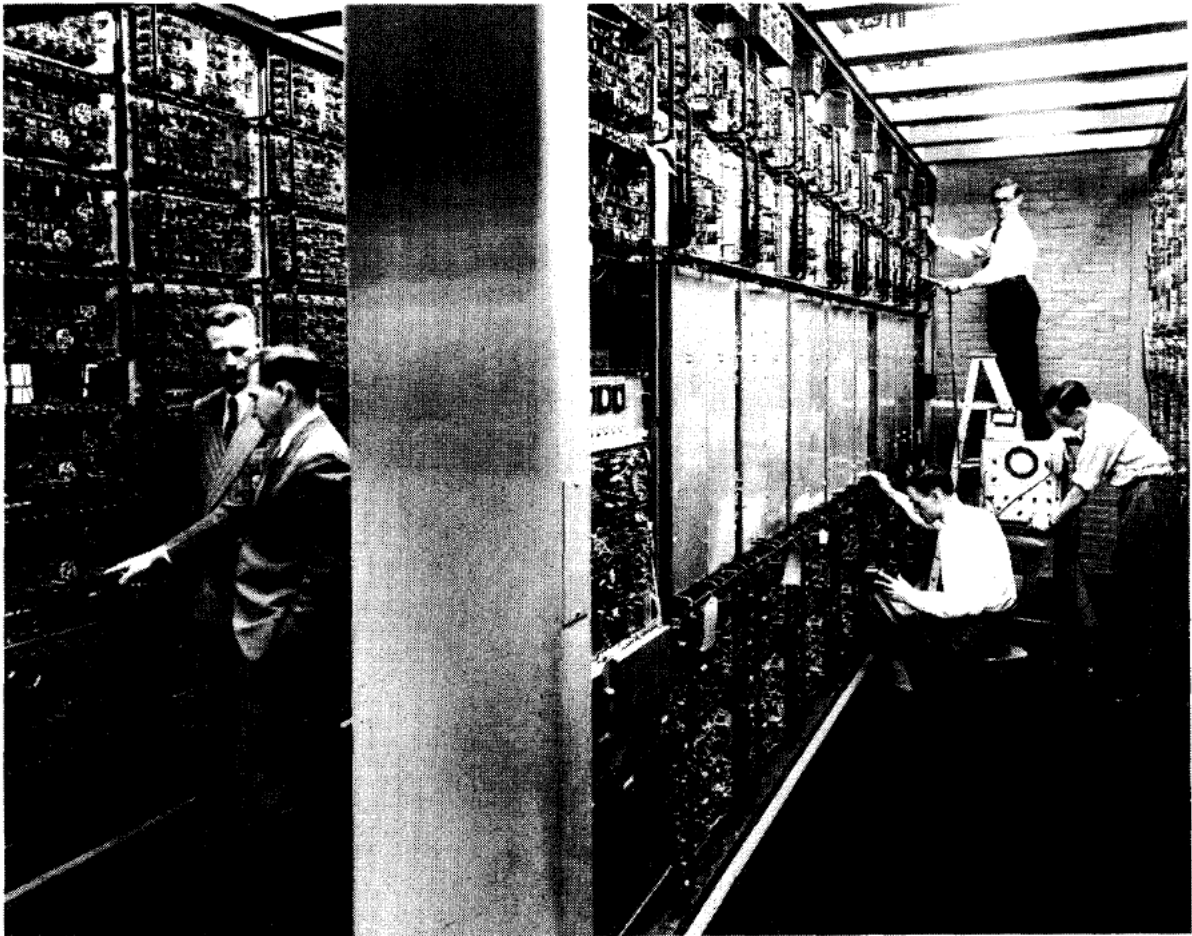


THE AIR FORCE GOES DIGITAL:
HOW MIT CONVINCED COMMANDERS TO COMPUTERIZE CONTINENTAL DEFENSE
1949-1953

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Senior Thesis 2015



The Whirlwind Computer. Jay Forrester is on the far left. Courtesy MITRE Archives.

“If anyone thinks that the SAGE was accepted because of its excellence alone, that person is a potential customer for the Brooklyn Bridge.”

~ George Valley

INTRODUCTION

When it was conceived in 1951, the Semi-Automatic Ground Environment (or, as it was almost exclusively known, SAGE) was the largest and most expensive computer system in the world. Its final design consisted of 24 direction centers spread across the country, each hosting two immense computers programmed with close to half a million lines of code. The SAGE was a continental air defense system which combined signals from hundreds of radars across the country, constantly monitoring flight traffic to allow the Air Force to identify and intercept any enemy bombers before they could devastate American cities. It was the first attempt to create a system where sensors report information about their external environment to a computer which uses the information to keep track of that environment. Today, we call such systems “the Internet of Things” and consider them to be the future of computing. Hugely ambitious, the SAGE system cost an estimated 10 billion dollars (in 1960’s currency) and took over ten years to become fully operational. It was more expensive and had more personnel working on it than the Manhattan Project.¹ And it never worked.

It would have been trivial for enemy bombers to jam the SAGE’s radars and render it useless. It was made obsolete by the time it was completed by the invention of the much faster inter-continental ballistic missiles. It did, however, precipitate revolutions in the fields of computer hardware and software engineering as well as the computer manufacturing industry. The research and development of the SAGE by scientists at MIT and the construction of its computers by IBM created digital computers as we know them today – complex, reliable and ubiquitous.

Before the SAGE, digital computers stored their information in accident-prone and costly vacuum tubes. Data could not be processed in real-time; programs had to be run in batches. Graphical interfaces did not exist, and there was no such thing as an operating

¹ “The SAGE Air Defense System.” Lincoln Laboratory, Massachusetts Institute of Technology. <https://www.ll.mit.edu/about/History/SAGEairdefensesystem.html> (accessed April 8, 2015).

system.² Most of the features we associate with modern digital computers were invented by engineers working on the computers which were central to the SAGE system. Development of the SAGE facilitated IBM's prosperous future in the digital computer business— in the 1950s more than half of IBM's income was from military sources. In the mid-1950's, one in eight people in the world who knew how to program were working on the SAGE.³ SAGE's demand for skilled programmers required MIT and its partners to train hundreds of people, jump-starting the software development industry in America.⁴ In 1958, when its programming was complete, the SAGE was the most complex piece of software in existence.⁵ The funding that the scientists at MIT fought to secure from the Air Force for their – incredibly expensive – digitally computerized air defense system may not have been used to effectively prevent Soviet air attacks, but it did enable breakthroughs in American technology and industry.

The digital computers of the SAGE were not the Air Force's only option for continental air defence. To many in the Air Force, the SAGE wasn't even the best option. Many leaders within the Air Force would have just as soon not wasted any money at all on a continental defense system. Most Air Force generals were former pilots who strongly believed in the efficacy of offensive air strikes as the best way to wage war. The threat of a nuclear-equipped air strike meant that the top leadership Air Force was under pressure from the President and the public to provide a defense, but it was not easy for the scientists at MIT to convince generals that their expensive, unreliable and untested digital computer was the right choice. Large parts of the Air Force would have preferred to fund the SAGE's competitor, a system from the University of Michigan known as ADIS, which was an analog update of the Air Force's existing radar defenses. Although far less technically advanced, ADIS was built with the needs and traditions of the Air Force in mind. SAGE, on the other hand, was a digital, automated, computerized creature which many in the Air Force did not trust.

² "A Perspective on SAGE: Discussion." *IEEE Annals of the History of Computing* 5 no. 4 (October 1983): 390.

³ Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*. (Cambridge: The MIT Press, 1996), 102.

⁴ "A Perspective on SAGE", 386.

⁵ Edwards, *The Closed World*, 102.

The difficulties that MIT faced in convincing the Air Force to adopt the SAGE turned largely on cultural differences. Military leaders seek to command and control their forces and to defeat their enemies. Scientists seek knowledge and to answer questions through experimentation and research. During the Cold War, when nations did not compete directly on the field of battle but in arms races where their scientists strove to out-innovate each other, Air Force generals and MIT scientists had to work together towards a common goal. The difficulties of this alliance and the shifts in power between the two groups are clearly illustrated in the story of the development of the SAGE. When the generals were deciding which air defense system to fund, they weren't evaluating which system was the product of greater strides in the field of computing. Technical considerations were far less important than how the system would fit with the general's preferred ways of commanding. To convince Air Force leadership to fund the development of the SAGE (and, consequently, modern digital computers,) the administration and engineers and scientists at MIT used salesmanship, bullying and inside connections. The battle for the Air Force to accept the SAGE over ADIS became a struggle about the Air Force's future place in an age of automation and the evolving relationships between scientific institutions and the military. The simple decision between two competing technologies held great significance for the future of MIT, the Air Force, and the field of digital computing.

A PREFATORY NOTE ON HISTORIES OF THE SAGE

The early history of the SAGE has been written by a number of historians interested in different aspects of its development. Kent Redmond and Thomas Smith's *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer* was published in 2000 as an expansion on work they had done for a previous book, *Project Whirlwind: The History of a Pioneer Computer*, published in 1980. Their work is the most detailed, memo-by-memo account of how each step in the SAGE's development, deployment and operation was carried out. Almost every account of the SAGE's origins relies on their work. The histories of SAGE which rely the least on *From Whirlwind to MITRE* are mainly interested either in tracking the purely technical details of the breakthroughs which it achieved or the role of the SAGE as a part of the wider operations of

the Air Force after WWII. James R. Shepley and Clay Blair Jr.'s *The Hydrogen Bomb* (1955), Samuel P. Huntington's *The Common Defense* (1961) and B. Bruce-Briggs' *The Shield of Faith* (1988) are examples of the latter category. These works outline the Air Force's efforts to create various kinds of defense systems and grapple with a new kind of air warfare after the invention of nuclear weapons. These works touch briefly on the SAGE but were more valuable to this paper for their colorful details about the Air Force's opinions of its scientist partners which were important for understanding the difficulties the two groups faced in working together.

More recently, historians have written about the SAGE in the context of broader accounts of the difficulties of managing of large scientific projects. Thomas P. Hughes' *Rescuing Prometheus* (1998) uses the story of the development of the SAGE as one example of the difficulties of managing huge systems developments projects. Stephen B. Johnson's *The United States Air Force and the Culture of Innovation* (2002) tracks the Air Force's efforts to utilize research and development through partnerships with scientific institutions and the creation of R&D focussed commands. Rebecca Slayton focusses on the management of the SAGE from MIT's point of view in her article "From A 'Dead Albatross' to Lincoln Labs: Applied Research and the Making of a Normal Cold War University" (2012). She writes in detail about the controversy in the MIT administration over the founding of the Lincoln Labs, which hosted the development of the system which became the SAGE, and connects that controversy to the crisis that MIT faced with regard to its special laboratories in the 1960's.

