COLD WAR INFRASTRUCTURE FOR AIR DEFENSE: THE FIGHTER AND COMMAND MISSIONS

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List of Acronyms

AAF	Army Air Forces
ABM	Antiballistic Missile
ACC	Air Combat Command
AC & W	Aircraft Control and Warning
ADC	Air Defense Command
ADIS	Air Defense Integrated System
ADTAC	Air Defense TAC
AEC	Atomic Energy Commission
AETC	Air Education and Training Command
AFIRO	Air Force Installation Representative Office
AFRC	Air Force Reserve Command
AFSWP	Armed Forces Special Weapons Project
ALCM	Air Launched Cruise Missile
AMC	Air Materiel Command
AMC	Air Mobility Command
ANG	Air National Guard
ARDC	Air Research and Development Command
BESM	*bystrodeistvuiushchaia elektronnaia schetnaia mashina*
BMEWS	Ballistic Missile Early Warning System
BUIC	Backup Interceptor Control
CADS	Continental Air Defense System
CIOS	Combined Intelligence Objectives Subcommittee
CDS	Comprehensive Display System
COC	Command Operations Center
CONAC	Continental Air Command
CONUS	Continental United States
DEW	Distant Early Warning
DoD	Department of Defense
ENIAC	Electrical Numerical Integrator and Calculator
FFAR	Folding-Fin Air-to-Air Rocket
FIS	Fighter-Interceptor Squadron
FIAT	Field Information Agency, Technical
FY	fiscal year
GAR	Guided Air Rockets
HABS	Historic American Building Survey
HAER	Historic American Engineering Record
IBM	International Business Machines
ICBM	Intercontinental Ballistic Missile
IRBM	Intermediate Range Ballistic Missile
JSS	Joint Surveillance System
LOLA	Live Ordinance Loading Areas
MCP	Military Construction Program
MIRV	Multiple Independently Targetable Re-Entry Vehicles
MIT	Massachusetts Institute of Technology
MLC	Military Liaison Committee
NACA	National Advisory Committee for Aeronautics
NACC	NORAD Automated Control Center
NAFTA	North American Free Trade Association
NART	Navy Air Reserve Training

NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCC	NORAD Control Center
NEACP	National Emergency Airborne Command Post
NGB	National Guard Bureau
NORAD	North American Air Defense
NSC	National Security Council
NWS	North Warning System
OTH-B	Over-the-Horizon Backscatter
OTS	Office of Technical Services
PACCS	Post-Attack Command and Control System
PAVE PAWS	Perimeter Acquisition Vehicle Entry Phased-Array Warning System
psf	pounds per square foot
SAC	Strategic Air Command
SAGE	Semi-Automatic Ground Environment
SALT	Strategic Arms Limitations Treaty
SCC	Super Combat Center
SDC	Systems Development Corporation
SDI	Strategic Defense Initiative
SLBM	Submarine-Launched Ballistic Missile
SRAM	Short-Range Attack Missile
START	Strategic Arms Reduction Treaty
SYSNET	System Network
TAC	Tactical Air Command
USACERL	United States Army Corps of Engineers Construction Engineering Research Laboratories
USAF	United States Air Force
VVHB	Very Very Heavy Bomber
WACS	White Alice Communications System
WAI	Weidlinger Associates, Inc.
WSEG	Weapons System Evaluations Group

Introduction

During fiscal year 1998-1999 Air Combat Command (ACC), Headquarters, Langley Air Force Base, sponsored two historic contexts focused on the Cold War bomber, fighter, and command/control missions within Strategic Air Command (SAC), Air Defense Command (ADC), and Tactical Air Command (TAC). The contexts address the history of flightline real property supporting these missions from 1947 to 1991, with an emphasis on buildings and structures of the 1947 to 1963 period. Organized as two companion volumes, *Cold War Infrastructure for Strategic Air Command: the Bomber Mission* and *Cold War Infrastructure for Air Defense: the Fighter and Command Missions*, the contexts substantially complete the inventory and preliminary assessment of Cold War infrastructure undertaken during 1995-1997 across ACC installations. Each context strives to achieve two basic goals and is intended to open discussions between real property managers across the Department of Defense (DoD).

The primary goal of the contexts is to establish a detailed history for categories of SAC, ADC, and TAC Cold War infrastructure. A growing number of individuals who interpret cultural resources within the Air Force, the National Park Service, and State Offices of Historic Preservation have come to believe that historic properties of the recent past are critically important to our nation's heritage. Air Force properties in particular offer a physical landscape through which historians can interpret not just the Cold War, but also modern achievements in structural engineering. Completed studies suggest that certain types of Air Force property, in documented cases, are potentially eligible for the National Register of Historic Places. The contexts seek to support the appropriate general assessments to date, to clarify areas of uncertainty, and to open doors to further research.

Over the past decade the Air Force has reviewed a number of studies assessing Cold War buildings and structures, beginning with work at Vandenberg Air Force Base in Southern California. Under the DoD Legacy Resource Management Program during fiscal years 1993 through 1996, complex and varied projects pulled together information and established benchmark histories for selected Cold War themes within the Air Force. While the resulting repository of reports still requires centralized and comprehensive assessment, much has been done. The Air Force Center for Environmental Excellence at Brooks Air Force Base, San Antonio, is compiling a bibliography of these studies and has partnered with the U.S. Army Corps of Engineers Construction Engineering Research Laboratories in Champaign-Urbana, Illinois, to distribute a newsletter tracking Cold War history projects. Yet, a critical difficulty has remained. Many of the reports are hard to access and predictably most new studies are unable to benefit from the work that precedes them. Often research is focused locally, with a case for National Register significance broadly made. In many instances, the significance argument is weak, tied only to general political history and big moments in the Cold War. Achievement of the historic infrastructure was indeed a *federal* program—usually with buildout across the nation in multiples ranging from about 20 to 60, but was a program with a particularly detailed engineering history. The paired *Cold War Infrastructure* volumes here presented offer readers that history, and supplement the existing regional assessments.

The secondary goal of the contexts is to initiate a dialogue tying the history of relevant Air Force property types to parameters of the National Register of Historic Places—such as character-defining features and integrity. Examples of such property types include the double-cantilever hangar required for maintenance of SAC bombers and the alert hangar manned by ADC and TAC for air defense. Buildings and structures such as these are defined by physical components that illustrate their historic significance, and many of these components are reflective of architectural and engineering details. Issues of National Register integrity for Air Force property relate to the amount of change over time. Not surprisingly, integrity is not as straightforward as it might seem. Integrity is also linked to architectural and engineering detail, and to the types of changes that affect the original character-defining features of the potential historic resource. Some changes do not materially damage integrity; others destroy it. At times, changes can even enhance integrity and strengthen historic significance, when changes occur early in the history of a structure and are really a fine-tuning of original planning and programmatic design.

Finally, the contexts briefly summarize the results of the multi-volume study, *A Systemic Study of Air Combat Command Cold War Material Culture*, completed by ACC in 1997. *Cold War Infrastructure for Strategic Air Command: the Bomber Mission* includes single-page abstracts, by installation, of the existing SAC bomber infrastructure discussed within its illustrated context of eight key property types. *Cold War Infrastructure for Air Defense: the Fighter and Command Missions* includes single-page abstracts, again by installation, of the existing ADC / TAC fighter and command/control infrastructure discussed within its illustrated context of seven key property types. Recommendations conclude both volumes, addressing remaining context and inventory issues across today's ACC installations, as well as considering broader parallel issues across the Air Force and DoD.

