating the balance between human and machine components—an issue conspicuously central to Lincoln's ultimate counter-proposal—providing little insight into the philosophies prevailing in Rome and Willow Run. It is true that ADIS, should it have ever been deployed, would almost certainly have required a greater number of personnel to handle operations due to its reliance on manual input in its direction centers and human filtering in the control centers. Whether this represented an engineering compromise in light of the urgent circumstances, or an acknowledgment that a human scope-reader could, for instance, decline to input a contact judged immaterial when the system was stressed to capacity, cannot definitively be answered. The dearth of affirmations of the latter, however, suggest the probability of the former.

3 The trouble with Cambridge

As stated more than once since the introduction, the received story of SAGE is, both intentionally and incidentally, the one told by the faculty, staff, and students from MIT who followed Project Whirlwind from the Research Laboratory of Electronics to MIT Lincoln Laboratory and, for some, the MITRE Corporation.[54] While interpretations differ, an outline

(Boston: Houghton Mifflin, 1957), 2–13. Previous chapters observed how air-defense workers also reduced the load on their superiors by modulating the information they presented them; more frequently reducing than expanding it, through prioritization, reduction, and filtering.

54. For convenience, the narratives most familiar to the field are, in roughly descending order, Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996), 75–111; Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects That Changed the World* (1998; repr., New York: Vintage, 2000), 15–67; and Atsushi Akera, *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S. Cold War Research* (Cambridge: MIT Press, 2007), 181–220; Johnson, *United States Air Force and the Culture of Innovation*, 117–172 should be known better than it is. As discussed previously,

of significant events has been well established. Nevertheless, some commentary remains in order, especially to incorporate more of the Air Force's stake in the program. In particular, representations of SAGE as a milestone in the management of complex technology appear overstated when reconsidered from the perspective of contract administration. Moreover, the rhetoric applied in selling the program appears highly problematic in light of the fact that the Air Force offices most directly affected by it had only a dim sense of what they were buying—or that it had definitely been purchased at all—until they had to confront the final product. To that end, a close reading of some documents already well known, and others much less so, will be in order here.

The remobilization of MIT

The early history of Project Whirlwind is very much the story of a continuing search for military patronage.[55] Its origin lies with a contract let by the Navy Special Devices Center to the MIT Servomechanisms Laboratory in 1944 for the design of an analogue computer to potentially replace the electromechanical control systems then used in the construction of pilot trainers. By 1946, Jay W. Forrester, MIT's lead on the contract, had convinced his sponsors that an analogue computer would be unsuited to the task and reoriented the project around a digital architecture inspired by the work of the Eckert–Mauchley group at the University of Pennsylvania.[56] Although the Navy continued to fund Forrester's group in connection with flight-training equipment, Forrester himself exhibited less interest in a specific application than the manifold possibilities of a general-purpose digital computer. As engineering and construction costs expanded far beyond the expectations of the Office

all of them owe a significant debt to the work the culminated in Redmond and Smith, *From Whirlwind to MITRE*, though the present dissertation does not claim to be an exception to this either.

55. This period is treated most thoroughly in Kent C. Redmond and Thomas M. Smith, *Project Whirlwind: The History of a Pioneer Computer* (Bedford, MA: Digital Press, 1980) and Akera, *Calculating a Natural World*, 181–220.

56. Cf. Thomas Haigh, Mark Priestley, and Crispin Rope, *ENIAC in Action: Making and Remaking the Modern Computer* (Cambridge: MIT Press, 2016); Stern, *From ENIAC to UNIVAC*.

of Naval Research, however, Forrester, a compulsive memorialist, began circulating white papers propounding Whirlwind's suitability for purposes surpassing numerical analysis—the primary use for early digital computers—and breaking new ground in communications, data processing, and automatic control.[57]

The laboratory was thus eagerly positioned to recommit itself to the Air Force's continental-defense program instead. Both necessity and convenience forced the union, since by 1949, ONR had indicated its intent to extricate itself from Forrester's costly enterprise following a series of critical technical assessments. Almost simultaneously, George Valley learned of Whirlwind through Jerome Wiesner, leading him to suggest in the final report of the Air Defense Systems Engineering Committee that the Air Force plug the budgetary gap left by ONR in order to use the computer as a testbed for the digital radar-relay equipment then under development at the Cambridge Research Laboratories.[58] As Valley's group began meeting with Forrester's early in 1950, John W. Marchetti discovered that the Watson Laboratories were also supporting Project Whirlwind and arranged for AFCRL to assume this contract on ADSEC's behalf. Already acting as the *de facto* project manager for ADSEC itself, the Cambridge lab again became legally and administratively obligated to a seemingly minor undertaking yet to be reconciled with its open-ended work statement.

ADSEC did not disband after delivering its final report in October 1950. While ostensibly an *ad hoc* body of the Air Force Scientific Advisory Board, it quickly transformed into a

57. Most significantly, Jay W. Forrester, Servomechanisms Laboratory, Massachusetts Institute of Technology to N. McLean Sage, Division of Industrial Cooperation, Massachusetts Institute of Technology, "Forecast for Military Systems Using Electronic Digital Computers," Report L-3, September 17, 1948, microfilm, MIT, MC665, ser. 16, box 5, reel 28; and Jay W. Forrester, Servomechanisms Laboratory, Massachusetts Institute of Technology to Special Devices Center, Office of Naval Research, United States Navy, "Alternative Project Whirlwind Proposals," Report L-4, September 21, 1948, microfilm, MIT, MC665, ser. 16, box 5, reel 28. See Akera, *Calculating a Natural World* for context.

58. Valley, a member of the physics department, was apparently unaware of Whirlwind at the time ADSEC had the idea of centralizing the collection of remote radar observations in digital "data analyzers." As director of the Research Laboratory of Electronics, Wiesner had likely read Forrester's memos and connected the two ideas immediately. For his part, Valley claimed to hear eventually about Whirlwind's poor reviews but afforded them little credit due to his overall confidence in the quality of MIT's engineering research. George E. Valley Jr., "How the SAGE Development Began," *IEEE Annals in the History of Computing* 7, no. 3 (July–September 1985): 208–209, doi:10.1109/MAHC.1985.10030.

quasi-official activity of the Cambridge Research Laboratories, taking upon itself the task of coordinating an engineering test. Over the next six months, technicians from CRL's Digital Data Relay Laboratory worked with MIT's Digital Computer Laboratory to connect the old MEW prototype, located at the Rad Lab's former test site in Bedford, with the Whirlwind installation on the MIT campus.[59]

The experiment was similar to the one conducted five years prior using the same radar, except in that case, a video image was transmitted over a microwave carrier. During the new series, however, a digitized *representation* of the radar image passed through a commercial telephone line and, after demultiplexing, entered Whirlwind's electronic storage. Equipment problems, technical limitations, and poor weather prevented the two teams from accomplishing much more than proving that radar signals could be input into a computer as data—no different, in principle, from a punched card—at which point they could be arbitrarily manipulated by programmed instructions. Serious questions lingered about the quality of the input and the computer's capability to process it quickly enough to sustain real organizational activity, but enthusiasm generally overwhelmed such concerns for the time being.

In the meantime, the Office of the Secretary of the Air Force pushed ahead with a campaign, leveraging the precedent set by ADSEC, to persuade MIT to establish an "air defense laboratory" operated on a premise similar to the wartime Radiation Laboratory. Not to belabor facts already in print, it is worth observing that the "Cambridge lobby" and its allies in Washington—most prominently, Louis Ridenour and Ivan Getting—agitated for this outcome more fervently than the administration of MIT. While never strictly opposed, both James R. Killian, president of the institute, and Julius A. Stratton, its provost, expressed deep reservations for a number of reasons: chiefly, because the Rad Lab had been a public

59. As described in Redmond and Smith, *From Whirlwind to MITRE*, 77–93. Incidentally, Whirlwind's role as an experimental testbed for automated air-defense did not monopolize the computer's time during its ten years in operation at MIT. A user community applied it to other problems as well, mostly in general scientific computation, just like its contemporaries at other universities.

service in a time of extraordinary national emergency, but a permanent successor ran counter to the organization's core mission, or so they claimed.[60]

Their principled response may have been, at least to some extent pretextual. MIT had more material concerns, such as the possibility of overextending campus resources, the risk of becoming financially dependent on a single contract of uncertain prospect, and the threat of diminishing a large and diversified industrial-research program, which partnered not only with the Air Force's direct rivals—the Army and the Navy—but also numerous private entities, who might begin to view the institute as a competitor rather than a collaborator. In any case, Killian was evidently satisfied by an agreement to charter the new laboratory as a joint initiative of all three of the armed forces, each of whom enjoyed full representation on its military advisory committee, though the Air Force member would serve as "first among equals."

During the negotiations that led eventually to the chartering of Project LINCOLN in July 1951, MIT did agree to host a study group, codenamed "Project CHARLES," with the intent of divining from ADSEC's meager statements the task to be accomplished by a potential new laboratory. Valley reprised a role as chair of the "long term improvement" panel, with four others returning as well, including John Marchetti, now joined by Jay W. Forrester along with 22 more scientists and engineers—almost all of them veterans of Division 14—gathered under the leadership of its former associate director, F. Wheeler Loomis. Their final product, dated August 1, was an impressive document, spanning three bound volumes and covering topics ranging from digital automation to guided missiles, integrated fire-control systems, navigation aids, electronic warfare, and "passive" measures such as population dispersal and post-attack recovery plans for strategic industries.[61]

The question was who it was supposed to impress. Like its official title, *Problems of Air Defense*, the final report of Project CHARLES offered little more than a concentrated

60. Redmond and Smith, *From Whirlwind to MITRE*, 95–127.

61. *Problems of Air Defense: Final Report of Project CHARLES*, 3 vols. (Cambridge: Massachusetts Institute of Technology, August 1, 1951), OCLC (2529755) includes the summary volume plus its two technical appendices.

summary of technical challenges well known to the military establishment, accompanied by speculative solutions justified by back-of-the-envelope calculations. Indeed, the study's own preface confessed that "few, if any, of the ideas embodied in this report will be found new or original."[62] Its core section, written by the long-term improvement panel, essentially recapitulated the work of the Valley committee, albeit in less esoteric terms, but with an update on the progress of the MEW–Whirlwind relay tests.

According to Malcolm M. Hubbard, the assistant director of the RLE, Project CHARLES merely "blessed [ADSEC's earlier proposal], sprinkling holy water on it, so to speak."[63] Although overly dismissive, it affirms the general impression that the final report intended to reach an audience located in two places only: the Office of the President of the Massachusetts Institute of Technology in Cambridge, and the Office of the Secretary of the Air Force in Washington. Its membership was entirely civilian, and mostly academic—MIT alone accounted for ten of its 28 participants, whereas 7 came from industry, and only 4 worked for the government. Only Marchetti drew a paycheck from the United States Air Force, though as a civilian engineering-manager, his perspective and expertise hardly represented the service's rank-and-file.

Since Killian had requested the study as a condition of his negotiation with the Office of the Secretary of the Air Force, the numerous "problems of air defense" identified by CHARLES likely reassured him that Project LINCOLN would be a true "air defense laboratory," with a robust, diversified, and independent research program, rather than a fickle contractual liability left to blow on the winds of fiscal politics. At the same time, the Air Force's civilian leadership also obtained a document bursting with prestige and credibility with which to convince their own bureaucracy.[64]

Achieving the latter objective appears to have been more difficult. While the Deputy

62. *Problems of Air Defense*, xx.

63. From an oral history interview quoted in Redmond and Smith, *From Whirlwind to MITRE*, 99.

64. Cf. Johnson, *United States Air Force and the Culture of Innovation*, 124–128.

Chief of Staff, Development, General Gordon P. Saville, and the Director of Research and Development, General Donald N. Yates, both followed the progress of Project CHARLES, they viewed it as another one of many sources of input then accumulating in their offices. "We intend that this study...be the forerunner of similar efforts in the fields of Tactical Air, Strategic Air, and Air Transportation," read the only memo Saville ever circulated on CHARLES specifically. "While the details of conducting these studies may differ in each case, they will all be oriented on the problem of creating sound 'Development Planning Objectives' as defined in DCS/Development Memorandum No. 37 of 8 September 1950."[65] In other words, the final report would not constitute a "plan" for administrative purposes, nor should it be regarded as a "mission statement" for Project LINCOLN, as Killian had insisted. Further down the chain, the document's meaning became even more obscure; it was clearly not a "procurement plan," upon which the Air Materiel Command could act, nor an "operational plan" of relevance to the Air Defense Command. Since numerous other studies of similar ambition had passed across desks and into filing cabinets in Dayton and Colorado Springs, field officers could not predict what, if any, official action it might generate.

What they almost certainly did not anticipate was that actions taken subsequently by a *private contractor*, virtually independent of the official Air Force, would impinge upon their own duties and obligations. The Air Force had succeeded in remobilizing MIT; by mid-1952, when Project LINCOLN was permanently established as MIT Lincoln Laboratory on the grounds of Laurence G. Hanscom Field, its staff had expanded to 1300 and its annual budget to $15 million. On the other hand, for the sake of granting MIT the independence it demanded, the Air Force had failed to create a management structure that could bring Lincoln to the same table as other stakeholders in the continental-defense program. The

65. Memo, Maj. Gen. Gordon P. Saville, Deputy Chief of Staff, Development, "DCS/Development Internal Management of Mission Evaluation Projects," March 29, 1951, NARA, RG 341, NM-15 160, 1951 series, box 3, D/R&D file no. 322 (Project CHARLES). On the "development planning" process, see Johnson, *United States Air Force and the Culture of Innovation*, 39–46.

laboratory appointed its own steering committee, and according to Lincoln's imprecise, single-page charter, the only Air Force representative to its internal governance would be the director of a three-seat, tri-service "advisory committee," a position initially filled by General Yates.[66]

As the holder of Lincoln's contract, however, the USAF did still retain ultimate authority, but under pressure for the Office of the Secretary, the responsibility for administering it devolved several times until August 1951, when it reached ADSEC's old partner, the Cambridge Research Laboratories—now the Cambridge Research Center—which, as a modestly sized science-and-engineering station, possessed neither the interest nor the capability to monitor such a singular initiative. In October, General James F. Phillips, AFCRC's military administrator, informed his superiors that, even though his office had signed the contract, he believed the charter precluded anyone but the Advisory Committee from overseeing Lincoln's technical program.[67] Indeed, "the 'administration' that the Center provided was really contract administration," wrote the unit historian. "Cambridge received money from the Air Force and made it available to the contractor" and "helped LINCOLN fight its battles to get the money it needed in a timely fashion." Nevertheless, "the Center figured that LINCOLN required as much in the way of 'support' overhead…as the rest of the Center program."[68] Although this unusual arrangement did unnerve a few USAF officials, several years would pass before they realized the extent of its malfunction.

66. Memo, Maj. Gen. Donald L. Putt, Acting Deputy Chief of Staff, Development to Maj. Gen. Ward E. Maris, Deputy Assistant Chief of Staff, G-4 for Research and Development, United States Army, and RADM M. E. Curts, Assistant Chief of Naval Operations, Readiness, United States Navy, "Project Lincoln," August 1, 1951, plus attachment, "Charter for the Operation of Project LINCOLN," in D/R&D file no. 322 (Project LINCOLN), NARA, RG 341, NM-15 160, 1951 ser., box 3.

67. *Case History on Project Lincoln*, Historical Branch, Office of Information, Air Force Cambridge Research Laboratories, n.d. [November 1956?], MIT Lincoln Laboratory Archives, U339562A, vol. 1, 6–7.

68. William H. Wood, Jr., *History of the Air Force Cambridge Research Center, 1 July–31 December 1952*, pt. 1 (Bedford, MA: Scientific Literature Branch, Air Force Cambridge Research Center, July 31, 1953), AFHRA (0476921), 95.

Meeting the threat from Rome and Michigan

Aside from some additional testing on the MEW–Whirlwind link, 1952 was a quiet year on the experimental end of MIT's air-defense program. In terms of engineering, though, the newly formed Lincoln Laboratory continued expanding rapidly as design work began on "Whirlwind II," the machine intended to prototype an operational air-defense computer. The Air Force facilities at Hanscom grew apace, as the Cambridge Research Center prepared to relocate its 2200 personnel from Boston and its adjoining communities to the site of Lincoln's temporary construction. Moreover, the 6520th Test Support Wing stood up on April 1 as a headquarters for the air-base group and the 6521st AC&W Squadron, which had likewise been recently activated in order to build, maintain, and operate a network of small radar stations to be used during a larger digital-relay test planned for 1953. It would also provide aircraft, pilots, and a crew to run a mock direction- center from the Whirlwind building once the experiment finally took place.[69] Its buildup, too, was explosive, more than doubling to 2100 positions assigned by the end of December, and even that represented a shortfall of several hundred billets.[70]

Indeed, despite the lack of an exciting demonstration, reports from the period seemed positively manic, with administrators complaining of overcrowding, deficiencies of money and manpower, and a general state of disorganization. While Lincoln Laboratory could not avoid these vicissitudes entirely, especially in the case of physical facilities, its technical program nonetheless remained relatively well insulated from the confusion prevailing throughout greater Air Force—at least until the University of Michigan released the ADIS proposal, UMM-100, on September 29, 1952. It is unclear whether Lincoln's leadership had previously perceived Michigan's project as a threat to their own, but the swiftness,

69. By name, the Barta Building, located at 211 Massachusetts Avenue. The structure is now part of a research complex owned by Novartis.

70. *History of the 6520th Test Support Wing, 1 April–30 June 1952* (Bedford, MA: 6520th Test Support Wing, United States Air Force, n.d. [1952?]), AFHRA (0462528); Wood, *History of AFCRC, Jul.–Dec. 1952*, pt. 1, Narrative, AFHRA, 115–137.

accompanied, perhaps, by a slight touch of bitterness, with which they swatted down UMM-100 demonstrated the seriousness immediately attached to it.

By October 13, Jay Forrester had already prepared L-65, the sixty-fifth in his series of "limited distribution" memoranda, for Colonel Peter Schenk, who still served as an executive assistant at USAF headquarters, to brandish in the Pentagon.[71] The document seized on the fact that with respect to ADIS, "only a broad outline of the system and its suggested performance have been presented" in order to infer that "the physical nature of the system is not sufficiently established to justify the degree of confidence in time schedules or estimates of equipment complexity," which he took for evidence of "a tendency to promise anything the Air Force, as customer, would like, independent of engineering realities."[72]

The fundamental dispute stemmed from the estimation of Project CHARLES, in mid-1951, that a "long term improvement" of the air-defense system—by which it meant Project LINCOLN—could enter service by the end of 1955. Lacking further insight into the development, the Air Defense Command, Rome Air Development Center, and Willow Run Research Center of the University of Michigan judged this improbable, offering ADIS as a solution feasible by 1955, with the system outlined by CHARLES more likely to become available some time between 1958 and 1960. Forrester not only rejected the counter-estimate, he inverted it, arguing that the relative states of development showed that Willow Run could have ADIS ready no sooner than 1958, while Lincoln Laboratory was making steady progress towards its 1955 deadline. Thus, if ADIS proceeded as an "interim" measure, then it would prove entirely superfluous. Worse, "the system should be expected to reduce our defensive capability in the critical years 1956 and 1957 if installed according to the schedule proposed by Rome and University of Michigan," because any "time saved by omission of prototype

71. David T. Griggs had left the position of Chief Scientist in mid-1952 without a successor. It remained vacant until February 1954, when Chalmers W. Sherwin, a Rad Lab alumnus and then-director of the Control Systems Laboratory at the University in Illinois, accepted the appointment. During this 18-month lapse, the retired general James Doolittle provisionally assumed the role in his capacity as a "special assistant" to the Chief of Staff, with Schenk as his aide and back-channel to MIT. Dwayne A. Day, *Lightning Rod: A History of the Air Force Chief Scientist's Office* (Washington: Chief Scientist's Office, United States Air Force, 2000), 61–68.

72. Memo, Jay W. Forrester, L-65, October 13, 1952, microfilm, MIT, MC665, ser. 16, box 5, reel 28, 3–4.

testing will be more than lost in field modifications, debugging, and by the disorganization caused by extensive revision of complicated equipment at remote points."[73]

L-65 included a Gannt chart for Forrester to illustrate the timeline projected in UMM-100, which accounted for two years of undifferentiated "lead time," with his own schedule divided into design, contracting, prototyping, revision, testing, debugging, and final checkout phases, pushing the operating date for 12 ADIS-equipped ADDCs from mid-1955 to mid-1958. Ultimately, "any air defense equipment which the Air Force wishes to have in widespread, useful operation in 1955 must be complete in operating system form in 1952." Lincoln Laboratory had already demonstrated working equipment and planned to operate a scale-model of a complete system within six months—Michigan did not.

While it is, of course, impossible to say what might have happened with ADIS had history evolved differently, Forrester's critique of UMM-100 was, despite its acerbic tone, an entirely reasonable application of industrial-engineering practice. On that score, Lincoln Laboratory had organized its research-and-development program far more assiduously, though the nature of its reaction to ADIS suggested it neither knew nor especially cared about its opaqueness to Air Force technology managers, even those directly involved in air-defense matters.[74] But Willow Run's project now had a name, as well as an accompanying proposal, and the eagerness with which the Air Defense Command, in particular, began incorporating UMM-100 into its operational planning likely impressed upon Lincoln's lead engineers the importance of such seeming banalities within the Air Force bureaucracy.

Although quarterly reports had also listed among Forrester's paperwork obsessions since the days of Project Whirlwind, and Division 6—the Digital Computer laboratory, which he directed—had issued an attractive, professionally bound and typeset one as recently as June, these evidently lacked the circulation or clarity necessary to achieve a comparable effect.[75] To that end, Jay Forrester and George Valley, as well as four other senior staff, began

73. Memo, Forrester, L-65, October 13, 1952, MIT, 2–3.

74. Redmond and Smith, *From Whirlwind to MITRE*, 129–144 detailed the early planning stages.

75. J. N. Ulman, Jr., ed., *Quarterly Progress Report, Division 6—Division Computer, 1 June 1952* (Cambridge:

taking time away from their other duties to compose the document eventually designated as MIT Lincoln Laboratory Technical Memorandum No. 20, or TM-20, the draft of which they completed in December 1952.[76]

Like the laboratory's Quarterly Progress Reports, TM-20 first appealed to the eye. Whereas UMM-100 had been typewritten and illustrated only by crude block diagrams, the response featured a proper print design, high-quality photographs, and original concept art.[77] Its title, too—*A Proposal for Air Defense System Evolution*—carefully elicited the organizational truism that air-defense technology could and should "evolve" without disrupting operations; to reinforce the point, the subtitle suggested that the document would outline only the "transition phase" of this evolutionary process, one that did not break radically from established procedure. For final emphasis, the subject of the proposal was called the "Lincoln Transition System," or LTS, a modest self-appellation that, by comparison, slyly cast ADIS, the "Air Defense Integrated System," as the riskier and more ambitious of the two programs. Whether intentionally or otherwise, the rhetorical flourish mimicked the language of the "interim program," the brand the Air Force had applied to its long-

Lincoln Laboratory, Massachusetts Institute of Technology, June 1, 1952), MIT, MC665, ser. 11, box 1. Although the title page noted that 250 copies were printed, it lacked a distribution list. The report was classified "confidential," likely to increase its visibility, but the relatively low security rating also limited the information that could be included, as well as signaling to the reader otherwise swimming in top-secret operational-planning documents that the contents were probably not very important. Later editions were marked "secret," which would have only marginally improved their standing.

76. Jay W. Forrester et al., *A Proposal for Air Defense System Evolution: The Transition Phase*, Technical Memorandum No. 20 (Bedford, MA: Lincoln Laboratory, Massachusetts Institute of Technology, January 2, 1953), declassified copy, labeled "second draft," first draft dated December 1, 1952, DTIC (AD0019216). While Forrester left MIT proper to head Division 6 (Digital Computer), Valley had assumed responsibility for Division 2 (Aircraft Control and Warning). TM-20 listed the two as its authors but also named H. W. Boehmer, leader of Group 22 (Cape Cod System); Robert R. Everett, associate director of Division 6; John V. Harrington, leader of Group 24 (Data Transmission); and C. Robert Wieser, leader of Group 61 (Cape Cod System) as contributors. Incidentally, Project LINCOLN was organized very much like the Radiation Laboratory—unsurprising, given that its director, F. Wheeler Loomis, had also been the Rad Lab's associate director—with divisions corresponding to major research areas and groups to tasks within them (groups were also numbered after the division to which they were assigned). Divisions 2, 6, and some groups of 3 comprised the majority of the air-defense program, and indeed, the majority of the laboratory, though MIT had also moved some of its other contract work there as well. Massachusetts Institute of Technology, Project LINCOLN, "Group Organization List," January 20, 1952, MIT, AC004, box 135, folder 4.

77. Note that the second draft cited here, while identical in content was not the production-quality edition dated January 20, 1953.

term radar-construction plan after the "radar fence" failed to earn an appropriation from Congress.

What the system was supposed to transition *into*, however, was not only ignored, but purposefully obscured. "The proposed Future System is essentially that of the Charles Report," claimed Forrester, Valley, and their co-authors, notwithstanding the fact that CHARLES had itself been written to justify the task undertaken by ADSEC, and which Lincoln Laboratory had been founded to continue, now under the banner of the Lincoln Transition System. Because the Future System "is further away and less well defined," they evaded any attempt to position or define it, except with a vague assertion that it "should be operating throughout the country in 1958." They did warn strenuously, however, that "the proposed Transition Phase...is a necessary step before the complete Future System," so "without it the Future System will be seriously delayed."[78]

It is possible the authors knew that the Air Defense Command had requested in October that the Air Force proceed with ADIS as described in UMM-100 and reconsider Lincoln's as-yet nameless program as a potential defense against ballistic missiles, leading them to conjure the "Future System" as a foil for their ongoing anti-bomber initiative.[79] Regardless, the Future System functioned merely to recast the computerization of American air-defense as a "transition," smooth and contiguous, rather than a perilous "revolution" in organizational technology. UMM-100 had staked out a similar position for ADIS, and Forrester's criticism of the Rome–Michigan proposal notwithstanding, TM-20 followed in the kind.