This essay intends to expand on previous work by focussing on the details of how MIT's proposed system won out over its chief competitor from the University of Michigan, the Willow Run Research Center's ADIS, and what that struggle reveals about the relationship between MIT and the Air Force. The two accounts which focus the most on this part of the SAGE's story are histories published by the MIT press: Paul Edwards' *The Closed World: Computers and the Politics of Discourse in Cold War America*. (1997) and Akera Atsushi's *Calculating a Natural World: Scientists, Engineers and Computers During the Rise of US Cold War Research* (2006). Edwards argues that the computerization of air defence forced the Air Force to change its conception of command and control. He places the SAGE within the context of other Cold War projects which illustrate a "closed world" world view; projects that attempted to quantify and

label every aspect of the world according to their Cold War alliance. Atsushi traces the connection between the development of computer hardware and the computer business and Cold War military research. He analyzes how the SAGE illustrates the academic, business, and military interests which influenced computer development. This essay elaborates on points which those works allude to about how MIT's institutional connections helped the SAGE and Lincoln Labs win the day. It connects also connects the details of the interactions between the Air Force and the scientists at Lincoln Labs contained in these works to the evidence which other works provide about the contemptuous attitudes Air Force members and academic scientists held toward each other.

This essay also contains a more in-depth discussion of the real advantages (from the point of view of the Air Force) of the system proposed by the Willow Run Research Center. Most accounts of the work done on air defence at Willow Run in histories of the SAGE rely heavily on interviews and accounts by MIT scientists. These tend to characterize the scientists at Willow Run as at best short-sighted and at worst incompetent, and describe their system as absolutely inferior. Research into the background of the Willow Run Research Center and its director, as well as accounts of that director's view of his own research, reveals different reasons for why the engineers and scientists at Willow Run chose to design their system differently. Despite the SAGE's technical advancements over its competitor, many of the Air Force rank-and-file preferred the Willow Run Research Center's systems. The director of Willow Run had a technical background and design philosophy which was far more familiar and agreeable to them. The SAGE's victory did not come from its technical brilliance. MIT's Lincoln Laboratory had connections and resources which the University of Michigan's Willow Run Research Center had no hope of matching.

"THE ENDLESS FRONTIER": MILITARY RESEARCH AFTER WWII

The importance of scientific research to military success became apparent to the American government at the start of WWII. In 1940, MIT was chosen by the newly-created National Defense Research Committee to host the Radiation Laboratory, a crucially important

facility which would research the use of microwaves and radar for tracking enemy forces.⁶ The “Rad Lab,” as it was known, significantly raised MIT’s profile as a premier research institution. During WWII, twenty percent of the nation’s physicists were employed at the Rad Lab, among them Columbia University’s Isidor Isaac Rabi.⁷ Prestigious faculty flocked to the lab because the urgency of wartime allowed them to operate with a minimum of red tape. George Valley, one of the researchers at the Rad Lab during the war, recalled that “in 1940 it had been decided that the amount of property that might be stolen would never pay for the cost of one ship lost because we were a day late, and in consequence we could walk into any Radiation Laboratory stockroom and take whatever we needed.”⁸ The Rad Lab was soon joined at MIT by the Servomechanisms Laboratory, the Confidential Instruments Development Laboratory and a host of others similarly based on partnerships between the government and the university.⁹

The resulting flurry of technological innovations not only helped the Allies prevail, but transformed MIT from a notable academic institution to the nation’s single largest wartime research and development contractor. By the end of the war, MIT had signed \$100 million worth of contracts.¹⁰ After the war ended, MIT continued to conduct research and development for the military. In 1944, MIT president Karl Compton, wrote in his annual report that “The temper of the times justifies the expectation that this type of contribution by M. I. T. to the national welfare will continue to be substantial.”¹¹ When James Killian succeeded him as MIT’s president in April 1949, his inaugural address reflected on “the obligations and ideals of an institute of technology.” His speech emphasized that universities should maintain independence from the government, but also that MIT “must continue to educate the imaginative and audacious minds that created the O.S.R.D. [Office of Scientific Research and Development] and mustered the democratic ranks of American scientists into invincible battalions, such as our own Radiation Laboratory here in Cambridge. We must be able again to

⁶ David Kaiser, *Becoming MIT: Moments of Decision*. (Cambridge: The MIT Press, 2010), 86.

⁷ *Ibid.*, 95.

⁸ 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 (2012): 265.

⁹ Kaiser, *Becoming MIT*, 90-91.

¹⁰ *Ibid.*, 95.

¹¹ Atsushi Akera, *Calculating a Natural World: Scientists, Engineers and Computers During the Rise of US Cold War Research*, (Cambridge: The MIT Press, 2006), 189-190.

beat an enemy to the draw, as we did in developing the atomic bomb.”¹² Military research was accepted as part of the normal activities (and indeed, moral responsibilities) of an academic scientific institution.

The closeness between universities and the military is illustrated by the recommendations of Vannevar Bush, the director of the emergency wartime department tasked with coordinating scientific research for military uses. As the war wound down, Roosevelt asked Bush to make recommendations on how the government could continue to support the spectacular rate of scientific innovation in America spurred by the war. Bush, a former Dean of Engineering at MIT, recommended in his report “Science: The Endless Frontier,” that the military should rely on the innovations of academic scientists. He wrote that “it is essential that the civilian scientists continue in peacetime some portion of those contributions to national security which they have made so effectively during the war.” Bush recommended that scientific innovation should come from universities rather than industry or the military. To achieve this, he called for research institutions at universities to be strengthened. Bush valued the academic environment as “most conducive to the creation of new scientific knowledge and least under pressure for immediate, tangible results.” He also recommended that a permanent replacement to his emergency wartime Office of Scientific Research and Development be established as a civilian headquarters for long-term military research.¹³ From the success of special laboratories like MIT’s Radiation and Instrumentation Laboratories, as well as the revolutionary achievements of the Manhattan Project, came renewed collaboration between universities and branches of the military. The recommendation of “Science: The Endless Frontier” that civilian scientists should continue to work with the military was put into action as the threat of the Cold War emerged.

The Air Force’s relationship with civilian scientists was particularly strong. When the Air Force was made an independent service from the Army in 1949, it lost access to the Corps of

¹² James Killian, “The Obligations and Ideals of an Institute of Technology,” *Technology Review* 51 (May 1949) accessed March 24, 2015, <https://libraries.mit.edu/archives/exhibits/inaugurations/killian.html>

¹³ Vannevar Bush, "Science The Endless Frontier," National Science Foundation, July 25, 1945, accessed January 8, 2015, <http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm>.

Engineers, Signal Corps, and Ordnance Corps, which housed most of the military's technical expertise.¹⁴ In anticipation of its independence, the Air Force created its own scientific department, known as the Scientific Advisory Board, during WWII. Its task was to "indicate the potential scientific lines of advancement that the Air Force might take to accomplish a predominantly offensive mission."¹⁵ Like the overarching Office of Scientific Research and Development, the Scientific Advisory Board was kept on after the end of WWII. The creation of a new Air Force command, the Air Research and Development Command (ARDC), in January 1950 further proved the Air Force's commitment to incorporating civilian scientists into the Air Force hierarchy.¹⁶ Air Force Chief of Staff Hoyt Vandenberg also took the step of appointing Radiation Lab veteran Louis Ridenour as the Air Force's first Chief Scientist. Technical advancements like radar, jet engines, and the swept-back wing were revolutionizing air power, and the Vandenberg wanted the U.S. Air Force to be ahead of the curve. As Ridenour explained to a friend: "I'm going to be the Van Bush of World War Two point seven."¹⁷

The development of the SAGE began with one of the members of the Air Force's Scientific Advisory Board: MIT Electrical Engineering professor George Valley, who served on its Electronics Panel. Valley was a blunt, no-nonsense physicist from New York who had developed bombsights at the Rad Lab during WWII, work which had necessitated trips to and from London during the Blitz. At the end of the war, he had joined the MIT faculty, specializing in cosmic ray research. In November 1949, Valley was alerted by a colleague to what he considered a serious danger: America's air defense radar stations were in a state of total disarray.¹⁸ Valley promised to investigate.

¹⁴ B. Bruce-Briggs, *The Shield of Faith: A Chronicle of Strategic Defense from Zeppelins to Star Wars*, (New York: Simon and Schuster, 1988), 48.

¹⁵ Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1907-1960*, (Maxwell Air Force Base, Ala.: Air University Press, 1971), 205.

¹⁶ Stephen B Johnson, *The United States Air Force and the Culture of Innovation, 1945-1965*, (Washington D.C.: Air Force History and Museums Program, 2002), 54.

¹⁷ James R. Shepley and Clay Blair, Jr. *The Hydrogen Bomb: The Men, The Menace, The Mechanism*. (New York: David McKay Company, Inc., 1954), 172.

¹⁸ Valley, Jr. George E. "How the SAGE Development Began." *IEEE Annals of the History of Computing* 7, no.3 (July 1985): 197-198.

“THERE IS NO DEFENSE”: AIR DEFENSE AFTER WWII

The invention of the atomic bomb four years earlier had changed the principles of how air defense should be conducted. In 1946, Louis Ridenour, an engineer at the Radiation Lab, wrote an essay titled “There Is No Defense”, about the prospect of other countries having the Bomb. Traditional air defence, in which a force used anti-aircraft guns or armed bombers, typically aimed to take down about 10 per cent of attacking planes. If enemy planes were armed with atomic or hydrogen bombs, Ridenour wrote, the traditional methods of air defence would be useless. Even if the U.S. Air Force could out-fight and destroy 90 per cent of an attacking force, the power of the weapons which escaped could wipe out entire cities. The new technology called for a new form of defense.

Until August 1949, the matter had little practical urgency. American military intelligence estimated that the Soviet Union would not have nuclear weapons for another four years.¹⁹ German scientists had been at the forefront of nuclear science since they discovered and explained nuclear fission, and they had been unable to develop a nuclear bomb. Few expected the Soviets, who were thought of as scientifically inferior to the Germans, to be capable of creating one before the mid-1950s.²⁰ Soviet air power was also dismissed. They had no long-range fleet, no long-range aviation successes in WWII, and “all the German reports said that Russians were lousy pilots.”²¹ Although concern over America's air defenses had risen following the attacks on Pearl Harbor in 1941, the end of WWII meant that concerns about air strikes returned to the theoretical realm. A recommendation in early 1948 by Subpanel on Early Warning of the Research and Development Board (RDB), a group of civilian engineers which advised the Secretary of Defense, for “immediate action to establish in a limited coastal area a project for engineering and operational test and evaluation of the combined elements of a system” was not acted on.²² The RDB established an Ad Hoc Panel on Air Defense in March 1949, but it never garnered enough political power or funding to serve more than an

¹⁹ Edwards, *The Closed World*, 88.

²⁰ Valley, “How the SAGE Development Began,” 197.

²¹ Bruce-Briggs, *The Shield of Faith*, 49.

²² Kent C. Redmond, and Smith, Thomas M., *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer*, (Cambridge, Mass.: MIT Press, 2000), 13.

educational function.²³ Although interest in air defense existed, little progress was made towards researching a new system.

The Soviet atomic bomb test in August 1949 changed all that. The American public began to demand protection. Civilians living in major cities or near key defense facilities like the Boeing factory or Hanford nuclear plant in Washington state were worried that they would be targeted in air attacks. For American citizens in 1949, the attacks on Pearl Harbour had been vivid examples of the kind of vicious surprise attack to which they were vulnerable. The Air Force, in its efforts to win support and recruit volunteers, emphasized the danger of an air attack. A radio advertisement which sought to recruit volunteers to a Ground Observation Corps exaggerated the threat:

Who will strike the first blow in the next war, if and when it comes? America? Not very likely. No, the enemy will strike first. And they can do it too – right now the Kremlin has about a thousand planes within striking distance of your home.