Chapter 1: Cold War Events and the Operational Infrastructure of the Air Force

During the more than half-century that unfolded between the closing months of World War II and winding down of the Cold War in 1989-1991, the U.S. War Department evolved into the Department of Defense as it is now understood, with its primary supporting arms of the Army, Navy, Marines, and Air Force, and its reserve forces of the Army, Air Force, and Air National Guards. American military infrastructure is predominantly a phenomenon of the 1939-to-present period, thus precisely paralleling the modern movement in Western European and U.S. architecture and engineering. The years bracketed by 1945 and 1991 also mirror a particular world condition with regards to the development of nuclear weapons. During these decades knowledge within the scientific community emerged exponentially, yet was closely held by the two competing super powers of the U.S. and the Soviet Union into the 1980s. Coupled with strides in physics and mathematics accompanying the shifts from atomic to thermonuclear weaponry, were significant gains in computer capabilities, electronics, and the conquest of near- and far-space—all of which directly supported military activities such as higher order aircraft, radar surveillance, command and control, satellite monitoring, long-range missiles, smart weapons systems, unmanned devices, and general intelligence.

1946-1950

The Army Air Forces (AAF), within the U.S. Army, had become an almost autonomous military arm by the close of World War II. The AAF represented the powerful changes that were coming about as air warfare dominated the strategies and defenses of nations at mid-century. As Air University professor Eugene M. Emme underscored in *The Impact of Air Power*, written for the Office of Civil and Defense Mobilization at the end of the 1950s, "the exploitation of air space [will] be of central importance in helping determine the ultimate fate of civilization," further noting that "[a]ir power must be dispassionately assessed by American professionals and students of military, diplomatic, and scientific affairs alike."[1] To accomplish these comprehensive goals, the War Department channeled significant energies into *air power*, even during times of federal funding cutbacks. Within the air arm of the U.S. military during 1945 through 1947 were more than the emerging technological advances of jets, aerial refueling, and jet-fighter and jet-bomber carried weapons. Also within the AAF, and soon to be Air Force, were the scientists and engineers focused on mastering space through specific surveillance, communications, and weapons systems, and through aeromedical programs determined to place man at ever-higher altitudes under stressed gravitational forces at Mach speeds.

The Germans

The outcome of World War II in Europe, stridently reinforced through the immediate onset of the Cold War, directly assisted both American and Soviet military efforts in the arena of near- and far-space. Both nations heavily removed, captured, and recruited German scientists and engineers between 1945 and 1955.[2] Through Project Overcast, and sequentially Project Paperclip and Project 63, the U.S. government brought over 650 German specialists into the country with their families. During the early post-war years, the Combined Intelligence Objectives Subcommittee (CIOS) kept a card file of the assumed locations of an additional 5,000 German scientists. While the 1945 to 1947 years rightly can be interpreted as chaos-driven, they were also systematic: the Office of Technical Services (OTS) in Washington, D.C., worked through the Field Information Agency, Technical (FIAT) in Germany to sponsor recruiters representing American businesses on over 3,000 field trips. These recruiters gathered industrial information of all kinds, including samples of experimental technology and equipment. The U.S. government microfilmed German scientific records, disseminating these to contractors supporting the military. Other large American intelligence operations involving the German scientific community included Apple Pie, using former German military personnel to assess the state of the Soviet industrial economy; Panhandle, paying former German military intelligence to continue its information gathering on the Soviet Union and the countries within its sphere of influence; Credulity, a continuous tracking of German scientists still desired, but not yet recruited; Echo, a plan to find German scientists dispersed to Eastern Europe; and

Esso, a study to move another 1,500 German scientists and engineers to the U.S. *American Men of Science* listed approximately one-fourth of the German emigrant group of 1945-1952: half of these men had Ph.D.s upon their arrival in the U.S.

While the best known of the German scientific community was Wernher von Braun's group of rocket specialists from Peenemünde—many of whom ended up working for the Army on its missile program at Hunstville—this group was relatively small, under 100 at its height in the late 1950s. Dispersed throughout the Air Force, particularly through the Air Research and Development Command (ARDC), the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA), and sister test installations within the Navy, were over 500 key men. Of note, a percentage of these individuals began leaving the civil service of the Army and Air Force for jobs with American military contracting companies like Bell, Martin, North American Aviation, Convair, Avco, and Raytheon by the late 1950s. The ripple effects of the German scientific-engineering community of World War II are many and subtle. Those who stayed within the U.S. military civil service system often worked at the GS-15 to GS-17 level—the uppermost grade levels within the system. Those who left were behind the scenes in noteworthy places. Convair manufactured the B-36. Bell, Martin, and North American Aviation designed and manufactured important early guided missiles, some planned and tested with special warheads. Avco designed the Atlas intercontinental ballistic missile (ICBM) warhead. Raytheon led the research, testing, and development for the large phased-array radars crucial to the American antiballistic missile (ABM) system and long-range radar surveillance.

Examples include Dr. Ernst A . Steinhoff, Dr. Martin Schilling, and Dr. Bruno Balke, among many. Steinhoff worked for ARDC over the life of his American career. He was both in and out of a direct liaison with the Air Force—running a recruitment effort for Project 63 in the early 1950s, building up the Air Development Center at Holloman Air Force Base through most of the decade; hiring with contractors tied to initial developments at Vandenberg Air Force Base, California; working within the RAND think tank in Santa Monica; taking a visiting professorship at the Massachusetts Institute of Technology in aerophysics; serving as a special assistant and scientific advisor to several key Air Force laboratories; and periodically speaking before the Scientific Advisory Board in Washington, D.C. At Huntsville with von Braun, Dr. Schilling became chief of the project management staff for the Army Guided Missile Agency's research and development division. Raytheon hired Dr. Schilling in 1958. Through 1976, he led the development of the large phased-array radar—retiring in the early stages of the Perimeter Acquisition Vehicle Entry Phased-Array Warning System (PAVE PAWS) project. The American system of large phased-array radars is only currently being completed, with the last radar in the group scheduled for operational status at Clear Air Force Station, Alaska, in 2000.[3] Dr. Balke was a military high-altitude conditioning and human endurance specialist, recruited from Germany in 1950. He worked at the Air Force School of Aviation Medicine in San Antonio, and eventually became chief of the bio-dynamics branch at the Civil Aeromedical Research Institute of the Federal Aviation Administration.[4]

The German brain drain into the American Air Force scientific-engineering community, and into the ranks of the Air Force's civil service and its contractors, is of more than passing consequence. The buildings and structures that made up the overall infrastructure of the Air Force Cold War built environment, excluding those of the supportive cantonments, were a direct outgrowth of the sequentially pioneered aircraft, weapons, and communications / surveillance systems. Design of the physical housing for the large phased-array radar is a case in point: the structure's form almost purely met the system's engineering parameters, and is architectonic rather than architectural. As such, what we see is really the design of Dr. Martin. Of additional interest, the German scientist-engineering group had a counterpart in architecture and engineering during these same decades. German architects and engineers, and German-educated professionals in neighboring Germanic countries (particularly Austria and Czechoslovakia), had steady contact with their American counterparts from about 1910.