More precisely, it specified how an air-defense operations center would function within the Lincoln Transition System. Also like UMM-100, TM-20 explained that during the "transition phase," automation would merely *assist* the crew in the performance of its familiar duties and not fundamentally alter them. The surveillance section would still monitor the

78. Project LINCOLN, "Group Organization List," January 1952, MIT, 3–4.

79. Gen. Benjamin W. Chidlaw, Commander-in-Chief, Air Defense Command to Gen. Hoyt S. Vandenberg, Chief of Staff, United States Air Force, October 13, 1952, quoted in Richard F. McMullen, *The Birth of SAGE, 1951–1958*, ADC Historical Study No. 33, vol. 1, Narrative (Ent AFB, CO: Headquarters, Air Defense Command, December 1965), AFHRA (0500702), 10–11.

airspace, just with clearer visualizations, processed by the computer, instead of raw detector signals; the movements-identification section would still classify contacts as friendly, hostile, or unknown, but with the computer's help to correlate them against flight-plan data, IFF returns, and so on; the weapons-assignment section would still designate targets for destruction by interceptor, guided missile, or anti-aircraft fire, only now the computer would recommend a tasking automatically; and intercept controllers would still vector aircraft toward the enemy, but only if they observed a situation warranting their intervention, as the computer itself could plot the course, as well as relay it to the pilot, or even directly into the autopilot, by means of an air–ground digital data-link.[80]

Meanwhile, plotters, tellers, scope readers, and other undesirables of the air-defense net would find their menial labor superseded by dependable electronics that never made a mistake because they became tired, distracted, nervous, apathetic, or inexperienced. Indeed, the brief statement of "system design principles" that dovetailed the report's functional description with its technical one featured a prominent treatment of "automaticity and the use of men." Possibly to assuage fears of a potential cut to ADC's troop allocation—a resource commanding generals guarded almost as fiercely as their budgets—the authors had already claimed that the LTS would *not* save manpower, only distribute it more efficiently.

Although accompanied by some clumsy deductions, the rhetoric did not break any new ground and mostly reiterated statements Valley had already advanced in the final reports of ADSEC and Project CHARLES, which UMM-100 had rehearsed as well. "In deciding whether to perform a given task automatically or manually, one must recognize that machines are best adapted to some operations and men to others," cut the old saw. "The machine is best at simple routine operations such as comparisons and correlations," along with the applications of those processes to air-defense operations, such as recording tracks, computing intercept geometry, and so on. "Men are best at tasks requiring the recognition of complex patterns" and "excel at the residual and peripheral functions which do not occur often enough to justify

80. Forrester et al., *Air Defense System Evolution,* 21–56 described the system's operation in functional terms.

mechanization" because of their "vast background of personal experience and doctrine which cannot be reduced to standard operating procedure." Balance would be achieved by allowing the machine to "prepare information in best form for human use and monitoring" while humans, and, ultimately, the commander, "monitor and approve any decisions made by the machine which affect the safety of men and aircraft."[81]

Thus retuned, the LTS sounded like an incremental, though strictly superior, improvement on the same ideas that motivated ADIS. While the contrast was not drawn directly, UMM-100 had emphasized the automation that could be implemented most simply and immediately; it featured a digital input-output system for receiving radar data and then cross- and forward-telling track information within an air-defense division. Its digital storage mechanism, ACDS, provided the working memory that facilitated the automatic conveyance of contacts, which console operators could manually tag with identifications and weapons assignments, and a pool for generating displays with a device as yet unspecified.[82] Essentially, TM-20 proposed a nearly identical input-output scheme, including buffer storage on magnetic drums, and retained the possibility of manual intervention, but it quite notably replaced ADIS's single-purpose ACDS store with a "central computer" capable of manipulating the contents of its own memory by programmed instruction.

At the time, the document could provide only estimates, since Division 6 had not yet completed the design of Whirlwind II, and indeed, had yet to convincingly demonstrate the suitability of its experimental magnetic-core memory.[83] At maximum capacity, however, the authors estimated an LTS installation could handle 600 tracks simultaneous—a ten-fold advantage over the 60-element ACDS store projected for ADIS. They likewise illustrated how

81. Forrester et al., *Air Defense System Evolution*, 59–60.

82. *Michigan Air Defense System Proposal*, 1–5.

83. Main memory was a major weakness for early computers. Whirlwind I had used "Williams tubes," a type of cathode-ray tube, similar to those found in television sets, which exploited phosphorescence to retain data for more than an instant (obviously, they needed to be read back and written out again every few milliseconds in order to persist). Although ferrite-core memory had been explored for years, they proved much more difficult to engineer than simpler electrostatic and electroacoustic storage elements. Cf. Redmond and Smith, *From Whirlwind to MITRE*, 144–252 on the design of Whirlwind II.

the 15-second sweep of a 4-RPM search radar could be divided into incremental stages of functionalized processing, with an estimated 4.7 seconds spared for future expansion, also an improvement over the 1.6 seconds reserved in the initial ADIS proposal.[84]

Rather than bluster, Forrester, Valley, and their collaborators may have understated the very substantial difference between the hybrid approach followed by Rome–Michigan and Lincoln's total commitment to digital electronics in order to demystify it. Their report did not call attention to the fact that, while the crew activity in an LTS facility itself might superficially resemble a traditional air-defense operations room, the central-computer concept would completely upend the field organization of the Air Defense Command. The issue was already a sensitive one, as Colorado Springs continued to wait on RADC to clarify the capabilities of automatic equipment before proceeding again to realign its air divisions, potentially activating or deactivating headquarters and shifting areas of operations, according to the number of tracks each Direction Center, and its corresponding Control Center, could handle simultaneously.

TM-20 obliterated the distinction between direction and control centers entirely, partitioning the LTS geographically into "Air Defense Sectors," each with a respective "Sector Control Center." This conflated the general understanding of a "sector," the region under the surveillance of a single radar-equipped ADDC, with a "division," which comprised several sectors reporting to a common ADCC. As much as the presentation strained to avoid such language, it is abundantly clear that the LTS intended to centralize *all* operational control within division in the facility that hosted the computer. Any distinction between ADDC and ADCC ceased to exist as individual radars served only to feed the encompassing new "Sector Control Center" with information remotely.[85]

From the perspective of ADC headquarters, which had to consider the consequences of what amounted to the most drastic doctrinal shift in its history, the organizational stakes

84. *Michigan Air Defense System Proposal*, 1–5; Forrester et al., *Air Defense System Evolution*, 50–51, 55–56.

85. Forrester et al., *Air Defense System Evolution*, 10–12.

far exceeded the pettiness of the technology politics.[86] TM-20's executive summary blandly stated that "the Transition System can have any desired degree of centralization or decentralization" and promised to discuss a "compromise," though never appeared to do so.[87] Instead, they projected the thorny question of organizational structure onto the computer's "programmed instructions."[88] The final report of Project CHARLES had done much the same while arguing in favor of computerizing air-defense operations, because "an ADCC is primarily an organization for correlating and processing a large amount of simple information and for using that information to make routine decisions." While "an analogue-type computer is, in general, circumscribed by its initial design...a digital computer can be quite thoroughly changed in function by the insertion of a new set of orders on a paper tape."[89]

CHARLES had had nothing else to say about computer programming, a deficiency that might surprise in retrospect, but which, according to the recent literature, was the outcome that should have been expected.[90] It counted among its primary authors mainly physicists and engineers, professionals who may have been intimately familiar with the principles and even the design of a digital computer, but would have rarely, if ever, deigned to punching cards or supervising shifts themselves. Thus, they were in a poor position to appreciate how writing programs that a computer could execute, reliably and efficiently, was a challenge entirely different from formulating an abstract algorithm, or blueprinting an arithmetic unit—a job that for years remained the province of lower status office-workers,

86. *ADC Historical Report, 1 Jan–30 Jun 1953*, vol. 1, Narrative, AFHRA, 11–12 hinted that Colorado Springs reacted to the surprise decision to implement TM-20 with bewilderment, primarily at the frustrating unwillingness on the part of higher headquarters to acknowledge its concerns.

87. Forrester et al., *Air Defense System Evolution*, 5.

88. According to Martin Campbell–Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge: MIT Press, 2003), 1–2, the first high-visibility usage of the term "software" dates to a 1966 issue of *Business Week*. Even then, it only became popular during the late seventies and early eighties.

89. *Problems of Air Defense*, 112.

90. For instance, Nathan Ensmenger, *The Computer Boys Take Over: Computers, Programmers, and the Politics of Technical Expertise* (Cambridge: MIT Press, 2010); Marie Hicks, *Programmed Inequality: How Britain Discarded Women Technologists and Lost Its Edge in Computing* (Cambridge: MIT Press, 2017); Janet Abbate, *Recoding Gender: Women's Changing Participation in Computing* (Cambridge: MIT Press, 2012).

rather than highly credentialed men of science.[91] Invoking the "paper tape" of programmed instructions became a convenient source of exemption from further elaboration. In other words, questions too difficult to answer at the preliminary stage were, rather, explained away with the assurance that a "master program" could be prepared to account for any contingency, with minimal cognizance of the tangible restrictions of memory, execution time, and program production and maintenance.

This points to the central theme of TM-20: flexibility. UMM-100 had already made its case for a "flexible" solution to the air-defense problem, proposing automated telling as a platform upon which to build a system of immediate usefulness without compromising its future adaptability. What mattered was the passage of precisely defined digital codes both into and out of the black box of the operations rooms. The organization and its equipment, meanwhile, could evolve as needed, and so long as the interface remained stable, the performance of any interconnected element should, in theory, remain unchanged, or perhaps even enhanced. This was, of course, idealized, leaving room for the LTS to surpass ADIS because "special-purpose features...which in other systems affect the physical design of equipment are handled in a general-purpose digital computer through the use of sequential control programs that are contained in perforated cards or tape," so that the "flexibility to meet changing requirements" could be achieved simply by "rewriting the control program [to] change the operating characteristics of the system."[92]

Even more auspiciously, "a new control program can be prepared for the computer if the logical organization of the system is affected," suggesting that air-defense units *themselves* could recover some of the organizational autonomy they had been gradually surrendering as their functions became more determined, and therefore more limited, by manufactured equipment. "A flexible system is of utmost importance," the authors insisted:

91. While not the earliest classic on software-project management, Frederick P. Brooks, Jr., *The Mythical Man-Month: Essays on Software Engineering* (Reading, MA: Addison–Wesley, 1975) is today probably the best-known text in the field written during its professionalization stage. See Ensmenger, *The Computer Boys Take Over*, 45–49.

92. Forrester et al., *Air Defense System Evolution*, 6.

> Most operations are controlled by programming instructions fed into the digital-computer part of the system. By changing these instructions, the organizational structure of the system can be changed without any change in the electronic structure; i.e., it can be used for different purposes without physical modifications of equipment. New kinds of weapons can be accommodated, new attack and defense procedures can be executed, and the balance of system capacity (that is, information storage, computing operations, and logical decisions) can be reallocated between the various tasks to be accomplished.[93]

To emphasize the elegance of the “paper tape” paradigm, TM-20 included an appendix with a simple example of computer programming, yielding the impression that the task would be easier than it was.

It also suggested that training a suitable workforce would be easier than it was. “The people who are best at programming and coding may have almost any academic background,” they claimed, citing Lincoln’s experience with the MEW–Whirlwind link and the upcoming test of the so-called “Cape Cod System,” the preparation of which then occupied about 50 programmers.[94] Since “the task is one of logical analysis,” it was “done best by the type of person who likes puzzles and who will make a meticulous, error-free analysis of a situation” with “a well-developed appreciation for the Air Defense problem” and “a physical system which contains a human organization and machines such as computers and aircraft.” Once Lincoln delivered the final code, “setting up computing programs” would be “comparable to establishing standard operating procedures to be used by people in a military organization,” requiring ADC to maintain only “a small staff of five to twenty persons to improve these programs and revise them to reflect new weapons and tactics” across the entire network.[95]

93. Forrester et al., *Air Defense System Evolution,* 20, 4.

94. Technically, there were two “Cape Cod” systems, so-named for the location of the primary AN/FPS-3 search radar at South Truro. The first one operated in the fall of 1953 and the second during the winter of 1954–1955. Both employed Whirlwind I, as Whirlwind II had not yet been completed. The debut of XD-1 was further delayed until the run of the Experimental SAGE Subsector from September 1957 to September 1958, a slippage caused largely, though not entirely, by the unexpected crisis of writing the master program. Redmond and Smith, *From Whirlwind to MITRE,* 303–335, 369–391. For comparison, recall that TM-20 projected the LTS would enter service during mid-to-late 1955.

95. Forrester et al., *Air Defense System Evolution,* 136–137. In reality, a staff this size was required to revise and adapt the program *at each site*. The primary workforce, contracted to the System Development Corporation,

Continuing with the badly flawed, perhaps willfully misinformed predictions that Forrester, Valley, and company issued with respect to computer programming would be to belabor a point made too easily in hindsight. No one had ever attempted to write a program like the one eventually implemented on the AN/FSQ-7, so even with greater insight and gentler motives, their best guesses might still have proved grossly inaccurate.[96] The more salient observation is the association between computer programming and organizational behavior at such an early stage. To an extent, this clarified the rhetoric introduced in Valley's ADSEC report, specifying which aspect of "system" most closely modeled the actions of a human organization. To a greater degree, however, it was explanation by exclusion, a conflation of technical and organizational behavior for the purpose of obscuring the former. "It is a stated advantage of ADIS that every man in the system can get out of store whatever information he wants whenever he wants it," Forrester himself wrote in L-65. "Now how does he know when to want this information? Is this done by S.O.P. [Standard Operating Procedure]? If so, precisely what is the S.O.P.?"[97] Evidently, he felt it less necessary to ask such questions of himself, at least for the purpose of selling an alternative.

TM-20's immediate effect is unclear.[98] Unlike Project CHARLES, the document clearly intended to persuade mid-level managers more than high-level executives. Most of its blemishes only replicated those of its archetype, UMM-100, which did receive a sufficiently warm reception in at least significant center of administration: the headquarters of the Air Defense Command. It nonetheless succeeded in surpassing its competitor in a final

employed several hundred programmers, even after the master program entered its maintenance phase.

96. The 1956 paper later reprinted as Herbert D. Benington, "Production of Large Computer Programs," *IEEE Annals in the History of Computing* 5, no. 4 (October–December 1983): 350–361, doi:10.1109/MAHC.1983.10102 is the canonical reference here. Among the many sources that touch upon the XD-1 computer-programming effort in some capacity, it has already been noted that Rebecca Slayton, *Arguments That Count: Physics, Computing, and Missile Defense, 1949–2012* (Cambridge: MIT Press, 2013), 17–39 is currently the best treatment in print.

97. Memo, Forrester, L-65, October 13, 1952, MIT, 4.

98. Redmond and Smith, *From Whirlwind to MITRE*, 253–261, 283–301 extracted the primary themes of TM-20, including evolution, flexibility, and the maturity of the experimental program described therein. Nevertheless, it gave little indication concerning its impact beyond Lincoln Laboratory, where it provided a basic plan for the work that continued into 1953.

section that described the preparations for the model Cape Cod System, accompanied by photographic evidence to prove the advanced state of Lincoln's program relative to the opposition.[99] Although lacking in critical areas, TM-20 at least looked like a plan with an articulated goal—certainly compared to its predecessors—and, more importantly, put a name to the laboratory's headline initiative.[100]

The wages of adhocracy

In any case, these factors probably did not affect subsequent events, the sequence of which is well known.[101] After reviewing as many sources as could be located on the matter, the common interpretation appears essentially correct.[102] To recapitulate, among his regular correspondence with Thomas K. Finletter, the Secretary of the Air Force, James R. Killian first threatened, in a letter dated December 21, 1951, to withdraw MIT from their agreement

99. *Problems of Air Defense*, 151–159.

100. There is some evidence that the decision to rename Project LINCOLN to Lincoln Laboratory had itself caused significant confusion. A "project" implied a final product, whereas a "laboratory" might be conducting any number of open-ended investigations that may or may not result in a development program, which would ordinarily be taken up by another agent.

101. Although first documented in *ADC Historical Report, 1 Jan–30 Jun 1953*, vol. 1, Narrative, AFHRA; McMullen, *Birth of SAGE*, vol. 1, Narrative, AFHRA is the work most cited by secondary sources, and in particular, Hughes and Edwards. (Hughes also consulted Killian's papers at MIT as referenced below.) Redmond followed their exhibits in preparing Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA, and though the Killian episode fell outside the scope of his writings with Smith on Project Whirlwind, it returned later as Redmond and Smith, *From Whirlwind to MITRE*, 263–270, the most detailed account published to date. Moreover, the perspective of John F. Jacobs, *The SAGE Air Defense System: A Personal History* (Bedford, MA: MITRE Corporation, 1987), 22–27 seems to have strongly influenced subsequent monographs.

102. The largest caches include the official papers of James R. Killian on the subject of Lincoln Laboratory from 1951 to 1954 in MIT, AC004, box 135, folders 4–7; the correspondence of the Office of the Secretary of the Air Force from 1951 to 1954 in OSAF file no. 000.8 (MIT) vols. 1–4, NARA, RG 340, A1 1-B, boxes 617, 969, 1230, and 1391; the correspondence of General Earle E. Partridge, Commander, Air Research and Development, Command, from 1952 to 1953 in AFHRA, microfilm, roll A1850; and the exhibits collected in: William H. Wood, Jr., *History of the Air Force Cambridge Research Center, 1 January–30 June 1953*, pt. 2B, Supporting Documents 47–183 (Bedford, MA: Office of Information Services, Air Force Cambridge Research Center, July 14, 1954), AFHRA (0476926); Redmond and Jordan, *Air Defense Management*, vol. 2, pt. A, Supporting Documents, AFHRA; and *Case History on Project Lincoln*, MIT Lincoln Laboratory Archives, vols. 2, 3. Unfortunately, the records most likely to add some nuance to the story are either classified or destroyed; it is also entirely possible that key actions were communicated verbally, precisely to avoid the creation of paper records.

unless the military ensured its commitment to Project LINCOLN.[103] The message came amid a flurry of peripheral communication between related parties regarding some dissatisfaction with the following year's budget, as well as payments still owed for the current cycle, both of which confirmed Killian's suspicion that LINCOLN was a financial liability. MIT did not have the capital to risk on a major development program, and the fee it charged the Air Force to administer the project left its operating budget exposed in case the funds should diminish, or worse, disappear entirely.

The challenge succeeded in dislodging enough money to satisfy the institute, but MIT clearly remained apprehensive. When the University of Michigan emerged as a potential competitor, however, this apprehension triggered a second round of budgetary brinkmanship. Another letter from Killian addressed to Finletter, dated January 9, 1953, again threatened to withdraw MIT and effectively proposed to settle the matter by contest between the two universities. Killian, ever the technocrat, chose his own weapon: an external review.[104] The secretary demonstrated the seriousness with which his office perceived the warning—and, incidentally, reveal that MIT held the higher hand—by dispatching a response by courier, rather than the post, within days of its receipt.[105]

While Finletter immediately agreed to terms, General Earle E. Partridge, the commander of the Air Research and Development Command, hedged his own agency's position in a January 28 memorandum sent both to Killian and Harlan Hatcher, the president of the University of Michigan.[106] Under pressure from the Air Defense Command to expedite

103. J. R. Killian, Jr., President, Massachusetts Institute of Technology to Thomas K. Finletter, Secretary, Department of the Air Force, December 12, 1951, attachment to memo, William A. M. Burden, Special Assistant (Research and Development), Office of the Secretary of the Air Force for Maj. Gen. D. L. Putt, Assistant Deputy Chief of Staff, Development, "Budgetary and Organizational Future of Project Lincoln," in OSAF file no. 000.8 (MIT), vol. 2, NARA, RG 340, A1 1-B, box 617.

104. J. R. Killian, Jr., President, Massachusetts Institute of Technology to Thomas K. Finletter, Secretary, Department of the Air Force, January 9, 1953, in OSAF file no. 000.8 (MIT), vol. 3, NARA, RG 340, A1 1-B, box 1230.

105. Thomas K. Finletter, Secretary of the Air Force to J. R. Killian, Jr., President, Massachusetts Institute of Technology, January 15, 1953, in OSAF file no. 000.8 (MIT), vol. 3, NARA, RG 340, A1 1-B, box 1230.

106. Lt. Gen. E. E. Partridge, Commander, Air Research and Development Command to James R. Killian, Jr., President, Massachusetts Institute of Technology, copy to Dr. Harlan Hatcher, President, University of

ADIS, Partridge acknowledged the request for a review but stated that since the shape of the future "Air Defense Electronic Environment" could not yet be predicted, ARDC would pursue both options until one proved itself over the other, or, at the very least, until the fiscal cycle finally forced the issue. Finletter had, by that point, vacated his office on the same day as Harry Truman, leaving the uniformed Air Force uncertain how Eisenhower's nominee, Harold E. Talbott, might choose to involve himself.[107] Partridge also had to consider the consequences for his own laboratories, which, in addition to the Rome Air Development Center, included the Wright Air Development Center (WADC), where Michigan remained a partner in the BOMARC program.

Although representatives from Bell Telephone Laboratories did conclude a review on terms not entirely favorable to MIT, by December 1953, their assessment no longer mattered.[108] The available evidence cannot identify a causative agent, but during the spring of 1953, General Partridge and his imminent successor, General Donald L. Putt, intimated to Hatcher at Michigan, as well as the leadership of Lincoln Laboratory, that ADIS would be discontinued. Commentators submit that Lincoln may have finally recognized the importance of persuading the Air Force's rank-and-file and successfully appealed to them directly; that they prevailed on IBM to refuse to negotiate with their competitors; that administrators at the University of Michigan never considered ADIS worth the fight; and that James R. Killian realized cynically, though not unjustifiably, that the Air Force had needed MIT much more than MIT needed the Air Force ever since General Arnold implored

Michigan, January 28, 1953, exhibit 57 in Wood, *History of AFCRC, Jan.–Dec. 1953*, pt. 2B, Supporting Documents 47–183, AFHRA.

107. The impending publication of Ralph E. Lapp and Stewart Alsop, "We Can Smash the Red A-Bombers," *Saturday Evening Post*, March 21, 1953, EBSCO (18941395) had also incensed the Air Staff, because not only did it skirt the press office, which was extremely unusual at a time when virtually all mass communications regarding national-security issues were coordinated with the military, it purportedly leaked classified information from a source in MIT's camp. Andrew H. Berding, Director, Office of Public Information, Office of the Secretary of Defense to Hugh Morrow, Associate Editor, *Saturday Evening Post*, January 22, 1953, in OSAF file no. 000.8 (MIT), vol. 3, NARA, RG 340, A1 1-B, box 1230 included a 20-page complaint as well as a request for self-censorship.

108. Bell Telephone Laboratories, "The Ground Environment Problem in Air Defense: An Appraisal of the Lincoln Transition System," December 17, 1953, in OSAF file no. 000.8 (MIT, oversize), NARA, RG 340, A1 82-A, box 1.

the staff of the Radiation Laboratory to join the Cambridge Field Station in October 1945.[109] The Cambridge lobby had succeeded in making itself indispensable in the Pentagon, and so, in a battle of institutional prestige, the outcome was virtually predetermined.

While the answer surely reflects all these causes to varying degrees, one point that has otherwise escaped notice is that, despite dangling a $15 million contract, ADIS had fared miserably at the request-for-proposal stage. Western Electric, the firm best suited to the task, simply returned the specifications without comment; Hughes and Bendix also declined while expressing some polite interest in subcontracting; Westinghouse responded with a bid that RADC never took seriously; and AC Spark Plug, a division of General Motors, replied with enthusiasm that evaluators interpreted as evidence of its inexperience.[110] Only General Electric tendered a document of sufficient promise, but it arrived after the initial review and might not have been scored by the time ARDC intervened officially.[111] On May 6, Partridge finally informed both Killian and Hatcher in writing that RADC would cease to fund development of the Air Defense Integrated System, though the action seems to have been expected for some time.[112] The same day, General Putt impressed upon administrators of CRC, RADC, and WADC the importance of reorienting their laboratories' programs exclusively around the Lincoln Transition System without delay and without complaint.[113]

109. This is mostly Redmond and Smith, supplemented by Hughes, as well as the oral histories they cited, with some extrapolation.

110. Memo, Lt. Col. James R. Cryer, Jr., Director of Procurement and Production, Rome Air Development Center for Brig. Gen. Clyde H. Mitchell, Deputy Director of Production, Air Materiel Command, "ADIS Program," March 10, 1953, in OSAF file no. 400.12, vol. 8, NARA, RG 340, A1 1-D, box 16.

111. General Electric, Electronics Division, "Design-Production Proposal for Air Defense Integrated System," March 18, 1953, in OSAF file no. 400.12, vol. 8, NARA, RG 340, A1 1-D, box 16.

112. Lt. Gen. E. E. Partridge, Commander, Air Research and Development Command to James R. Killian, Jr., President, Massachusetts Institute of Technology, copy to Dr. Harlan Hatcher, President, University of Michigan, January 28, 1953, exhibit 54 in Wood, *History of AFCRC, Jan.–Dec. 1953*, pt. 2B, Supporting Documents 47–183, AFHRA.

113. Maj. Gen. D. L. Putt, Vice Commander, Air Research and Development Command to Commanding General, Air Force Cambridge Research Center, "Revision of Command Policy Pertaining to Lincoln Transition System"; to Commanding General, Wright Air Development Center, "Revision of Command Policy Pertaining to ADEE"; and, to Commanding General, Rome Air Development Center, "Revision of Command Policy Pertaining

This appear to be a clear "moment of decision," regardless of whether the parties primarily responsible can be definitely identified. Setting aside the contention that, in an idealized bureaucracy, the decision-making *should* be observable, the Air Force was not even following its own rules. If the Office of the Secretary had been respecting the organization's formal division-of-labor, it would have deferred action on a specific contract to the major commands assigned and staffed for the purpose. As an executive high-office, it simply did not possess the resources to cast its gaze evenly on such initiatives; for instance, while ADIS was projected to cost about as much as the LTS during Fiscal Year 1954, MIT's case file accumulated nearly 200 pages of paperwork during Finletter's tenure, but the University of Michigan less than a dozen.[114]

The bureaucratic process, moreover, was moving in reverse. According to the regulations, the Air Defense Command should have issued a document called a "qualitative operational requirement" describing its equipment needs, which Air Force headquarters needed to certify as a "general operational requirement," before industrial procurement could be authorized.[115] Such a requirement was not approved until February 1955, meaning it had to be written to explain why a program *already in progress* should be initiated.[116] Even the "development directive" authorizing the disbursement of research-and-development funds on a digital computer for the "air defense centralized system" was not generated until

to ADIS," May 6, 1953, exhibits 62–64 in Wood, *History of AFCRC, Jan.–Dec. 1953*, pt. 2B, Supporting Documents 47–183, AFHRA.