The Ground Observation Corps itself demonstrated the widespread fear of Soviet air attack. Because the radar fences which were the Air Force's best defense system at the time could easily miss low-flying planes, the Air Force recruited a large group of civilian volunteers to staff visual observation posts. By 1953, the Ground Observer Corps were running over 8,000 full-time observation posts staffed by 305,000 volunteers.²⁴ Volunteers were expected to watch the sky and call a local air base if they thought they were witnessing a Soviet attack. By playing up the threat of an enemy air strike, the Air Force had put itself in the position of being expected to provide some kind of defense for Americans, even if that defense was mostly symbolic, as most certainly was the case for its Ground Observer Corps.

The American government and senior Air Force staff realized the urgent need for improved strategic defense systems. A report from the National Security Council in the spring of 1950 recommended spending 20 per cent of America's gross national product on building up national defense. President Truman doubled the Air Force's size, from 48 to 95 air groups.²⁵

²³ Ibid., 16-17.

²⁴ Edwards, *The Closed World*, 89-90.

²⁵ Ibid., 88-89.

Air Force leadership also took note. Chief of Staff Hoyt Vandenberg wrote a memorandum to the other members of the Joint Chiefs of Staff citing the “desperate need” for a reliable continental air defense system. General Muir S. Fairchild, Vandenberg’s Chief of Staff, passed the memo on to the Scientific Advisory Board on which Valley served in November. Valley had, coincidentally, sent a letter to the Scientific Advisory Board’s chair Theodore von Karman also in early November, noting the air defense deficiencies which he had been alerted to and suggesting that the SAB should look into them²⁶. A few weeks later, the SAB set up the Air Defense System Engineering Committee (ADSEC) at the request of vice-chief of staff General Fairchild. George Valley chaired the committee, and the group came to be known as the Valley Committee.²⁷ The Valley Committee was tasked with developing “equipment and techniques – on an air defense system basis – so as to produce maximum effective air defense for a minimum dollar investment.”²⁸

Air Force leadership also coveted an air defense system because they were facing stiff competition from the Army in that area. The services competed fiercely during this era. In the early days of the Cold War, each service had the same goal: to prove its usefulness in a general WWII-style war against Russia.²⁹ The Air Force had only gained independence from and equality to the Army in 1949, so it was at a disadvantage in any type of competition. By 1950, the best existing air defense system in America was Project NIKE, an anti-aircraft system developed and operated by the Army. In the summer of 1944, Army ordnance officer Jake Schaefer had worked out a plan for a surface-to-air missile that could intercept a jet-propelled aircraft. Previously, anti-aircraft guns had been effective enough against propeller-driven planes, but jet-propelled aircraft could outdistance them easily.³⁰ His system consisted of a radar to track a target, a radar to track a missile, and a computer to calculate the interception point and guide the missile by radio. Thus an area could be defended from air attack relatively cheaply, using relatively little equipment.

²⁶ Redmond and Smith, *From Whirlwind to MITRE*, 19.

²⁷ Valley, “How the SAGE Development Began,” 200.

²⁸ Valley, “How the SAGE Development Began,” 199.

²⁹ Samuel P. Huntington, *The Common Defense: Strategic Programs in National Politics*, (New York: Columbia University Press, 1961), 378.

³⁰ Bruce-Briggs, *The Shield of Faith*, 46.

The Army's Ordnance Corps argued that the system, named Project NIKE, was an extension of the antiaircraft gun, and therefore they should be responsible for developing and operating it. The Air Force, which at that point in 1944 was still a sub-division of the Army, argued that they should be responsible for it, as it was an air defense system. The War Department eventually concluded that anything with a wing, even if it was guided rather than flown by a pilot, would be classified as an aircraft and was therefore the purview of the Air Force. A rocket with only a fin was deemed to be closer to a new type of cannon shell, making it a type of artillery and the rightful responsibility of the Ordnance Corps to develop.³¹ When the Air Force was made into a separate service, the Joint Chiefs of Staff decided that the Air Force would be in charge of continental air defense and "area" defense weapons, while the Army was responsible for "point defense."³² NIKE was close to operational by 1952. In early 1950, the Air Force needed a plan for a continental air defense system which could outperform Project NIKE or face losing funding to the Army.

GEORGE VALLEY GOES TO WORK

The Air Defense System Engineering Committee that the Air Force's Scientific Advisory Board formed to investigate the problem of air defence was composed of seven academic scientists who met every Friday at the nearby Air Force Cambridge Research Laboratories. The group bandied about several ideas on how air defense could be revolutionized: Dr. Louis Ridenour, chief scientist to the USAF Chief of Staff, suggested installing a system of microphones throughout the country; Dr. Allen Donovan, vice-president of Cornell Aeronautical Laboratory, looked into whether pilots should be directed to ram the tails of their aircraft through an enemy plane's wings. According to Valley, he eventually hit upon the idea of connecting a computer to the Air Force's existing radar outputs so that it could calculate the position of planes in American airspace.³³ The use of a digital computer would allow their system to complete the complex calculations required to identify a low-flying plane in real time. The Valley Committee went to work on the details, figuring out what the kinds of calculations

³¹ Ibid., 47.

³² Bruce-Briggs, *The Shield of Faith*, 48.

³³ Ibid., 205-206.

were that needed to be made, and seeking approval from the Air Force. To carry the radar signals to the central computer, Valley made a partnership with Bell Telephone Laboratories, and received permission from Bell Laboratories vice-president Donald A. Quarles in the fall of 1950 to rent telephone lines for the use of the Air Force. Valley also got the green light to partner with Bell Telephone Laboratories from Air Defense Commander Lieutenant General Ennis Whitehead. Valley on Whitehead: “He wore gold-rimmed glasses and the standard ‘command personality’ – an air of regal dominance that can be assumed by commanding generals when on active duty.”³⁴ The Valley Committee’s work was in full swing in the fall of 1950.

What Valley did not have to hand was a computer that could make the necessary calculations in real time. Fortuitously, the exact machine he needed was being developed on MIT’s campus: the Whirlwind computer. The Whirlwind had started as an analog flight simulator housed in the Servomechanisms Laboratory and funded by the Office of Naval Research (ONR). Traditional flight simulators could provide the experience of flying only one particular plane. The Navy hoped that they could develop a more efficient machine which would be capable of simulating many different models. The project was led by Jay Forrester, a graduate student who had been the assistant director of the Servomechanisms Lab during the war.³⁵ By mid-1946, Forrester had decided to build a digital computer which would be capable of running a general flight simulator as one of its applications.

TECHNICAL EXCURSIS:

To understand why Forrester made this choice, it is necessary to know a little bit about the difference between analog and digital computers. Whereas digital computers actually represent numbers, usually encoded in binary, and operate on them directly, an analog computer is a machine which uses *physical quantities* such as voltages or lengths to represent numbers. Analog computers are usually built for a specific purpose, using physical quantities and operations which are *analogous* to the problem which the user wants to solve. For

³⁴ Ibid, 201-202.

³⁵ Kaiser, *Moments of Decision*, 92.

instance, a slide rule is a simple analog computer. The user moves the slide a certain length which represents the numbers to be multiplied, and interprets those numbers and the result using the scale. A mechanical watch is also an analog computer. The watchmaker builds gears which are the right size and move together in the right way relative to each other to represent minutes and hours. The physical movement of the hands around the watch face is interpreted by the person using the watch to tell time. By the late 19th century, physicists could build machines which were analogous to any mathematical equation, just as the movements of a watch's gears is analogous to the "equation" we use to measure time (60 minutes in an hour, 12 hours in half a day). For any equation describing the trajectory of bombs or planes, a physicist could construct a complex analog computer which would allow a user to make the calculations far faster than they could by hand.³⁶

Where analog computers failed to meet Forrester's needs for the Whirlwind was their speed and accuracy. The cutting edge electro-mechanic analog computers of the day used relays as the fundamental components of their circuits. Relays are small physical electromagnetic switches. The time these relays took to physically move from open to close was about 1 to 10 milliseconds. The vacuum tubes which early digital computers used as the building blocks of their circuits were much faster. A vacuum tube works by transmitting or not transmitting an electrical current. The movement is all of microscopic electrons, which have far less inertia and move much faster than the switch of a relay. For this reason, electronic digital computers could perform calculations in real time, while electro-mechanical analog computers could not.³⁷ Analog computers were also less accurate, as the measuring of the physical components involved introduced small sources of error which grew with the complexity of the machines and number of measurements necessary.³⁸ With digital computers, precise measuring is not a concern because numbers are entered and represented as integers. Finally, analog computers require frequent tune-ups because the physical components involved need to be perfectly aligned. Digital computers can break, of course, but they do not have the same maintenance requirements. Forrester later credited Perry Crawford, who worked for the

³⁶ Goldstine, *The Computer from Pascal to Von Neumann*, 39-40.

³⁷ *Ibid.*, 144.

³⁸ Edwards, *The Closed World*, 77.

Special Devices Center of the U.S. Navy at the time, with suggesting to him that using digital technologies to build the Whirlwind would allow it to achieve speed and accuracy which analog computers could not offer.³⁹

The Whirlwind's budget grew to astronomical proportions through the end of WWII, even as the ONR's overall budget declined. In fiscal 1949, MIT asked the ONR for \$1.5 million to support Whirlwind, which was almost 80 per cent of the ONR's entire budget for mathematics research.⁴⁰ In December 1949, an Ad Hoc Panel issued a report to the Research and Development Board of the Office of the Secretary of Defense criticizing Project Whirlwind for incurring unreasonable military R&D costs without an explicit military mission.⁴¹ By March 1950, the ONR had reduced Forrester's budget for the following fiscal year to \$250 thousand, far less than the amount he had suggested to them.⁴²

Forrester had already begun seeking military justifications for his work. In September of 1948, a report from Forrester and his project engineers to MIT's President mentioned in its cover letter that Project Whirlwind had been seeking practical applications for their work through "visits and exchange of information with commercial and military laboratories."⁴³ Forrester wanted to keep his machine alive, and MIT administrators were also eager to preserve a digital computer which they thought could be used for calculations by other engineering and science departments. MIT Provost Julius Stratton hoped that MIT could establish an interdepartmental laboratory where Whirlwind could "be dominated by the users rather than the operators."⁴⁴ In March 1950, Stratton met with representatives from the ONR to discuss bringing the Whirlwind under more centralized control at MIT.

Although the timing of Valley's urgent need for a digital computer just as the Whirlwind's budget was being decreased seems almost too fortuitous to be a coincidence, there is no evidence that Valley was aware of the funding crisis in MIT's Servomechanism's Lab.

³⁹ "A Perspective on SAGE," 376.

⁴⁰ Edwards, *The Closed World*, 79.

⁴¹ Redmond and Smith, *From Whirlwind to MITRE*, 45.

⁴² Edwards, *The Closed World*, 91.