During the teens and twenties, architects Antonin Raymond, Rudolph Schindler, and Richard Neutra, and engineers John Kalinka and Anton Tedesko, immigrated to the U.S. Raymond, Schindler and Neutra all hired with Frank Lloyd Wright in Chicago very early in their American careers. Kalinka and Tedesko hired with Roberts & Schaefer, another Chicago firm, while maintaining active connections with the German firm Dykerhoff & Widmann. With the rise of Hitler during the 1930s, the situation quickly became much more complex. A number of internationally prominent architects left Germany for Great Britain, Turkey and South America, and, by late in the decade or early in the 1940s, for the U.S. Those choosing America included Mies van der Rohe, Ludwig Hilberseimer, Walter Peterhans, Eric Mendelsohn, Konrad Wachsmann, Paul Weidlinger, and Walter Gropius, clustering in the Boston-(Harvard)-to-New York – New Jersey (Princeton) corridor and in Chicago (Illinois Institute of Technology). Raymond, Mendelsohn, and Wachsmann worked directly for the War Department in the early 1940s, designing test structures for the Chemical Warfare Service, with assistance from Hilberseimer and from Detroit architect Albert Kahn. Weidlinger and Wachsmann patented an innovative double-cantilever hangar in 1945, and in 1949 Weidlinger formed Weidlinger Associates, a collaborate of engineers based in New York that undertook multiple assignments for the American military specializing in long-span structures, as well as blast-proof and hardened construction. Weidlinger Associates handled numerous airfield assignments, civil and military, including full services for Lajes Air Force Base in the Azores in 1955. The blast-proof specialty encompassed U.S. embassies worldwide; above- and underground command and control, and intelligence, facilities; and research and development military testing centers.[5] Wachsmann would surface again during the early Cold War for hangar design, as a special consultant to the Air Force, not unlike Dr. Steinhoff.[6]

Engineer Anton Tedesko, like Wachsmann, also made key contributions to the design and development of Air Force structures. When Dr. Tedesko came to the U.S. in the middle 1920s, he brought with him a special contractual agreement for the American distribution of the Zeiss-Dywidag [*Dy*kerhoff & *Wid*mann *A.G.*]—or ZD—thin-shell concrete construction system. An early prominent Tedesko example of ZD construction was a building for the World's Fair in Chicago during 1934. By the late 1930s, Tedesko, through the Chicago firm Roberts & Schaefer, was designing hangars, shops, and depot facilities for the U.S. Navy and Army. Tedesko's large-span thin-shell concrete hangar of 1947 for Strategic Air Command (SAC) was among the very first significant Cold War infrastructure designed for the Air Force, and was the largest hangar in the world when erected. Tedesko also later became a special consultant to Air Force headquarters, 1955-1970, as a "troubleshooter [for] decisions leading to innovative solutions for new construction and renovation." Dr. Tedesko, with a Roberts & Schaefer team, designed underground launch control domes for the Air Force ballistic missiles, and for the launch pad and control dome of the Atlas Centaur space vehicle for NASA at Cape Canaveral. In the middle 1960s—nearly 20 years after his hangar for SAC—he designed and engineered the assembly and launch facilities for the Apollo manned lunar landing program. The architectural-engineering work of Konrad Wachsmann and Anton Tedesko, in particular, was strongly tied to the scientific-engineering research and advancements of the Wernher von Braun Peenemünde group.[7]

<u>The Major Commands and First Generation Infrastructure</u>

The Air Force itself was a Cold War phenomenon, created in tandem with the Department of Defense (DoD) (replacing the War Department) and the National Security Council in July 1947 through the National Defense Act. Even the term, Cold War, originated during 1947 as a reaction by journalist Walter Lippmann to "The Sources of Soviet Conduct," an article written by George F. Kennan for *Foreign Affairs* and published the exact month, July, of the birth of the Air Force.[8] The National Security Council (NSC) was the issuer of key Cold War policy statements throughout the 1950s, while the Air Force took on its Cold War mantel across its lead commands. For the latter, the Air Force sustained its structure as set up in March 1946 by the AAF, with three primary commands: SAC, Air Defense Command (ADC), and Tactical Air Command (TAC). In October 1947, formal Air Force structure expanded to include Air Materiel Command (AMC), as well as commands directing the Air University, the Air Proving Ground, training, and geographical jurisdictions worldwide. After 1947 the Air Force added the ARDC.[9] Directly supportive of the AAF, and then the Air Force, was the Air National Guard (ANG). General Carl Spaatz, Chief of Staff of the War Department, who had established SAC, TAC, and

ADC in 1946, had prioritized funding for SAC and TAC. The early Cold War air defense mission fell almost entirely to ANG, and then ADC. Each of the operational Air Force commands had special, pressing needs. AMC and ARDC focused on storage of materiel, and, research, development, testing, and evaluation missions associated with weapons systems and equipment.

On 1 August 1946, President Truman signed into law the Atomic Energy Act, which established civilian control over the research, development and management of what would become nuclear energy. The Congressional controversy of civilian versus military responsibility and oversight was enormous, with Connecticut Senator Brian McMahon and Michigan Senator Arthur H. Vandenberg taking the respective opposite positions. Vandenberg's amendment to the McMahon Bill essentially gave the military veto power over the administrative agency, the Atomic Energy Commission (AEC). A Military Liaison Committee (MLC) channeled the interface between the AEC and DoD at the policy level, while a key new entity, the Armed Forces Special Weapons Project (AFSWP), handled the operational level. Secretary of War Robert Patterson and Secretary of the Navy James V. Forrestal established the AFSWP, effective 31 December 1946. The AFSWP became responsible for the armed forces' development of nuclear energy. The AFSWP took over the management of the Sandia Laboratories in New Mexico, expanding the labs for nuclear weapons production, testing, and engineering of storage facilities. From 1946 into the middle 1950s, the AFSWP built and operated national and operational atomic, and as of 1954, thermonuclear, bomb storage sites in the U.S. and internationally. Known as Q Areas, these weapons depots were special, and supported the strategic bombing mission of General Curtis LeMay's SAC beginning in October 1948.[10]

ADC and ANG

Each command within the new Air Force required infrastructure to sustain its mission.[11] Priorities lay first with SAC, yet initial activities concentrated within ADC and ANG. Military planners assumed that sole possession of the atomic bomb, coupled with a lead in the race for long-range aircraft, allowed for a delay in permanent provisions for air defense. Regardless, radar and fighter-interceptor capabilities were manifest. ANG and ADC cobbled together the defensive mission, 1946-1948, reusing World War II radars and operating command and control, as well as ground observation stations, in makeshift quarters. Available American pursuit aircraft were all propeller-type. AAF airfields had runways only long enough to support the F-47 and the F-51, but lacked the minimum length of 7,000 feet required for jet operation. While the paperwork went forward to activate and expand mothballed installations, the AAF authorized the design and construction of a Cold War alert hangar through the National Guard Bureau (NGB). Conflicts in military jurisdiction, and in the seeking of independent power, encouraged only contradictory relations between the AAF and the NGB, with ANG suffering accordingly. Federal and state interests, too, were at cross purposes over who would fund installation sites, infrastructure, aircraft, manpower, and training. Finally, ADC and NGB did not clearly allocate responsibilities for air defense. As a result, ANG grew on paper, but actual air defense readiness was acknowledged as poor, with facilities suspended in the past.

A single element of air defense did see formalized design in the late 1940s: the radar system and its command and control. Orchestrating the information received from the makeshift radars and ground observers, with the task of sending fighter-interceptor aircraft aloft to check perceived threats or patrol, ADC did recognize the explicit need for electronic control of air space. Again the responsibilities of the AAF/NGB, ADC, and ANG are confused, with an ANG plan for 24 "direction" and 12 "control" centers the first to be put forth, at an Omaha conference, in January 1947. After the AAF transitioned into the Air Force in mid-summer, ADC developed its first formal post-World War II air defense plan, Supremacy, that autumn, with announcement immediately following the Soviet display of its Tu-4 long-range bomber. Approved as the Radar Fence Plan, Supremacy called for a comprehensive radar system with 18 command and control centers in the U.S., Canada, and Greenland. The 1947 Radar Fence Plan received strong impetus for achieving infrastructure with world events of 1948. The Joint Chiefs of Staff estimated that the Soviet Union possessed 200 Tu-4s in February, the month that the Communists took over Czechoslovakia. In March the NSC issued its NSC-7 document, taking a hard anti-Soviet stance. The Air Force immediately undertook air defense war games, and went on its first Cold War alert in the Pacific Northwest and Alaska. In June the Soviets blockaded Berlin, with President Truman sending B-29s to Europe the next month. The world situation continued to deteriorate during 1949, producing two catalytic events: the Soviets conducted their first atomic test on 29 August and in September the Red Army overran the government of China. By mid-October the Air Force had completed formal drawings for ADC's aircraft control and warning (AC&W) radar stations, and, for its first generation of command and control centers, work executed by the Chicago firm of Holabird, Root & Burgee.