114. To give a sense of scale, only 450 of the 9,000 people who worked at Air Force headquarters in 1953 worked in the Office of the Secretary of the Air Force. Figures from George M. Watson, Jr., *The Office of the Secretary of the Air Force, 1947–1965* (Washington: Center for Air Force History, 1993), 281.

115. United States Department of the Air Force, "Qualitative Operational Requirements," Air Force Regulation (AFR) 57-3 (Washington: GPO, May 23, 1951), MSFRIC; United States Department of the Air Force, "Research and Development: Planning and Management Procedures—Documentation," Air Force Regulation (AFR) 80-30 (Washington: GPO, July 30, 1953), MSFRIC.

116. The Lincoln Transition System was authorized on the pretext of General Operational Requirement (GOR) No. 3, "An Continental Aircraft Control & Warning System for 1952–1958," ADW 51-1, Director of Requirements, Headquarters, United States Air Force, December 27, 1951, exhibit 71 in Wood, *History of AFCRC, Jan.–Dec. 1953*, pt. 2B, Supporting Documents 47–183, AFHRA, but that document had been actually initiated the CADS program at Western Electric (see below). GOR No. 79, dated February 24, 1955, eventually satisfied the provisions of AFR 80-20.

March 1953—more than 18 months since the signing of AF18(600)-11, the Project LINCOLN contract, in August 1951.[117]

The wages of this "adhocracy" needed to paid immediately.[118] Among the first charges would be integration with the F-99 BOMARC, an antiaircraft cruise-missile developed jointly between the University of Michigan and the Boeing Corporation. Since the ADIS proposal had evolved from the F-99's ground-based fire-control system, the Lincoln Transition System now assumed the responsibility for guiding the missile to its target.[119] While the architects of the LTS had advertised its "flexibility" to adapt to arbitrary weapons systems such as BOMARC, no plan specified how the two programs should begin working to accommodate one another. The office managing the development of the F-102 Delta Dagger, moreover, encountered the same dilemma.[120] A digital data-link was supposed to feed vectors received from the LTS into the aircraft's flight computer automatically, as well as to identify the interceptor to ground controllers, but who would design, build, and test the equipment? The transmission protocol? The network of air–ground communications relays?

Lincoln insisted its obligations lay in the design-engineering of the prototype for the central computer, the XD-1, and the production model, officially designated the AN/FSQ-7,

117. Development Directive No. 3065, "Air Defense Centralized System—Transition Phase," Headquarters, Air Research and Development Command, March 3, 1953, exhibit 70 in Wood, *History of AFCRC, Jan.–Dec. 1953*, pt. 2B, Supporting Documents 47–183, AFHRA. Here, TM-20 did prove useful, as the directive essentially declared it the plan to be implemented.

118. Here, the invocation of "adhocracy" is purely glib. Some theories of organizational structure have incorporated the term, popularized by Alvin Toffler, into descriptive models: cf. Henry Mintzberg, *The Structuring of Organizations: A Synthesis of the Research* (Englewood Cliffs, NJ: Prentice–Hall, 1979), 431–465. The only intended parallel is that the contravention of bureaucracy is not abnormal, even if it is usually perceived as such.

119. All guided missiles with a range less than 150 miles remained the province of the Army; therefore, the F-99 had been designed to attack targets between 150 and 250 miles from the launcher—a distance far exceeding the limits of airborne radar. Thus, its flight would be guided remotely until the missile came close enough to acquire the target on its own.

120. Richard F. McMullen, *History of Air Defense Weapons, 1946–1962*, ADC Historical Study No. 14 (Ent AFB, CO: Historical Division, Headquarters, Air Defense Command, 1962), redacted copy provided by Command History Office, US Northern Command, Peterson AFB, CO, 263–267, 302–366 described the test programs for SAGE integration with the F-102 and F-99, respectively. Redmond and Smith, *From Whirlwind to MITRE*, 393–410 characterized Lincoln's attitude regarding systems integration, drawing upon Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA and Murphy, *Prologue to the Hanscom Complex*, AFHRA, among others.

as well as the digital radar-relay unit, the AN/FST-2.[121] Subcontracts would let to IBM for the computers and to Burroughs for the relay. All else should devolve on the manufacturers of the weapons themselves. By the time the Cape Cod tests concluded late in 1953, neither the F-99 nor the F-102 were as yet near enough to operational service for Lincoln's deferral to amount to more than some tedious coordinating conferences between engineers, but construction of a continental-spanning network of AN/FSQ-7 facilities—complete with power generation, cooling, ventilation, and telecommunication—needed to be scheduled right away. To perform the task, the Air Force badly required the services of the Western Electric Company, which both parties regarded as a leading authority on the workings of the continental air-defense system as a whole.[122]

As the manufacturing arm of the Bell System, Western Electric enjoyed a privileged relationship with all the armed forces. Notable among its specialties was the engineering of the world's largest electronic system: the telecommunication network of the United States and Canada. In December 1950, WECO had signed a contract through Air Defense Command headquarters for a project called "CADS," for "Continental Air Defense System." CADS, unlike CHARLES, was a field survey of operating equipment and procedures for the purpose of recommending improvements to the nationwide AC&W network as it existed, or soon would so. In scale, it overwhelmed all previous efforts; at its peak in 1952, CADS occupied 50 engineers full-time, who completed 172 substudies by the time they delivered their final

121. This finesses some interesting but insufficiently relevant details regarding the relationship between MIT and IBM; evidently, what the former called fastidiousness, the latter often interpreted as obstreperousness. The curious may consult, as usual, the relevant chapters of Redmond and Smith, *From Whirlwind to MITRE*, though that account, as has been repeatedly noted, tends to bury some points of contention, not least of them being the years-long litigation between the two parties over the patent on magnetic-core memory. Jacobs, *The SAGE Air Defense System*, on the other hand, found all the bloody-mindedness positively amusing, at least years after the fact; see also, Emerson W. Pugh, *Memories That Shaped an Industry: Decisions Leading to IBM System/360* (MIT Press: Cambridge, 1984). On the Burroughs equipment: W. A. Ogletree et al., "AN/FST-2 Radar-Processing Equipment for SAGE," paper presented at IRE–ACM–AIEE Eastern Joint Computer Conference '57: Computers with Deadlines to Meet, Washington, DC, December 9–13, 1957: 156–160, doi:10.1145/1457720.1457748 .

122. Stephen B. Adams and Orville R. Butler, *Manufacturing the Future: A History of Western Electric* (Cambridge: Cambridge University Press, 1999), 148–183 is relatively light on WECO's air-defense work. Fagen, *National Service in War and Peace*, 546–547, 573–581 contains a few remarks limited to BTL's supporting research.

report in January 1954.[123] From vacuum-tube reliability to maintenance-crew training to site calibration and radio- and telephone-operator protocol, Project CADS delivered 191 numbered recommendations filling six large volumes, excluding the summary report. Since WECO had already built and installed much of the AC&W complex itself, the Air Defense Command never questioned which firm should construct the Lincoln Transition System's physical plant. When ADC began preparing a statement-of-work in early 1954, it even played with designations like "CADS II" and "Super CADS."

It was thus profoundly embarrassed when Western Electric disclaimed the terms of their agreement in December 1954.[124] The root cause was, again, the position of Lincoln Laboratory with respect to the Transition System. If its directors had demurred from the role of a systems engineer for the air-defense program as a whole, they refused to allow another firm to assert itself over their own program as well. After the Air Force sided with Lincoln in a dispute over the AN/FSQ-7 production schedule, WECO's legal department found the liability intolerable. While the industrial giant would continue to provide manufacturing, construction, and installation services, it demanded that ADC delete the project management responsibilities with which it had previously been tasked.[125] By the start of 1955, then, general management of the centralized air-defense system remained at large, with the Air Force caught between Lincoln's confidence in itself and its disdain for impositions.

This was an inauspicious point for the air-defense computer to pivot from a research project to a development program. In truth, jurisdictional squabbles over contracting

123. Western Electric Company, *Continental Air Defense System: Final Report of the CADS Project,* Summary (Whippany, NJ: Bell Telephone Laboratories, January 30, 1954), AFHRA (0500634), 3–19. The remainder of this summary volume is a remarkable material culture of the air-defense network.

124. Technically, the statement had to be drafted jointly with the Air Materiel Command after the procurement and logistics agency rightly complained to Washington about a combat arm circumventing its industrial-program planning.

125. Redmond and Jordan, *Air Defense Management,* vol. 1, Narrative, AFHRA, 23–26. Large quantities of correspondence and contracting documents can be found in OSAF file no. 400.12, vols. 7, 8, NARA, RG 340, A1 1-D, boxes 15, 16 (see the following remarks on John W. Flatley).

authority and managerial power abounded throughout the 1950s, a symptom of delegating many of the administrative duties previously monopolized by government agencies to the private sector.[126] The boundary between "research" and "development" had always been hazy, but wherever the shift to "production" occurred, the line was clearly demarcated by an exponential increase in spending. Running the entirety of Lincoln Laboratory had cost the Air Force about $20 million per year—not even a rounding error compared to its $15 billion annual budget—but the involvement of WECO, IBM, and their subcontractors multiplied the figure tenfold.

The apprehension of military administrators grew with the size of the disbursements. Following the inconsequential decision, made years before, to let the Cambridge lab pay out *per diems* to the members of George Valley's ADSEC committee, the weight of the anxiety had fallen increasingly on AFCRC. In December 1954, ARDC headquarters forwarded a study suggesting that Lincoln Laboratory may have defied Western Electric in breach of its contract, and, even more distressingly, might be spending substantial sums appropriated for research purposes on procurement and production engineering in violation of federal law. Although ARDC asked the Cambridge Research Center to enforce the terms of the contract in its possession, it was again observed that the Lincoln charter seemed to preclude even the contract administrator from taking remedial action.[127]

Clearly, the United States Air Force had bought something very expensive, but was it a laboratory, a computer, a technological system, or a project administration? By mid-1955, MIT, IBM, and WECO were drawing against contracts worth hundreds of millions

126. Although generally less critical of privatization, the problems of contracting out the service of administration recurs throughout Johnson, *United States Air Force and the Culture of Innovation*; Thomas C. Lassman, *Sources of Weapon Systems Innovation in the Department of Defense: The Role of Research and Development, 1945–2000*, CMH Pub 51-2-1 (Washington: US Army Center of Military History, 2008); and Elliot V. Converse III, *Rearming for the Cold War, 1945–1960*, vol. 1 of *History of Acquisition in the Department of Defense* (Washington: Historical Office, Office of the Secretary of Defense, 2012). The rise of systems management ensconced in public bureaucracies like NASA and the Air Force Systems Command can be seen as a countervailing trend to the predominance of the "prime contractor" concept, as well as the emergence of private firms with significant systems-integration businesses, such as STL, RAND, and MITRE.

127. *Case History on Project Lincoln*, MIT Lincoln Laboratory Archives, 15–16.

of dollars with no instrument with which to assure their liaison with one another, with interrelated projects, or even with the agencies whose money they spent, aside from their mutual goodwill. The Inspector General opened an investigation, the Pentagon threatened to wrench the program from the Air Research and Development Command, and whether by this path, or some other, word reached Capitol Hill as well. In the fall, a group of examiners led by John W. Flatley, the director of the Federal Supply Bureau, and a member of the House Appropriations Committee's Surveys and Investigations Staff, began flooding the Office of the Secretary of the Air Force with documentation requests while federal agents repeatedly visited Hanscom, Rome, Dayton, and Baltimore armed with intrusive questions and prepared with points of criticism.[128] Congress took no action on whatever they found; it was never even reported into the public record.[129] Nevertheless, the message had been received.

But while Air Force officials deliberated over how to revise Lincoln's charter and assimilate its many stakeholders into a regular project organization, parties tended to act in remarkably good faith. Although the weakness of the restraints preventing them from doing otherwise present a disturbing counter-factual, it is impossible to say whether deficiencies of oversight delayed the program more than its internal difficulties. If 1955 was a year of unmitigated frustration for the Air Research and Development Command, the Air Defense Command at least succeeded in recapturing some of the initiative it lost with ADIS. As a particular necessity of the discouraging effort to develop the "master program" for the XD-1 computer, Division 6 at last collaborated with ADC on a document that merged both the latter's concern for its organization and the former's obsession with engineering.[130] Still

128. The volume of documents requested by the Flatley group, and the reports of their sites visits, exceed 5,000 pages, all in OSAF file no. 400.12, vols. 1–11, NARA, RG 340, A1 1-D, boxes 13–17, plus oversize enclosures in boxes 20, 21, and 26.

129. According to record searches through ProQuest Congressional, accessed January 30, 2015. Flatley and other members of his group did occasionally testify to House committees on procurement practices within the Department of Defense, but always in general terms phrased as opportunities for improvement, at least in unclassified hearings.

130. The detachment ADC sent to Hanscom in 1953 to work out the SAGE Operational Plan was permanently

more constitution than common law, the SAGE Operational Plan, also called the "maroon bible," finally specified in writing the intended behavior of organizational-technological system with precision sufficient to guide more specific plans about the numbers, locations, and implementation schedule for the anticipated SAGE Air Defense Sectors.[131]

Its publication on March 7 also marked the date on which the "Semiautomatic Ground Environment" officially superseded the "Lincoln Transition System," although TM-20 had already been presumed obsolete anyway. No longer bound by the pressure and persuasion, the SAGE Operational Plan, and its many annexes and amendments, drifted sharply from the form of its predecessor. Instead of a rhetorical wedge, informed by a general impression of air-defense operations, it read more like a bound volume of standard operating procedures, phrased in the future tense, a display of technical virtuosity grounded by mundane military precision. That SAGE would never fully achieve this pristine ideal, but nonetheless continue to work around them, even better demonstrates the confusing dualities between builder and user, hardware and software, and technology and organization.[132]

established shortly after it was published to help guide the implementation of the XD-1 master program; it later moved to Santa Monica when the System Development Corporation took over programming for the AN/FSQ-7: Armand M. Talignani and John C. Meyers, *History of the 4620th Air Defense Wing (Experimental SAGE) for the Period 1 June 1955–30 June 1958* (Santa Monica: 4620th Air Defense Wing, n.d. [1958?]), AFHRA (0461731).

131. *Operational Plan: Semiautomatic Ground Environment for Air Defense* (Ent AFB, CO: Headquarters, Air Defense Command, March 7, 1955), in OSAF file no. 160 (oversize), NARA, RG 340, A1 1-D, box 5.

132. The weakness in the architecture will be obvious to a professional computer analyst, but at the time, no expert could yet say whether it was insurmountable. Briefly, the computer executed synchronously, meaning that each step in the master program's main loop needed to finish processing before it could move on to the next. This was intended to take less than 15 seconds, so that the system updated its state once per rotation of a standard 4-RPM search radar. Under heavy load, however, the loop might take longer than 15 seconds to execute, causing displays to refresh more slowly, user inputs to back up in a storage buffer, and radar data to fall behind track calculations. In extreme cases, the phosphors on the operators' displays would go dark before the computer could instruct the CRT how to light them again, belated inputs would exceed the size of the buffer and never be acknowledged, and the tracks stored in memory would be so out of date that they could not be automatically correlated with new data. Cf. Kristy, *Man in a Large Information Processing System*; Bernd Ulmann, *AN/FSQ-7: The Computer That Shaped the Cold War* (Berlin: De Gruyter Oldenbourg, 2014).

4 The integration of cross-organizational systems

Late in 1955, an Army–Air Force dispute over SAGE control of Nike antiaircraft missiles became the first practical manifestation of the problem of integrating organizational technology across vertical lines of bureaucratic authority. The site of the initial confrontation was a new military headquarters, more typical of overseas than in the United States—called the Continental Air Defense Command (CONAD), a predecessor, of sorts, to the modern NORAD.[133] The establishment CONAD in 1954 created a combined command staff with representation from the Army, Air Force, and Navy, with its senior leadership consolidated in Colorado Springs.[134]

In particular, the Air Defense Command and the Army Antiaircraft Command (ARAA-COM) required coordinated procedures for employing their respective weapons in the destruction of enemy aircraft while avoiding laying fire on friendly aircraft. The issue had been contested for decades, but coordination became both more urgent and more demanding as Army emplacements transitioned from World War II-era antiaircraft artillery to guided surface-to-air missiles in the Nike family, some of which would even carry nuclear warheads—motivating the foundation of CONAD.[135] Naturally, the operational plan drawn up in the Air Force side of the shop called for Nike missiles to receive their firing instructions directly from the SAGE computer at the regional Air Defense Direction Center. Meanwhile, at the Army Signal Engineering Laboratories in Red Bank, New Jersey—the site from which the Air Force's own ground-electronics program had grown—was also developing a comput-

133. Technically, NORAD assumed the primary functions assigned to CONAD upon its establishment in September 1957, but CONAD persisted in order to execute the US interest in the binational defense organization until 1975: Lloyd H. Corbett Jr. and Mildred W. Johnson, *A Handbook of Aerospace Defense Organization, 1946–1980* (Peterson AFB: Office of History, Aerospace Defense Center, December 31, 1980), AFHRA (1039702), 1–16. NORAD is otherwise beyond the scope of this dissertation, although, incidentally, it has drawn considerably more interest from Canadian historians than American ones: cf. Richard Goette, *Sovereignty and Command in Canada–US Continental Air Defence, 1940–1957* (Vancouver: University of British Columbia Press, 2018); Joseph T. Jockel, *Canada in NORAD, 1957–2007: A History* (Montreal: McGill University Press, 2007).

134. Schaffel, *The Emerging Shield*, 241–254.

135. On Nike's operational deployment, Christopher J. Bright, *Continental Defense in the Eisenhower Era: Nuclear Antiaircraft Arms and the Cold War* (London: Palgrave Macmillan, 2010).

erized air-defense system: the AN/FSG-1, or "Missile Master." Like SAGE, Missile Masters would generate automatic firing-solutions for Nike batteries from inputs relayed digitally from remote sensors, and, as of 1955, the Army planned to deploy at least ten of them.[136]

Technology decisions and divided command

Lieutenant General Stanley R. Mickelsen, the ranking Army officer at CONAD, interpreted the ADC proposal as a usurpation of his command authority, which was already a sensitive issue, in light of the fraught construction of CONAD itself. Indeed, CONAD was practically a dummy organization for the Air Defense Command itself; its headquarters was co-located with ADC's in Colorado Springs, where ADC officers performed most of its duties as part-time assignments. Mickelsen wasted few opportunities to disparage his own unit's marginal position within the administration, going so far as to mock how even directives from Washington were being "expanded locally" and his staff "furnished additional 'principles'...of such a nature as to seriously and unfavorably affect the operational effectiveness of the Antiaircraft Command to an extent that I would be remiss if I did not advise you of their deleterious effects."[137]

General Earle E. Partridge, who had since been promoted to serve as a dual-hatted commander to both ADC and CONAD, attempted to bargain with Mickelsen, allowing ARAACOM to formulate its own proposal, but ultimately contended that SAGE and Missile Master would create, in essence, two separate, redundant, and conflicting air-defense systems.[138] Never-

136. Virtually nothing has appeared in print regarding the Missile Master program. A brief chronicle of the Army Antiaircraft Command (ARAACOM), and its successor, the Army Air Defense Command (ARADCOM) was reprinted as Stephen P. Moeller, "Vigilant and Invincible," *Air Defense Artillery* (May–June 1995): 2–42, OCLC (643957250).

137. Lt. Gen. S. M. Mickelsen to Commander in Chief, Continental Air Defense Command (CINCONAD), "Integration of SAGE into CONAD Operations," December 20, 1955, in exhibit 2 in Richard F. McMullen, *The Birth of SAGE, 1951–1958*, ADC Historical Study No. 33, vol. 2, Supporting Documents 1–18 (Ent AFB, CO: Headquarters, Air Defense Command, December 1965), AFHRA (0500703).

138. Gen. E. E. Partridge, Commander in Chief, CONAD to Chief of Staff, USAF, "Operational Plan for Deployment of NIKE in the SAGE Era," March 23, 1956, in exhibit 6 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA.

theless, Partridge's counterpart had held from the start that since SAGE–Nike integration implicated the "doctrine, organization, deployment, logistical support, administration and operations of this Command in such a fundamental manner," it would have to be considered "by other agencies of the Army" together with the "other basic functions of the Army."[139] In other words, Mickelsen rejected Partridge's authority as the commander of ADC to dictate ARAACOM's operational plans, his secondary assignment as Commander-in-Chief, CONAD notwithstanding. Instead, the Army should determine the most appropriate means to direct ARAACOM forces in combat. Since the disagreement crossed service boundaries, only the Joint Chiefs, or, more likely, the Secretary of Defense, could settle the issue.

While ostensibly hinging on a question of bureaucratic jurisdiction, technical concerns weighed heavily on both sides as well. Although similar in many ways, the AN/FSG-1, or "Missile Master," descended from a different research tradition than the AN/FSQ-7 that motivated SAGE. Whereas the latter was a general-purpose digital electronic computer, the former, which incorporated a less sophisticated digital computer in a much more limited capacity, had evolved from specialized, servomechanical fire-control devices developed as gun-laying aids for artillery pieces.[140] The two engineering traditions had nearly converged since the war's end—Missile Master, for instance, also incorporated a digital-electronic computer, albeit in a more limited capacity—enough to raise the possibility of integration, though not enough to do so without significant cooperation from the Army Signal Corps, which managed the program's specifications together with its prime contractor, the Martin

139. Mickelsen to CINCONAD, "Integration of SAGE into CONAD Operations," December 20, 1955, in exhibit 2 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA.

140. More specifically, the adaptation of gun-laying radar for the Army's surface-to-air-missile program, which was eventually consolidated as Project NIKE; cf. Fagen, *National Service in War and Peace*, 355–394. The Evans Signal Laboratory initiated development of Missile Master, originally coded Project 414A, in 1952 and activated a testbed facility at Fort Meade, Maryland in 1954: Charles L. Bachtel, "Army Air Defense, a Continuing Task," *Signal* 21, no. 4 (December 1966): 15–18; D. E. Eisenberg, A. E. Miller, and A. B. Shafritz, "Multiweapon Automatic Target and Battery Evaluator," paper presented at IRE–ACM–AIEE Eastern Joint Computer Conference '57: Computers with Deadlines to Meet, Washington, DC, December 9–13, 1957: 71–75, doi:10.1145/1457720.1457733 . (Incidentally, the latter paper, which describes the MATABE computer employed in Missile Master, was part of the same proceedings that disclosed the first technical summary of the AN/FSQ-7 and its associated equipment.)

Company.[141] Thus, the Army Antiaircraft Command could legitimately claim that Missile Master matched its precise operational needs by design, and that any external interference could only degrade its effectiveness in combat—essentially the same argument that ADC had deployed *against* SAGE, and in favor of ADIS, just a few years earlier.

The practical barriers to technical compatibility were indeed substantial. Missile Masters exchanged data between one another, as well as the Nike batteries under their control, with 750-bit-per-second data links, while all the equipment within a SAGE sector did so at 1300 bits-per-second. If SAGE and Nike were to interoperate, a digital modem would have to be installed somewhere on the line in order to translate the output from one machine into a form suitable for input into the other, and conversely. Transmission protocols would also have to be written, and the configuration of both systems altered accordingly.[142] But who would engineer them, and where would funding for the multi-million-dollar modification project come from? The Army and the Air Force maintained separate R&D organizations, with no common venue for designing, funding, or administering such a project. System integration would thus add costs on top of the funds already appropriated to the two programs individually and delay their operational dates while the necessary changes were implemented, manufactured, and tested.[143]

In May 1956, General Bergquist, now the operations chief at Air Force headquarters,

141. The Army actually classified the AN/FSG-1 as a *fire distribution* system; the central computer tracked the status of weapons, input from the sites of Nike missile launchers, in relation to the trajectories of hostile aircraft, as relayed by surveillance radar, and then calculated an assignment of targets to weapons within the defended area. The automation was intended assist the battle staff at an Army Antiaircraft Operations Center issue simultaneous instructions to the crews of the individual Nike batteries, who would employ a more conventional fire-control system to execute the assignment after it had been handed off: United States Department of the Army, *U.S. Army Air Defense Fire Distribution System AN/FSG-1 (Missile Master)*, Department of the Army Field Manual (FM) 44-10 (Washington: GPO, February 13, 1963), OCLC (952478055); United States Department of the Army, *U.S. Army Air Defense Employment*, Department of the Army Field Manual (FM) 44-1 (Washington: GPO, February 25, 1964), OCLC (952477778); United States Department of the Army, *Army Air Defense Command Posts*, Department of the Army Field Manual (FM) 44-8 (Washington: GPO, August 29, 1962), OCLC (952477778).

142. McMullen, *Birth of SAGE*, vol. 1, Narrative, AFHRA, 74–75.

143. Gen. E. E. Partridge, Commander-in-Chief, CONAD to Commanding General, Army Antiaircraft Command, "Re: Integration of SAGE into CONAD Operations," January 3, 1956, in exhibit 2 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA.

accompanied the entourage that argued ADC's case before the Armed Forces Policy Council, with Charles E. Wilson, Secretary of Defense, presiding.[144] The policy in question was the scope of the "operational control" specified in its "terms of reference"—in essence, the charter it had received from the Joint Chiefs in 1954. In its original form, the document stated that "CINCONAD [Commander-in-Chief, CONAD] will exercise operational control over all forces assigned or otherwise made available by the Joint Chiefs of Staff or other proper authority, for defense of the continental United States against air attack."[145] To this end, General Partridge, CONAD's commanding officer, told the council:

> It is my interpretation of the CONAD Terms of Reference that CINCONAD has been vested with the authority to control and direct all air-defense weapons which may be available to him in conducting the air defense of the Continental United States. It is axiomatic that authority to control implies the right to specify the method by which the control is to be exercised...With respect to the control of the NIKE weapon, I have a choice of two methods: 1. Integrate it into the air battle along with all the other air defense weapons; or 2. Establish a separate system for control of this weapon.[146]

The subtle implication was that *operational* control also imposed a certain degree of *technological* control. As an Air Force officer, Partridge could not dictate research-and-development policy to the Army Signal Corps, but as commander of the joint continental-defense mission, he could tell his superiors what equipment he needed to do his job.