⁴³ Redmond and Smith, *From Whirlwind to MITRE*, 59.

⁴⁴ Slayton, "From a 'Dead Albatross' to Lincoln Labs," 264.

Nonetheless, Valley's connections at MIT certainly helped the money-hungry Whirlwind find the well-funded Air Force project which could save it. Forrester knew about ADSEC's mission and was aware that it was being led by an MIT faculty member. After Valley complained to his colleague Jerry Wiesner, an electrical engineer and administrator of MIT's Research Laboratory for Electronics, about the difficulty of finding a machine which could quickly gather and compute information, Wiesner suggested to him that Forrester's work at the Servomechanisms Laboratory might be the solution to his problems. Wiesner brought Valley and Forrester together for lunch at MIT's Faculty Club in late January of 1950. The two then coordinated a tour of the Whirlwind machine, which led to their agreement that Valley would get the Air Force to fund the Whirlwind as a tool for an air defense system.⁴⁵ Valley wrote that he was "surprised by the warmth of my reception at Whirlwind."⁴⁶

Valley had heard ominous things about the Whirlwind from colleagues – it was too expensive, poorly designed, not useful and other complaints "that seemed mostly based on emotion and bruised toes"⁴⁷ For ADSEC, however, its expense was less than or comparable to "some of the astronomical prices... had from industry."⁴⁸ And after investigating for himself, Valley was satisfied that the Whirlwind was technically adequate and that the people working on it were intelligent and ready to learn. The Office of Naval Research and MIT agreed to allow the Air Force to partly fund the Whirlwind for use in an experimental air defence system for one year only. Stratton was initially not pleased by the distraction for the team of Project Whirlwind, as he had hoped it could be put to work on academic problems and used by other departments for research. Valley wrote that soon after the decision to rent the Whirlwind for a year for the study of air defence, "I found myself snubbed in the halls of MIT by a personage very high in its administration."⁴⁹ However, the Valley Committee's need for a real-time computer very likely saved the Whirlwind from being shut down due to lack of funding. And after Valley had obtained an offer from the Air Force to fund Whirlwind on an ongoing basis

⁴⁵ Redmond and Smith, *From Whirlwind to MITRE*, 29-32.

⁴⁶ Valley, "How the SAGE Development Began," 208.

⁴⁷ *Ibid.*, 208.

⁴⁸ *Ibid.*, 208.

⁴⁹ *Ibid.*, 210.

through the establishment of a new air defense laboratory, he recalled that “I noticed that I was out of the MIT administration’s doghouse.”⁵⁰

On April 6 1950, Valley submitted a progress report on ADSEC’s proposed system to the Air Force. By September, the Whirlwind researchers could demonstrate that it was possible to receive radar data, manipulate it, and display it on a cathode-ray tube with their computer. Valley imagined that the end of ADSEC’s work was near. He assumed that once they could show the Air Force proof that their system would work, they could make their recommendations, and disband. Valley thought that ADSEC’s purpose was “to tell the Air Force what to do, not to actually do it for them.”⁵¹ He was looking forward to getting back to physics-as-usual.

Unfortunately for Valley, when the Korean War started in July 1950, influential former colleagues of Valley’s from the Radiation Lab took jobs at Air Force Headquarters as it expanded to counter the threat. Former Radiation Lab assistant director Louis Ridenour and MIT professor Ivan Getting were Valley’s friends, and it was impossible for him to refuse to demonstrate what the ADSEC committee was working on with Whirlwind. They were duly impressed. On November 20 1950, Ridenour sent a memorandum to deputy chief of staff for development General Saville, recommending that ADSEC’s work be continued through a research contract negotiated with a “suitable institution in the Cambridge area.”⁵² Ridenour added that “a very tentative exploration of the matter with MIT has indicated that they would consider taking such a contract as that proposed.” Ridenour made his next move when Valley was at the Pentagon for a meeting. Valley recalled that Ridenour “coaxed” him into drafting a letter to MIT President James Killian proposing that MIT host a new air defence laboratory, which Ridenour in short order had typed, signed by Air Force Chief of Staff General Hoyt S. Vandenberg, and sent on to Killian.⁵³

Leaders at MIT were, however, of mixed opinion about hosting a new Special Laboratory. On the one hand, the Rad Lab and other wartime special labs had been hugely successful at attracting prestigious faculty and winning enormous sums of money for the

⁵⁰ Ibid., 213.

⁵¹ Ibid., 213.

⁵² Ibid., 213.

⁵³ Ibid., 212.

university through defense contracts. On the other, their size forced the university to hire researchers who did not contribute to teaching. And despite Bush's hope that research conducted in universities would have a longer-term focus than that of profit-driven companies, MIT's administrators had found that special laboratories put the university in the uncomfortable position of competing with corporations in the defense industry. Stratton was wary that a military service could not be trusted "to maintain policies that are essential for successful operation of university projects."⁵⁴ In these ways, the endeavor was at odds with MIT's educational mission.

In a meeting with Air Force representatives in January 1951, Killian and Stratton insisted that MIT would only agree to host an air defense laboratory if they could first conduct a broader study. Valley was a relatively junior member of the Electrical Engineering faculty, and Stratton was wary that although his air defense study "shows a high level of technical competence in relatively narrow fields ... [air defence] involves economic and sociological factors quite as important as the purely technological ones and that no analysis to date has taken these properly into account."⁵⁵ Valley's colleagues agreed. Hill recalled, "What stuck in my craw was that... here was a major project to be based on a very small study that hadn't been reviewed by anybody except the people who wanted it."⁵⁶ Stratton was further concerned that top-notch physicists would not be attracted by a mere air defense laboratory. He urged Killian to make the focus of the laboratory information processing, and appoint a "strong-minded, imaginative steering committee."⁵⁷ MIT decided to establish Project Charles, a committee headed by Dr. F. W. Loomis, (and named after the nearby Charles River), to investigate solutions to the air defence problem.

The greatest effect of Project Charles was that the doubts of his colleagues motivated George Valley to prove that his air defense proposal was viable. Although he had previously longed to get back to studying cosmic rays, he was now committed to developing a computerized air defense system. The committee ended up backing Valley's recommendations,

⁵⁴ Slayton, "From a 'Dead Albatross' to Lincoln Labs," 267.

⁵⁵ *Ibid.*, 269.

⁵⁶ *Ibid.*, 269.

⁵⁷ *Ibid.*, 269.

and endorsing the establishment of the air defense laboratory which was known as Lincoln Laboratories.⁵⁸ The doubts of Radiation Lab veterans like Hill, Zacharias, and Stratton, however, had irked Valley. He recalled that their “statements did strike home to me, for several of these men were my seniors at MIT, and one of them had helped recommend me for tenure.”⁵⁹ Instead of getting back to physics as usual, Valley was spurred to accept a position as Lincoln Labs’ Director of Air Control and Warning in December 1951. Forrester later described Valley’s role at Lincoln Labs as “the person who would call up generals in the middle of the night, tell them what they should do, and ask for support.”⁶⁰ Forrester himself headed the digital computing division. Lincoln Laboratories was funded by all three services, at the behest of MIT administrators who worried that being too dependent on only one service would leave them vulnerable. Lincoln Labs’ first task was to conduct yet another study to identify how work on air defense should proceed. Because it took place over the summer of 1952, this study became known as the Summer Study.

MORE THAN THE AIR FORCE BARGAINED FOR

The hesitations of MIT’s administrators were well-founded. Not everyone within the Air Force was convinced of the necessity of a new air defence system – especially not an expensive one. The Air Force had begun to rebuild their offensive capabilities as well as to pursue the creation of a new defense system following the USSR’s detonation of an atomic bomb in August 1949. The Strategic Air Command (SAC) was revamped into a first-rate force, led by General Curtis E. LeMay. LeMay had joined the Air Force as a student at Ohio State University and had quickly risen through the ranks after personally leading several dangerous missions during WWII. Nicknamed “Big Cigar” because of his fondness for them, LeMay was renowned for his discipline, belligerence, and strong belief in the effectiveness of strategic bombing.⁶¹ His attitude, and the prevailing doctrine in the Air Force, regarding nuclear weapons in the early 1950’s was one of “prompt use”. “Prompt use” meant a pre-emptive attack in any situation

⁵⁸ Ibid., 271.

⁵⁹ Valley, “How the SAGE Development Began,” 212.

⁶⁰ Jay Forrester, “Whirlwind’s Success,” *The Computer Museum Report* (Spring 1988): 12.

⁶¹ Shepley and Blair, *The Hydrogen Bomb*, 167.

where it appeared that a strike by the USSR might be imminent. LeMay is said to have told a group of SAC pilots that that he “could not imagine a circumstance under which the United States would go second” in a nuclear war.⁶²

The policy of prompt use rendered strategic defense useless. War plans from the early 1950’s show that the Air Force had concentrated its radars and interceptors around weapons labs and cities with high populations. The bomber bases of the Strategic Air Command were left unguarded.⁶³ If Soviet planes were flying towards America, the SAC intended it to be because they were retaliating against an American Air Force strike. There was no need to defend American bomber bases – the planes would already be in the air. There would be no need for warning; the attack would be expected. In August 1947, a panel of Air Staff officers had reported that a large commitment to an air defense system “would be disastrous since real security lay in offensive capability.”⁶⁴ Although the Air Force Chief of Staff General Hoyt Vandenberg may have been concerned about responding to the fears of the President and the public with promises of a working air defense system, the leadership of the Strategic Air Command saw no use for it.

This spirit of the offensive was a part of Air Force identity. The idea of the efficacy of strategic air warfare and swash-buckling, roguish pilots was ingrained into the culture, going back to World War I AAF commander - and Air Force legend - Billy Mitchell who believed that the best defense was a good offense and that any war could be won by attacking cities from the air. Strategic air attacks had also been a major part of the Allied Victory in WWII. The United States Strategic Bombing Survey, conducted in 1945, had concluded that “allied air power was decisive in the war in Western Europe.”⁶⁵ As an offensive striking force led by a legendarily bold pilot, the SAC fell squarely within this offensive tradition. The SAC also held a degree of independence from the leadership of the Air Force in that it reported directly to the Joint Chiefs

⁶² Edwards, *The Closed World*, 84-85.

⁶³ Bruce-Briggs, *The Shield of Faith*, 77.

⁶⁴ Edwards, *The Closed World*, 86.

⁶⁵ “United States Strategic Bombing Survey” in *The United States Strategic Bombing Survey: over-all report (European war)*. Washington: U.S. Govt., 1945.

of Staff.⁶⁶ Despite the directive from Chief of Staff Hoyt Vandenberg to pursue continental defense, the leadership of the SAC held strongly to the Air Force's traditional offensive doctrine.