SAC

Immediately post-World War II, SAC's bomber inventory housed the B-29 Superfortress, the plane that had dropped atomic bombs over Hiroshima and Nagasaki. In 1946, the Soviets began design of their long-range bomber, the Tu-4, modeled directly on B-29s captured during 1944. The B-29 was SAC's first Cold War aircraft, and even as late as the close of 1948 the Air Force had modified only 60 of the planes to carry the atomic bomb. Its infrastructure, hangars, and ancillaries were reused from World War II facilities, but SAC set out immediately in 1947 to plan for the next generation of bomber, the B-36. The B-29, and its updated version the B-50, was considered a "very heavy bomber," while the upcoming Convair B-36 was typed during its debut as a "very, very heavy bomber." The designations carried over to the needed hangar. The VVHB hangar for SAC was an AAF facility, with the Tedesko thin-shell, concrete hangar widely discussed in engineering journals. The Roberts & Schaefer drawings date to May 1947—predating both the Air Force and the term Cold War by a few months. The Tedesko hangar was under construction during 1948-1949, with the first B-36s accepted into the SAC inventory as of 1948. The immediate predecessor for the VVHB hangar was also a Tedesko thin-shell concrete hangar, at Wright-Patterson Air Force Base in Dayton, Ohio, of 1943-1945. The VVHB hangar of 1947 was a remarkable engineering achievement—no less so for its abrupt replacement by an even larger, expandable, steel double-cantilever hangar of 1951 designed by the Philadelphia firm Kuljian Corporation. SAC would erect the Kuljian hangar worldwide in about 55 multiples between 1951 and 1955, adapting it for the B-36, the B-47, and the B-52.

Clearly key to the unfolding mission of SAC were the AFSWP Q Areas. The classified munitions depots were in design as of 1946 through the engineering firm of Black & Veatch. Sandia Laboratories, moved from Los Alamos adjacent to Kirtland Air Force Base in Albuquerque and quickly known as Sandia Base, maintained overall responsibility for atomic and thermonuclear bomb development, production, and assembly. Actual fabrication operations went in place at several locations in the midwestern U.S., with several electrical and mechanical parts facilities set up in pre-existing aircraft manufacturing plants in Kansas City. Black & Veatch was also a Kansas City firm—and one that became pre-eminently associated with nuclear weapons storage facilities and security systems design for the military from its initial work for the AFSWP forward. The first four Q Areas were all national sites, operated and managed directly by the AEC. Initial completion was in early 1948, with two others ready in 1949. As of 1950, Q Areas would be built immediate to forward-area SAC bases on both coasts and in South Dakota, with still others in construction in French Morocco. These Q Areas, although smaller than the national sites, were alert facilities. The AFSWP built about 20 total Q Areas by the middle 1950s.[12] The Berlin blockade of 1948 had encouraged the AFSWP to push its program, but it was the Soviet detonation of a fission device in 1949 that led to a significant stepping up of nuclear bomb research and atomic bomb stockpiling.

For non-cantonment infrastructure at military airfields, then, the period immediately following the formal close of World War II focused on the transition from the AAF to the Air Force, with the beginnings of base expansion suitable for the new Cold War situation; the integration of the German scientist-engineers and architect-engineers into the design process for Air Force infrastructure, aircraft, missiles and weapons systems, and space flight; the formalization of the operational Air Force missions within SAC, ADC, TAC, and ANG; and, the establishment of a working accord between the AEC and the AFSWP over nuclear weapons development—with the appearance of the first Air Force Cold War infrastructure in the form of atomic bomb storage facilities (1946-1948), a hangar for the B-36 (1947), and air defense command and control centers (1949), and with these first structures all of reinforced concrete design and executed by firms in Kansas City and Chicago.

The 1950s

The decade of the 1950s set the stage for the entire 40-year period to come. Although these 10 years were fluid, characterized by the transition from buildings and structures of World War II; by experimental knowledge of nuclear effects; by the rapid sequential deployment of new fighter and bomber aircraft; by the emerging weapons systems; and by the rise of alert status, new base construction, and heightened world conflicts, they also codified what the Cold War would look like at the Air Force flightline. SAC, ADC, and TAC required new infrastructure, typically with construction overseen by the U.S. Army Corps of Engineers. Plans for air defense and strategic bombing capabilities, as well as for intelligence reconnaissance and surveillance, went forward based on building schemes present in 1946-1950—with some significant additions in the arenas of centralized command and control, and, in sophisticated radar.

Evolution of the Directorate of Civil Engineering

The assignment of engineering design responsibilities within the early Cold War Air Force was a complex and complicated matrix. On the surface of it, responsibilities fell to the U.S. Army Corps of Engineers, with standardized construction of buildings and structures in multiples. In actuality, the transition from the jurisdiction of the Army to that of the Air Force was not particularly smooth, and, for the three years following the July 1947 formal designation of the Air Force, events were confused. In addition, much of the earliest Air Force internal engineering direction came from the Navy's Bureau of Yards and Docks. The first in-house engineering function for the Air Force resided at the Air Staff level, with the use of special consultants from the private engineering sector to review existing infrastructure and provide advice in research and development. Engineers within the Air Force worked with ideas and needs generated by military planners, as well as with the suggestions (and sometimes designs) provided by the special consultants. Then Air Force engineering provided design parameters to private-sector engineering firms—through the Army Corps of Engineers. The base architectural and engineering designs for the Air Force were all the work of individual engineering firms before about 1959.

After finalizing designs, and often after aborted efforts, the Air Force then authorized the standard design—typically also superceding it with a revised version at a later date. The task of revision almost always fell to a different engineering firm that than responsible for the base design and specifications, with that firm's name replacing the originating firm's name in the title block on the drawings. And, when structures were needed in multiples—as they usually were—the regional Army Corps of Engineers office often overlaid its name in the title block, or allowed the local architectural-engineering firm that adapted the drawings to the job site to do the same. Both procedures further obscured the ability to trace the actual engineering designer. By the close of the decade, the Air Force issued manuals of standardized designs, with no hint of the true design and engineering process present. When one remembers that there typically was a private-sector engineering firm responsible for the base design, and that within that firm there was a single lead engineer responsible for the specific project, it becomes very unusual to truly know who should be credited with design. In some cases, knowing the special consultant to the Air Force is the important information. On other occasions knowing the private-sector firm is enough. And at times, the lead project engineer within the responsible firm is the individual who needs to be uncovered.

The evolution toward the Air Force Directorate of Civil Engineering and standardized design began formally in March 1942, when a War Department circular made the Army Air Forces equal in status to the Army Ground and Supply Forces. In mid-1944, the AAF civil engineering function became organized as the Air Installations Division. At the close of World War II, the responsibilities of what were titled Air Engineer Offices directly conflicted with the duties of the Army Corps of Engineers.

When the Air Force became an autonomous military branch in July 1947, its founding legislation prescribed the staggered transfer of engineering and real property management from the Army to the Air Force. Real property did not fully transfer until June 1948, and in July the Air Force took over "all functions, powers and duties relative to construction, but prescribed that [it] was to utilize the services of the Army for contract construction." Specifically the Air Force – Army engineering arrangement broke down as assigning to the Air Force the responsibility for all preliminary plans and specifications, and to the Army (effectively, the Army Corps of Engineers) "contract construction"—getting the Air Force preliminary plans to a private-sector engineering firm for final execution.[13] In addition to the Army Corps of Engineers, the Navy Bureau of Yards and Docks also acted as a construction management agency for the Air Force.[14] Key in this process, of course, was the level of preliminary design.