144. More precisely, Charles Erwin Wilson, the former CEO of General Motors, nicknamed "Engine Charlie" to distinguish him from Charles Edward Wilson, or "Electric Charlie," the latter of whom had been the CEO of General Electric, as well as the Director of the Office of Defense Mobilization under President Truman. The Armed Force Policy Council is a standing committee provided by the National Security Act (originally called the War Council) which includes, by law, the Secretary of Defense as its chair, the three secretaries of the military departments, and the three chiefs of each service; although intended as a deliberative body with decision-making power, it seems to have only functioned as such in a limited capacity during the 1950s, and has otherwise become a regular meeting for sharing information between agency representatives: Edgar F. Raines Jr. and David R. Campbell, *The Army and the Joint Chiefs of Staff: Evolution of Army Ideas on the Command, Control, and Coordination of the U.S. Armed Forces, 1942–1985*, CMH Pub 93-3 (Washington: US Army Center of Military History, 1986), 85, 134.

145. "Terms of Reference and Mission," annex to memo, Joint Chiefs of Staff, "Continental Air Defense Command," JCSM-68-54, August 2, 1954, reprinted in Richard I. Wolf, ed., *The United States Air Force: Basic Documents on Roles and Missions* (Washington: Office of Air Force History, 1987), 279.

146. "Operational Concept for Control of Air Defense Weapons," transcript of briefing for Armed Forces Policy Council by Gen. E. E. Partridge, CINCONAD, May 3, 1956, 1–2, in exhibit 12 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA.

More specifically, the duty to issue *military requirements*—a concept derived from an Army commander's historical prerogative to set the conditions of logistical support—was his, at least insofar as it concerned continental defense.[147] Partridge thus invoked the commander's responsibility for his unit's materièl to advance SAGE as the logical means with which to direct Nike missiles:

> I am now prepared to recommend the system which, in my opinion, must be adopted. It is a system based on the integration of the firepower of all air defense weapons; a system which employs a single operational control channel down to the lowest level where sufficient intelligence is available to permit a coordinated and integrated effort; a system which eliminates unnecessary duplication at a substantial monetary saving; a system which will provide the American people with the most air defense for their tax dollar.[148]

That system would, of course, be SAGE, and SAGE alone. By losing Missile Master, the Army would not forfeit its command prerogative; rather, it would merely "integrate" the functions of two separate facilities into an efficiently centralized operations center, where Army officers would still perform their statutory roles on a joint command staff.

147. The Army's mobilization for both the world wars observed the same principle—adapted from a British model—in which the "high command" assumed responsibility for raising, training, and equipping forces within the "zone of the interior" (in this case, the continental United States) and then consigned them to the supreme authority of the commander of the "theater of operations" into which they deployed. In principle, the overseas commander enjoyed near-absolute discretion over the organization, administration, and employment of all the resources that Washington decided to place at his disposal, while in practice, theater headquarters negotiated continually with the high command over both general policies, such as the scope and pace of the mobilization, as well as specific matters concerning the composition of various types of units. There are numerous secondary sources that attest this characterization during World War II; for example, Roland G. Ruppenthal, *Logistical Support of the Armies*, The United States Army in World War II: The European Theater of Operations, CMH Pub 7-2-1, 7-3-1 (1953; repr., Washington: US Army Center of Military History, 1995), though George Forty, *US Army Handbook, 1939–1945*, 2nd ed. (Stroud, Gloucestershire, UK: Alan Sutton Publishing, 1998), 1–35 provides an adequate schematic for those disinclined to pour through multiple volumes of official history. United States Department of the Army, *Field Service Regulations, Administration*, War Department Field Manual (FM) 100-10 (Washington: GPO, November 15, 1943), OCLC (654244791) codified the doctrine in effect during the war, though the basic language varied only slightly between successive revisions of the *Field Service Regulations* dating back to at least 1914. A "military requirement" was actually a formal document, often formulated by the staff of a field command for review by USAF headquarters, declaring the need for equipment meeting the specified criteria, the certification of which normally triggered the process of research, development, and procurement, as per AFR 57-3, "Qualitative Operational Requirements," May 1951, MSFRIC; AFR 80-30, "Research and Development Planning and Management Documentation," July 1953, MSFRIC; among others.

148. Partridge briefing to Armed Forces Policy Council, May 3, 1956, 4, in exhibit 12 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA.

Meanwhile, the scope of SAGE operations, the general asserted, neatly encapsulated the Air Force's official mission with respect to continental defense: surveillance, target acquisition, weapons direction, and ultimate supervision of the air battle. As a purely technological object, he argued, the AN/FSQ-7 computer was, by its very nature, agnostic to service affiliation; rather, it could only execute programmed instructions and could therefore direct Nike batteries just as impartially as Missile Master. The Air Force nonetheless made certain to have its operations chief qualify during the subsequent briefing (as described below) that "human judgment...can be inserted when desired," and since "operators will be capable of overriding computer decisions," an Army crew at a SAGE Direction Center would have the same freedom of action as at one of their own Antiaircraft Operations Centers, but with even better information available upon which to base their decisions.[149]

Since the mechanization of organizational functions was projected to become increasingly common in the coming years, as the Army, Navy, and Air Force deployed more and more weapons platforms toward similar objectives, Partridge claimed to see no other viable path for the continental air-defense program than "integration" under a unified commander. Still, the general realized that his legalistic argument, precise yet abbreviated, would probably not sway the council on its own. To that end, his remarks served to introduce General Bergquist's technical briefing, which attempted to refute specific elements of the Army critique point by point while also advancing the Air Force notion of "integration" toward a rhetorical climax.

Integration: "technical" or "functional"?

After countering several allegations concerning SAGE's speed, range, and reliability, General Bergquist continued Partridge's attack by contesting that, in proposing an independent network of search radars to support Missile Master, the Army not only threatened to wastefully

149. "Operational Concept for Control of Air Defense Weapons," transcript of briefing for Armed Forces Policy Council by Maj. Gen. K. P. Bergquist, CINCONAD, May 3, 1956, 8, in exhibit 12 in McMullen, *Birth of SAGE,* vol. 2, Supporting Documents 1–18, AFHRA.

duplicate the Air Force's prior investments, but also could physically interfere with a carefully calibrated pattern of electromagnetic radiation. Bergquist concluded by reiterating Partridge's position, with a special accent on the connection between command authority and technical compatibility. "We feel that the crux of the matter is operational control," he said. "Three points are important here":

> First, control of forces, or in this case weapons, must be at the level where sufficient information is available to fully exploit the *combined* capabilities of the available weapons.
>
> Secondly, proven principles of war apply—concentration of force, economy of force and flexibility.
>
> Thirdly, air defense requires a family of weapons operated by a thoroughly integrated system.[150]

But proceeding with Missile Master "would be contrary to these three points," Bergquist emphasized. In order to resolve the issue, as well as to set a precedent for future interservice, and even international conflicts, the Joint Chiefs should therefore revise the CONAD Terms of Reference to clarify CINCONAD's power to set requirements for air defense.[151]

The situation was remarkably similar to Bergquist's experience attempting to prepare an air defense of the Hawaiian islands—a parade of what the Winter Study Group later called a "crisis in command." Many of the same symptoms presented: dissonance between technical and organizational behaviors, maladjustment to a rapidly changing inventory of abstruse equipment and methods, misapprehension between commanders and subordinates, and uncertain lines of bureaucratic authority—each placing a greater demand on, and raising another barrier toward, cooperation between multiple stakeholders. Notably, neither the phrases "command and control" nor "command and control system" entered

150. Bergquist briefing to Armed Forces Policy Council, May 3, 1956, 10–11, in exhibit 12 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA, emphasis in original.

151. It is worth observing that the stakes for the contest with Army were higher than the outcome of the dispute itself, because it was also expected to set a precedent for the Air Force's relationship with the Navy—in particular, the integration of SAGE with the TALOS ship-launched surface-to-air missile, as well as air- and seaborne radar pickets—which had not yet reached fulfillment to their relatively smaller scale and earlier phase of development. The likelihood of negotiating technological behavior across the boundary of national sovereignty with the Canadian armed forces also loomed on the horizon.

into the discussion at this stage, suggesting that the conflict between SAGE and Missile Master remained, as of 1956, too local to motivate a classification beyond the continental-defense mission. However, at least one conceptual tool had evolved in confrontation with these problems, which Partridge had already invoked loosely, though in the spirit of General Saville's briefing to Secretary Forrestal nearly a decade prior; namely, that of *integration*.

Although the concept held special significance within the emerging practice of systems engineering, it elicited subtly different shades of meaning in an instance such as the Missile Master dispute. During his remarks, Bergquist sought to sharpen the blade. In the first case, integration merely implied technical compatibility: Nike, from the Air Force perspective, must "integrate" with SAGE just as an aircraft's radio gear was "integrated" into the airframe. The former had to be engineered to withstand vibrations and the stress of flight maneuvers, to draw power from bleed air, to occupy a precise mass and volume, and otherwise present no unmitigated interference with other components, either physically or electromagnetically. Likewise, the latter would ideally incorporate airborne electronics as a known constraint in order to maximize aerodynamic performance without too badly compromising the effectiveness of the aircraft's radar, communications, countermeasures, and so on.[152]

The second case, however, did not map so easily onto an established disciplinary practice. Both Partridge and Bergquist spoke of an "integrated" air-defense system as a composite of organizational functions: namely, those of the Army and the Air Force. This rhetoric suggested not only common—or, at least, compatible hardware—but also a unified concept of operation, including a delegation of responsibility between respective commanders that matched legal authority to technological behavior. Although the two notions of "integration" were as yet not differently labeled, the Winter Study later attempted to distinguish them through nomenclature:

> First, by *technical integration* we mean emphasis on the use of a common communication system, and at each command on use of similar computers, displays, communication

152. Cf. Johnson, *United States Air Force and the Culture of Innovation*, 27–58, especially for bibliographic references.

> switching equipment and programming languages. For example, a SAGE-like system could be designed where each headquarters would have a center adapted to its individual needs. (An extreme form of technical integration would use common computing and display facilities for several commands.)
>
> Next by *functional integration* we mean emphasis on insuring that all operating command functions are clearly and appropriately assigned to the commands, that the commands coordinate their plans and communicate actions with one another as required for mutual support and overall effectiveness, and that a strong higher command provide overall direction of forces and management of change.[153]

While the authors identified the former as necessary, the latter activity was deemed to be absolutely critical to the orderly implementation of military command-and-control systems.

Internecine conflicts like the one between SAGE and Missile Master exacted a price on their respective programs in terms of time, money, and performance. Ideally, SAGE–Nike integration would have been planned years in advance, in technical and organizational terms, and not merely triaged once the conflict became unavoidable. The fact that the Air Force *had* planned for it from an early stage, but without consulting the Army, which continued its own program despite knowing about the other, only emphasized the underlying problem. No unitary site existed for the conceptual planning and engineering management necessary to realize the concept of "functional integration" between the two services.

As for Missile Master, Secretary Wilson decided on mutual appeasement, the resolution most common during the second golden-age of interservice rivalry: a period of cutbacks in defense spending triggered by Eisenhower's approval of the "New Look" policy in 1953.[154]

153. Winter Study Group, *Final Report*, September 1960, RG 340, 107, emphasis in original.

154. In short, the New Look attempted to restrain the defense budget by emphasizing nuclear deterrence through massive retaliation, leading to a decline in non-nuclear forces that strongly disfavored the interests of the Army and the Navy relative to the Air Force: cf. Saki Dockrill, *Eisenhower's New Look: National Security Policy, 1953–1961* (New York: St. Martin's, 1996); Robert J. Watson, *Into the Missile Age, 1956-1960*, vol. 4 of *History of the Office of the Secretary of Defense*, ed. Alfred L. Goldberg (Washington: Historical Office, Office of the Secretary of Defense, 1997); Campbell Craig, *Destroying the Village: Eisenhower and Thermonuclear War* (New York: Columbia University Press, 1998); Robert R. Bowie, and Richard H. Immerman, *Waging Peace: How Eisenhower Shaped an Enduring Cold War Strategy* (Oxford: Oxford University Press, 1998). Conflicts over implementing the necessary budget cuts dominated "Engine Charlie" Wilson's troubled tenure as Secretary of Defense, culminating in the acrimonious Thor–Jupiter controversy, which was also settled by contriving a reason to give both the Army and the Air Force what each of them wanted: E. Bruce Geelhoed, *Charles E. Wilson and Controversy at the Pentagon, 1953 to 1957* (Detroit: Wayne State University Press, 1979); Armacost, *The Politics of Weapons Innovation*.

The extent to which the Joint Chiefs modified CONAD's Terms of Reference directly in response to Missile Master remains unclear; the revision, issued in September 1956, mostly concerned itself with weightier matters of organizational policy, and Partridge had visited Washington several times that spring to lobby the Armed Forces Policy Council about other issues related to CONAD's authority as well.[155] Nevertheless, the new document awarded partial victories to both sides, definitely granting air-defense commanders operational control over all weapons within their respective areas, including surface-to-air missiles, by designating CONAD as a "joint command" and assigning both ADC and ARAACOM as non-combat components.[156] The move, however—which Partridge, incidentally, opposed, breaking even with USAF headquarters—also reinforced the prerogative of each service to equip its own forces before turning them over to CONAD, allowing the Army to keep its Missile Masters, so long as they could be retrofitted to accept instructions from SAGE.

In other words, one organizational machine prevailed over the other. Under normal conditions, a SAGE sector would automatically relay firing instructions to the Missile Master, where they could be manually reviewed, at the Army commander's discretion, before execution by the Nike batteries. However, the Missile Master would direct the missiles itself in the event that the SAGE network failed or entered one of two partially degraded states. General Partridge established a joint Army–Air Force working group on the CONAD staff to settle the precise method of employment to draft what can only be described as

155. The new Terms of Reference effected a major reorganization that implicated not only CONAD, but the disposition of all the nation's combat forces in North America; furthermore, the new structure was intended to build the legal framework into which the Canadian Armed Forces could eventually be incorporated through a binational agreement, achieved less than a year later with the establishment of NORAD: Goette, *Sovereignty and Command in Canada–US Continental Air Defence*, 170–191.

156. Lloyd H. Cornett et al., *Continental Air Defense Command Historical Summary, July 1956–June 1957* (Colorado Springs: Directorate of Command History, Headquarters, Continental Air Defense Command, September 15, 1957), redacted copy provided by Command History Office, US Northern Command, Peterson AFB, CO, 1–14; see also Edward J. Drea et al., *History of the Unified Command Plan, 1946–2012* (Washington: Joint History Office, Office of the Chairman of the Joint Chiefs of Staff, 2013), 17–20. Unmentioned in the preceding passage is NAVFORCONAC, the small contingent the Navy had delegated for service for CONAC in 1954. As a member of the Joint Chiefs of Staff, however, the Chief of Naval Operations did exercise considerable political influence over the evolution of CONAD, as he typically sided with the Army in resisting the Air Force's predominance over the continental-defense mission.

"jurisdictional-technical treaties"—detailed instructions for Missile Master crews to observe under each of SAGE's four operating modes. Subsequent testing plans also specified the digital information that SAGE and Missile Master computers would have to exchange in order to support the operational concept.[157]

Nevertheless, CONAD, even elevated to the level of a joint command, was still far from a research and development agency; it could only try to coordinate operational plans with the many firms and offices charged by some legal instrument with implementing the two programs. The conference that devised the operational testing plan in 1957, for instance, demanded representation from no fewer than eight military commands and five private contractors.[158] The loosely managed integration effort prolapsed even farther behind the frustratingly elastic schedules for SAGE and Missile Master. Incremental design changes cascaded across organizational boundaries, forcing costly redesigns and modifications. The management collective even struggled to keep its widely scattered technical documentation in order.[159] Consequently, SAGE–Missile Master integration testing had only just begun when the Winter Study Group came together late in 1959, with operational capability still more than a year away.

157. Culminating in Report, "Proposed Employment of Antiaircraft Weapons in the SAGE Era," prepared jointly in conference, August 9–17, 1956, Headquarters, Continental Air Defense Command, Ent AFB, CO, enclosure in OSAF file no. 21-56 (SAGE Program, oversize), NARA, RG 340, A1 1-F, Box 111, the blueprint for SAGE–Missile Master integration worked out between representatives of the Air Force, and the major contractors for their respective systems, including Lincoln Laboratory, Western Electric, the Martin Company, and others.

158. Memo, Col. Samuel C. Galbreath, Acting Director of Requirements, Headquarters, United States Air Force, "Draft of CONAD Plan for Testing SAGE/Missile Master," July 31, 1957, exhibit 22; and Study Group Report, "Extension of Nike Battery Data Loop to the SAGE Direction Center," September 1, 1957, exhibit 23; both in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA.

159. For example, the minutes attached to memo, Lt. Col. Dale R. Tidball, Deputy Chief, ADES Project Office, Electronic Defense Systems Division, Air Materiel Command, "SAGE Phasing Group Meeting 10 July 1957," July 15, 1957, exhibit 18 in McMullen, *Birth of SAGE*, vol. 2, Supporting Documents 1–18, AFHRA included the summary of a withering fifteen-point critique of the organization's inaptness prepared by the Office of the Deputy Chief of Staff, Materiel.

The crisis tendency of technology management

While insufficient to contain a fractious military-political dispute such as the one that broke in 1956, the Air Force had taken a few tentative steps toward expanding the sphere of participants in Project LINCOLN, officially rebranded in 1953 as the Lincoln Transition System, or LTS. During the spring of 1954, for instance, a technical-information group called the Air Defense Engineering Service (ADES) began meeting in New York City, essentially to ameliorate Western Electric's concerns about accepting the contractual obligation to construct the LTS network without managerial control over the industrial program. Although it engendered little enthusiasm among its members, some of whom dismissed it as an "impractical and an unwise dilution of critical scientific talent," it was the only arrangement acceptable to Lincoln Laboratory, which, though preoccupied with the design of the central computer, its software, and peripheral components, nonetheless refused to cede the system design to another party, even to build out the necessary infrastructure.[160]

The existence of ADES deferred the search for a better arrangement until mid-1956, as the turmoil surrounding integration problems like Missile Master could be neglected no longer. By that point, General Partridge, speaking for the Air Defense Command, perceived little choice but to inform USAF headquarters that "experience to date has been that action taken to overcome major problems connected with SAGE is characterized by delay and in effectiveness, largely caused by the fact that the present structure, missions, and authorities of the agencies involved are not suited to the task."[161] Similar complaints had inspired the Air Force Inspector General to savage the premise of managing a program on the scale of the continental air-defense system with an *ad hoc* committee as flimsy as ADES. According to the IG, SAGE was not a "weapons system" at all, but a multilateral defense program,

160. Col. A. R. Shiely, Jr., Chief, Air Defense Systems Operations Division, Headquarters, Air Research and Development Command, to George E. Valley, Associate Director, Lincoln Laboratory, April 20, 1956, quoted in Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA, 29.

161. Lt. Gen. Earle E. Partridge, Commander, Air Defense Command, to Maj. Gen. Donald L. Putt, Deputy Chief of Operations, Headquarters, United States Air Force, "Air Defense Development Program," August 13, 1956, quoted in Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA, 28.

demanding firm direction from a single, coordinated, unambiguous authority.[162]

As observed previously, the finding caused General Thomas D. White, the Air Force's Chief of Staff, to consider assuming direct control through a special "crash program" like General Bernard Schriever's extraordinary organization, which, following the recommendations of the Teapot Committee, among others, had taken over all ballistic-missile development responsibilities in 1954.[163] Nevertheless, the ballistic-missile program had experienced its own problems under Air Force supervision. At bottom, the postwar practice of "systems management," incipient as it may have been, had evolved primarily in the context of procuring mass quantities of sophisticated aircraft. As early as the 1920s, the Army air-arm had pursued the path of private investment, rather than military self-sufficiency, in order to satisfy its technological demands, but soliciting external contractors, while still maintaining the propriety of free enterprise, required new legal instruments and elaborate administrative controls. Thus, questions lingered as to whether procedures intended for the research, development, and production of aircraft could even be applied to "systems" other than piloted aerodynamic vehicles.[164]

For instance, the distinction between development and production, reified by the organizational separation between the Air Research and Development Command and the Air Materiel Command, was less meaningful to a ballistic missile, each of which could only fly once, and hence, required substantial manufacturing capabilities to even commence flight testing. The decision cycle, divided between the warring kingdoms of AMC and ARDC, became so cumbersome that President Eisenhower eventually removed the program from normal channels entirely, placing it in the hands of an executive committee that answered directly to the Secretary of Defense, with the Air Force acting as steward.

162. USAF Inspector General, *Survey of Project SAGE*, RG 341.

163. On Von Neumann's recommendations, and the overall reorganization of the national ballistic-missile program, see Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945–1960* (Washington: Office of Air Force History, 1990), 93–118.

164. Cf. Converse, *Rearming for the Cold War*, 465–506; Johnson, *United States Air Force and the Culture of Innovation*, 59–110.

The case appeared even hazier with respect to large "electronic supporting systems" like SAGE, which would eventually become known broadly as "command and control systems," because, according to the Inspector General, they should not be construed as "weapons systems" at all. Although revisions of Air Force Regulation 20-10, "Weapon System Project Offices," later added an allowance for Electronic Supporting Systems Project Offices (ESSPOs), in addition to the Weapons System Project Offices (WSPOs) intended to manage aerospace programs, the official guidance offered no meaningful distinctions between them.[165] Thus, the task of adapting rules and procedures written with WSPOs in mind devolved to ARDC's middle-management for ground electronics, which, while still split between Rome and Cambridge, quickly began consolidating around the site of Lincoln Laboratory.

The first ESSPOs dated roughly to the break-up of the Air Defense Engineering Service in 1957. ADES, while assuming WSPO-like responsibilities, possessed none of the teeth of a proper management organization, and neither did its intended product necessarily resemble a weapons system in the first place. Instead of duplicating the special arrangement made for the ballistic missile program—which ARDC's commander, General Thomas S. Power, successfully argued would defeat the purpose of retaining a dedicated "research and development command" at all—the Air Force replaced ADES with a two-level structure under ARDC's direction. The trunk of the SAGE program became Project 216L (later redesignated 416L) with its own ESSPO located at Hanscom Field.

Simultaneously, General Power established the Air Defense Systems Management Office, or ADSMO, also at Hanscom, to organize the "total air defense system," which included such other programs as the Distant Early Warning line, the F-102 interceptor, the long-range BOMARC surface-to-air missile, in addition to the AN/FSQ-7 computer and its

165. United States Department of the Air Force, "Organization—General: Weapons System Project Offices," Air Force Regulation (AFR) 20-10 (Washington: GPO, March 24, 1958), MSFRIC carried over language introduced by a 1956 change order to the 1954 regulation that specified a "support system" as "a composite of equipment, skills, and techniques which, while not an instrument of combat, has the capability of performing a clearly defined function in support of an Air Force mission," but nevertheless stipulated that, for formal purposes, "the term *support system* may be substituted for *weapon system* wherever it appears."

associated computer-programming effort. Rather like ADES before it, ADSMO was a joint effort between ARDC, AMC, and ADC, but it lacked representation from essential contractors, and its ranking officer was, moreover, a mere colonel, with little suasion over the generals whose cooperation he needed badly to secure. To mitigate these issues, obvious from the start, the arrangement shifted once more in 1958, when ARDC headquarters promoted ADSMO from a field office to an operating division, now called "ADSID," the Air Defense System Integration Division.[166]

At the same time, MIT spun off the majority of Lincoln Laboratory's Division 6 into the non-profit MITRE Corporation, which immediately contracted itself wholly to ADSID. The move finally granted the overall air-defense effort a modicum of stability relative to its recent experience, as well as a dedicated systems-integration firm finally willing, and ostensibly able, to perform the job. General Bergquist even vacated his posting as the Air Force's Director of Operations—one of the premier assignments in the entire service—to take charge of ADSID.

An unattributed document dated May 1959 proposed a philosophy for ADSID consistent with the concept of "integration" that Bergquist had articulated three years prior, when he helped litigate the USAF's case against Missile Master before the Armed Forces Policy Council. "All of the elements of the required Air Defense System are complex in themselves," the author emphasized, echoing General Saville's conception of the continental aircraft-control and warning system, stated more than a decade prior. "To a degree not found in other systems, these elements, though widely separated by geography, are entirely interdependent upon one another to accomplish the functions for which they are intended."[167]

The argument proceeded by example, citing several cases in which SAGE direction centers switched data between sensors and weapons—evidence to the effect that the digital

166. Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA, 23–41, 47–51.

167. "Need for Unique Treatment of Air Defense Systems," May 5, 1959, 1–2, in exhibit 8 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 3, Supporting Documents 1–17 (December 1956–June 1959), AFSC Historical Publication 64-32-III (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485182).

computer was a different kind of technological object presenting its own challenges to rational management. "The computer hardware and its program must be developed, proven and tested concurrently with the computer itself," went the claim. While still invoking the language of "concurrency" fashionable in ARDC's prevailing management-speak, by asserting that computer hardware was not merely a container for infinitely pliable software—as the report of Project CHARLES had seemed to suggest—the statement acknowledged that the former constrained the latter, with tangible consequences for how these two interlocking systems should be designed and implemented.

The document further observed that "since many operational procedures, tactics, and techniques, and processes must be interwoven into a digital computer during the development period, the standard management procedures employed by ARDC and AMC under Air Force Regulation 20-10 are not sufficient." In particular, even a lateral "WSPO-to-WSPO and WSPO-to-ESSPO coordination job of tremendous proportions" could only achieve a "negative kind of compatibility," which was to say, minimizing technical interference.[168] Although such compatibility was a necessary and perhaps sufficient condition for aircraft and missile development, what computerized systems needed was *positive* compatibility—not merely a lack of interference, but the existence of interoperability.

ADSID considered itself to be the agent of this independent change—a visionary for the future as well as an arbiter for the present. With its own authorizing regulation in hand and a dedicated systems-integrator under contract, its staff would be free to exchange ideas between technical and operational personnel at the earliest stages of the development process. But while General Bergquist's ambitions for systems integration may have been clear and emphatic, it diverged from the situation manifested within the offices and hallways of the hastily constructed campus. Indeed, the rapid multiplication of claims on organizational authority at Hanscom Field, accelerated by the creation of ADSID, only further confused

168. "Need for Unique Treatment of Air Defense Systems," 4, in exhibit 8 in Murphy and Smith, *History of AFCCDD*, vol. 3, Supporting Documents 1–17, AFHRA.

the already abashed bureaucracy for managing the procurement of "electronic support systems" like SAGE.