The MIT scientists who made up the Lincoln Lab's Summer Study, by contrast, were enthusiastic about their ability to use revolutionary technologies to decrease the offensive potential of nuclear weapons. Many of the physicists who were working at MIT after WWII had refused to participate in the development of nuclear weapons at the Manhattan Project or at Los Alamos. Valley, for instance, had refused to work on the Manhattan Project, and recalled how he "had lobbied to Congress against the May-Johnson bill that would have placed nuclear energy entirely in the control of the Department of Defense" and "had made innumerable speeches to... anybody who would listen" about the dangers of nuclear weapons.⁶⁷ Members of the Summer Study had ideologies opposite to the offensive "prompt use" ideas of the SAC. They were eager to use their technical abilities and influence with the Air Force to make the world safer through a strong defense system. Zacharias, one of the associate directors of Project Charles, reportedly told one of the Summer Study's participants that "if these people don't come to the right conclusion, then I'll dismiss them and begin another study." Another scientist later admitted "We all knew the conclusions we wanted to reach."⁶⁸

The Lincoln Summer Study's report confirmed Dr. Valley's findings that the United States' current defense was inadequate, and that it was technically possible to build a system which could defeat between 60 and 70 percent of incoming aircraft. In particular, it placed high priority on the construction of a distant early warning radar line across northern Canada.⁶⁹ The total estimated cost of the recommendations made in the Lincoln Summer Study's report was between 16 and 20 billion dollars.⁷⁰

⁶⁶ Shepley and Blair, *The Hydrogen Bomb*, 166.

⁶⁷ Valley, "How the SAGE Development Began," 197.

⁶⁸ Edwards, *The Closed World*, 95.

⁶⁹ Huntington, *The Common Defense*, 329.

⁷⁰ Joseph Alsop and Stewart Alsop, "Eisenhower Warned of Danger of Atom Bomb Attack," *New York Herald Tribune*, March 16, 1953: 1, 17, 19.

The Summer Study's findings reportedly "generated a first-class row", with the Air Force claiming that it had been "by-passed" by its scientists.⁷¹ MIT Provost Julius Stratton noted in a letter to Killian that the Summer Study's presentation was met by the Air Force with "'more belittling remarks than I indicated in my letter to [Zacharias].'"⁷² The details of the Summer Study's findings were leaked to the press despite an agreement between MIT and the Air Force that they would not be published. Its recommendations also made their way through unofficial channels to the White House, the State Department, and the office of the Secretary of Defense.⁷³ Air Force leadership was reportedly "disturbed" by the findings of the Summer Study Group. Two years after the Summer Study Group report, Lloyd Berkner wrote that "many efforts were made to ignore or to suppress the findings of the Lincoln Summer Study and little effort was made to demonstrate how the ideas might work out... the Armed Forces refused to recognize the serious state of the air-defense problem or to admit that it could be improved by radical measures."⁷⁴

In the opinion of SAC leadership, an air defense system would not only be useless but a drain on resources which could be better spent building up the bomber fleet. The Summer Study scientists were ridiculed as "the Maginot Line boys from MIT."⁷⁵ Brigadier General John K. Gerhart warned of the dangers of spending "billions on defense gadgetry at the expense of our deterrent strike and air superiority forces."⁷⁶ At the time, most planes could reach the Soviet Union from America only by refueling on remote bases, and would have had to attempt to land in Afghanistan or the Canadian Arctic after attacking.⁷⁷ For the "prompt use"-minded leadership of the SAC, the billions of dollars which the Lincoln Summer Study suggested be poured into building a continental defense system could have gone towards ensuring that American pilots would make it home safely from their offensive strike.

⁷¹ Joseph Alsop and Stewart Alsop. "Matter of Fact: The New President." *New York Herald Tribune*, November 5, 1952: 29.

⁷² Slayton, "From a 'Dead Albatross' to Lincoln Labs," 275.

⁷³ Shepley and Blair, *The Hydrogen Bomb*, 186.

⁷⁴ Huntington, *The Common Defense*, 335.

⁷⁵ Edwards, *The Closed World*, 95.

⁷⁶ Slayton, "From a 'Dead Albatross' to Lincoln Labs," 274.

⁷⁷ Bruce-Briggs, *The Shield of Faith*, 79.

Although the National Security Council adopted all the proposals made by the Lincoln Summer Study Group, and officially approved them in October 1953, many members of the Air Force remained unenthusiastic about strategic air defense. The Air Force had agreed to fund the Lincoln Laboratory, but budgeting billions of dollars to implement an early warning radar line and its other potential creations was a different story. Zacharias later claimed that air defense was finally “sold to Truman over the dead body of the Air Force.”⁷⁸ Although the top leadership and scientific advisors of the Air Force had been eager to work with the scientists at MIT on the problem of air defense, the generals who strongly believed in the doctrine of “prompt use” thought that this phenomenally expensive system was more than they had bargained for.

A (WILLOW) RUN FOR THEIR MONEY

Critics of the Lincoln Labs’ approach to air defense had no trouble finding issues which raised concern. At the time, digital computers were seen as little more than experimental oddities with purely academic or scientific applications.⁷⁹ Bell Laboratories was having success building analog computers for the Army’s comparable NIKE anti-aircraft guided missile defense.⁸⁰ According to Valley, when the Valley Committee first began to consider working with the Whirlwind in 1949, “almost all the groups that were realistically engaged in guiding missiles thought in terms of analog computers.”⁸¹ Valley recalled:

We in Lincoln were cast, by some, in the role of heretics to a state religion, and when we criticized analog devices and refused to employ them, we were regarded as unrepentant sinners... Many engineers of the aerospace industry, more friendly toward us, sincerely didn’t believe digital computers could be reliable enough to be trusted with such an important system.⁸²

⁷⁸ Edwards, *The Closed World*, 95.

⁷⁹ Herman H. Goldstine, *The Computer from Pascal to von Neumann*, (Princeton, N.J.: Princeton University Press, 1972), 251.

⁸⁰ Edwards, *The Closed World*, 67.

⁸¹ Valley, “How the SAGE Development Began,” 206.

⁸² *Ibid.*, 219.

Institutions like Bell Laboratories and MIT's Servomechanisms Lab, which had invested much time and money into analog technologies saw digital computers as a threat. Engineers trained to program and maintain analog computers during WWII felt the same way. Robert Wieser, who worked on the Whirlwind under Jay Forrester, recalled the struggle to get the Air Force to adopt the Lincoln Lab's system as a direct competition between analog and digital technologies: "We also won the cause for digital computers. If there's anyone who thinks we didn't win, just go to Radio Shack and try to buy an analog computer."⁸³ Air Force skepticism of the work done at Lincoln Labs was encouraged by the hostile attitude of the analog computing industry, members of which strongly believed that analog computing was the way of the future.

The ongoing ambivalence in the Air Force towards the work done at Lincoln Laboratories on what was called the Lincoln Transition System resulted in their simultaneous pursuit of an alternative system. The Air Force also supported development of a more decentralized air defense system which used analog computers at the University of Michigan's Willow Run Research Center. The Air Force's relationship with Willow Run was older than its partnership with MIT, and the way that the institutions related was fundamentally different. The Air Force had long held nuclear physicists and theoretical scientists like their new partners at MIT in contempt. What members of the Air Force were interested in was flying planes. In the words of an industry insider, "Flying was why there was an Air Force, not to be sitting in a hole in the ground and shooting missiles at some other country or somebody else's aircraft."⁸⁴ Although the Scientific Advisory Board and work done at the Radiation Lab had been an important factor contributing to the Air Force's victories in WWII, little of that work had to do with flying or designing and building aircraft. Consequently, Air Force officers had little regard for the opinions of MIT-affiliated scientists about air power. "Air Force generals liked to tell the story of how one nuclear physicist worked eight fruitless months on the control system of a guided missile, only to be shown that all that was needed was two more square feet of tail surface."⁸⁵

The feeling was mutual. George Valley's memoirs of working on the SAGE are filled with lightly disparaging portraits of military men who care more about seeming impressive than

⁸³ Robert Wieser, "From World War II Radar Systems to SAGE," *The Computer Museum Report* (Spring 1988): 16.

⁸⁴ Bruce-Briggs, *The Shield of Faith*, 66-67.

⁸⁵ Shepley and Blair, *The Hydrogen Bomb*, 171.

understanding the technical task at hand. He went so far as to compare his Air Force colleagues to the obstinate and antiquated knights from Mark Twain's *A Connecticut Yankee in King Arthur's Court* who are more interested in foolish chivalry than valuable scientific advancements.⁸⁶ The contemptuous attitudes which the Air Force and the scientists at the Lincoln Labs held towards each other undoubtedly added to the difficulties they had in dealing with one another.

The Willow Run Research Center, by contrast, had its roots in the more traditional Air Force activity of building bombers. During WWII, the Army Air Force had created an outpost at the Willow Run airport as the headquarters of its effort to harness the manufacturing power of the local automobile industry for the production of aircraft. At the end of the war, the Air Force facility at Willow Run was transferred to the University of Michigan. The University of Michigan was eager to capitalize on an opportunity to get involved in military contracting, and created a new administrative unit, the Engineering Research Institute, to manage Willow Run and other Laboratories. Starting with a study of defenses against V2-type rockets, the Willow Run Laboratories had begun work on continental air defense under the auspices of the Air Force well before Lincoln Laboratories was even established at MIT.⁸⁷ Willow Run engineers also worked on designing surface-to-air guided missiles – not quite WWII dogfighters, but flying machines nonetheless.⁸⁸ Harry H. Goode, the man who became director of Willow Run Laboratories in 1952, also had experience in the scientific disciplines which were more familiar to airmen than George Valley's cosmic ray research. He had worked for the Navy's Special Projects Branch on flight simulations and aircraft instrumentations.⁸⁹ Where MIT had begun working with the Air Force in purely a scientific advisory capacity, Willow Run had begun as an operational airfield. The cultural gap that frustrated both sides during the Lincoln Labs' work on air defense was much narrower for the scientists and engineers at Willow Run.

⁸⁶ Valley, "How the SAGE Development Began," 224.

⁸⁷ Aker, *Calculating a Natural World*, 297.

⁸⁸ Robert M. Howe, "Analog Computers in Academia and Industry: A history of analog computing at the University of Michigan and the founding of Applied Dynamics International," *IEEE Control Systems Magazine*, June 2005, 37.

⁸⁹ Isaac Auerbach, "Harry H. Goode, June 30, 1909–October 30, 1960," *IEEE Annals of the History of Computing*, 8 no.3 (July-September 1986): 257.

This difference not only expressed itself through interactions between the MIT scientists and members of the Air Force, but through the technical systems themselves. The system being developed at Willow Run was known as the Air Defense Integrated System for Surveillance and Weapon Control (ADIS). ADIS employed a large and complex electromechanical analog computer, which had been made by combining the two analog computers at the laboratories' disposal.⁹⁰ Goode thought that "aircraft-system designs... [were] naturally suited to the analog machine" because the work to be done was solving large sets of differential equations.⁹¹ He could not have been alone in that opinion; scientists had been solving differential equations with analog computers known as "differential analyzers" since the early 20th century.