After the three-year transition period from the Army to the Air Force, in 1950, the Air Force civil engineering function grew larger and more formal, redesignated the Directorate of Installations, and during the next year the Air Force liaison offices within the Army Corps of Engineers were formalized as Air Force Installations Representative Offices. The Air Force elevated its Directorate of Installations to the Assistant Chief of Staff level to facilitate Cold War base expansion in 1954. The Army Corps of Engineers continued to carry out contract construction. By the mid-decade the reliance on special consultant engineers for key program advice was ending, but the need for another type of advice was just coming into its own—that for missile ground support facilities. The Air Force itself commented in 1962 that "[i]t had become evident that the designer of the missile ground environment had to work in an integrated fashion with the designer of the missile."[15] In March 1959, the Directorate of Installations changed names to the Directorate of Civil Engineering. Throughout the 1950s, the engineering staff of the Directorate had grown, with deputy directors assigned the tasks of site selection; installation master planning; real property design, engineering, and construction management; development and preparation of engineering manuals, criteria, plans, and specifications; and, repairs.[16]

Achieving Standardized Design

A primary, early Cold War goal of the Directorate of Installations, and subsequently of Civil Engineering, was putting in place a definitive system for the design and construction of Air Force infrastructure. Making the transition from the AAF, the Air Force inherited at least one key design from the Army, that of the VVHB hangar of 1947. The Air Force initially attempted to rely on the engineers who had designed for the Army and the Navy during World War II. To piece this together requires looking at the available card index retained by the Headquarters, Army Corps of Engineers—an index system that was set up within the Construction Division of the Air Force Directorate of Installations after June 1952, but which is no longer fully extant.[17] A good example is the Washington, D.C., engineering firm of Mills & Petticord. Records show that Mills & Petticord designed a group of lean-to hangars for the NGB of the Army during 1948 and 1949, and that at the outset of the 1950s they handled at least the design for an ADC readiness hangar, nose docks for the B-29 and B-50, an unbuilt version of an ADC alert hangar, and two versions of the steel double-cantilever B-36 hangar that predate that hangar's assignment to Kuljian Corporation. For the two key structures in this group—the ADC alert hangar and the SAC double-cantilever hangar—other firms replaced Mills & Petticord to become the final selected firms for the needed Cold War design, a clear indication that a forward-looking vision that addressed engineering and military design problems in a new way was paramount.[18]

In early 1953, the Directorate of Installations commented that the agency lacked good design documentation, and that it had "duplicate sets of records" and "inconsistent and conflicting information." The solution was the development of design and engineering manuals for Air Force real property, then in the planning stages. The manual program, which had been approved in September 1952, featured 16 projected manuals outlining standards and criteria for Air Force construction. Air Force Manual 88-2 was planned for architectural, structural, and communication design.[19] Later in the year progress for the manual program included Air Force Manuals 88-5, 88-6, and 88-7, treating grading and drainage; runways, road, and parking areas; and, railroad trackage.[20] In 1954, the Directorate of Installations made rare mention of two of its special consultants of the first part of the decade, Konrad Wachsmann and Peter Kiewit. Kiewit reported directly to the Under Secretary of the Air Force, and was assigned the task of analyzing "procedures and methods of Air Force construction," thereafter making recommendations. Wachsmann had served as special consultant for hangar design.[21] Kiewit Construction, in Omaha, specialized in mining and underground construction, with expertise focused in concrete construction. During 1954, 1955, and 1956 the Directorate of Installations made concerted moves to achieve standardized drawings, taking the drawings that existed and contracting for "definitives." For these, the Air Force issued contracts to firms like Daniel, Mann, Johnson & Mendenhall (Los Angeles); Giffels & Vallet (Detroit); and, John H. Graham & Associates (Washington, D.C.).[22] The manuals and the definitives essentially completed the process of standardization.

Prefabricated Structures, the Steel Industry, and Mobilization

The early 1950s also witnessed the continuation of the mobilization tradition that had been effective during World War II.[23] To achieve infrastructure quickly, the AAF had employed prefabricated buildings and structures that could be shipped as standardized parts anywhere in the world and bolted together on site. The AAF often employed this type of construction for combat aircraft hangars. Companies manufacturing prefabricated steel buildings for the Army included the Butler Manufacturing (Kansas City), Luria Engineering (New York and Bethlehem, Pennsylvania), the Armco Drainage and Metal Products (Middletown, Ohio), the Detroit Steel Products Company (Detroit), and, the International Steel (Evansville, Indiana).[24] Of this group, Butler, Luria, Detroit Steel Products and International Steel all had very strong roles in early Cold War construction for the Air Force—particularly for ADC and SAC. Butler manufactured at least one of the four alert hangar types for supporting the air defense mission. Luria handled another of the alert hangars; the first ADC readiness and maintenance hangars (supporting the alert hangar), and, the first standardized wing docks for SAC bombers—all in 1951 and 1952. For the ADC alert hangars, including the final buildout design by Strobel & Salzman, the situation was particularly complicated: one of the Butler hangars featured two generations of clam-shell door that were separately manufactured by another company, McKee Door, and by Luria. The Strobel & Salzman hangar had two unbraced canopy doors, of gravity and non-gravity types, that were also manufactured by two different companies, Continental and International Steel.[25] Butler and International Steel continued to provide prefabricated structures and structure components to the Air Force at least into the early 1960s.

The role of the steel industry was itself of note. One company, Detroit Steel Products, made Fenestra metal building panels. Buildings sheathed in these panels were cost effective and very quick to erect. SAC chose Fenestra-panel buildings for its first Cold War airmen barracks of 1951 at Offutt and Ellsworth Air Force Bases in Nebraska and South Dakota. Dedicated by Curtis LeMay himself, the sets of two barracks at each base were a deliberate tribute to both economy and modernism, with those at SAC's Offutt headquarters named Ellsworth and Loring Halls to reference the connected importance of SAC bases.[26] Another company, Bethlehem Steel, had advertised manufacturing 4,400 tons of steelwork for 80 portable hangars in *Engineering News-Record* in early 1945—for the AAF and likely through Luria, whose plant was in Bethlehem, Pennsylvania. Bethlehem described these hangars as "demountable" with "interchangeable" sections. The task of this period of World War II was to continue sweeping toward a victory: "Now the job is to provide a hangar for the big bombers [B-29s], and do it in the shortest possible time." The process would also be attractive during the Cold War mobilization of 1951, heightened by U.S. entry into war with Korea.

> Skids are hauled up, containing bundles of steel sections, bolts, and wrenches. The members, each light enough to be handled by one or two men, are bolted together to form three-hinged arches, 39 feet high and about 148 feet across.

> Gin poles set up the arches, and connect them together with sway frames and purlins. Steel sheets serve as roof covering and tarpaulins as end walls.[27]

And yet a third company, Pacific Iron and Steel of Los Angeles, was responsible for a transitional, variant double-cantilever B-36 hangar built, at most, only twice—once at Kirtland Air Force Base in New Mexico, and likely a second time in French Morocco—both instances in 1951 and both connected to strategic locations critically associated with atomic bomb storage.[28] The three steel companies, Detroit, Bethlehem, and Pacific, covered the U.S. coast to coast.