A rather unflattering picture from the fall of 1958 survives in a candid report to Major General John W. Sessmus, Power's successor at ARDC, and authored by a retired colonel named Oliver G. Haywood, who, after departing for private industry, returned to observe the situation at Sessmus's personal request.[169] Compared to an industrial firm, Haywood believed, the Air Force technology organization suffered for serious want of discipline. An ESSPO, for instance, might receive directives from multiple sources—ARDC, AMC, ADSID, or others—leaving the office to sort through their relative priority. Whether these directives constituted orders, or merely suggestions, moreover, tended to be a matter of interpretation, though in any event, these instructions rarely contained deadlines or other measurable, enforceable conditions in the first place.[170]

Any deficiency in oversight, however, could not be blamed on a lack of resources at higher headquarters. In fact, according to Haywood, the large staff at ARDC's Baltimore headquarters tended to overwhelm the staffs of the perpetually shorthanded ESSPOs with ponderous but unnecessary assignments. The bureaucracy was so ungainly that responsibilities seemed to remain perpetually unclear, tasks perennially at large, and the same offices continually at odds. However leaders intended it to function, a slow process of haltingly moving toward consensus had emerged as its only method of coping. "I was told by so many officers," he claimed, "that they could make or obtain decisions only by agreement of all interested agencies that, if management by agreement is not the command philosophy,

169. O. G. Haywood to Commander, ARDC, "Management of Electronic Systems," June 10, 1956, exhibit 4 in Murphy and Smith, *History of AFCCDD*, vol. 3, Supporting Documents 1–17, AFHRA.

170. Haywood's use of business as a foil for government inefficiency did not go unchallenged, as another commentator remarked that "it may be that discipline was poor in ARDC, and it may be that its headquarters was too large, but the comparison with industry is surely irrelevant. The inference seems to be that private industry is an ideal model for organizations of all kinds, and that it is only through culpable bureaucratic perversity that government agencies have failed to pattern themselves on this model." Murphy, *Prologue to the Hanscom Complex*, AFHRA, 32. For a general critique of this rhetorical tactic, see Joanna L. Grisinger, *The Unwieldy American State: Administrative Politics Since the New Deal* (Cambridge: Cambridge University Press, 2012).

people in the field need some education as to what is the command philosophy."[171]

Haywood specifically called out Air Force Regulation 20-13, the order authorizing the activation of ADSID, as a source of considerable disputation due to the variance of interpretation encouraged by its intentionally cryptic composition.[172] Absent high-level clarification, General Bergquist's power to act as a sort of "single manager" for air-defense systems rested on his ability to convince others to that effect, much as it had during the latter months of 1941, when he had struggled to perform a very similar task on the island of Oahu.

"If it works, then it is already obsolete"

The gradual accumulation of public and private resources, all adjacent to the same plot of land, created the impression of a military-industrial-academic complex more literal than any other in the country.[173] As it coalesced into a distinct community with its own sense of purpose, the site became widely known as the "Hanscom Complex," though more grandiose toponyms such as "Science City" were at times entertained by the local press.[174] Its mission—and, incidentally, its unfortunately large collection of acronyms—expanded

171. Haywood to Commander, ARDC, "Management of Electronic Systems," 6, exhibit 4 in Murphy and Smith, *History of AFCCDD*, vol. 3, Supporting Documents 1–17, AFHRA.

172. United States Department of the Air Force, "Organization—General: Air Defense Systems Integration Division," Air Force Regulation (AFR) 20-13 (Washington: GPO, March 21, 1958), MSFRIC; some brief commentary appears in Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA, 49–51.

173. An similar installation did come together over the following decade on the site of a shuttered Douglas Aircraft plant in El Segundo, just south of Los Angeles International Airport, as part of the Air Force ballistic-missile program. The motivation for its creation were similar: to concentrate management offices from across government and industry, as well as technical staff representing non-profit and quasi-academic organization such as the Aerospace Corporation. However, the host organizations were much too large and began spinning off to other locations throughout Southern California almost as quickly as the central facility, now called the Schriever Space Complex, could be physically assembled. Timothy C. Hanley and Harry N. Waldron, *Historical Overview, Space and Missile Systems Center, 1954–1995* (Los Angeles AFB: History Office, Space and Missile Systems Center, Air Force Space Command, April 1996), 3–7, OCLC (606074178).

174. In April 1960, the *Boston Globe* began running a twenty-part editorial series by Ian Menzies, its longtime science correspondent, and a perennial cheerleader for the Route 128 technology industry, all published under the banner, "Science City: Our Mysterious Neighbor." Each headline touted some economic or material benefit of one of the many R&D programs by the Air Force agencies at Hanscom Field: Ian Menzies, "Science City: World's Great Research Center Is Right in Our Own Backyard," *Boston Globe*, April 24, 1960, ProQuest (107820407) was the lead article in the series.

for the penultimate time in January 1960, the day that the Air Force Command and Control Development Division (AFCCDD) and the Electronic Systems Center (ESC) both activated at Hanscom. The former was, like ADSID, a division of the Air Research and Development Command, while the latter was subordinated to the Air Material Command, which had previously participated at Hanscom only as a joint member of its various project offices.[175]

The new facilities owed their existence to the proliferation of Electronic Supporting Systems Project Offices, in addition to SAGE—or, Project 416L, according to the revised nomenclature—which now numbered one among nearly two dozen. Some new projects related to air defense, while others were only inspired by the same promise of computer automation that the SAGE program had pushed nearly into operational service. These were the first of the so-called "Big L systems," and their corresponding ESSPOs moved to Hanscom, or at least to temporary accommodations nearby, at the same time as the AFCCDD and the ESC.

Planning documents suggest that economy was the greatest consideration, though officials presumed that a physically contiguous organization would be more cohesive as well. The Secretary of the Air Force himself had answered the question—why Hanscom?—when Governor Nelson Rockefeller, along with a significant contingent within New York's congressional delegation, pressed him to expand the site of the Rome Air Development Center instead.[176] The new facility had to compete for the nation's best scientists and engineers, he argued, much as Eugene Zuckert had in 1949, and in this respect, Oneida County was not Massachusetts Route 128.[177] Thus, while the fact of geographical concentration in

175. As mentioned previously, the key official histories documenting the process of relocation and reorganization are: Murphy and Smith, *Foundation of the Hanscom Complex*, AFHRA; Maltais, *History of the Electronic Systems Center, 1959–1960*, vol. 1, Narrative, AFHRA; and Redmond and Jordan, *Air Defense Management*, vol. 1, Narrative, AFHRA. Most of the basic facts presented in the following passages can be easily found in one, or more than one, of the references above.

176. Maltais, *History of the Electronic Systems Center, 1959–1960*, vol. 1, Narrative, AFHRA, 17–34. The "planning documents" referenced above were compiled in Murphy and Smith, *History of AFCCDD*, vol. 3, Supporting Documents 1–17, AFHRA and Richard E. Maltais, *History of the AMC Electronic Systems Center, 2 November 1959–30 June 1960*, vol. 2, Supporting Documents (Bedford, MA: Historical Office, Office of Information, Electronic Systems Center, n.d. [1961?]), Supporting Documents, vol. 2, AFHRA (0476828).

177. On the Massachusetts electronics industry and its geographical concentration along Boston's inner

the Boston suburbs predated the actual deliberation about managerial cohesion, powerful members of the Cambridge lobby would have mobilized in favor of Hanscom Field had the outcome ever been seriously challenged.

After the reorganization, no fewer than four Air Force agencies existed in the same place: the Command and Control Development Division (CCDD) of the Air Research and Development Command; the Electronic Systems Center (ESC) of the Air Materiel Command; the remainder of the Air Defense Systems Integration Division—though the establishment of CCDD and ESC pushed it into an even more a liminal position in the rapidly expanding management complex—the Cambridge Research Center; as well as about a dozen special-project offices. This is not yet to mention the presence of Lincoln Laboratory, the MITRE Corporation, and the Massachusetts Institute of Technology. In addition, space was alloted for representatives from about 80 major firms contracted or subcontracted for work on the Big L systems.[178]

Of course, the electronics industry observed their patrons carefully, and company men descended on the new site even as it assembled. They came to sell, but also to invest. With so many of their best customers now clustered together, contractors could compare the latest military fashions with less risk of picking a loser. Although Air Force managers encouraged them by inviting the Hanscom community to identify especially promising trends in digital electronics, their general counsels also warned government employees about the danger of

beltway, see AnnaLee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge: Harvard University Press, 1994) or the more journalistic Susan Rosegrant and David R. Lampe, *Route 128: Lessons From Boston's High-Tech Community* (New York: Basic Books, 1992). Also relevant is Lily Geismer, *Don't Blame Us: Suburban Liberals and the Transformation of the Democratic Party* (Princeton: Princeton University Press, 2015), an important contribution to the historiography of postwar political demography, which takes the growth of Route 128's bedroom communities as its subject.

178. Although many of the details changed as the plan was implemented, the the reorganization mostly followed the blueprint proposed in report, Col. William H. Congdon, Deputy for Electronics, Directorate of Systems Management, Headquarters, ARDC to Headquarters, ARDC, n.d. [October 1, 1959?], exhibit 28 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 4, Supporting Documents 18–56 (July 1959–November 1959), AFSC Historical Publication 64-32-IV (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485183).

violating federal anti-corruption laws.[179] The bazaar-like atmosphere apparently became so tumultuous that the staff at the Electronic Systems Center, which, as a subsidiary of AMC, controlled most of the money, began mocking Hanscom's many prophets of electronic ecstasy with the impish epigram, "if it works, then it is already obsolete."[180]

How all these pieces would fit together, and what they would mean for national defense as a whole, remained open questions primed for investigation by the favored tool of the industrial-academic elite: a special study. In gross, the effort patterned itself after the classic "summer study"—if not the same season—drawing a cohort of self-selected experts from various institutional backgrounds together during a quiet period in the academic calendar. Due to snares in its execution, however, the proceedings dragged on from January until September 1960, and thus the body became known, rather inaccurately, as the Winter Study Group (WSG), and its final product as the Winter Study Report (WSR).

With about 150 participants, it was also, quite possibly, the largest such study organized to date. Other studies with similarly broad mandates, such as *Toward New Horizons* in 1944; Project CHARLES in 1951; and John von Neumann's "Teapot committee," which began meeting in 1953; typically numbered only a few dozen, though the rosters of Project Lamplight in 1955; and the Gaither Committee in 1957, both approached the century mark.[181] In fact, when the Secretary of the Air Force learned of the expert body, he even assigned it *its own* expert body, packed with former OSRD elites like Albert Hill and Jerrold Zacharias.[182] Nev-

179. The ubiquitousness of contractors on the premises apparently created such a potential for flagrant graft that the commander of the Electronic Systems Center convened a meeting with his staff to explicitly state his policy that "when you are in doubt regarding your relationship with a member of industry, don't do it": Maltais, *History of the Electronic Systems Center, 1960–1961,* vol. 1, Narrative, AFHRA, 86–90.

180. Speaking notes marked "for presentation to AFA [Air Force Association]," presumably by Maj. Gen. Clyde H. Mitchell, Commander, AMC Electronic Systems Center, April 6, 1960, 5, exhibit in Richard E. Maltais, *History of the AMC Electronic Systems Center, 2 November 1959–30 June 1960,* vol. 3, Supporting Documents (Bedford, MA: Historical Office, Office of Information, Electronic Systems Center, n.d. [1961?]), AFHRA (0476829).

181. For basic facts, commentary, and references concerning the studies mentioned above, see Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944–1986* (Washington: Air Force History and Museums Program, 1988); also, the early chapters of Ann K. Finkbeiner, *The JASONs: The Secret History of Science's Postwar Elite* (New York: Viking, 2006) and David L. Snead, *The Gaither Committee, Eisenhower, and the Cold War* (Columbus: Ohio State University Press, 1999).

182. Maj. Gen. James Ferguson, Vice Commander, ARDC to Gen. Thomas S. Power, Commander-in-Chief,

ertheless, while boosting the effort's legitimacy, the recorded minutes actually demonstrate minimal interest on the part of the august members of the steering committee.[183]

Even by the precedents set by other elite advisory bodies, the Winter Study Group was an ambitious project. The initial study plan, drafted in December, called for an iterative approach to the "command and control problem," as it was now being called. The core System Panel would first create an overall "threat picture" for the 1965–1970 time period. From this, it would then deduce the necessary countermeasures. However, the need would not be measured in missiles, aircraft, or submarines—the usual quantities in long-range strategic planning—but in terms of organization. In other words, the System Panel first wanted to know what sort of functions the Air Force would have to perform in order to fulfill the military-political role anticipated of it in the near future. Meanwhile, a clutch of 14 specialty panels, with interlocking memberships, were supposed to project the technological state-of-the-art in their respective fields roughly five to ten years into the future.[184]

Some time before March 1, the two subgroups would draft reports such that the Systems Panel could consolidate their expert opinions with its own background work, in order to prepare a set of "realistic requirements" for a unified Air Force command-and-control system,

Strategic Air Command, "Participation in ARDC Winter Study Group," January 14, 1960, exhibit 72 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 5, Supporting Documents 57–74 (December 1959–January 1960), AFSC Historical Publication 64-32-V (Bedford, MA: Historical Division, Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485184).

183. The "scientific guidance group" met eight times between January 21 and September 5. Although it did deliver a final report for the Secretary of the Air Force, by that time, its attendance had dwindled to just the executive management of Lincoln Laboratory and the MITRE Corporation, who, as members of the Hanscom community, could hardly have been expected to provide input impartially. "Report of the Scientific Guidance Committee of the Winter Study Group," September 23, 1960, exhibit 246 in Murphy and Smith, *History of AFCCDD*, vol. 11, Supporting Documents 224–289, AFHRA.

184. Although the AFCCDD volumes contain hundreds of documents that cumulatively sum to an almost daily account of the progress of the Winter Study, one document is particularly useful, both for its brief narrative, but also for numerous attachments that included the study's plan, roster, schedule, and other working documents: namely, H. G. Stever, "Winter Study Group Status Report," February 5, 1960, revised July 24, 1960, exhibit 78 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 6, Supporting Documents 75–85 (January 1960), AFSC Historical Publication 64-32-VI (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485185). Unless it is necessary to cite a more specific document, the following passage will rely mostly on this compilation.

as anticipated in the year 1965. The results were to be published as an interim report on April 15, and at that point, the specialty panels would dissolve into "operational requirements teams." These teams were intended to individually review the current Big L systems in order to determine how well their existing designs matched with the interim recommendations. As recommendations returned to the System Panel, an "optimal" configuration, balancing requirements against feasibility and economy, would ostensibly take shape. Both subgroups were then supposed to finalize their reviews and adjourn about six weeks later, leaving only a subset of the System Panel behind to write up the results for circulation on July 1.

Report of the Winter Study Group

Optimistic is perhaps too modest a description for this scheme, and no evidence suggests that the study process actually unfolded in such a manner. The aggressive proposal originated from a pair of meetings held in the fall of 1959 between representatives of the main stakeholders in the Hanscom Complex. Among them were John F. Jacobs and Lieutenant Colonel John L. Lombardo, both longtime veterans of Whirlwind, Lincoln, and SAGE. Jacobs, then the systems director at the MITRE Corporation, had been with Project Whirlwind since his first year in graduate school at MIT, while Lombardo was the SAGE liaison at Air Force headquarters before reporting for duty at Hanscom.[185]

Jacobs and Lombardo also reached out beyond their immediate community to the Wright Air Development Division in Dayton, where they entreated William J. Sen, a civilian engineer and top manager in the USAF's airborne electronics program. Like Jacobs and Lombardo, Sen had become thoroughly familiar with the bureaucratic pathologies of cross-organizational systems during the course of his multi-year assignment supervising the development of air–ground data links for the F-102 interceptor, which had been designed to

185. Jacobs later wrote a memoir recounting his experience with SAGE and MITRE, which the prior literature has referenced frequently: Jacobs, *The SAGE Air Defense System*. However, besides the brief professional biographies included in the Winter Study's materials, little information about John Lombardo or William Sen (see below) is readily apparent.

receive its vectoring and target instructions automatically from SAGE direction centers.[186] Jacobs and Lombardo assumed roles as the Winter Study's "executive directors," while Sen acted as General Bergquist's personal liaison, at least until Gordon N. Thayer, an executive at Bell Labs, assumed a chairmanship once the project began flailing in March.[187]

No one alive could claim more familiarity with the technical and managerial challenges of developing a military "command and control system" than the men responsible for plotting the Winter Study, since the term itself was their coinage, and the report, an effort to crystallize and advocate their understanding of it. The rather quixotic schedule to which their leadership committed points up the group's essential dilemma: the vagueness of the boundary between command, control, and virtually every other domain of scientific, engineering, and military expertise. Intelligence estimates, organizational analysis, conceptual framework, system design, technical prospectus, management review—the Winter Study subsumed them all under the mandate of its sweeping statement-of-work.[188]

The architects understood the relevance of all these considerations, but what they did not anticipate—in advance of the experiment—was the difficulty of herding an ensemble interested in everything from machine learning to ergonomics. As the final report itself acknowledged, although the study could assemble the leading experts in computers, radar, telecommunications, and the various other electronic components pertaining to the design and operation of command-and-control systems, there were no experts in command-and control-systems themselves. SAGE notwithstanding, no one had ever attempted to design

186. The stakes here had been especially high, as unreliable data-links were implicated in several fatal accidents.

187. When it became obvious that the study would drag on long beyond the end of winter, Albert G. Hill, MIT physicist and veteran of the "Cambridge lobby," suggested approaching Thayer, a respected outsider, in order to ease ARDC's apprehension that the project had devolved into an unrestrained expression of Hanscom boosterism. Minutes and agenda, Third Meeting of the Winter Study Scientific Guidance Group, MITRE Corporation, Bedford, Massachusetts, March 3, 1960, exhibit 112 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 7, Supporting Documents 86–131 (February 1960–March 1960), AFSC Historical Publication 64-32-VII (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485186).

188. Draft, "Statement of Work," n.d. [November 5, 1959?], exhibit 43 in Murphy and Smith, *History of AFCCDD*, vol. 4, Supporting Documents 18–56, AFHRA.

anything like the hypothetical "1965 system" before.[189]

The project did commence according to schedule, on January 11, 1960, when the System Panel first met on the campus of the MITRE Corporation, the study's official host, in Bedford, Massachusetts. Specialty panels also began meeting in January, and by February 5, the WSG engaged 110 members in full-time activities. The number rose gradually over several months as the specialty panels filled out their rosters.[190] Nevertheless, few, if any traces of the group's eminently rational plan of study remained visible in the final report itself. The association had largely dispersed in the spring, leaving behind it a mass of unassimilated working papers on a variety of loosely related subjects. The task then fell to the rump of permanent members, most of whom belonged to the nebulous "Concepts Panel," a small and rather late addition to the study's roster, to formulate a coherent set of recommendations for their sponsors.[191]

Ultimately, it was the residuum of the Concepts Panel that conceived—or, at least, decided to promote—the language of "crisis" that so unsettled study's patrons, almost to the point of invalidating the entire enterprise. The group's working documents show Jacobs, Lombardo, and Bergquist, acting through William Sen, attempting to lead the few members remaining toward a synthesis that reflected the ideas already in circulation at the Hanscom Complex, particularly their definitions of "technical" and "functional" integration. Peter J. Schenk, who had, a decade earlier, numbered among Gordon Saville's "Young Turks,"

189. Murphy and Smith, *Foundation of the Hanscom Complex*, AFHRA, 1–28 and Howard R. Murphy, *Early History of the MITRE Corporation: Its Background, Inception, and First Five Years*, MITRE Report M72-110 (Bedford, MA: MITRE Corporation, June 30, 1972), 198–217, Internet Archive, Bitsavers Collection, https://archive.org/details/bitsavers_mitreM7211heMITRECorporationJun72_22060658 briefly summarize these events; also recall the note above regarding the progress reports compiled by or on behalf of Guyford Stever.

190. "Winter Study Group Directory," April 1960, exhibit 134 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 8, Supporting Documents 122–161 (August 1960), AFSC Historical Publication 64-32-VIII (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485187).

191. Memo, H. D. Benington, MITRE Corporation, "Summary of Command Systems Concept Panel Section III," June 17, 1960, exhibit 174 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 9, Supporting Documents 162–192 (August 1960), AFSC Historical Publication 64-32-IX, vol. 9, (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485188).

and one of the Cambridge lobby's first allies, provided key input as the panel's executive secretary, though now as a civilian, rather than an active-duty officer of the United States Air Force. It was, however, a solid-state physicist from Bell Laboratories—relatively untraveled in defense circles—named W. Thornton Read who surpassed his peers' interest in the project, and, by all indications, drafted the report of the Concepts Panel almost entirely by himself, which Schenk, Lombardo, and Jacobs subsequently reworked into a summary volume for the entire study effort.[192]

Indeed, throughout the fall of 1960, the cry of "crisis in command" had spread even beyond the small community at Hanscom Field, unnerving the Air Force as it did so. "Wide Defense Shift Urged to Ease 'Command Crisis,'" read the front page of the October 10 edition of the *New York Times*, with "Crisis Already Here" added for emphasis.[193] While the article itself suggested that Richard Witkin, the *Times*' aerospace correspondent, had received classified information from a confidential source, General Bergquist had, in fact, already outlined the main conclusions on September 23 in his speech at the Air Force Association's industry seminar, a public event that Witkin himself referenced. "Revolutionary advances in the destructive power of weapons and in the speed and range of delivery systems have created a 'crisis in command,'" he said in that earlier address, following the Winter Study Report nearly verbatim, its security classification notwithstanding. "The extreme quantity and abstract quality of data, the compression of decision times, and the necessity of rigid

192. Manuscript, W. T. Read, "Operational Concepts," June 22, 1960, exhibit 176 in Murphy and Smith, *History of AFCCDD*, vol. 9, Supporting Documents, 162–192, AFHRA; manuscript, "Winter Study Group Final Report, Draft C," handwritten note reading, "this version prepared by Thornton Read," August 25, 1960, exhibit 203 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 10, Supporting Documents 193–223 (August 1960), AFSC Historical Publication 64-32-X (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485189). Read's name will be familiar to solid-state physicists due to the phenomenon of "Frank–Read dislocation," first observed during the 1950s: F. C. Frank, "The Frank–Read Source," *Proceedings of the Royal Society, A: Mathematical, Physical, and Engineering Sciences* 371, no. 1744 (June 10, 1980): 136–138, doi:10.1098/rspa.1980.0069. According to the publication record, Read appears to have later become an occasional commentator on arms-control issues for various university-affiliated think tanks, though whether he continued to advise the government in an official capacity remains unclear.

193. Richard Witkin, "Wide Defense Shift Urged to Ease 'Command Crisis'," *New York Times*, October 10, 1960, ProQuest (115132158).

central control to avoid accidents, have imposed this crisis on the operational commanders."[194] Bergquist's staff also circulated the same material as a press release, which was cited widely by newspapers and popular magazines like *Electronics*, *Missiles and Rockets*, and *Air Force and Space Digest*.[195] The MITRE Corporation, who administered the study for the Air Force, even invoked the "crisis in command" in its fall recruiting campaign.[196]

Despite the enthusiasm emanating from General Bergquist's office, other Air Force elements did not receive the publicity with favor. Early drafts of the Winter Study Report had signaled the potential controversy as early as mid-summer.[197] Then, four days after the *Times* article, a MITRE memorandum precluded the study members from offering statements without official review. By the time of the Scientific Advisory Board meeting in late October, Air Force headquarters had, pending an assessment by ARDC, designated the report as a sensitive internal document and resolved to limit its distribution even within the organization.[198] Nevertheless, too many representatives from organizations essential to the Air Force's research-and-development program had participated to bury the results

194. News release, Office of Information, Air Force Command and Control Development Division, L. G. Hanscom Field, Bedford, Massachusetts, "Crisis in Command," remarks by Maj. Gen. Kenneth P. Bergquist, Commander, AFCCDD before AFA Industry Seminar, San Francisco, California, September 23, 1960, exhibit 245 in Murphy and Smith, *History of AFCCDD*, vol. 11, Supporting Documents 224–289, AFHRA.

195. "Single Air Force Agency Proposed," *Electronics* 33, no. 4 (January 22, 1960): 38–39; Hal Gettings, "AF Moves to Avert Command 'Crisis,'" *Missiles and Rockets* 7, no. 16 (October 17, 1960): 24–25; Kenneth P. Bergquist, "Crisis in Command," *Air Force and Space Digest* 43, no. 12 (December 1960): 105–106.

196. "Meeting the Crisis in Command with Large-Scale, Computer-Based Electronic Systems," MITRE Corporation recruiting advertisement, *Boston Globe*, January 15, 1961, A15, ProQuest Historical Newspapers (762855757).

197. The first sign of trouble was the caution with which General Schriever's office proposed to formulate the letter announcing the delivery of the first drafts to Air Force headquarters: TWX, ARDC to AFCCDD, RDLDC 17-8-8-E for Col. Kincaid, 1806Z (i.e. 6:06 PM UTC), August 18, 1960, exhibit 207 in Murphy and Smith, *History of AFCCDD*, vol. 10, Supporting Documents 193–223, AFHRA. The final, official USAF rebuttal followed in memo, Lt. Gen. Roscoe C. Wilson, Deputy Chief of Staff, Development, Headquarters, United States Air Force to Air Research and Development Command, March 10, 1961, exhibit 371 in Howard R. Murphy and Charles J. Smith, *History of the Air Force Command and Control Development Division, 16 November 1959–31 March 1961*, vol. 14, Supporting Documents 360–399 (March 1961–July 1961) AFSC Historical Publication 64-32-XIV (Bedford, MA: Electronic Systems Division, Air Force Systems Command, July 1964), AFHRA (0485193).