Analog computers were also familiar to officers in the Air Force. They were the natural choice for military applications like antiaircraft guns or aircraft instrumentations because their inputs and outputs were physical signals like electric voltages or gear rotations which could be directly applied to the machines which they were controlling, or displayed through dials to be interpreted by the machines' operators. Digital computers, on the other hand, generated numerical data which needed to be converted or interpreted.⁹² Military officers who had experience with computers had experience with *analog* computers. The result was that military officers rarely understood the advantages of the Lincoln Labs' digital system. Valley recalled the difficulties of communicating with Air Force officers:

Officers are hired to win fights. Although today we have officers educated in computer science, in the early 1950s the average field-grade officer had served in the war and been educated by it, and he was familiar only with analog instrumentation. If he had taken any technical refresher courses since the war, they had most likely been about nuclear explosives. If you said the word computer to most officers, you implied an analog computer with its characteristic limitations, even though you might actually have spoken the words digital computer.⁹³

⁹⁰ "The Engineering Research Institute" in *The President's Report for 1951-1952*. (Ann Arbor, MI: University of Michigan, 1953), 413.

⁹¹ Harry H. Goode, "Simulation – Its Place in System Design", *Proceedings of the I.R.E.* 39 no. 12 (December 1951): 1503.

⁹² Edwards, *The Closed World*, 67.

⁹³ Valley, "How the SAGE Development Began," 220.

This cultural difference made it difficult for officers to follow the work of the Lincoln Labs. Although Valley disagreed, Air Force officers were convinced that the Willow Run Research Center's planned system would be operation sooner than the Lincoln Transition System.⁹⁴ Their inability to communicate about digital computing undoubtedly contributed to the lack of confidence that the Air Force had in the work done at Lincoln Labs.

The engineers at Willow Run were focussed on the details of how Air Force officers could use their tools to "win fights": what the centers would look like; what the chain of command would be; how many officers would be required.⁹⁵ The director of the Willow Run Research Center, Harry H. Goode, is recognized today as a pioneer of system design, the process of developing systems which satisfy a user's requirements. After his work on ADIS, he went on to write the first system design textbook *System Engineering*, which was published by McGraw-Hill in 1957.⁹⁶ The Lincoln Lab scientists were interested in developing the hardware first. Valley was convinced that once the actual computer which could identify enemy planes and give coordinates to interceptors was built, "the operational problems on which the other laboratory was concentrating would practically solve themselves."⁹⁷ Valley believed that the details of how the system should be used were better left to the Air Force. This highly technical approach left them with a significantly less compelling sales pitch.

The Lincoln Labs team gradually became aware of this, and drew up a plan called Technical Note 20 which contained a few more details about how the system would eventually operate. Robert Wieser, a member of the team working on programming the Whirlwind, recalled the response of General Gordon Saville, who was the deputy chief of staff for development at the time:

George Valley brought in General Gordon Saville of the Air Force. He was about five and a half feet tall, feisty, had a strong voice and understood his own opinions. After he read [Technical Note 20] he came back, went to the head of the table, threw it down and said, 'You're the worst damn salesman I ever met. This report is stinko profundo. What you ought to do is start all over again, and maybe if you worked real hard you might work your

⁹⁴ Slayton, "From a 'Dead Albatross' to Lincoln Labs," 276.

⁹⁵ Valley, "How the SAGE Development Began," 221.

⁹⁶ Machol, Robert E., "Harry H. Goode, System Engineer," *Science* 133 no. 3456 (March 1961): 865, accessed March 24, 2015, <http://www.jstor.org/stable/1706532>.

⁹⁷ Valley, "How the SAGE Development Began," 222.

way up to medium sorry." We listened to him carefully and began to understand that it's one thing to explain something that lies outside a person's experience and yet another thing to explain something that lies outside his imagination.⁹⁸

The aircraft manufacturing background of the Willow Run Research Center meant that the scientists there had a better understanding of the importance of control to Air Force culture. What Valley dismissed as "operational details" were of central importance to the Air Force, and approaching the problem from a system design perspective allowed the Willow Run scientists to recognize that. As Valley discovered, trying to sell generals on the details of a system without including information about how it could be used to command and control the battlefield was useless.

In fact, Willow Run's ADIS was designed to better fit the needs of the Air Force than the Lincoln Transition System. ADIS was based on the British Comprehensive Display System (CDS), which used telephone and teletype lines to send radar data to a single site so that the paths could be manually plotted. The Willow Run Laboratories proposed to improve on the CDS by automating the transfer of information between different sites, each of which could track up to a hundred planes, and providing analog devices to make the calculations required to plot the planes and interceptor paths easier.⁹⁹ Recognizing the Air Force's love of tradition, Goode had purposefully designed the system to be a small update to the pre-existing system of using decentralized radar sites to survey the skies rather than a dramatic overhaul. He was aware that a decentralized and minimally automated system would be easier for the Air Force to accept and use.¹⁰⁰ Goode died in October 1960, about a year before the SAGE was finally fully deployed. An obituary by a friend and colleague stated that "he believed that his understanding of system reliability and the value of a decentralized defense system had never been fully appreciated."¹⁰¹

The Air Force was well aware of the differences in the two systems' designs. In a letter to MIT President James Killian in January 1953, General Partridge, the head of the Air Force

⁹⁸ Wieser, "From World War II Radar Systems to SAGE," 15.

⁹⁹ Edwards, *The Closed World*, 97.

¹⁰⁰ Machol, "Harry H. Goode, System Engineer," 865.

¹⁰¹ Auerbach, "Harry H. Goode, June 30, 1909-October 30, 1960," 257.

Research and Development Command (ARDC) laid out the differences between the two systems: ADIS decentralized data processing and weapon control and centralized threat evaluation facilities, whereas the Lincoln Transition System centralized all of its functions.¹⁰²

The amount of automation which the Lincoln Transition System proposed was overwhelming to members of the Air Force. "To officers steeped in a tradition of human command, the idea of a machine analyzing a battle situation and issuing orders was at best suspicious, at worst anathema."¹⁰³ Being told by a machine exactly where and how to fly made the pilot extraneous to the whole system. Were it technically feasible, a guided missile could accomplish the same results. This went against the offensive spirit and valorization of flying ability which the Air Force cherished. The ADIS, on the other hand represented a small update to the current radar station system which was much closer in line with the Air Force's preferred way of operating.

The Lincoln Labs' budget was another strike against it. Goode, the director of the Willow Run Research Center, believed that "extensive simulation of the entire system must be run before the system is built." Exercises in detection and interception were run as simulations on the computers at the research center.¹⁰⁴ Goode made this decision specifically because he recognized the economic cost of constructing a system which may or may not work.¹⁰⁵ Valley, however, insisted on running tests with real airplanes and real radars even before programming was complete on the Lincoln Labs' system. Starting in the spring of 1952, frequent experiments were run using the "Cape Cod System", which consisted of short and long range radar stations in the Cape Cod area with a control center in Cambridge. The scientists at the Lincoln Lab conducted test runs with SAC bombers playing the role of hostiles and interceptors from the Aerospace Defense Command (ADC) and Air Research and Development Center (ARDC) as the American planes.¹⁰⁶ The Air Force granted them the use of six bombers, three interceptors, and a company of airmen who made up the 6520th Aircraft Control and Warning Squadron

¹⁰² Thomas Hughes, *Rescuing Prometheus*, (New York, NY: Pantheon Books, 1998), 43.

¹⁰³ Edwards, *The Closed World*, 96.

¹⁰⁴ "The Engineering Research Institute," 412.

¹⁰⁵ Goode, "Simulation – Its Place in System Design," 1502.

¹⁰⁶ M. Astrahan, and J. Jacobs, "History of the Design of the SAGE Computer - AN/FSQ-7," *Annals of the History of Computing* 5 no. 4 (October 1983): 342-343.

(Experimental).¹⁰⁷ Valley considered these live experiments a valuable demonstration of the Lincoln system's capabilities. However, for the budget-conscious and defense-wary Air Force, this was seen as a nuisance: "Instead of praising us for our realistic approach to the problem, some visiting officers tended to think we were just using a particularly expensive and clumsy way to simulate, and for them this was a mark against us, as compared with our chief competitors at another university."¹⁰⁸ What the MIT scientists saw as an advantage, the military men and the Willow Run scientists recognized as a drawback.

The competition between the Lincoln Labs and the Willow Run Labs was further complicated by the relationship between the arms of the Air Force which were providing direct support to them. ADIS was partnered with the ARDC's Air Development Center in Rome, New York (RADC). The Air Force Cambridge Research Laboratories in Cambridge, Massachusetts, was Lincoln Lab's partner. These centers were meant to provide support for the "engineering functions", including consulting with manufacturers of system components to procure materials for the proposed systems.¹⁰⁹ Valley remembers the two centers as being "at loggerheads", and thought that the RADC had closer social connections to the Air Defense Command (ADC) in Colorado Springs.¹¹⁰ As a result, the leadership of the ADC favored the ADIS. The ADC's Commander, General Benjamin W. Chidlaw, thought that the Lincoln system was "rather nebulous" and that ADIS was better suited for the "here and now."¹¹¹

Chidlaw's estimation of the timelines of the ADIS and the Lincoln Transition System was likely correct. Forrester recalled that "we went in with an estimate that ran maybe ten times as much money and five times as much time as Michigan did."¹¹² A report from the University of Michigan puts the volume of research sponsored by the government at the Willow Run Research Center between 1952 and 1953 at slightly over 5 million dollars.¹¹³ By contrast, Jay Forrester had once requested slightly over 5 million dollars from the Office of Naval Research

¹⁰⁷ Valley, "How the SAGE Development Began," 215.

¹⁰⁸ *Ibid.*, 221.

¹⁰⁹ Hughes, *Rescuing Prometheus*, 43.

¹¹⁰ Valley, "How the SAGE Development Began," 221.

¹¹¹ Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense 1945-1960*. (Washington, D.C.: Office of Air Force History United States Air Force, 1991): 210.

¹¹² "A Perspective on SAGE," 383.

¹¹³ "The Engineering Research Institute," 406.

just for the Whirlwind's development.¹¹⁴ The Whirlwind's engineering challenges also grew beyond original estimates. As a director of the Lincoln Lab, Valley struggled to control the Whirlwind's budget just as the ONR had. Given that offensive-minded generals and divisions of the Air Force saw little purpose in building any air defense system, the Lincoln system's relatively high cost was certainly a mark against it.

FRIENDS IN HIGH PLACES

MIT President James Killian was not happy about the threat that the ADIS posed to the Air Force's support of the Lincoln Lab's system. In a letter to Air Force Secretary Thomas Finletter Killian wrote that "he was disturbed... by the continuation of competitive and possibly redundant development programs." Killian requested from that the Secretary of Defense initiate a technical evaluation of the Lincoln program which would pay "particular attention" to its relationship to competing systems. Killian sharply wrote "we stand ready to withdraw". He reminded Finletter that MIT was more than willing to shut down the Lincoln Lab based on the incompatibility between running a national defense research project and MIT's educational mission.¹¹⁵ In effect, he threatened that MIT would walk away from the project unless the Air Force committed to the Lincoln Labs as their sole contractor.

Killian was uncomfortable with the financial risk that MIT sustained by running such a costly laboratory with funding which could be withdrawn and sent to a competitor. Although the Air Force had pledged funding for the Lincoln Labs through the end of December 1953, the government's fiscal year began on July 1st. Killian worried that, after the arrival of the Eisenhower administration in office in January 1953, Air Force priorities would change and their funds for the Lincoln Lab would run out by the end of June. If the Eisenhower administration cut funding to the Air Force and the Air Force cut funding to Lincoln Labs, MIT would be left to cover the difference out of its endowment. Matters were made worse by the fact that the Lincoln Lab's funding was already reduced because the Navy had cut some of its contributions to MIT in late 1951.¹¹⁶

¹¹⁴ Edwards, *The Closed World*, 99.