Other major conditions of the early 1950s supported the initial turn to prefabricated steel structures. First, and foremost, was the need for speed due to the onset of the Korean War in June 1950 (and its escalation with the entry of Communist Chinese troops in November)—compounded through the beginnings of a true nuclear arms race, with President Truman ordering the development of the hydrogen bomb in January 1950 and authorizing an expansion of atomic bomb stockpiling in October. Additional conditions, though, were equally favorable toward steel mobilization construction: cement shortages affecting reinforced concrete construction from 1947 into 1957 (directly counterpointed by the resurgence in the availability of steel following shortages in the industry due to military construction);[29] military funding priorities for aircraft and weapons systems; and the sheer fluidity of strategic and tactical planning—where the new installations were thought to be most crucial. The Detroit Steel Products Company's Fenestra panels, used by SAC for its premier airmen dormitories, were also specifically engineered for "earthquake, wind and bomb-resistance" as a part of non-self-framing buildings.[30]

The Major Commands and Second Generation Infrastructure

The Air Force added significant infrastructure to its Cold War real property during the 1950s, ranging from complete modification of existing World War II bases to the construction of entirely new installations—the latter especially noteworthy across the northernmost tier of the U.S. Expansion of the built environment mirrored strategic and tactical needs generally, and progressively improved jet aircraft; weapons technologies, storage, and security; and, communications and surveillance systems.[31]

ADC and TAC

Immediately following the initial Soviet fission device test and emergence of a Red China in late 1949, and the crossing of the North Korean military into South Korea on 25 June 1950, ADC began to address its lack of infrastructure seriously. The command began to construct the Holabird Root & Burgee designs for the 85 AC&W radar stations and their accompanying command and control. One of the first of the initial command and control stations—monitoring one of the 11 continental U.S. air defense regions—was that at McChord Air Force Base, near Tacoma-Seattle, Washington, under construction as of 1951. During 1954 and 1955, ADC expanded this first command and control system to 16 stations, continuing to use the 1949 Holabird Root & Burgee drawings. The American air defense system of the 1950s was tiered: numerous radar stations tracked the skies, supported by a civilian ground observer corps who scanned for low-flying bombers with binoculars and manned telephones in Operation Skywatch. The first completed permanent radar stations of late 1952 still had the coverage problems associated with the World War II heavy radar equipment reused in the Lashup network of the late 1940s. After 1953, low-altitude stations, gap-fillers, surveyed the 5,000-to-200-foot range, and as the decade progressed the air defense shield came to include northern early-warning systems: the Pinetree Line, the Mid-Canada (McGill) Line, the Distant Early Warning (DEW) Line, and the White Alice Communications System (WACS). The radar network became even more comprehensive with Navy radar picket ships, manned Atlantic Ocean stations (the Texas Towers), and early-warning patrol aircraft (the EC-121 Warning Star). At the command and control stations, ADC personnel mapped the reports and maintained the ability to authorize fighter aircraft at regional Air Force bases to check out, intercept, or escort what were interpreted as Soviet bombers.

Directly complementing the ADC radar, and command and control, network were the alert hangars for the fighter aircraft, with distinctive alert aprons. ADC alert hangars were an extremely interesting phenomenon. Initial construction was in early 1951, with two main types going in place simultaneously—a Butler mobilization type four-pocket hangar and a permanent four-pocket hangar designed by the New York architectural-engineering firm Strobel & Salzman. The gable-roofed Butler building, with a distinctive clam-shell door, harkens back to World War II Butler hangar designs. The flat-roofed Strobel & Salzman building represents an entirely new approach. ADC introduced a second generation, substantially enlarged alert hangar in 1956-1957 to accommodate the longer and taller fighter jets, also modifying both the Butler and the Strobel & Salzman first generation hangars. The successive new fighter jets also required runway lengthening throughout the decade, from the initial 5,000-to-7,000-foot runways in 1951 to 8,000, 9,000, 11,000, and 13,000 feet by 1957. In rare cases, ADC supported a double-squadron, eight-pocket alert hangar at an installation, of both the Butler and Strobel & Salzman types. Clusters of support structures accompanying the ADC alert hangar at the flightline included readiness and maintenance hangars (three successive generations, 1951, 1953, and 1956); ready shelters (1956); munitions storage, checkout, and assembly structures (three types, 1951, 1954, 1956-1958); a readiness crew dormitory; squadron operations; and a flight simulator. Two other prefabricated steel alert hangars supported the air defense mission at a few locations in the U.S. and overseas.

The 1950s Cold War evolution towards advanced delivery systems for both tactical and strategic weapons, with an emphasis on radar surveillance and standing alerts for air defense, focused on increasingly sophisticated command and control. Immediately following World War II, scientists working in university laboratories were aware that accurate data handling was at the threshold of change. Scientists understood that computer technology could support radar and other communications, interpreting, processing, and disseminating information with new speed. University-based air defense computer research at the Massachusetts Institute of Technology, the University of Illinois, and the University of Michigan from 1950 through 1953 led to a computerized air defense network, the semi-automatic ground environment (SAGE). Although SAGE had been planned as the brains of an air defense web protecting against both bombers and ICBMs, only aircraft detection was possible as-built. Costs were horrific and ADC downscaled the project several times as construction went forward. International Business Machines (IBM) manufactured the computer system for SAGE. The Air Force abandoned its initial ideas to adapt the Holabird Root & Burgee command and control network directly for SAGE: the computer equipment was too just large, and required extensive refrigeration for its operation.

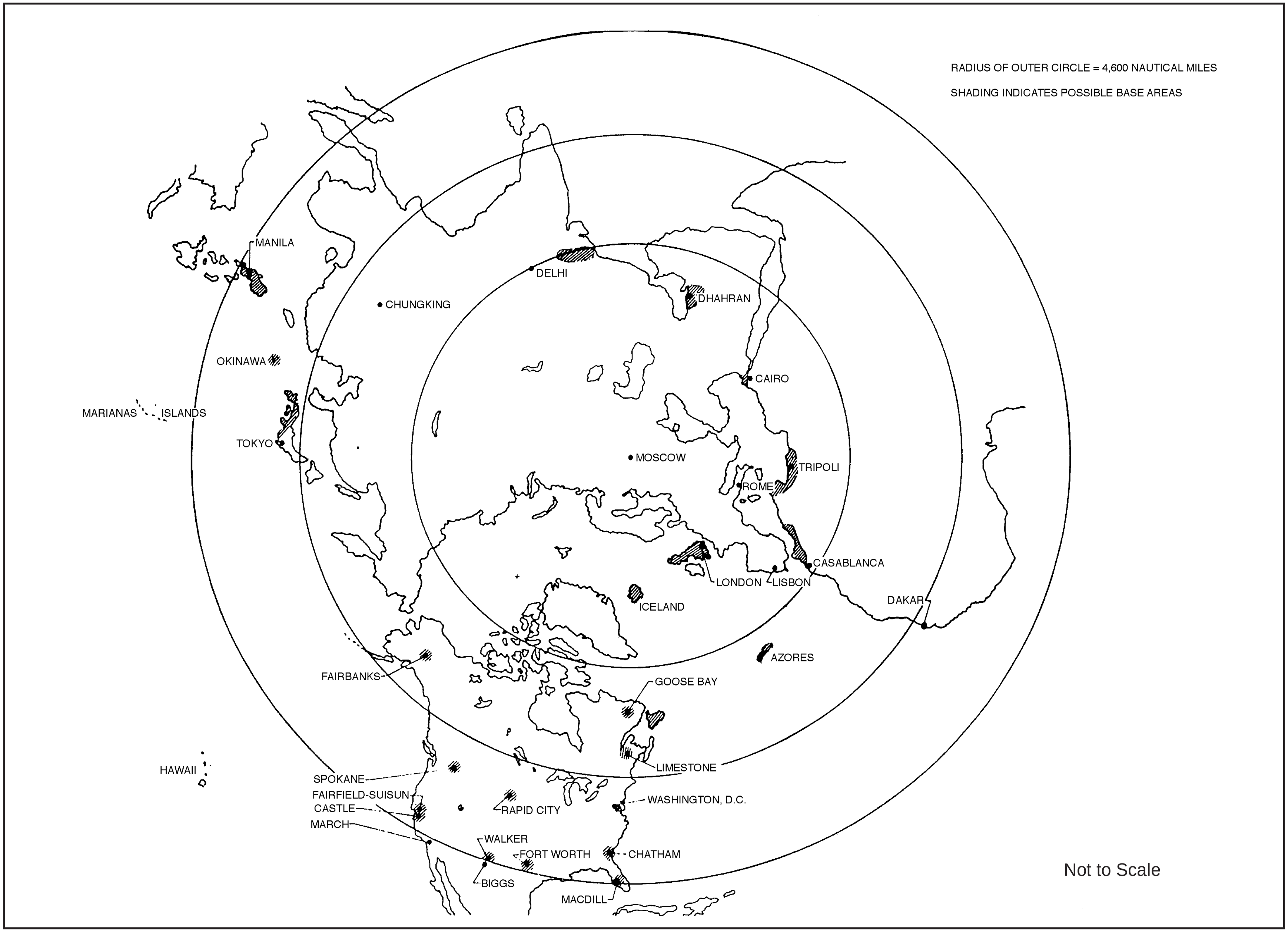
Tiered to Western Electric, the architectural-engineering firm Burns & Roe of New York designed the infrastructure for combat and direction centers, and for accompanying power stations. SAGE allowed a four-fold increase in considered air defense scenarios, and in aircraft-weapons deployment—making it possible and desirable to shift the air battle to the wing level. ADC put 23 direction centers in place at the subsector level, leaving the task of higher decisions for only three locations in the west (McChord Air Force Base), in mid-America (Truax Air Force Base, Madison, Wisconsin), and in the east (Syracuse Air Force Base, New York). The three combat centers were combined at installations also sustaining direction centers, and sometimes at installations having the first generation manual command and control centers designed in 1949. SAGE direction and combat centers represented a maturation of the earlier AC&W system. The SAGE direction center at McGuire Air Force Base in New Jersey was the first of the network to be operational, in mid-1958. The remainder of the command and control web was complete in early 1960.