198. Memo, J. F. Jacobs, MITRE Corporation, "Distribution of Winter Study Reports," October 11, 1960, exhibit 270 in Murphy and Smith, *History of AFCCDD*, vol. 11, Supporting Documents 224–289, AFHRA; memo, William J. Sen, Special Assistant to Commander, AFCCDD, "Winter Study Group Releases," November 23, 1960, exhibit 287 in Murphy and Smith, *History of AFCCDD*, vol. 11, Supporting Documents 224–289, AFHRA.

entirely, so to placate the experts, as well as to appease the employers who had lent them, a bowdlerized edition entitled, “The Challenge of Operational Command,” was released into the gray literature in March 1961.[199]

5 Conclusion: The beginning of command-and-control

At least at the level of intention, the general meeting of the Scientific Advisory Board in September 1960 did more than debut the Winter Study Report; it aimed to deflect criticism of the USAF’s besotted management of electronic systems. In its original form, the draft of General Bergquist’s remarks for the Scientific Advisory Board were just as assertive as his September address to the Air Force Association. Nevertheless, the words actually recorded at the October conference—reviewed personally by the Air Force’s development chief, General Roscoe C. Wilson—sounded much more conciliatory.[200] In fact, no uniformed speaker on the agenda even acknowledged the putative “crisis in command,” and only General Bergquist countenanced the substance of the Winter Study Report itself.[201]

He had his reasons, believing that work in the spirit of ADSID could only proceed coherently if it were transferred to NORAD, which, though dominated by a USAF component, had been established under a binational treaty, beyond the legal authority of any single US Government agency. Since NORAD was the ultimate *user* of integrated air-defense systems,

199. “Winter Study Report: The Challenge of Command and Control,” AFCCDD TR-61-4 (Bedford, MA: Air Force Command and Control Development Division, March 31, 1961), exhibit 392 in Murphy and Smith, *History of AFCCDD*, vol. 14, Supporting Documents 360–399, AFHRA. Read himself contributed to the smuggling of the Winter Study’s conclusions across the security fence by virtue of his academic associations; Thornton Read, *Command and Control*, Policy Memorandum No. 24 (Princeton: Center of International Studies, Woodrow Wilson School of Public and International Affairs, Princeton University, June 15, 1961) nearly the beat the Air Force’s own bowdlerization to press, and since his paper was unclassified, rather than “confidential,” its ideas propagated rapidly through civilian institutions.

200. Manuscript, “Remarks by Gen. K. P. Bergquist at the SAB 24 October 1960,” with handwritten note reading “Gen. B, copy of SAB speech for discussion with Gen. Wilson —Sen,” October 22, 1960, exhibit 276 in Murphy and Smith, *History of AFCCDD*, vol. 11, Supporting Documents 224–289, AFHRA. The draft differs in several important respects from the talk compiled in the proceedings: Air Force Scientific Advisory Board, *Report on Proceedings, October 1960*, AFHRA, 71–73.

201. The Hanscom lobby itself was nonetheless well represented; SAGE veterans such as Albert G. Hill, Charles A. Zraket, Herbert D. Benington, all spoke as well.

though, it also seemed the most logically positioned to articulate its own needs for them, as well as to coordinate actions between the cross-organizational stakeholders responsible for research and development.[202] Likewise, with an imminent reorganization proposing to merge the Air Materiel Command with the Air Research and Development Command to form the Air Force Systems Command, Bergquist remained in negotiations with the plan's architect, General Bernard Schriever, to attach the Command and Control Development Division directly to the Department of Defense, rather than see it continue to work through several USAF intermediaries.[203] The logic was the same; if the Air Force was serious about the national urgency of "integrating" both technological and organizational elements in order form unified military command-and-control systems, then it also needed to recognize the limits of what it could accomplish unilaterally.

Rather than offer its resources to the Department of Defense, the Schriever reorganization retained the Electronic Systems Division, consolidated from the units stationed at Hanscom Field, as an operating activity of the new Air Force Systems Command.[204]

202. Bergquist had been agitating to formalize the relationship between NORAD and ADSID until the latter was absorbed into AFCCDD in late 1959. Evidently he found it obnoxious that NORAD, OSD, and even the FAA were beginning to contract with private entities affiliated with Hanscom, such as Lincoln and MITRE, without a central office to manage the overall program at the site. Maj. Gen. K. P. Bergquist, Commander, ADSID to Brig. Gen. C. B. Root, AMC BMEWS Manager, "BMEWS Briefing," October 23, 1959, exhibit 84 in Kent C. Redmond and Harry C. Jordan, *Air Defense Management, 1950–1960: The Air Defense Systems Integration Division*, ARDC Historical Publication 61-31-II, vol. 2, pt. B, Supporting Documents 45–90 (Bedford, MA: Historical Branch, Office of Information, Air Force Command and Control Development Division, February 1961), AFHRA (0485179).

203. The circumstances that culminated in the establishment of the Air Force Systems Command are extremely complex: Michael H. Gorn, *Vulcan's Forge: The Making of an Air Force Command for Weapons Acquisition, 1950–1985*, 2 vols. (repr., Andrews AFB, MD: Office of History, Headquarters, Air Force Systems Command, 1989), vol. 1, 51–81; Converse, *Rearming for the Cold War*, 457–506. Briefly, it was motivated by the perceived inefficiency of dividing responsibilities for science, engineering, and industrial programs between two agencies—ARDC and AMC—as well as frustration with the bureaucratic conflicts between them as managers fought for control over the billions of dollars pouring into the USAF's ballistic missile program. While the Air Force Systems Command absorbed the majority of ARDC and AMC in 1961, the latter's maintenance and supply functions were assumed by the new Air Force Logistics Command, created at the same time.

204. This is treated mainly in the latter chapters of Murphy and Smith, *Foundation of the Hanscom Complex*, AFHRA. Unfortunately, the story of the Electronic Systems Division becomes very difficult to follow after March 1961; the reorganization was apparently so disruptive that the agency could not spare the resources necessary to prepare the periodic summaries required by the Air Force historical program. (Note that even AFCCDD's chronicles were compiled more than four years after it had disbanded, which is apparently how long it took for the ESD history office to begin clearing parts of its backlog.)

Bergquist himself took charge of the Air Force Communications Command—a promotion away the front lines—until retiring in 1965. While the Hanscom Complex would continue to adapt to the unique problems it confronted, it would have to so within the strictures of the Air Force Systems Command, whose regulations responded increasingly to the needs of aerospace programs as aircraft, missiles, and satellites dominated its attention during the heady years of the 1960s.[205]

Notwithstanding an outcome unfavorable to the Hanscom lobby, the final report of the Winter Study Group noted a "surprising agreement on the manifestations of [the] crisis in operational command," the underlying causes of which related to the frantic pace of the nuclear-arms race:

> The crisis in operational command capability is the result of a technological revolution in weaponry. The planner and commander are confronted with both conventional and nuclear weapons; many forms of delivery; and extremely complex control, sensor and weapon systems whose potential capabilities can only be gradually realized. But these capabilities have short useful lives before a new wave of systems comes into the field. Similarly, the enemy threat changes as his weaponry improves. The available decision cycle for war planning and force employment becomes shorter and shorter but the consequences of these decisions are greater and greater.[206]

Although the final report found the recent accumulation of computer automation projects to be an entirely reasonable response, uncoordinated development had nevertheless become a problem in itself: "The mushrooming requirements for command systems and more automation are a symptom of a crisis in operational command capability." The Air Force

205. In particular, Bergquist pushed Schriever to accommodate a notion of what the Hanscom community called "advanced planning" into the AFR 375-series regulations that codified the Air Force's systems management procedures. Broadly, the idea was to encourage organizational stakeholders to work out the technological behavior of future systems in collaboration with one another. Schriever, on the other hand, was advancing a more centralized model in which the research-and-engineering administration basically provided a service to using organizations by executing programs to their specification. While the new Electronic Systems Division did retain an office intended to facilitate this type of "advanced planning," it appears to have been mostly powerless to induce cooperation among the increasingly autonomous System Project Offices. Col. Robert J. Lynch, Director of Advanced Planning to Gen. Bergquist, Commander, "Proposal for Development of a Command and Control Plan," March 28, 1961, exhibit 390; manuscript, "Meeting on Air Force C&C Systems," Massachusetts Institute of Technology, April 13, 1961, exhibit 397; both in Murphy and Smith, *History of AFCCDD*, vol. 14, Supporting Documents 360–399, AFHRA.

206. Winter Study Group, *Final Report*, September 1960, RG 340, 81. This language mostly reflected W. Thornton Read's draft of the report of the WSG's Concepts Panel.

organization was, compared with its initial state in 1947, now trying to accomplish vastly more elaborate goals with increasingly sophisticated technological objects.

While sharing in the spirit of LeMay's own sentiment, which proposed to enable better human decisions through superior technology, the rhetoric of the Winter Study Group exceeded the comfort of Air Force leaders. Indeed, the final draft sacrificed alliteration for tact, limiting the "crisis" to "operational command," so as to avoid the appearance of accusing military officials of incompetence in every respect. "What the Winter Study Group tried to do," according to Gordon N. Thayer, the AT&T vice-president who chaired the committee, "was to come up with a logical way of thinking about the command and control system problem and then to recommend some management techniques for getting on with the job of developing such systems."[207] Despite the diplomatic phrasing, this seemingly benign approach had immediately ensnared the study's participants in intractable problems of strategic-nuclear policy. In applying computers to nuclear command and control, Thayer emphasized before the assembly, management could not be decoupled from the national military-political decision-making process.[208]

To illustrate further, in the subsequent talk, Thornton Read declared that "the basic purpose of command and control systems is to match people to weapons." The significance of this observation lay in the fact that "the requirements on command and control systems are also affected by the nature of the forces to be controlled, and the strategy with which they are to be used." In other words, "long term strategic choices will affect the requirements for and characteristics of command and control systems that are developed; and these in turn affect the strategic, or you might say, tactical choices that it will be possible to make in the short term." If the nation did not carefully manage the formulation and implementa-

207. Air Force Scientific Advisory Board, *Report on Proceedings, October 1960*, AFHRA, 47.

208. While technically a Hanscom "outsider," Thayer had helped manage the radar-systems program at Bell Telephone, the MIT Radiation Laboratory's largest industrial partner during the war. From that position, he moved upward into an executive position in AT&T's military electronics division, where he would have remained a close colleague to members of the Cambridge and Hanscom lobbies. "Institute News and Radio Notes," *Proceedings of the IRE* 40, no. 11 (November 1952): 1616.

tion of system requirements, then technical limitations, not the reasoned calculations of responsible decision-makers, would bound the set of actions performable in a future crisis.

Thornton Read's remarks outlined a significant fraction of his contribution to the Winter Study Report, which was, in essence, a philosophy of technology for the age of intercontinental ballistic missiles. Decision, unlike the time available with which to make it, could not be compressed beyond the fundamental limits of human cognition. It could, on the other hand, be simplified through the process of reduction. A command-and-control system was thus *the sum total of decisions already made*, packaged into machines and operators, so that the relevant authorities could more readily comprehend the moment of final judgment.[209]

Even more than limiting the choices available, technological behavior would also determine the situations that could be understood—all the more reason to carefully plot its future development in advance. Recognizing that some measure of human control must be sacrificed in order to save it, Read offered that "strategy should *not* be '*built into*' the command and control system. The purpose of the system is rather to maximize the number of ways in which we can use the force."[210] Nevertheless, the Winter Study Group realized that the Big L systems lacked any sort of master conceptual plan whatsoever, and that their task, as authors, was to rationalize, *ex post facto*, the existence of multiple computer automation projects idiosyncratically conceived, independently designed, and separately managed.

When the time came for Bergquist to close the afternoon session with his own *summa* on the report, he said that while "individually, most of the command and control systems appear to meet the requirement as presently stated and are technically feasible...collectively,

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209. Once again, a brief note of comparison is in order between the ideas expressed by the air-defense establishment and the concept of "technological inertia" mostly familiar from the work of Thomas Hughes. While the former clearly manifests the latter, it demonstrated less concern for system efficiency, from the perspective of builders and managers, than for the potential influence on the organizational behavior of the system's users, which, in their conception, implicated the very highest levels of government, and thus, the global actions of nuclear-armed nation-states.

210. Air Force Scientific Advisory Board, *Report on Proceedings, October 1960*, AFHRA, 65, emphasis in original. The argument expanded in Read, *Command and Control* and eventually infiltrated the mainstream academic discourse through other sources, a point that will be touched upon in the final conclusion.

they fail to pass the conceptual, integration and costing criteria."[211] By retreating tactically on the narrowest possible construal of the study's official mandate, the general still implied what previous speakers had observed quite plainly, that the constellation of existing designs could realistically support only one model of nuclear conflict: a massive retaliation upon imminent warning of surprise hemispheric attack.

The Air Force was, in fact, building strategy into America's nuclear command and control infrastructure, and in the most haphazard fashion. As routine products of a vast military bureaucracy, the Big L programs were proceeding in almost total isolation, both from one another and from national authorities. They exposed what might be called, for lack of a better analogy, the Air Force's collective unconscious—an implicitly shared set of organizational priorities that had ossified since the last world war, and now appeared too arcane and too inflexible to meet the demands of the impending era of missiles and satellites. Sheer automation, unresponsive to evolutions in strategy and doctrine, might encourage political leaders to make an inherently dangerous "snap judgment" with nuclear weapons, simply because the instrumentation for more careful deliberation did not exist.[212]

211. Air Force Scientific Advisory Board, *Report on Proceedings, October 1960*, AFHRA, 71.

212. Read had introduced the phrase, "snap judgment" into an early draft of the Winter Study Report, after which it became a slogan repeated nearly as often by the study's promoters as "crisis in command." In particular, variations on the statement, "the best solution to the problem of compressed time is not elaborate data-processing facilities designed to make quick reactions safe, but a survivable and perhaps quite simple system designed to make quick reactions and snap judgments unnecessary," occurred in numerous proselytizing materials offered by Read, Jacobs, Bergquist, and others after the study had concluded. The formulation here quotes directly from Winter Study Group, *Final Report*, September 1960, RG 340.

Conclusion

The organization of technology and the technology of organization

> That man has aggregated to himself enormous power by means of his science and technology is so grossly banal a platitude that, paradoxically, although it is as widely believed as ever, it is less and less often repeated in serious conversation. The paradox arises because a platitude that ceases to be commonplace ceases to be perceived as a platitude. Some circles may even, after it has not been heard for a while, perceive it as its very opposite, that is, as a deep truth. There is a parable in that, too: the power man has acquired through his science and technology has itself been converted into impotence.[1]
>
> Joseph Weizenbaum, *Computer Power and Human Reason*, 1976

On Friday, May 24, 1946, about a hundred Americans received a telegram from Albert Einstein. "The unleashed power of the atom has changed everything save our modes of thinking," it read, "and we thus drift toward unparalleled catastrophe."[2] Newspapers reprinted the words, which the ages transformed, like so many others of the eminently quotable theorist, into a Great Utterance: the wisdom of a hermetic seer who, gazing upon gnostic mystery, recoiled in awe and horror.

Einstein, however, did not send the message himself. It was, from the perspective of our more cynical present, overgrown with mass-marketing incumbents, a targeted fund-raiser, one of several released under Einstein's signature during the "scientists' movement,"

1. Joseph Weizenbaum, *Computer Power and Human Reason: From Judgment to Calculation* (New York: W. H. Freeman, 1976), 258.

2. "Atomic Education Urged by Einstein: Scientist in Plea for $200,000 to Promote New Type of Essential Thinking," *New York Times*, May 26, 1946, ProQuest (100998236); see also Alice Calaprice, ed., *The Ultimate Quotable Einstein* (Princeton: Princeton University Press, 2011), 274.

or, what we would now call a single-interest lobby.[3] "We need two hundred thousand dollars at once for a nation-wide campaign to let the people know that a new type of thinking is essential if mankind is to survive and move toward higher levels," it concluded:

> This appeal is sent to you only after long consideration of the immense crisis we face. Urgently request you send immediate check to me as chairman, Emergency Committee of Atomic Scientists, Princeton, N.J.

Hardly the stuff of headlines today. My building's mailroom has a wastebin, a convenient receptacle for such glossy solicitations, grinning endorsements, star-spangled sentiments, and similarly "urgent" correspondence. Every fall it fills to overflowing, in phase with the election cycle.

Americans have now lived with the atomic bomb just five years fewer than the Social Security check, and two decades longer than Medicare, Medicaid, or the Voting Rights Act, and yet unlike these other pillars of the liberal state, it alone stands beyond serious dispute. For the citizen of today—harried, insecure, and politically despondent—the bomb exposes few symbols to protest or to defend, few causes with which to identify and connect.[4] After surfacing long enough to impose its geopolitical grandeur, it sank back into holes and into oceans, deeper and darker than ever had before, finally beyond mind as well as sight.

So far as official policy goes, America's nuclear complex pursues neither weapons nor capabilities; instead, it manages "modernization," "life extension," and "stockpile sustainment" programs, with public agendas so seemingly banal that their discussion echoes in congressional chambers vacant except for representatives of the laboratories, agencies,

3. On the Emergency Committee of Atomic Scientists, see Susan Marie L. Caudill, "A New Sense of Power: Albert Einstein and the Publicity Campaign for World Government," (PhD diss., University of Tennessee, 1989), ProQuest (9021002).

4. There is now a robust literature of historical, sociological, theoretical, and moral commentary on civic disengagement in American life. The formative work was Robert D. Putnam, *Bowling Alone: The Collapse and Revival of American Community* (New York: Simon & Schuster, 2000), with other notables including Theda Skocpol, *Diminished Democracy: From Membership to Management in American Civic Life* (Norman: University of Oklahoma Press, 2003); Sheldon S. Wolin, *Democracy Incorporated: Managed Democracy and the Spectre of Inverted Totalitarianism* (repr., Princeton: Princeton University Press, 2010); and Chris Hedges, *Empire of Illusion: The End of Literacy and the Triumph of Spectacle* (New York: Nation Books, 2009), which in many ways expressed the anxieties of the Bush era. For a critique, see Ben Berger, *Attention Deficit Democracy: The Paradox of Civic Engagement* (Princeton: Princeton University Press, 2011).

and contractors responsible.[5] Only the occasional scandal, gaffe, or mishap can dispel our absurd contentment, like Camus's Sisyphus, chasing down the boulder. Here, between the grabbing hands of neoliberalism and neoconservatism, there is only the incoherent accretion of severally managed interests: the clutches that strangle our increasingly desperate political culture, which could not shut a portal to Hell lest it upend some constituency.

1 The Power of the Atom

How strange that such incomparable power—"the basic power of the universe," as it was first announced—should now languish in obscurity.[6] Perhaps if they could have seen, by the bomb's early light, that the "Atomic Age" when the world spun tremulous on a nuclear tip, would not last even five decades, they might have expected it to end in flames, for those were the Manichean terms in which they framed it.[7] "The power of the atom has been unleashed," the *New York Times* declared on the very first Sunday after Hiroshima. "We have

5. In a recent hearing, Representative Jim Cooper, the ranking Democrat on the House Armed Services Subcommittee on Strategic Forces, noted wryly that "this is, we should point out, probably one of the few hearings in which actually the attendance of the subcommittee compares favorably with the attendance in the audience," a fact attested by the cameras present. House Committee on Armed Services, *Interim Report of the Advisory Panel on the Governance of the Nuclear Security Enterprise* 113rd Cong., 2nd sess., March 26, 2014, 9, CIS (HRG-2014-ASH-0042). Despite the lack of public interest, America's aging nuclear arsenal is rapidly approaching a crisis of unaffordability; some cost projections exceed $300 billion over the next decade, and perhaps as much as $1 trillion over the next 25 years: Congressional Budget Office, *Projected Costs of U.S. Nuclear Forces, 2014–2023*, Pub. No. 4618 (Washington: Congressional Budget Office, December 2013), CIS (CMP-2013-CBO-0189); Jon B. Wolfsthal, Jeffrey Lewis, and Marc Quint, *The Trillion Dollar Nuclear Triad: US Strategic Nuclear Modernization Over the Next Thirty Years* (Monterey, CA: James Martin Center for Nonproliferation Studies, January 2014), http://cns.miis.edu/opapers/pdfs/140107_trillion_dollar_nuclear_triad.pdf . While the laboratories sell "modernization" as essential maintenance, skeptics argue that these programs amount to *de facto* weapons development, and yet with the end of nuclear testing, it remains unclear how much can be accomplished with "virtual weapons science," as in Hugh Gusterson, "The Virtual Nuclear Weapons Laboratory in the New World Order," *American Ethnologist* 28, no. 2 (May 2001): 417–437, doi:10.1525/ae.2001.28.2.417.

6. References to the "basic power of the universe" became entirely routine after the phrase was incorporated into President Truman's carefully worded announcement of the atomic bombing of Japan: Harry S. Truman, "Statement by the President Announcing the Use of the A-Bomb at Hiroshima," August 1945, 1946, American Presidency Project, https://www.presidency.ucsb.edu/node/231158 .

7. Cf. Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (1985; repr., Chapel Hill: University of North Carolina Press, 1995), 47–106; Lawrence S. Wittner, *One World or None*, vol. 3 of *The Struggle Against the Bomb*, by Lawrence S. Wittner (Stanford: Stanford University Press, 1993), chap. 4; Spencer R. Weart, *Nuclear Fear: A History of Images* (Cambridge: Harvard University Press, 1988), chap. 6.

entered upon a new era in the history of mankind":

> The development is of Promethean significance. Generations millenniums hence may look back upon these years when atomic energy was first put to work in the same spirit in which we now think of the less well documented occasion when man first learned the use of fire.[8]

Our dilemma was epochal, universal, mythological. "We are here to make a choice between the quick and the dead," Bernard Baruch famously said before the United Nations in June 1946. "Let us not deceive ourselves: we must elect world peace or world destruction."[9]

A power "unleashed" was a power that could still be "harnessed," as shade brings shelter from the burning sun. Liberalism, organization, and control—or the extinction of the human race. Either commit to the global project, or die. But which did we choose, and when? Who made the decision, and how?

The answer from idealism

There are reliable, even canonical answers to these questions. In the United States of America, nuclear weapons attended the rise of a new form of elite rule: covert, autonomous, and closely held to an implacable combination of political, technical, and corporate interests.[10] Whether styled the "military-industrial complex," the "garrison state," the "imperial

8. Harry M. Davis, "We Enter a New Era–The Atomic Age: Here Is the Momentous Story of the Atom Whose Energy Science Has Now Unleashed," *New York Times Magazine,* August 12, 1945, ProQuest (305956812).

9. "The American Proposal for International Control, Presented by Bernard M. Baruch," *Bulletin of the Atomic Scientists,* July 1, 1946, 3, doi:10.1080/00963402.1946.11458002.

10. Expressed by a wide variety of figures over multiple decades, what I call the "canonical" interpretation encompasses many styles of theory, method, and discourse. Perhaps it is unsurprising, then, that search for "synoptic" views have been relatively uncommon in the literature. Some exceptions are Ronald E. Powaski, *March to Armageddon: The United States and the Nuclear Arms Race, 1939 to the Present* (Oxford University Press: Oxford, 1987); Michael S. Sherry, *In the Shadow of War: The United States Since the 1930s* (New Haven: Yale University Press, 1995); Julian E. Zelizer, *Arsenal of Democracy: The Politics of National Security—From World War II to the War on Terrorism* (New York: Basic Books, 2010); Mary L. Dudziak, *War Time: An Idea, Its History, Its Consequences* (Oxford: Oxford University Press, 2012); and Paul A. C. Koistinen, *State of War: The Political Economy of American Warfare, 1945–2011* (Lawrence: University of Kansas Press, 2012). For perspectives and references, see Paul A. C. Koistinen, *The Military-Industrial Complex: A Historical Perspective* (New York: Praeger, 1980) and especially Alex Roland, "The Military-Industrial Complex: Lobby and Trope," in *The Long War: A New History of U.S. National Security Policy Since World War II,* ed. Andrew J. Bacevich (New York: Columbia University Press, 2007), 335–370. Note that some sources have identified elements of the postwar arms-buildup already at work long before the invention of the atomic bomb, or even the foundation of the

presidency," or some other epithet, the system that governed the nuclear arms-race has been called illiberal, undemocratic, an abuse of executive privilege, and a cynical ransom on the common good.[11] Even apologists do not deny such power exists; on the contrary, they say it is a necessity foreseen by the Constitution itself, like Caesar bidden to safeguard the Senate.[12] Although its role in deciding various Cold War outcomes does remain as disputatious as ever, we need no longer historicize it in the shadow of the Cold War itself.[13]

United States. While essentially a genre unto its own, some classics are William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society Since A.D. 1000* (Chicago: University of Chicago Press, 1982); Daniel R. Headrick, *The Tools of Empire: Technology and European Imperialism in the Nineteenth Century* (Oxford: Oxford University Press, 1981); and Geoffrey Parker, *The Military Revolution: Military Innovation and the Rise of the West, 1500–1880*, 2nd ed. (1988; Cambridge: Cambridge University Press, 1996).

11. Pillars of the tradition include C. Wright Mills, *The Power Elite* (Oxford: Oxford University Press, 1956); Harold L. Nieburg, *In the Name of Science* (Chicago: Quadrangle Books, 1966); Seymour Melman, *Pentagon Capitalism: The Political Economy of War* (New York: McGraw–Hill, 1970); Arthur M. Schlesinger, *The Imperial Presidency* (1973; repr., Boston: Houghton Mifflin, 2004). The theme continues in more recent examples such as Gary Wills, *Bomb Power: The Modern Presidency and the National Security State* (New York: Penguin, 2010); Jonathan Schell, *The Seventh Decade: The New Shape of Nuclear Danger* (New York: Metropolitan Books, 2007); and Elaine Scarry, *Thermonuclear Monarchy: Choosing Between Democracy and Doom* (New York: W. W. Norton, 2014). Of course, the interpretation has had its challengers, most notably, perhaps, Aaron L. Friedberg, *In the Shadow of the Garrison State: America's Anti-Statism and Its Cold War Grand Strategy* (Princeton: Princeton University Press, 2000). However, in turning away from nuclear warfare specifically, the literature since 9/11 has revealed even more durable continuities within the national-security state, particularly with respect to the intelligence community, e.g. Andrew J. Bacevich, *The New American Militarism: How Americans Are Seduced by War* (Oxford: Oxford University Press, 2005); James Risen, *Pay Any Price: Greed, Power, and Endless War* (Boston: Houghton Mifflin, 2014); Michael J. Glennon, *National Security and Double Government* (Oxford: Oxford University Press, 2015); Scott Horton, *Lords of Secrecy: The National Security Elite and America's Stealth Warfare* (New York: Nation Books, 2015); Tom Engelhardt, *Shadow Government: Surveillance, Secret Wars, and a Global Security State in a Single Superpower World* (Chicago: Haymarket Books, 2014).

12. This is a tenet of neoconservatism, an intellectual defense of which has been taken up in John Yoo, *The Powers of War and Peace: The Constitution and Foreign Affairs Since 9/11* (Chicago: University of Chicago Press, 2005); and John Yoo, *Crisis and Command: A History of Executive Power From George Washington to the Present* (New York: Kaplan, 2011); among other opinions rendered by the author of the notorious "torture memos." By way of comparison, Louis Fisher, *Presidential War Power*, 3rd ed. (Lawrence: University of Kansas Press, 2013) is the standard text in the field.