¹¹⁵ Redmond and Smith, *From Whirlwind to MITRE*, 266.

¹¹⁶ Johnson, *The United States Air Force and the Culture of Innovation*, 147.

Finletter, evidently threatened, responded immediately via hand-carried letter to Killian, agreeing to a review at a later time. He did not, however, give Killian his commitment to the Lincoln system, telling him that “we feel it is our duty to support such efforts but assure that they will not detract from the Lincoln program.”¹¹⁷ Lieutenant General E. E. Partridge, the Commander of the ARDC, also refused to give Killian the commitment he wanted. Two weeks after Finletter’s response, Partridge sent a letter to Killian stating that “to carry out the... [air defense] program in the shortest possible time, the maximum of cooperation and coordination between all agencies concerned [MIT and other] will be required.” He reiterated that the Air Force would support both projects until they found that there was sufficient “factual information” to determine which was superior. Partridge sent the same message to the Willow Run Laboratories.¹¹⁸

Meanwhile, other institutions were pressuring the Air Force to make a decision. The Eisenhower Administration, having come into office on a pledge to reduce military budgets, was eager to see the Air Force pay for the development of only one of the two systems. In early 1953, the Secretary of Defense commissioned a report from an ad hoc committee on continental defense led by Dr. Mervin J. Kelly, the director of Bell Laboratories. Bell Labs had collaborated with MIT throughout its work on air defence, starting with George Valley’s request to Bell Lab’s vice president Donald Quarles, whom he “felt a filial affection towards”, that Western Electric should carry the Air Force’s radar data through its telephone lines.¹¹⁹ Dr. Kelly was also a Life Member of The Corporation of the Massachusetts’s Institute of Technology starting in November 1953.¹²⁰ Kelly’s report reiterated the need for better air defense and was favorable to the work being done at Lincoln Labs.¹²¹ Valley recalled that the Kelly Committee’s report gained the Lincoln Labs support from a few Air Force leaders, and helped to calm worries within the organization. However, more support was needed:

¹¹⁷ Ibid., 147.

¹¹⁸ Hughes, *Rescuing Prometheus*, 42.

¹¹⁹ Valley, “How the SAGE Development Began,” 201.

¹²⁰ “President’s Report,” *Massachusetts Institute of Technology Bulletin* 89 no. 2 (November 1953): 2, accessed March 29, 2015, <https://libraries.mit.edu/archives/mithistory/presidents-reports/1953.pdf>.

¹²¹ Robert Buder, *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 and Schuster, 1996), 387.

A person unfamiliar with the military might think that once we had the office of the Secretary of Defense behind us, we needn't worry about what all the majors and colonels and generals thought, but persons experienced with the Department of Defense will not think that way, for they will recognize that new weapons cannot easily be shoved down the military's throat. Those officers who are competent to walk a project through the Pentagon are also the ones smart enough to know a gone goose when they smell one. If a project isn't pushed by a competent operational type, it will not necessarily fail, but it will flounder, experience errors of procedure, and suffer delays; the weapon will be unlikely to see service use.¹²²

Although the Kelly Committee report ensured that the Lincoln Labs had the support of the highest levels of the military, the fact that the ADC still favored the ADIS meant that the Air Force did not yet decide between the two.

The time for that decision, however, was nearing. In response to Killian's pressure and the results of the Kelly Report, the Air Force arranged for generals from the Air Defense Command and Air Materiel Command to attend demonstrations of both the ADIS at Willow Run and the Lincoln Transition System at MIT. Valley explained the details and design of the Lincoln Transition System to the Air Force members and put on a showcase of live interceptions using coordinates calculated by the Whirlwind, with pilots' radio communications played over loudspeakers and the action displayed on as images on cathode-ray tubes. Then, Valley accompanied the generals to Willow Run Laboratories, where interceptions were merely simulated using pen-and-ink plotters. To Valley's chagrin, "this trivial exercise in preprogrammed curve plotting had impressed the majority of the officers as much as had the real thing shown them at Lincoln."¹²³ Even more frustratingly, for the Air Force, the demonstrations were inconclusive. They would continue to fund both Willow Run's ADIS and the Lincoln Transition System for the foreseeable future.¹²⁴

In these uncertain times for the Lincoln Labs, IBM emerged as a staunch supporter. IBM's executive vice-chairman and director of sales and product planning (and son of Thomas Watson Sr., who had been IBM's chairman and CEO since 1914) Thomas Watson Jr. was highly

¹²² Valley, "How the SAGE Development Began," 221.

¹²³ *Ibid.*, 222.

¹²⁴ Buder, *The Invention that Changed the World*, 387.

enthusiastic about getting the company into the field of digital computing. IBM's competitor Remington Rand had already come out with UNIVAC, a digital computer for the business market. Watson wrote in his memoirs that although "there wasn't a single solitary soul in IBM who grasped even a hundredth of the potential a computer had... what we could understand was that we were losing business."¹²⁵ Watson had been desperate to win the contract to work with MIT to build the SAGE prototype. He called it "the most important sale of my career."¹²⁶ Cuthbert Hurd, who had done post-graduate work at MIT before accepting a position with IBM as its Director of Applied Science in 1949, remembered that the decision to produce the model SAGE for the Lincoln Laboratories had been "a very big event at IBM" which at the time had only a small laboratory in Poughkeepsie focused on digital computers.¹²⁷ IBM's initial collaboration with MIT had been keenly pursued by Thomas Watson Jr., and the subsequent contract to build a prototype was an important step in IBM's orientation towards the field of digital computing.

IBM's leadership was so eager to continue their work with the engineers at the Lincoln Laboratory, and to potentially win the contract to build the whole system, that they were prepared to reject a request from the Air Force that they support Michigan's efforts. When Jay Forrester met with IBM executives in New York in October 1952, he brought up the threat that the Lincoln Transition System was facing from the ADIS, which elements of the Air Force wanted to push into production for near-term air defense. IBM executives "sought to reassure Forrester that, although IBM could not 'for policy reasons... refuse a 701 machine to Michigan, it would make clear to both the University of Michigan and the Air Force that it could 'only provide limited manpower for adapting the computer to ADIS'."¹²⁸ Besides their desire to get more out of the work which IBM had already put into the Lincoln Labs project, its executives

¹²⁵ Thomas Watson and Peter Petre, *Father, Son & Co.: My life at IBM and beyond*, (New York: Bantam Books, 1990), 227.

¹²⁶ Watson, *Father, Son & Co.*, 230.

¹²⁷ Nancy Stern (Interviewer) and Cuthbert Hurd (Interviewee), *An Interview with Cuthbert C. Hurd* [Interview transcript], January, 1981, accessed from Charles Babbage Institute Center for the History of Information Processing Website.

<http://conservancy.umn.edu/bitstream/handle/11299/107368/oh076cch.pdf?sequence=1&isAllowed=y> .

¹²⁸ Redmond and Smith, *From Whirlwind to MITRE*, 265.

hoped that by working with MIT they would gain insights into the production of digital computers which could be used to gain advantages over its competition. George Valley's colorful recollection of IBM's support for the Lincoln Labs was that "a general summoned the IBM management to the Pentagon, and ordered them to cease cooperating with Lincoln and to start helping the other laboratory... They stood up and said 'NO!'."¹²⁹ Internal memos from the ARDC note that it was difficult to find a contractor interested in manufacturing the ADIS system.¹³⁰ IBM went even farther in its support of Valley and the Lincoln Transition System: sales executives were sent to the laboratory to help correct Lincoln's chronic lack of salesmanship. "Their parting words were 'George [Valley] and Jay [Forrester], in our business we've discovered that it is necessary to give the customer a little of what he thinks he wants, in order to maintain oneself in a position to give him what he really needs.'"¹³¹

After the Air Force accepted the Lincoln Transition System over the ADIS, Jay Forrester again chose IBM as the manufacturer of the computer components for the system. Watson was relieved. He later wrote that "I worked harder to win that contract than I worked for any other sale in my life."¹³² The value that IBM got from its collaboration with MIT ended up being well worth its trouble. The engineering, software programming, and computer maintenance personnel that IBM hired to work on SAGE helped the company dominate the computer industry. Subsequent IBM computer systems also benefitted from the hardware and software features which had been developed to give the SAGE its necessary speed and reliability. Cuthbert Hurd later stated that "the experience IBM gained from its work on the SAGE system was significant to the future success of the company."¹³³ Thomas Watson Jr. wrote in his memoir that IBM engineers "took what we'd learned working for the Air Force on SAGE and used it to skip a grade, so to speak, in computer development."¹³⁴ IBM was a powerful

¹²⁹ Valley, "How the SAGE Development Began," 222.

¹³⁰ Redmond and Smith, *From Whirlwind to MITRE*, 269.

¹³¹ Valley, "How the SAGE Development Began," 222.

¹³² Watson and Petre, *Father, Son & Co.*, 232.

¹³³ Cuthbert C. Hurd, "Early IBM Computers: Edited Testimony," *Annals of the History of Computing* 3 no.2 (April 1981): 174.

¹³⁴ Watson and Petre, *Father, Son & Co.*, 243.

supporter of the Lincoln Transition System, and its efforts to ensure SAGE's success certainly paid off.

As Valley saw it, the Air Force chose the Lincoln Labs' system purely because of his ability to harness his inner Air Force commander and order it to happen. He relates an entertaining anecdote of the time when he and Goode were invited to an air defense conference in the south of England in early 1953:

He was obviously awed by all the brass, especially by the British superbrass, those sirs and milords who were also professors, air vice-marshals, and so on. He had not learned, as I had learned from General Whitehead, that in such a situation you stuck a cigar in your face, blew smoke at the intimidating crowd, and overawed the bastards. During the ensuing discussion I realized that he had only the vaguest ideas about physics, electronics, aerodynamics-apparently anything technical.¹³⁵

Eventually, Valley became so exasperated that he shouted at the rival director: "I blew my top. "SHUT UP! SIT DOWN!" I thundered, and then sat down myself, abashed by the sound of my own voice."¹³⁶ Valley entirely credits the Air Force's adoption of the Lincoln Lab's system to his ability to bully them into accepting it. Valley writes, "From that time on, the Lincoln system was truly accepted, but if anyone thinks that SAGE was accepted because of its excellence alone, that person is a potential customer for the Brooklyn Bridge. It was accepted because I shouted an impolite order at the leader of the competition, and he obeyed me. We were at the court of King Arthur, and I had prevailed."¹³⁷

Valley *probably* puts too much emphasis on his own forcefulness carrying the day, but his point about the loudest voices being counted the most has merit. Without the determination of Killian to ensure the reliability MIT's military contracts and IBM to look out for their own profits, the Air Force could easily have dismissed the Lincoln Transition System as too expensive, risky, and foreign to their way of operating. Instead, they formally announced that they would continue to fund only the Lincoln Transition System on May 6 1953, although no further "factual information" about either of the systems had been obtained. In contrast to

¹³⁵ Valley, "How the SAGE Development Began," 224.