Changes in the projected methods of Soviet attack, due to the probability of a shift to reliable ICBMs by the early 1960s, nearly eclipsed the sophistication of SAGE. During 1959 the Joint Chiefs of Staff authorized true hardening of the North American Air Defense (NORAD) Command Operations Center (COC) then at Ent Air Force Base in Colorado, with new facilities constructed at Cheyenne Mountain, outside Colorado Springs (although construction remained uncompleted until 1966). In an attempt to harden the critically exposed SAGE direction centers, and the three finished SAGE combat centers, ADC briefly planned for 10 Super Combat Centers (SCCs). ADC planned the SCCs as below ground structures, with smaller, upgraded computers. Outpaced by the evolving world situation, ADC cancelled the SCC program. Throughout the 1950s, the numbers and jurisdiction of both the air defense regions and the supportive fighter-interceptor squadrons changed continuously. Increased emphasis focused on planning for long-range, early warning surveillance radars after the Soviet launching of Sputnik in 1957. The Ballistic Missile Early Warning System (BMEWS) began construction in 1958 at Clear, Alaska; Thule, Greenland; and, Fylingdales Moor, Great Britain. From this point onward, early warning radars were intimately linked with ballistic missile defense and were the bedrock infrastructure, along with the advancing ICBM systems themselves, for what can be described as the second half of the Cold War.

SAC

At the outset of the 1950s, SAC was only at the threshold of its Cold War buildup. Curtis LeMay, then Lieutenant General, took over the command in late 1948, moving SAC headquarters from near Washington, D.C., at Andrews Air Force Base, to Offutt near Omaha. LeMay interpreted Offutt Air Force Base, in the central U.S., as a more protected location than one near the nation's capitol. SAC's first bombers were primarily World War II B-29s, with the B-50 and B-36 arriving in the SAC inventory during 1948 and 1949. In 1950 SAC had about 1,000 total aircraft—a figure that would triple by 1959, paralleling an increase in personnel strength from 85,000 to 262,000.[32] As was true for ADC, SAC received the funding it required for expansion directly due to the outbreak of the Korean War and to the heightened arms race with the Soviet Union, although SAC was well on its way in the late 1940s. In the design and engineering of its infrastructure, SAC, even more than ADC, responded to the shifting dynamics of planning for a possible war. As of about 1951, SAC organized its future bases in concentric rings focused on distances from Moscow and with the outermost ring 4,600 nautical miles from the symbolic target (Map 1).[33] SAC's first key bases were those across the West, Southwest, lower Midwest, and South. Yet even as these bases geared up, SAC's strategy changed. Installations sited and built from scratch were underway across the upper tier of states just below the Canadian border, and heavily concentrated in New England, with other pre-existing AAF locations completely modernized. "Bombers taking off from New England instead of New Mexico, for instance, could reach their targets more quickly and with fewer refuelings or stops, since they would be closer to begin with."[34] Installations with unobstructed runways of 12,000 to 13,000 feet, whose pavement was the outcome of significant experimentation for the weight of the very heavy B-36, and soon the B-52 and the KC-135 tanker, became the centerpieces of the command.

Simultaneously, SAC established itself as a global military arm. The Air Force inherited World War II overseas bases from the AAF in Asia, Alaska, Newfoundland, Germany, Great Britain, Bermuda, the Azores, Libya and Saudi Arabia. At certain of these locations, SAC built up a Cold War presence. Yet key to its plans for strategic second strike capabilities, SAC needed significant new sites. With planning underway in 1948, SAC focused on North Africa—specifically French Morocco—for a large presence of men, rotating aircraft, training, and nuclear weapons depots. Morocco installations went in at the four locations of Nouasseur, Sidi Slimane, Benguerir, and Boulhaut (with a fifth intended at El Djema Sahim). By mid-decade SAC had accompanying refueling bases, supported by a huge oil pipeline project with fuel tank farms, in progress in lower Spain at Torrejon, Zaragoza, and Moron. Morocco, in particular, is important due to construction there during the transitional years of 1951-1953. Immediately following the work in Morocco, SAC undertook bases in Newfoundland, Labrador, and Greenland, with those at Thule and Goose Bay significant for their role not just for SAC, but also for ADC.[35] Early in the 1950s, SAC developed a reflex operation between its southern bases and Morocco, with B-36 and B-47 wings rotating to North Africa for extended temporary duty. During the middle and late 1950s, SAC adopted a dispersal program—spreading out its potential as a Soviet target by placing its aircraft, weapons, and personnel on many more bases, with each bombardment wing having two additional installations to which it could disperse.[36]



Map 1. **Future Strategic Air Command Bases, 1951.**
Reproduced from *History of the AMC Supply Support of the Strategic Air Command 1946-1952.*

Initial SAC infrastructure of the 1950s included the buildout of the 1946-1948 planned nuclear munitions depots, the Q Areas; construction of the thin-shell, concrete B-36 hangars designed by Anton Tedesko in 1947 (at Loring and Ellsworth Air Force Bases in Maine and South Dakota) with plans for large-scale construction SAC-wide; runway construction for the heavy bombers; and use of prefabricated steel structures for nose and wing docks, and, for airmen dormitories. SAC set up its first headquarters at Offutt during 1948 in a small, three-story brick administrative building designed by Albert Kahn in 1941. Of passing symbolic note, the building appears to be the visual model for the thick-walled, reinforced concrete, faux-office structure built at the Q Areas to store nuclear detonator pits. By late 1951, SAC moved on to a new program of expansive infrastructure. At this time, SAC took on a large building program for the final selected heavy bomber maintenance hangar. A steel, double-cantilever hangar designed by Kuljian, the structure was expansible to accommodate up to six B-36s at once. The 1947 hangar was not expansible, and could only accommodate two bombers. Added to this were the cement shortages and the substantial overruns in time and cost for the thin-shell, concrete B-36 hangars. A single double-cantilever hangar, expanded to its largest configuration, replaced nine planned concrete hangars at Loring in 1952—with the two hangars adjacent to one another on the flightline, illustrating the rapidly shifting dynamics of SAC infrastructure within the 1947 to 1952 period.[37]