13. In truth, the historiography of the Cold War has always been deeply politicized by the context in which it is written, a fact unchanged even by its conclusion. What has changed is less the result of new documentary evidence (at least not for Americanists, where state secrecy remains largely intact) but rather the diversity of historical "experiences" on offer, which have expanded greatly from the classic arguments over diplomatic politics. Cf. Melvyn P. Leffler, "The Cold War: What Do 'We Now Know'?" *American Historical Review* 104, no. 2 (April 1999): 501–524, doi:10.2307/2650378; Joel Isaac and Duncan Bell, introduction to *Uncertain Empire: American History and the Idea of the Cold War*, ed. Joel Isaac and Duncan Bell (Oxford: Oxford University Press, 2012), 3–16; Tony Judt, "Whose Story Is It? The Cold War in Retrospect," in *Reappraisals* (New York: Penguin, 2008), 368–383; Odd Arne Westad, "The Cold War and the International History of the Twentieth Century," in *Origins*, vol. 1 of *The Cambridge History of the Cold War*, ed. Melvyn P. Leffler and Odd Arne Westad, (Cambridge: Cambridge University Press, 2010), 1–19, noting the bibliographic essay on 508–510. Some of the key volumes confronting the Cold War's historiographical issues include Odd Arne Westad, ed., *Reviewing the*

So while I accept the canonical answer in outline, a quarter-century of nuclear stagnation has all but obviated its central problematic. At this point, it seems irrelevant whether nuclear weapons are "illiberal" or "undemocratic" when the states identified as the world's most liberal democracies continue to develop, deploy, and depend on them—either directly or through a military alliance—essentially unopposed by their respective populations. "During the Cold War, there was a weighty reason, if not a sufficient one, for possessing the weapons," Jonathan Schell said shortly before his recent death. "It turned out our grip on these things was tighter and our attraction to them was deeper or stranger than the reasons we gave ourselves during the forty-plus years of the Cold War."[14]

Should the trend prove as persistent as it appears, we will need to reconsider what these objects are, what it is that they do, and what sort of processes construct, operate, and maintain them. Perhaps it never was the weapons, or even the superpowers, that really mattered. Perhaps the very notion of an "arms race" misconstrues whatever it is that binds us to them and them to us, today as in the past.

We could start by observing that America's postwar debate over the "power of the atom" encompassed more than politics, but *political organization*. Indeed, the fundamental

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Cold War: Approaches, Interpretations, and Theory, Nobel Symposium 107 (New York: Frank Cass, 2000); Ellen Schrecker, ed., *Cold War Triumphalism: The Misuse of History After the Fall of Communism* (New York: New Press, 2004); Michael J. Hogan, ed., *America in the World: The Historiography of American Foreign Relations Since 1941* (Cambridge: Cambridge University Press, 1995) and its exceptionally thorough revision: Frank Costigliola and Michael J. Hogan, eds., *America in the World: The Historiography of American Foreign Relations Since 1941*, 2nd ed. (Cambridge: Cambridge University Press, 2014). For the history of science and technology as well, the pattern has been mostly the same: the foundational themes have not been overthrown so much as reoriented, with attention refocused on the subtleties, particulars, and pluralities of the Cold War experience. See Hunter Heyck and David Kaiser, "Focus: New Perspectives on Science and the Cold War—Introduction," *Isis* 101, no. 2 (June 2010): 362–366, doi:10.1086/653097 and Naomi Oreskes, introduction to *Science and Technology in the Global Cold War*, ed. Naomi Oreskes and John Krige (Cambridge: MIT Press, 2014), 1–9, the latter especially for its copious endnotes.

14. Bill McKibben, "Jonathan Schell," Postscript, *New Yorker*, April 7, 2014, 22. For clarity, I have elided some nested quotations. Schell was perhaps the most literate voice of the antinuclear movement, known best for the acclaimed long-form essay, Jonathan Schell, *The Fate of the Earth* (New York: Knopf, 1982), first published as a series of three articles in the *New Yorker* in February 1982. The strange durability of nuclear weapons became a major puzzle for his final publication, Schell, *The Seventh Decade*. On the other hand, foreign-policy realists have had little trouble adapting the Cold War paradigms to the security dilemmas of today, e.g. Paul Bracken, *The Second Nuclear Age: Strategy, Danger, and the New Power Politics* (New York: Henry Holt, 2012); Brad Roberts, *The Case for U.S. Nuclear Weapons in the 21st Century* (Stanford: Stanford University Press, 2016).

legislation never considered *whether* America should have a nuclear program, only *how* it would be administered.[15] This recalls Robert Michels' enduring claim that governance is a necessary chore, which the masses cannot practicably perform themselves, even if they could spare the time and care. Organization is democracy's constant companion—its familiar spirit—notwithstanding a tendency to become an end unto itself. "Who says organization, says oligarchy," Michels concluded.[16]

Although the canonical view of nuclear history has drawn a similar line from democracy to oligarchy, it intersects infrequently with the technical means of rulership so important to Michels. The story of nuclear weapons is predominantly a story of the concentration of power; from the outside, it rushes inward, collapsing onto a point or condensing into a monolith, an undifferentiated whole, whose presence inexorably separates the omnipotent from the disfranchised.[17] Upon inspection, however, the monolith does crack, the whole

15. Richard G. Hewlett and Oscar E. Anderson Jr., *The New World, 1939–1946*, vol. 1 of *A History of the United States Atomic Energy Commission* (University Park: Pennsylvania State University Press, 1962) remains the authority on the Atomic Energy Act's legislative history, though for a broader view, see David M. Hart, *Forged Consensus: Science, Technology, and Economic Policy in the United States, 1921–1953* (Princeton: Princeton University Press, 1998).

16. Robert Michels, *Political Parties: A Sociological Study of the Oligarchical Tendencies of Modern Democracy*, trans. Eden Paul and Cedar Paul (1915; Glencoe, IL: Free Press, 1949), 401. Pamela S. Tolbert and Shon R. Hiatt, "On Organizations and Oligarchies: Michels in the Twenty-First Century," in *Oxford Handbook of Sociology and Organization Studies: Classical Foundations*, ed. Paul Adler (Oxford: Oxford University Press, 2009), 174–199 is a modern reflection on Michels' thesis and its applications. Cf. Mills, *The Power Elite*; Tom Bottomore, *Elites and Society*, 2nd ed. (1964; London: Routledge, 1993); G. William Domhoff, *Who Rules America? Power, Politics, and Social Change*, 5th ed. (1967; Boston: McGraw–Hill, 2006). Of course, the concept of government evolving (or devolving, or even *revolving*) between elite, majoritarian, and tyrannical phases is positively ancient: see, e.g. Zena Hitz, "Degenerate Regimes in Plato's *Republic*," in *Plato's "Republic": A Critical Guide*, ed. Mark L. McPherran (Cambridge: Cambridge University Press, 2010), 103–131 or G. W. Trompf, "The Polybian *Anacyclōsis* or Cycle of Governments," in *The Idea of Historical Recurrence in Western Thought: From Antiquity to the Reformation* (Berkeley: University of California Press, 1979), 1–59.

17. This is not to say that such concentration went unopposed, whether popularly or internally. The obligatory reference on international antinuclear movements is Lawrence S. Wittner, *The Struggle Against the Bomb*, 3 vols. (Stanford: Stanford University Press, 1993/2003), though Lawrence S. Wittner, *Confronting the Bomb* (Stanford: Stanford University Press, 2009) provides a helpful condensation. With respect to the technical-scientific experts who designed and built the weapons, Kelly Moore, *Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945–1975* (Princeton: Princeton University Press, 2008); Matthew Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge: MIT Press, 2012); and Sarah Bridger, *Scientists at War: The Ethics of Cold War Weapons Research* (Cambridge: Harvard University Press, 2015) have all recently complicated the moral dichotomy familiar from Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical and Biological Sciences* 18, no. 1 (1987): 149–229, doi:10.2307/27757599 and Dan Kevles, "Cold

fragment, and the point reveal its hidden qualities.

Structured however imperfectly, organization is the power to have power today, but it is a power dispensed fitfully through the mazes and tunnels of a metaphysical playground, where even parents lose track of which children are theirs. If democracy is technically infeasible, as according to Robert Michels, then so too is despotism; for the tyrant can fathom the jungle no better than the mob. Economists call this phenomenon the "principal-agent problem"; in political ethics, it is the "problem of many hands"; those who study corporate governance or the history of business refer to the "separation of ownership and control," but I suppose that it is the uncoupling of actions from consequences, incentives from outcomes, or *power* from *authority*.[18] While we may rightfully distrust what some of us do in the name of all of us, the few can also fear the many, and even the one fear the few. Nuclear weapons are physically the most powerful products of human artifice, and yet from day to day that power falls not to the many, nor the one, but rather, the managers.

The logistics of rational authority

In an organization as vast as the defense establishment, the tip of the pyramid is a point of instability and a precipice in all directions. Even a *military* organization—the apotheosis of hierarchy—actually moves along many axes, not just "upward" or "downward," "inward" or "outward." Rather, it is multidimensional and nondisjoint—cross-cut and overlaid with boards, panels, liaisons, special projects, "dual-hatted" officials, *ad hoc* coordinating com-

War and Hot Physics: Science, Security, and the American State, 1945–1956," *Historical Studies in the Physical and Biological Sciences* 20, no. 2 (1990): 239–264, doi:10.2307/27757644. However, I tend to view local resistance as the exception that proves the rule.

18. Charles Perrow, "Economic Theories of Organization," *Theory and Society* 15, no. 1–2 (January 1986): 11–45, doi:10.1007/BF00156926 reviews agency theory; Dennis F. Thompson, "Moral Responsibility of Public Officials: The Problem of Many Hands," *American Political Science Review* 74, no. 4 (December 1980): 905–916, doi:10.2307/1954312 introduced the "many hands" language to the question of political accountability; and Adolf A. Berle and Gardiner C. Means, *The Modern Corporation and Private Property* (New York: Macmillan, 1933) is the classic on ownership *versus* control in corporate governance. Similar features can be seen in the concept of "technostructure," as in John Kenneth Galbraith, *The New Industrial State* (Boston: Houghton Mifflin, 1967), and the narrative of Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Harvard Belknap, 1977), both of which I will return to later.

mittees, and other bodies that continuously adjust and realign their partially overlapping spheres of influence. In operation, it can sometimes resemble a confederation of "task forces" more than a lineal chain of command, in which crises compete with chronic issues for finite human attention.[19] Institutional norms quite often disfavor arbitrary pronouncements from higher authorities, who must regularly trust their staffs to negotiate matters among themselves.[20] When leaders act, they can never know the options completely or

19. It could be said that America does not have *a* military organization at all, but rather, *many*, with each one forced to adapt its institutional structures, styles, and legacies in order to accommodate certain legally prescribed centers of cross-institutional cooperation. This is an immensely complicated history that I have only been able to engage in passing, but among my references and motivations are: Otto L. Nelson, *National Security and the General Staff* (Washington: Infantry Journal Press, 1946); Ray S. Cline, *Washington Command Post: The Operations Division*, The United States Army in World War II: The War Department, CMH Pub 1-2 (1951; repr., Washington: Center of Military History, 1990); William R. Kintner, *Forging a New Sword: A Study of the Department of Defense* (New York: Harper, 1958); Paul Y. Hammond, *Organizing for Defense: The American Military Establishment in the Twentieth Century* (Princeton: Princeton University Press, 1961); John C. Ries, *The Management of Defense: Organization and Control of the U.S. Armed Services* (Baltimore: Johns Hopkins University Press, 1964); James E. Hewes Jr., *From Root to McNamara: Army Organization and Administration, 1900–1963*, CMH Pub 40-1 (Washington: Center of Military History, 1975); William W. Momyer, *Airpower in Three Wars* (1978; repr., Maxwell AFB, AL: Air University Press, 2003); Arthur T. Hadley, *The Straw Giant: Triumph and Failure; America's Armed Forces—A Report From the Field* (New York: Random House, 1986); James A. Winnefield and Dana J. Johnson, *Joint Air Operations: Pursuit of Unity in Command and Control, 1942–1991* (Annapolis: Naval Institute Press, 1993); Clayton R. Newell and Michael D. Krause, eds., *On Operational Art* (Washington: Center of Military History, 1994); Kenneth Allard, *Command, Control, and the Common Defense*, rev. ed. (1990; Washington: National Defense University Press, 1996); Amy B. Zegart, *Flawed by Design: The Evolution of the CIA, JCS, and NSC* (Stanford: Stanford University Press, 1999); Michael D. Krause and R. Cody Phillips, eds., *Historical Perspectives of the Operational Art: An Anthology*, CMH Pub 70-89-1 (Washington: Center of Military History, 2005); Michael A. Palmer, *Command at Sea: Naval Command and Control Since the Sixteenth Century* (Cambridge: Harvard University Press, 2005); Daniel R. Beaver, *Modernizing the American War Department: Change and Continuity in a Turbulent Era, 1885–1920* (Kent, OH: Kent State University Press, 2006); Douglas T. Stuart, *Creating the National Security State: A History of the Law That Transformed America* (Princeton University Press: Princeton, 2008); Brian McAllister Lind, *The Echo of Battle: The Army's Way of War* (Cambridge: Harvard University Press, 2007); Michael R. Matheny, *Carrying the War to the Enemy: American Operational Art to 1945* (Norman: University of Oklahoma Press, 2011); and Roger Z. George and Harvey Rishikof, eds., *The National Security Enterprise: Navigating the Labyrinth* (Washington: Georgetown University Press, 2011). As a more concise alternative the mass of materials cited above, Theodore W. Bauer and Harry B. Yoshpe, *Defense Organization and Management* (Washington: Industrial College of the Armed Forces, 1967) presents a synthetic, albeit didactic overview of the US armed forces in the postwar era; Alice C. Cole et al., eds., *The Department of Defense: Documents on Establishment and Organization, 1944–1978* (Washington: Office of the Secretary of Defense, Historical Office, 1978), though undigested, is a helpful complement as well. Although the sample here covers a variety of approaches to the subject of military organization, even a superficial examination will confirm that civilian academics have favored studies of "high command" as an agent of policy formation, leaving the tactical, operational, and administrative aspects almost exclusively to military historians, whose methods are often keyed to the needs of professional military education.

20. Ries, *The Management of Defense*, though dated, took a highly unusual stand against the centralization and hierarchization of the national-security system, arguing that it contravened a working design on the specious assumption that the Secretary of Defense should function as an executive instead of a political power-broker.

deduce their consequences perfectly, and neither does their verdict enact itself, nor causes report their own effects. Decision is nevertheless the executive's obsession, as if the pretext of officialdom could sweep all these vicissitudes into a receptacle as convenient as "the button," the "red telephone," or the "nuclear football."

While the historical trend indeed points toward consolidation, this has been a study of the gaps and fissures, the magma cracking as it cools. Its guiding tension can best be described as a conflict between local experience and universal expectation. As often as we see the logic in our immediate circumstances—why we do things how we do when we do them—we nonetheless perceive the *system*, the universal totality that looms indistinctly beyond our view, as absurd, incongruous, malignant: an irrational composite of outcomes that all seemed reasonable enough in themselves. These frustrations exempt no one; neither us, the "great unwashed," nor the "powers that be," as we identify them; such that even power, just by coming into being, thrashes against the ironic awareness of its own circumscription. Whether or not such a totality exists is irrelevant here; what matters is that we *expect* the whole to behave as rationally as its parts, and that we *experience* life, both distant and imminent, in opposition to it.[21]

2 Bureaucracy and the bomb

This dissertation has reassembled a few of the many disaggregated pieces of America's organization for "commanding" and "controlling" its nuclear forces prerequisite to their

21. In addition to previous references on bureaucracy, cf. David Graeber, *The Utopia of Rules: On Technology, Stupidity, and the Secret Joys of Bureaucracy* (New York: Melville House, 2015); Ben Kafka, *The Demon of Writing: Powers and Failures of Paperwork* (New York: Zone Books, 2012); Michael Lipsky, *Street-Level Bureaucracy: Dilemmas of the Individual in Public Services*, 2nd ed. (1980; New York: Russell Sage Foundation, 2010); Brian J. Cook, *Bureaucracy and Self-Government: Reconsidering the Role of Public Administration in American Politics*, 2nd ed. (Baltimore: Johns Hopkins University Press, 2014). In the end, however, the indispensable guides to the literature on organization studies, though dated, proved to be Charles Perrow, *Complex Organizations: A Critical Essay*, 3rd ed. (New York: Random House, 1986) and James Q. Wilson, *Bureaucracy: What Government Agencies Do and Why They Do It* (New York: Basic Books, 1989); the former surveys organization theories, while the latter synthesizes case studies, but both express a certain reluctance to universalize their conclusions, without neglecting the importance of particulars.

coming together between the years 1958 and 1962. By that point, America's defense establishment had organized itself into the possibility of a sudden, catastrophic, and potentially inadvertent nuclear war. While touching occasionally upon the deepest anxieties of leadership, my focus has lied primarily with management—the methodical hand—rather than the heroic powers of intervention. As its mundane actions accumulated, progressively higher echelons grew increasingly eager to stake their own claims on the outcome, intercessions that could appear less rational than capricious and random. Again and again the question was raised—*who made the decision, and how?*—and again and again the answer seemed less important than preserving the right to ask it.

Origins of nuclear command-and-control

The period from 1958 to 1962 will be especially worthy of future consideration, because a considerable body of literature has already defined the "before" and "after" states.[22] As we have seen, in the 1950s, the multifarious components of the national-security state developed scattered and wildly inconsistent administrations to manage the complex problems of nuclear warfare, from strategic planning to tactics, communications, budgeting, research and development, policy-making, and so on. Different organizational actors made entirely separate assumptions about what a nuclear war would be like and how it should be fought.

Within a decade, however, a definite pattern had emerged: a pattern followed for the remainder of the Cold War and, for the greater part, recognizable still today. It included, among others, the concept of a strategic-nuclear "triad," which reconciled the nuclear ambitions of the three armed forces; a staff organization to coordinate their war plans; preemptive transfers of operational weapons from the Atomic Energy Commission to units in the field; the concentration of strategic direction in the Office of the Secretary of Defense,

22. See preceding notes, or the bibliography, for references to William Arkin, Desmond Ball, Bruce Blair, Paul Bracken, Stephen Cimbala, Peter Feaver, Fred Kaplan, David Pearson, David Alan Rosenberg, Scott Sagan, and John Steinbruner; as well as L. Wainstein et al., *The Evolution of U.S. Strategic Command and Control and Warning, 1945–1972*, IDA Study S-467 (Alexandria, VA: Institute for Defense Analyses, International and Social Studies Division, June 1975), declassified copy, DTIC (ADA331702).

especially with respect to research and development policy; unified procedures for budgeting and program monitoring; and finally, what most sources associate with "command and control": *a centrally managed infrastructure of facilities, vehicles, communications, and other resources intended to allow political authorities—and particularly, the President of the United States—to discharge their legally constituted responsibilities as military commanders*. The contrast is obvious, but the transformation remains to be fully historicized.

What I have interrogated is how nuclear warfare both did and did not change the meaning of "command and control" with respect to military force. My route has been rather indirect, because, as the final chapter observed, "command and control" did not assume its current meaning until the late 1950s, at the very end of the story recounted here; as such, it was essential to reference the jargon sparingly not only to avoid anachronism, but also the semantic traps endemic to the subject. Today, management consultants speak of the "command and control" of corporate strategy, police and fire departments claim to exercise it in emergency operations and public-utility companies in the generation, delivery, and inspection of power, water, gas, and telecommunication services—and yet for all its applications, military and civilian, its usage remains indeterminate.[23]

What I have established is that, for all its many valences, command-and-control acquired its present meaning in the context of defending the American continent from attack by Soviet bombers. Veterans of the SAGE program introduced it in the late 1950s in order

23. Another history remains to be written concerning the transportation of military ideas about command-and-control systems to domestic services, primarily through applications to law enforcement and crisis management, which appears to have been at least partly facilitated by the same government-contracted systems-integration firms established as a consequence of the SAGE program: cf. Robert C. Brictson, ed., *Symposium on Emergency Operations*, SP-2579 (Santa Monica: System Development Corporation, September 1, 1966), DTIC (AD0640543); Kent W. Colton, *Police and Computer Technology: A Decade of Experience Since the Crime Commission—Summary* (Washington: National Institute for Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, Department of Justice, September 1979), OCLC (572206951); Kent W. Colton, Margaret L. Brandeau, and James M. Tien, *A National Assessment of Police Command, Control, and Communications Systems* (Washington: National Institute of Justice, Department of Justice, January 1983), OCLC (604199502). See also Claude Baum, *The System Builders: The Story of SDC* (Santa Monica: System Development Corporation, 1981) for some discussion of how the company attempted to expand its business to non-military clients; also relevant is Jennifer S. Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America* (Baltimore: Johns Hopkins University Press, 2003).

to generalize the computerization of air defense to other rigidly performed, time-critical organizational activities, with particular respect to nuclear operations. Thus, continental air-defense can be called the first command and control "problem" in the sense that the solution entailed the research and development of a command and control *system*.

Of course, the label was only applied retroactively, once SAGE had already entered its production and deployment phase, and other complex electronic systems, conceived on similar principles, had already claimed a disproportionate share of the nation's budget and scientific manpower. Before then, SAGE specifically constituted an "air defense" system, but it was not the first such "system" to be so represented. On the contrary, officials had for more than a decade ruminated over a discursive framework that would capture the "systemic" qualities peculiar to air defense, which they understood as fundamentally different from the mainstream of system-thinking of the time.

Evolution of air-defense thinking

Why air defense, and not, say, naval fleet operations?[24] After all, the problem of marshaling military forces at sea shares many of the same characteristics, both technical and procedural, as directing aircraft from the ground. While the two problems and their respective genealogies could be usefully compared, the simple fact is that at the time, for reasons thoroughly explained, the United States Air Force and its industrial–scientific partners predominated over the formation of military-political concepts related to the prosecution of

24. Indeed, there is a good case for ascribing, or at least expecting, the historical primacy of the latter. The Department of the Navy is practically a microcosm of the military as a whole, consisting of a ground force—the United States Marine Corps—and an air arm, as well as, of course, the fleet itself. Thus, the form of military command-and-control required in air-defense applications was, by midcentury, already fairly typical of complex land-sea-air operations conducted by the Navy alone, or as the dominant component. Cf. Palmer, *Command at Sea*; Timothy S. Wolters, *Information at Sea: Shipboard Command and Control in the U.S. Navy, From Mobile Bay to Okinawa* (Baltimore: Johns Hopkins University Press, 2013); David L. Boslaugh, *When Computers Went to Sea: The Digitization of the United States Navy* (Los Alamitos, CA: IEEE Computer Society Press, 1999); and Vinny DiGirolamo, ed., *Naval Command and Control: Policy, Programs, People, and Issues* (Washington: AFCEA International Press, 1991). In addition, Allard, *Command, Control, and the Common Defense* reflects on the different command traditions of the Army, Air Force, and Navy.

nuclear war, whether offensively or defensively.[25] However, I can suggest some additional features unique to air defense.

First, due to its sheer volume compared to the size and speed of its combatants, a battlefield in the air was essentially invisible. It could not be observed directly, only represented. Although I have also mostly eschewed referencing information theory, except insofar as it reflected the mentality of the actors themselves, a large-area defense net expended most of its energy gathering and filtering the data it needed to construct timely displays. Since these displays aspired to represent physical airspace, they were scoured relentlessly for sources of "error" and "delay," which usually turned out to be human, and therefore, perceived as subjective.[26]

While analysts tended to idealize air-defense networks as abstract information systems, in an uncannily modern sense, there was, at least for a time, some recognition that subjectivity could manifest benignly, as when tellers or filterers prioritized urgent reports and withheld more dubious ones, in order to focus the attention of ground controllers. However, the implicit goal was always to surmount such "limitations": to present displays that were literally up-to-the-minute—or, ultimately, even the second—as accurately and completely as possible. In time, designs on objectivity completely replaced any comprehension of representation as a collective act of organizational self-knowledge in favor of predictable, automatic behavior. The routine acts of discernment that kept the manual operations intelligible would be removed from the hands deemed most fallible and judgment concentrated

25. Although some of these references are duplicative, the list of most important sources includes David Alan Rosenberg, "'A Smoking Radiating Ruin at the End of Two Hours': Documents on American Plans for Nuclear War With the Soviet Union, 1954–1955," *International Security* 6, no. 3 (Winter 1981–1982): 3–38, doi:10.2307/2538605; David Alan Rosenberg, "The Origins of Overkill: Nuclear Weapons and American Strategy, 1945–1960," *International Security* 7, no. 4 (Spring 1983): 3–71, doi:10.2307/2626731; Steven T. Ross, *American War Plans, 1945–1950* (New York: Garland, 1988); Scott D. Sagan, "SIOP-62: The Nuclear War Plan Briefing to President Kennedy," *International Security* 12, no. 1 (Summer 1987): 22–51, doi:10.2307/2538916; Fred Kaplan, *The Wizards of Armageddon* (New York: Simon & Schuster, 1983); and Edward Kaplan, *To Kill Nations: American Strategy in the Air-Atomic Age and the Rise of Mutually Assured Destruction* (Ithaca: Cornell, 2015).

26. In addition to Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1996), this argument clearly resonates with David F. Noble, *Forces of Production: A Social History of Industrial Automation*, 2nd ed. (1984; New Brunswick, NJ: Transaction, 2011) as well.

in the appropriate authority: the commanding officer, or the duty controller acting as his delegate.

Second, air-defense operations, effectively by their nature, had to work through multiple intersecting chains of command, at least within the United States. Although a loose confederation between Army, Navy, and Air Force components eventually did form under NORAD's binational mandate, the American military tradition strongly disfavored a unitary air-defense organization. By way of contrast, the Soviet Union tended to segregate its air-defense functions from the major services and even elevated the Air Defense Forces, or PVO [*voyska protivovozdushnoy oborony*], to co-equal status in 1954.[27] Nevertheless, the United States likely could not have constitutionally combined all the relevant military and civilian authorities—absent some form of martial law—no matter how it organized its armed forces.

Thus, despite a modest consolidating trend among radar, interceptor, and anti-aircraft units, the prevailing model for air defense within the continental United States had to rely primarily upon coordination and liaison. By keeping the number of organizational stakeholders relatively high, this pattern imposed a high premium on command-post activities, increasing the staff and communications capacity required to work effectively. Maintaining long-term cross-organization agreements and understandings remained a constant concern for the air-defense commander, in addition to the burden of supervising daily operations, because by the time an emergency did occur, the response would be limited by the provisions that could be foreseen and negotiated in advance.