¹³⁶ *Ibid.*, 224.

¹³⁷ *Ibid.*, 224.

Killian and Valley's intense efforts to force the acceptance of the Lincoln system, the University of Michigan's administrators took the news gracefully. They indicated that they were willing to work with the Lincoln lab on any issues which would contribute to the solution of the air defense problem.¹³⁸

VICTORY FOR LINCOLN LABS

MIT's position as a powerful center of research and development was a major source of the Air Force's distaste for Lincoln Labs, but it was also the key to securing the SAGE's future. Despite their mutual dislike, the Air Force had invested too much money into the Lincoln Labs to risk having Killian decide to walk away.¹³⁹ Besides, as a young and barely-established service, the Air Force could not afford to lose research and development resources of MIT's calibre. The Air Force may have been supplying the funding, but MIT's institutional connections meant that they could manipulate the situation to their advantage. In the words of the Air Force's official history book, "Lincoln's power play proved successful."

From its beginning, Valley's vision of a digitally computerized air defense system had the advantage over the Air Force's objections. The essential work of MIT's Rad Lab during the war led to George Valley's position on the Air Force's Scientific Advisory Board and his friendship with fellow Rad Lab alumnus and Air Force chief scientist Louis Ridenour. This Rad Lab legacy made it almost inevitable that Valley would be able to pursue his investigation of the problem of air defense and that MIT, at Ridenour's urging, would host an air defense laboratory. Valley's connections at MIT led him to discover that the digital computer he was looking for was being built on MIT's campus. The fact that his mission provided the perfect excuse to fund the Whirlwind, an innovative but disastrously expensive experiment in digital computing, was a bonus for its director Forrester and made it all the more essential for MIT's administration that the Lincoln Labs should succeed.

The Air Force's dislike for the Lincoln Laboratories and its scientists is illustrated by the reaction of top Air Force officials to its Summer Study. Generals were aghast at the price tag on

¹³⁸ Redmond and Smith, *From Whirlwind to MITRE*, 268.

¹³⁹ Schaffel, *The Emerging Shield*, 212.

the study's recommendations, and derided an automated air defense system as a foolish Maginot Line-like endeavor which would only foster a dangerous false sense of security. Although Air Force chief of staff Hoyt Vandenberg was accountable to the demands of the President's Office and the public for protection from a nuclear attack, generals who favored a strategy of "prompt use" were loath to pour money into anything other than improving the Air Force's strategic bombing capacity. The difference between what the scientists and the generals wanted was more than just tactical, it was cultural. The Air Force valorized daring airstrikes and flying prowess. Physicists who were only interested in the workings of electrons and magnets were looked down upon; their opinions about air defense were discounted. Extensive automation of the Air Force's operations was also seen as anathema to the service's values. The theoretical, high-tech concerns of the MIT scientists were repugnant to the aggressive pilots who made up the Air Force.

The contrasting approach of the Willow Run Research Center to the problem of continental air defence shows exactly how the cultural differences between the Lincoln Lab and the Air Force translated into decreased support for their system. Willow Run Research Center was born out of an operating air field which had been a part of a push to harness automotive facilities for aircraft manufacturing. This background meant that the engineers and scientists at Willow Run had a better idea about what was important to members of the Air Force. Valley's memoirs ridicule the work done at Willow Run as vapid, technically illiterate pandering to the Air Force's unrealistic desires. For Willow Run Research Center director Harry H. Goode, however, catering a system to a user's needs was a central tenant of his philosophy. Goode was a pioneer of systems design, and recognized that any air defense system had to account for the humans who used it. As a result, he purposefully designed the ADIS to be a small, analog update on the current decentralized system of radar stations. Analog computers were familiar to military officers because of their widespread use as bombsights and antiaircraft gun controllers, so members of the Air Force could easily understand their advantages. Goode's attitude towards live experiments also kept the needs of the Air Force in mind. He preferred simulations to test his system because they were far cheaper than Valley's method of using a squadron to run tests. By contrast to ADIS, the Lincoln Transition System seemed to Air Force

officers like an unintelligible, highly costly, shot in the dark. At Lincoln Labs, figuring out how to make the system appealing to Air Force officers was of a far lower priority than the engineering problems which they faced. They didn't have a sales pitch; they expected the Air Force to recognize their technical expertise and trust that they knew best.

Fortunately for Lincoln Labs and the future of digital computing, MIT's prestige and connections meant that the Air Force didn't have much of a choice. Valley remembers the Lincoln Labs' victory as turning on his confrontation with Goode. He believed that after his outburst, Air Force officers recognized that he and the Lincoln Transition system were worthy of their respect.

Voices louder than Valley's also supported the Lincoln Labs. Dr. Mervin J. Kelly's favorable report garnered them the support of the Secretary of Defense. IBM's insistence on working with Lincoln Labs over their competitor was also crucial – and a great business decision. Finally, Killian's threat to end the operations of the laboratory which he had had reservations about opening forced the Air Force to make their commitment. The same theoretical scientific prowess which was the source of the cultural gap between the MIT scientists and the Air Force made MIT a resource which was too valuable to lose.

Without the Lincoln Labs' powerful connections, it is easy to imagine that the Air Force would have rejected the expensive, experimental digital system. The Air Defense Command did not care that the Whirlwind was a revolutionary type of computer. They were not interested in how much faster and more accurate it was than an analog machine. In fact, its ambition and newness was a drawback. The Air Force would rather have clung to its traditional ways of operating, with the incremental update of the ADIS and its advantage of conserving funds which could be put towards better aircraft. In spite of the Air Force's distrust and objections, Valley and the Lincoln Labs fought their way to acceptance. Lincoln Labs scientist Zacharias claimed that air defense was "sold to Truman over the dead body of the Air Force."¹⁴⁰ The digital computers which are so essential to our lives today, too, were made possible in spite of the military service which funded them.

¹⁴⁰ Edwards, *The Closed World*, 95.

BIBLIOGRAPHY:

- Akera, Atsushi. *Calculating a Natural World: Scientists, Engineers and Computers During the Rise of US Cold War Research*. Cambridge: The MIT Press, 2006.
- Alsop, Joseph, and Stewart Alsop. "Eisenhower Warned of Danger of Atom Bomb Attack." *New York Herald Tribune*, March 16, 1953: 1, 17, 19.
- Alsop, Joseph, and Stewart Alsop. "Matter of Fact: The New President." *New York Herald Tribune*, November 5, 1952: 29.
- "A Perspective on SAGE: Discussion." *IEEE Annals of the History of Computing* 5 no. 4 (October 1983): 375-398.
- Astrahan, M., and J. Jacobs. "History of the Design of the SAGE Computer - AN/FSQ-7." *Annals of the History of Computing* 5 no. 4 (October 1983): 340-349.
- Auerbach, Isaac. "Harry H. Goode, June 30, 1909-October 30, 1960." *IEEE Annals of the History of Computing*, 8 no.3 (July-September 1986): 257-260.
- Bruce-Briggs, B. *The Shield of Faith: A Chronicle of Strategic Defense from Zeppelins to Star Wars*. New York: Simon and Schuster, 1988.
- Bush, Vannevar. "Science The Endless Frontier." National Science Foundation. July 25, 1945. Accessed January 8, 2015. <http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm>.
- Edwards, Paul. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge: The MIT Press, 1996.
- Forrester, Jay. "Whirlwind's Success." *The Computer Museum Report* (Spring 1988): 10-13.
- Futrell, Robert Frank. *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1907-1960*. Maxwell Air Force Base, Ala.: Air University Press, 1971.
- Goldstine, Herman H. *The Computer from Pascal to von Neumann*. Princeton, N.J.: Princeton University Press, 1972.
- Goode, Harry H. "Simulation – Its Place in System Design," *Proceedings of the I.R.E.* 39 no. 12 (December 1951): 1501-1506.

- Howe, Robert M. "Analog Computers in Academia and Industry: A history of analog computing at the University of Michigan and the founding of Applied Dynamics International," *IEEE Control Systems Magazine*, June 2005.
- Hughes, Thomas. *Rescuing Prometheus*. New York, NY: Pantheon Books, 1998.
- Huntington, Samuel P. *The Common Defense: Strategic Programs in National Politics*. New York: Columbia University Press, 1961.
- Hurd, Cuthbert C. "Early IBM Computers: Edited Testimony." *Annals of the History of Computing* 3 no.2 (April 1981): 163-182.
- Kaiser, David. *Becoming MIT: Moments of Decision*. Cambridge: The MIT Press, 2010.
- Killian, James. "The Obligations and Ideals of an Institute of Technology." *Technology Review* 51 (May 1949): 429-440. Accessed March 24, 2015.
<https://libraries.mit.edu/archives/exhibits/inaugurations/killian.html>
- Johnson, Stephen B. *The United States Air Force and the Culture of Innovation, 1945-1965*. Washington D.C.: Air Force History and Museums Program, 2002.
- Machol, Robert E. "Harry H. Goode, System Engineer." *Science* 133 no. 3456 (March 1961): 864-866. Accessed March 24, 2015. <http://www.jstor.org/stable/1706532>.
- "President's Report," *Massachusetts Institute of Technology Bulletin* 89 no. 2 (November 1953): 1-306. Accessed March 29, 2015.
<https://libraries.mit.edu/archives/mithistory/presidents-reports/1953.pdf>.
- Redmond, Kent C., and Thomas M. Smith, *From Whirlwind to MITRE: The R&D Story of the SAGE Air Defense Computer*. Cambridge, Mass.: MIT Press, 2000.
- Schaffel, Kenneth. *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense 1945-1960*. Washington, D.C.: Office of Air Force History United States Air Force, 1991.
- Shepley, James R., and Clay Blair, Jr. *The Hydrogen Bomb: The Men, The Menace, The Mechanism*. New York: David McKay Company, Inc., 1954.
- Slayton, Rebecca. "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 (2012): 255-82.

Stern, Nancy (Interviewer) and Cuthbert Hurd (Interviewee). *An Interview with Cuthbert C. Hurd* [Interview transcript]. January, 1981. Accessed from Charles Babbage Institute Center for the History of Information Processing Website.

<http://conservancy.umn.edu/bitstream/handle/11299/107368/oh076cch.pdf?sequence=1&isAllowed=y> .

“The Engineering Research Institute” in *The President's Report for 1951-1952*. Ann Arbor, Michigan: University of Michigan, 1953.

“The SAGE Air Defense System.” Lincoln Laboratory, Massachusetts Institute of Technology.

<https://www.ll.mit.edu/about/History/SAGEairdefensesystem.html>

(accessed April 8, 2015).

“United States Strategic Bombing Survey” in *The United States Strategic Bombing Survey: over all report (European war)*. Washington: U.S. Govt., 1945.

Valley, Jr. George E. "How the SAGE Development Began." *IEEE Annals of the History of Computing* 7, no.3 (July 1985): 196-226.

Watson, Thomas and Peter Petre. *Father, Son & Co.: My life at IBM and beyond*. New York: Bantam Books, 1990.

Wieser, Robert. “From World War II Radar Systems to SAGE.” *The Computer Museum Report* (Spring 1988): 15-16.