Finally, the fact of coincidence should not be ignored that when it came to "command and control," the term was already available. While never codified, the term had been a reliable "stock phrase," within the culture of Anglo-American military operations for decades; loosely, to describe an intricately designed though usually *ad hoc* configuration

27. See, for instance, the chapters on Soviet air-defense doctrine, strategy, and organization interspersed throughout *History of Strategic Air and Ballistic Missile Defense*, 2 vols. (1972; repr., Washington: US Army Center of Military History, 2009). Owing to a serious dearth of English-language sources—except for a handful of enthusiast publications, which generally lack bibliographic references—the subject is otherwise inaccessible to Americanists, absent further training.

of units and headquarters.[28] When vague apprehensions about the atomic future began circulating the day after Hiroshima, it was always tempered by a sense of both cautiousness and continuity. The bomb may have represented a disruptive technological challenge, but it was hardly the first such challenge in military history, especially recent military history, which had also witnessed the introduction of rifles, machine guns, high explosives, tanks, battleships, submarines, aircraft, telegraphy, and radio.[29] The military profession had always learned eventually—though not always rapidly—how to accommodate all of these disruptions into its command tradition, so why should the atomic bomb, or the ballistic missile, be any different?

Therefore, "command and control," in the context of a "command-and-control system," evoked a similar sense of skepticism among military and civilian interlocutors. It expressed fear of the future and faith in the past to supply the confidence required to meet the challenge of that future. As air-defense officials proceeded to build up their capabilities incrementally, they did so cognizant, though seemingly dubious, of the potential for radical disruption, an attitude consistent with previous observation of the tension between "evolutionary" and "revolutionary" change. Nuclear command-and-control was not so much a novel conceptualization as a reconceptualization, just as the path toward radical systematization had already been chosen long before the end of World War II. In the light of the atomic flash, even old ideas appeared new.

28. The term appears frequently in World War II documents, usually in organization plans that separated "operational control" of a unit or units from their "administration"; that is, in cases where a unit would be placed under another commander's authority for the purpose of completing a specific mission, while retaining its identity, as well as elements of its material support, according to its permanent affiliation. British and American forces relied on this principle extensively in the war against Germany: see, for instance, Forrest C. Pogue, *The Supreme Command*, The United States Army in World War II: The European Theater of Operations, CMH Pub 7-1 (1954; repr., Washington: US Army Center of Military History, 1989). It is also, probably not coincidentally, the circumstances under which the air-defense "para-organization" evolved during the late 1940s, in which commanders of air-defense divisions only temporarily assumed command of flying units regularly assigned to one of the four home air-forces.

29. The volume of literature here is overwhelming, but see Alex Roland, *War and Technology: A Very Short Introduction* (Oxford: Oxford University Press, 2016) for a bibliographic essay as concise as it is recent.

Technology and social authority

Summed together, these points strongly suggest that the technology of air defense was tightly coupled to its organization. Indeed, it is difficult to specify distinctions between them. Planes appeared on Air Force radar no matter their owner, but only Air Force planes were likely to carry a transponder that allowed ground controllers to automatically interrogate and identify them. Although Navy or civilian pilots could still be hailed by radio, of course, they often followed different air-to-ground communications habits and procedures, and the quality of the voice transmission varied greatly with topography and atmospheric conditions. The air-defense center might attempt to correlate the track with flight-plan data on file, but this again depended on the commitment of the flying organization (or private pilot) to providing the information in the first place. At last, the observation and its identification would have to be relayed, transcribed, interpreted, and displayed, a process which, while typically described as "manual," should be understood as an elaborate chain of human tool-using, including headsets, radar scopes, papers, grease pencils, and plotting boards. Each motion was highly interactive, in that the outcome compounded the results of previous steps and dependent on human proficiency as well as the availability and reliability of the equipment. In many important respects, then, the question of which elements should be understood as technical in nature, as opposed to organizational, seems highly arbitrary.

Thus, in classifying what "command and control" could mean to the military officer, the science adviser, the defense official, or the industrial engineer, I have also had to decide what it should mean for me. In my observation, whenever it comes into use, there is always a presumption of *technology*, and there is always an understanding of *organization*. It is, as it were, a hybrid born by the necessity of thinking through the two concepts together: *the technology of organization*, or equivalently, *the organization of technology*.[30] Nuclear weapons

30. Again, I am aware of no source that makes this claim so explicitly, although, as referenced in the introduction, it is certainly possible to interpret Lewis Mumford, *The Myth of the Machine*, 2 vols. (New York: Harcourt, Brace, Jovanovich, 1967) in such a fashion, and possibly others as well. The argument is also not the same as Hughes' observation that management organizations are needed to structure technology into systems: Bernward Joerges, "Large Technical Systems: Concepts and Issues," in *The Development of Large Technical*

urged this uncomfortable synthesis, because they threatened destruction so total, perfected with violence so quick, that even the simplest, seediest ministrations of government—the sorting of mail, or the filing of papers—imposed material constraints on the global confrontation.

So "command and control," as I understand it, identifies the social authority derived from knowledge conferred on the right people, by the right means, and at the right time. By the 1960s, nuclear arms had accumulated such that few doubts remained whether the superpowers *could* lay one another to waste all but instantaneously.[31] Merely killing the enemy was no longer the sufficient problem. Thus did a new question emerge, one impossibly more difficult to answer. Could such killing serve a *rational end*? This is an epistemic question—one of the great quandaries of the era—but also a question of *Gesellschaft*: the impersonal bond, the association of rules and reasons that collectively gives rise to the modern social order.[32] Information and authority are interdependent; knowledge legitimizes decision, but to know is also to become responsible for the action.[33] *Command and control is the logistics of*

Systems, ed. Renate Mayntz and Thomas P. Hughes (Boulder: Westview Press, 1988), 9–36. On the other hand, JoAnne Yates, *Control Through Communication: The Rise of System in American Management* (Baltimore: Johns Hopkins University Press, 1989) suggested that the process of organizing the modern corporation may itself have been an act of system-building, but distinguishing a "builder" from a "user" is difficult when the logic of bureaucracy already depends on the legitimacy of the technology used to effect it.

31. Indeed, the formal shift in nuclear-strategic policy from "massive retaliation" to "mutual assured destruction" was predicated on precisely this assumption: Lawrence Freedman, *The Evolution of Nuclear Strategy*, 3rd ed. (London: Palgrave Macmillan, 2003), 232–257. The actual production of nuclear weapons by the United States, Soviet Union, and other nations was documented in Thomas B. Cochran, William M. Arkin, and Milton M. Hoenig, *Nuclear Weapons Databook*, 5 vols. (Cambridge, MA: Ballinger, 1984).

32. The dichotomy between *Gesellschaft* and *Gemeinschaft*—"society" and "community," respectively—as contrasting forms of interpersonal relations originated with Ferdinand Tönnies, *Community and Civil Society*, ed. Jose Harris, trans. Jose Harris and Margaret Hollis (Cambridge: Cambridge University Press, 2001). To differentiate his own ideas from Tönnies, the original manuscripts of Max Weber, *Economy and Society: An Outline of Interpretive Sociology*, ed. Guenther Roth and Claus Wittich, trans. Ephraim Fischoff et al. (Berkeley: University of California Press, 1978) actually used the terms *Vergesellschaftung* and *Vergemeinschaftung*, which are harder to render in English, but are often translated roughly as "associationship" and "communitization," or similar. Although, technically, my characterization of a social order arising from a collective acceptance of "rules and reasons" is closer to Weber's *Vergesellschaftung*, conflation with Tönnies's *Gesellschaft* is now fairly typical of English-language texts.

33. Although this statement is strongly normative, it is a norm enforced by the institutions of bureaucracy and democracy alike. See Dennis F. Thompson, *Restoring Responsibility: Ethics in Government, Business, and Healthcare* (Cambridge: Cambridge University Press, 2005).

rational–legal authority, the technopolitics of who needs to know what in order to validate an organizational response.

It is a unfortunate fact of the era that to its leading political and intellectual figures, as well as American polity in general, more terrifying than the devastation itself was the chance that it might come about *illegitimately*, which is to say, accidentally, unintentionally, breaching the official calculations of national interest and subverting the state organization for pursuing it.[34] Sanction required leaders to always *choose* the course of action, but also, to always know their circumstances well enough to choose *correctly*. Without decision, without *authority*, there could not be "war"—only killing. In order to serve rational ends, nuclear war had to be disciplined, quantified, reduced and redefined formally, and then subjected to management. In a word, it had to be *bureaucratized*. And so it was, for all the contradictions that entailed—at least well enough to satisfy them, and us, in bewildering perpetuity.

3 Managing the unmanageable

Suppose that in fifty years, the world looks rather like it does now—and, indeed, one of the cruelest symptoms of our time is how difficult it is to even imagine otherwise—with the same international structures, domestic coalitions, and nuclear arsenals, though perhaps

34. Journalism like Peter Wyden, "The Chances of Accidental War," *Saturday Evening Post*, June 3, 1961, EBSCO (17970918) first raised public awareness of the inherent risk and vulnerability of nuclear weapons, a warning advocated and legitimized by Fred Iklé, then an analyst at the RAND Corporation, who lated headed the United States Arms Control and Disarmament Agency; many sources credit Fred Iklé, *On the Risk of an Accidental or Unauthorized Nuclear Detonation*, RM-2251 (Santa Monica: RAND Corporation, October 15, 1958), redacted copy, http://www.rand.org/pubs/research_memoranda/RM2251.html for informing the policy response, as well as the public reaction. Along similar lines, Stephen J. Whitfield, *The Culture of the Cold War*, 2nd ed. (Baltimore: Johns Hopkins University Press, 1996), 218–225 and Steve Call, *Selling Air Power: Military Aviation and American Popular Culture After World War II* (College Station: Texas A&M University Press, 2009), 157–162, among others, regard the near-simultaneous release of *Dr. Strangelove; Or, How I Learned to Stop Worrying and Love the Bomb*, directed by Stanley Kubrick, Blu-ray disc (1964; New York: Criterion, 2016) and *Fail Safe*, directed by Sidney Lumet, DVD (1964; Culver City, CA: Sony Pictures Home Entertainment, 2000) as a landmark in the cultural turn against the absurd rationalism driving the nuclear stalemate; see also Weart, *Nuclear Fear*, 273–280;. On the Iklé report, see Eric Schlosser, *Command and Control* (New York: Penguin, 2013), 190–196, though incidentally, Schlosser's conception of the term "command and control" tends to emphasize the more specific issue of *nuclear safety*: clearly, a closely related area of concern, but not one especially well realized until the mid-to-late Cold War, as should be apparent from the evidence presented here.

comparatively reduced, still upholding the realist foreign policy of the United States. What might the histories say then? Far from idle speculation, such questions are asked routinely in Washington, where 50 years provides merely a rough upper-bound on the increasingly "long now" of national-security planning, and technology managers program even their budgets for 25 years.[35] Every choice imposes a multi-decade, multi-billion-dollar constraint on every subsequent choice, sinking each one deeper in the past, while looking even further into the future, until perhaps the "strategic present"—the sensorium of the American state—surpasses the human lifespan, if it has not already done so.

Consider, for example, that a Joint Strike Fighter will have been on display at the National Air and Space Museum for *fifteen years* by the time the operational testing and training concludes on the production model. Implementing a concept studied in the 1980s, the controversial F-35 will enter service between 2018 and 2038, according to the latest schedule, which contemplates no retirement at least until the 2060s.[36] This is deep time indeed, when decision must yield to the priorities of the dead while foisting its costs on those as yet unborn—certainly compared to the presumed instantaneity of nuclear war. Instead, we confront the possibility that complex technologies, pursued across an unbounded strategic present, may yet diverge even further from our immediate needs. With them, we build our grand cathedrals, rising so slowly that no one generation could ever see its end from the beginning, except that we, unlike the architects of Old Europe, conflate seconds with centuries.[37]

35. For instance, United States Department of Energy, *Fiscal Year 2019 Stockpile Stewardship and Management Plan: Biennial Plan Summary—A Report to Congress* (Washington: National Nuclear Security Administration, October 2018), https://www.energy.gov/sites/prod/files/2018/10/f57/FY2019%20SSMP.pdf projects through the end of Fiscal Year 2043 and includes some statements that attempt vague forecasts of the 2050s and beyond. Although public documents generally adopt a 25-year outlook, reporting on nuclear issues suggest that internal discussions about long-term weapons development plans extend into 2070s.

36. As of this writing, Jeremiah Gertler, *F-35 Joint Strike Fighter (JSF) Program*, CRS report no. RL30563 (Washington: Congressional Research Service, April 23, 2018), https://fas.org/sgp/crs/weapons/RL30563.pdf is the most current reference for legislators on the program's status, with a brief overview of its history and future management plan, with citations to progress reports and status updates from DoD and GAO.

37. Marvin Trachtenberg, *Building-In-Time: From Giotto to Alberti and Modern Oblivion* (New Haven: Yale University Press, 2010) argues that medieval architects understood time, or more precisely, *duration*, to be

What Talcott Parsons rendered loosely as the "iron cage," Max Weber called literally, a "shell hard as steel" [*stahlhartes Gehäuse*].[38] We are not prisoners so much as refugees, survivors: a species like the lonely hermit crab, which scavenges its shelter among the calcareous husks of dead sea-life. Rationalism is our home, whether it suits us or not, and though we may make what hearth of it we can, we cannot help but to refashion the debris washed up on our shores. The nuclear world carved an entire reef of such "shells hard as steel," hollowing niches and chambers for itinerant safety-seekers, the organisms that secreted them long since having dissolved on the tide. It is understandable, therefore, that we should attribute so much vitality to the forces that shaped our immediate surroundings, and yet a reef is built up in layers, so the crevices that confine us now, grew likewise within burrows cut deeper still. A monolith will not suffice to explain all the features that flow from the interstices. Organization, bureaucracy, management—these things had split the atoms of power, before science unleashed the power of the atom.

Thus, in a world so often criticized for moving faster than the speed of thought, management is the force that remembers where it has been and anticipates what to do next. Since emerging from the late-nineteenth century, the stewards that study and calculate our commodities have loyally tended whatever commodities we consign to them—or which they construct for themselves—gradually, parochially, and disjointedly minding the business we call our commonwealth.[39] Inherently neither progressive nor regressive, inclusive nor

among their building materials, as each edifice reflected the sustained values of its community, rather than the singular vision of its designer.

38. Max Weber, *The Protestant Ethic and the Spirit of Capitalism*, trans. Talcott Parsons (1930; repr., New York: Scribner, 1948), 181; Peter Baehr, "The 'Iron Cage' and the 'Shell as Hard as Steel': Parsons, Weber, and the *stahlhartes Gehäuse* Metaphor in the *Protestant Ethic and the Spirit of Capitalism*," *History and Theory* 40, no. 2 (May 2001): 153–169, doi:10.1111/0018-2656.00160.

39. Although there are many positivist theories of management, I associate it with the historical phenomenon most familiar from Chandler, *The Visible Hand*, especially chaps. 12 and 13, which concern the professionalization of business managers in the late-nineteenth century. Chandler identified "management" with the "administrative coordination" of decentralized industrial processes within a large firm. Significantly, this activity acquired a vitality of its own, with methods, competence, and priorities distinct from the traditional ownership and financing of the enterprise, despite its legally subordinate position. John Kenneth Galbraith likewise attributed the decline of entrepreneurial power to what he called "technostructure," observing that "the modern business organization, or that part which has to do with guidance and direction, consists of

exclusive, static nor dynamic, management is the idealized "rule of nobody" that seeks only stability—every risk assessed, every contingency planned, every interest protected.[40] In a sense, nuclear weapons are the ultimate managerial commodities. Their intrinsic danger is almost incalculable, and yet we feel still safer with them than we can even imagine without them, precisely because we have learned how to manage them.

numerous individuals who are engaged, at any given time, in obtaining, digesting or exchanging and testing information." Galbraith saw technostructure as the critical innovation that allowed an organization to multiply "ordinary" skills through conscientious, deliberative, consensus-based decision-making, though it also generated the frustratingly slow and equivocating group processes that we often disparage as mere "management." Galbraith, *The New Industrial State*, 60–71. William H. Whyte, *The Organization Man* (New York: Simon & Schuster, 1956) and C. Wright Mills, *White Collar: The American Middle Classes* (1951; repr., Oxford: Oxford University Press, 1956) pointedly expressed some of this anxiety. For a social history of management and the rise of white-collar labor, see Olivier Zunz, *Making America Corporate, 1870–1920* (Chicago: University of Chicago Press, 1990); or for a text surveying the historiographical issues of the period, Glenn Porter, *The Rise of Big Business, 1860–1920,* 3rd ed. (Wheeling, IL: Harlan Davidson, 2006).

40. The phrase belongs to legal reformer Philip K. Howard, a critic of what he perceives as an excessive deference to procedure, leading to a "value-free philosophy of public action," which instead rewards mere compliance, itself often designed to favor incumbents, over action better suited to the circumstances: Philip K. Howard, *The Rule of Nobody: Saving America From Dead Laws and Broken Government* (New York: W. W. Norton, 2014). The routinized protection of interests also recalls Ulrich Beck, *Risk Society: Towards a New Modernity,* trans. Mark Ritter (Newbury Park, CA: Sage, 1992), though I stress management's role in assessing legal, financial, and political risks, as well as technical and environment ones.

Notes on Sources

The following abbreviations are used in the citation of documents not "generally available," which is to say, papers in archival collections, or digital resources held by specific online repositories. In the latter case, many of these documents are, in practice, more "generally available" than documents typically treated as such, at least according to standard bibliographic conventions.

Items held by any one of the Anglosphere's three largest national libraries—the Library of Congress, the British Library, and the Library and Archives of Canada—have been cited without additional locating information. To works that have evaded indexing by national libraries while still finding their way into the public or semi-public collections of universities, municipalities, government agencies, or online databases such as HathiTrust, Google Books, or the Internet Archive, I have appended OCLC identifiers instead. The reader will likely consider it immaterial whether the copy I examined was obtained from my own university's library, borrowed from another with which it shares a lending agreement, or consulted online.

Finally, I abhor the impermanence of URLs, which motivates my general preference for persistent identifiers, or "handles," for digital resources. The Document Object Identifier (DOI) system is now common enough that it is specifically treated in the Chicago Manual of Style, with instructions on how to resolve registered handles. For other systems, the description accompanying each abbreviation will explain the usage of its corresponding identifier, as of this writing.

AFHRA Air Force Historical Research Agency.

Air University, Maxwell Air Force Base, Montgomery, Alabama.

AFHRA is an archival collection; its holdings are unique and otherwise unavailable except to researchers on site. Unlike most archives, however, every document in its possession has been described and catalogued individually. These are indexed by an idiosyncratic system of call numbers, invented by a former curator, as well as numeric identifiers specific to IRIS, the internal reference database. Since the call numbers are more useful for discovery than retrieval, I have elected to cite IRIS numbers exclusively. These are sufficient to recall a document's database entry, including its corresponding call number, as well as the document itself. At present, the reference staff will also respond to modestly sized requests from the public without necessarily invoking the Freedom of Information Act.

Although most AFHRA materials cited here have been fully declassified, much of its collection retains security markings and cannot be provided to researchers in the unclassified reading room. It is, however, possible to request an on-site review, in which case a redacted photocopy will be provided if possible. (Most prohibitions on very old documents result from the intermingling of Restricted Data, which is controlled under the Atomic Energy Act, and thus, can only be released on the authority of the Department of Energy.) These cases have been noted as well. Moreover, while archival sources are typically excluded from bibliographies, a few narrative histories have been added due to their length, significance, or monographic perspective. Moreover, due to the requirements of the Air Force history program, even monograph-like studies are usually appended by one or more bound volumes of "supporting documents," the exhibits of which I cite as if they were unpublished papers contained in a manuscript collection.

CBI Charles Babbage Institute.

Archives and Special Collections, University of Minnesota, Twin Cities.

The papers referenced by this dissertation are all held under CBI 90, Records of the Burroughs Corporation, 1880-1998, series 98, Records of the System Development Corporation, 1946-1982, a collection of 23 boxes kept by Claude Baum and used in the writing of his 1981 corporate memoir, *The System Builders*.

CIS Congressional Information Service.

ProQuest Holdings, Ann Arbor, Michigan.

An indexing and distribution service for congressional publications that was eventually purchased by LexisNexis, and later, ProQuest, which now offers an online collection of scanned microfilm under the ProQuest Congressional brand. The new database still retains the old CIS identifiers, however, which are generally more useful, and certainly more intelligible, than the SuDoc call numbers issued by the Government Publishing Office. Of course, hearings, committee prints, and the United States Congressional Serial Set can be found in other forms and through other means as well, but CIS identifiers have been added for convenience.

DTIC Defense Technical Information Center.

Department of Defense, Fort Belvoir, Virginia.

DTIC operates a clearinghouse of technical documentation, now primarily digital, for defense agencies and their contractors. It has existed in some form since 1945 and its web portal is currently located at http://www.dtic.mil . Although users enjoy superior access privileges through a registration system, the public can still search and—if the item has been digitized—view documents that have been declassified and cleared for public release. The web interface changes frequently, but the document identification numbers remain stable and functional as retrieval keys: each is prefixed by "AD" (for "ASTIA document," a relic of DTIC's predecessor, the Armed Services

Technical Information Agency), followed by a seven-character string. In some cases, searches of DTIC's restricted-access database needed to be requested under FOIA, as well as documents that had never been declassified, approved for public release, or digitized for public viewing. While I have noted these instances, I have also observed some of the documents provided in response to my requests later added to the public interface.

EBSCO EBSCOhost.

EBSCO Information Services, Birmingham, Alabama.

All newspaper, magazine, and journal articles cited from EBSCO's database products include their accession number, with which they can be retrieved through the main interface. Like ProQuest, EBSCO products are generally available only through an institutional subscription, though the use of accession numbers is often for convenience, in cases where the document is obtainable elsewhere.

FOIA Freedom of Information Act.

Any document obtained through a Freedom of Information Act request will note in its citation the office that handled the case. In the future, the same office should be able to provide that document under a simple request for public information.

MSFRIC Muir S. Fairchild Research Information Center.

Air University, Maxwell Air Force Base, Montgomery, Alabama.

The Air University library is located in the same building as the Air Force Historical Research Agency. While its circulating collection has been entered into OCLC, it also hosts the Air University's "authority library," consisting of superseded Air Force regulations, manuals, and other organizational publications dating back to the Second World War. Binders and bound volumes of these materials used to be available on the open stacks but have since been moved to an area with access controlled by the reference staff. Specific citations to MSFRIC refer to the "authority" collection.

MIT Massachusetts Institute of Technology.

Institute Archives and Special Collections, Cambridge, Massachusetts.

Citations reference MIT's manuscript collections by number. The titles associated with each collection referenced are as follows.

AC004 Records of the Office of the President, 1930–1959.

MC365 Papers of Albert Gordon Hill.

MC665 Project Whirlwind Collection.

NARA National Archives and Research Administration.

Archives II, College Park, Maryland.

The world's dullest treatise could be written about the Kafkaesque qualities of the National Archives, College Park. The fact that *The Guide to Federal Records* is already this treatise, and that is virtually useless for its intended purpose, serves only to underscore the point.

At NARA, a manuscript collection's proper title is an unreliable method of retrieval, since the titles input into the Master Location Registry (MLR) are often abbreviated or truncated to the point of unintelligibility. Although other systems have been implemented over the decades, only the old "entry number" classification covers all the facility's holdings, and consequently, it is still the one used to lookup the stack locations needed for pull requests in the reference room.

Footnote citations follow the MLR pattern of listing the record group (RG) followed by an entry number prefixed by its "finding aid." (This is really a misnomer, since vanishingly few entries have actually been described in a conventional finding aid.) For reference, the titles corresponding to each manuscript collection are as follows, divided by record group and subdivided by the entry number with its finding-aid prefix.

RG 330 Records of the Office of the Secretary of Defense.

- **NM-12 341** Records of the Research and Development Board, Communications and Records Control Branch, Records Relating to Organizational Plans and Policies, the Allocation of Research and Development Responsibilities, to the Several Military Departments, and Recommendations of the Fiscal and Budgetary Impacts Aspects of Programs, 1946–1953.

RG 340 Records of the Office of the Secretary of the Air Force.

- **A1 1-B** Central Decimal Correspondence File, 1947–1954.
- **A1 1-D** General Decimal Correspondence File, 1955.
- **A1 1-F** General Correspondence File, Security Classified, 1956–1965.
- **A1 82-A** General Decimal Correspondence File, Security Classified, 1954.

RG 341 Records of Headquarters, United States Air Force (Air Staff).

- **NM-15 10** Records of the Office of the Chief Scientist; Decimal Correspondence File of the Special Assistant to the Chief of Staff Related to Organization of Research and Development Activities, 1951–1953.
- **NM-15 160** Records of the Office of the Deputy Chief of Staff, Development; General File, 1950–1952.
- **NM-15 335-A** Records of the Office of the Director of Plans, Office of the Deputy Chief of Staff, Operations; Central Decimal Correspondence File, Top Secret, 1942–1954.
- **NM-15 336** Records of the Office of the Director of Plans, Office of the Deputy Chief of Staff, Operations; Central Decimal Correspondence File, Secret, 1942–1954.
- **NM-15 339-A** Records of the Policy Division, Office of the Director of Plans, Office of the Deputy Chief of Staff, Operations; Correspondence and Publications Related to Policy, Administration, and Planning, 1947–1949.

OCLC Online Computer Library Center.

Online Computer Library Center, Dublin, Ohio.

Currently, OCLC's primary public interface is WorldCat: https://www.worldcat.org . Since the consortium aggregates metadata provided by participating members, the same work may have multiple entries corresponding to different formats, printings, or slight variations in classification or data input. Some of these entries may be linked together, but many are not. So, when including OCLC identifiers in citations, I have generally chosen the entry corresponding to the specific copy of the work examined; in other cases, however, it made sense to reference a "consensus" entry, with more access possibilities, than an isolated one. These possibilities may include one or more digital collections, which are especially useful sources of government publications, as they belong to the public domain.

PRO ProQuest.

ProQuest Holdings, Ann Arbor, Michigan.

As with EBSCOhost, objects retrieved from any ProQuest database product (with the exception of former CIS material) are cited by their accession number.

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