President Truman authorized American development of a hydrogen bomb—a thermonuclear nuclear weapon—in January 1950, and by October, a concerted expansion of U.S. nuclear weapon production. The events of 1949 to 1951 directly contributed to the stockpiling efforts of the AFSWP. By 1951 the American stockpile had reached 438 bombs; by 1952, 832 bombs; by 1953, 1,161 bombs. The Air Force also began actively developing long-range nuclear missiles through its military contractors. In October and November of 1952, after the election of Dwight D. Eisenhower as President, two more events escalated the arms race: the British detonated their first atomic bomb, and the U.S. its initial hydrogen fusion device. The Soviet Union simultaneously progressed on its advanced computer program, the *bystrodeistvuiushchaia elektronnaia schetnaia mashina* (BESM) [high-speed electronic calculating machine], approaching U.S. computer work of the late 1940s. In 1953, Joseph Stalin died and Nikita Khrushchev ascended to power, while the Soviet Union detonated its first hydrogen test device in August that same year. During 1954, the situation became extremely tense. In September, 44,000 Soviet troops participated in a live nuclear wargames exercise, conducting battle through radiation zones and at ground zero after a Tu-4 dropped a medium-yield atomic bomb in the South Urals Military District. Chinese and Soviet military leaders observed the wargames together, filming the exercise and developing new field manuals.[38] Important U.S. policy statements of 1953 and 1954, the NSC-162/2 and the Killian Report, advised toward the capability for massive retaliation in a nuclear war, but posed the probability that deterrence was the logical choice—with limited nuclear exchange.[39]

During 1954-1956, SAC significantly enhanced its installation infrastructure in reaction to the changing world dynamic. SAC initiated construction of an underground, hardened command center at its Offutt headquarters in 1954, with completion in 1956. Simultaneously SAC called its first bomber alerts, with a rapidly evolving reconfiguration of its bomber aprons from large rectangular parking areas to grouped clusters of parked aircraft to a formal alert pattern by 1957. Specific nose docks for the B-47 mirrored the sweptback wings of the bomber itself, with nose docks sometimes moved from one installation to another to accommodate strategic planning. By 1956 SAC alerts were 24-hour, with precise requirements for ever-faster takeoffs dependent on the type of scenario in test. Formalized alert aprons went in at the first bases before 1957, with a 45-degree entry runway, and with individual aircraft parking pads at right angles to the stub. Almost as soon as construction was in progress, however, SAC changed to a double-angled configuration with parked aircraft themselves at a 45-degree angle to the stub. The final configuration, dubbed a herringbone or Christmas tree, first used house trailers for alert crew quarters next to the individual bombers on alert. The alert areas went in at 65 SAC installations nationwide during 1956 to 1960, with a partially below ground, reinforced concrete alert quarters for the pilots built at each apron. The alert quarters, called moleholes, were in effect partially hardened, and not surprisingly were designed by the same Omaha architectural-engineering firm responsible for SAC's underground command center of this same period, Leo A. Daly. With dispersal, SAC made some of its alert aprons bomber-only and some tanker. By the early 1960s bombers and tankers were sometimes on alert at a single installation—with tanker pens in addition to the Christmas tree configuration and with house trailers again brought to the tarmac.

SAC's infrastructure was symbolic as well as functional. From the large program for the double-cantilever maintenance hangars of 1951-1955, to the Christmas trees and moleholes, to its underground command and control center and the simultaneously expanding ICBM program, SAC made its presence visible and known. Unlike ADC and TAC, SAC also told the world—certainly the Soviet Union—about itself. Three times Hollywood made SAC and Curtis LeMay the subject of widely popular films. In 1954, *Strategic Air Command*, with actor James Stewart, showcased the B-36 and the B-47. In 1962, *A Gathering of Eagles*, starring actor Rock Hudson, depicted SAC alerts, using the molehole and alert apron at Beale Air Force Base in Northern California. And in 1964, director Stanley Kubrick made *Dr. Strangelove*, based on a SAC-gone-awry portrait in a British novel titled *Red Alert* (of 1958). Even the popular writer Tom Clancy would comment in *The Sum of All Fears* of 1991 that SAC's second generation underground command center at Offutt Air Force Base—also designed by Leo A. Daly, in 1984-1989—was commissioned not to replace an obsolete 30-year old center of the middle 1950s, but because SAC needed to match the imagery of Hollywood.[40] While not really the case, the Cold War buildings and structures of 1950s SAC did in fact project a powerful picture.

After 1960

During the later 1950s and into the 1960s the dynamics of the Cold War altered dramatically with the advent of deployable ICBMs. As these unmanned nuclear weapons became more reliable, of greater range, and smaller, military planning evolved accordingly. SAC activated the first Thor intermediate range ballistic missiles (IRBMs) and Atlas ICBMs at Vandenberg Air Force Base in Southern California in 1958. The next year, SAC undertook Project Big Star, planning rail-mobile deployment for the Minuteman I ICBM, then still in research and testing. Each of the IRBM and ICBM programs required large-scale infrastructure, with ancillary support, particularly checkout and assembly buildings. First emplacements of Atlas and Titan ICBMs governed dynamics into the middle 1960s, followed by emplacements of the Minuteman I series. Command and control facilities for squadrons of missile silos were hardened underground and manned. Following the Cuban missile crisis in October 1962, the Post-Attack Command and Control System (PACCS) augmented the SAC Looking Glass airborne command and control unit at Offutt Air Force Base that had been initiated in 1960. A National Emergency Airborne Command Post (NEACP) also went in place at Andrews Air Force Base near Washington, D.C., and SAC dispersed three support squadrons to Westover (Massachusetts), Barksdale (Louisiana), and March (California). PACCS used modified KC-135s capable of carrying personnel, cargo, and intelligence platforms.

By 1965, the Air Force assumed that a Soviet first strike would be ICBM in character, but would be followed by a second bomber strike, and would require a combined bomber and ICBM retaliation. To accommodate improved computerized command and control, ADC built the Backup Interceptor Control (BUIC) system, physically adapting selected Holabird Root & Burgee AC&W radar stations for this purpose. Like SAGE, BUIC came on in stages. BUIC I was manual, operational in 1962-1963 at 27 former AC&W radar sites. By 1966, when the 14 BUIC IIs were all on line, including a training facility, only 13 SAGE complexes remained active. SAGE was further reduced to only six installations by 1970. The SAGE/BUIC facilities continued to monitor aircraft approaches, and were never ICBM early warning sources. In 1966 also, the Soviet Union deployed an ABM system protecting Moscow, and nuclear fears escalated further. The U.S. followed with announcements of its development of multiple independently targetable re-entry vehicles (MIRVs) designed to overpower the Soviet ABM system, and with the emplacement of the Minuteman II series. In 1969, the U.S. deployed American ABM and large phased-array radar technologies—in development since the late 1950s—as the Safeguard Site in North Dakota and as the AN/FPS-85 radar at Eglin Air Force Base in Florida, the latter in development since 1962.

Realistic defense in a nuclear attack, however, was assumed to be minimal, and accordingly, emphasis shifted away from tactical forces. At the close of the 1960s, the combined ADC, TAC and ANG fighter-interceptor squadrons totaled 33, only two squadrons more than had been marshaled for air defense in 1946, and nearly four times fewer than those available in the middle 1950s. At this same time, SAC maintained 100 percent of its missiles on alert, combined with 40 percent of its bombers. The SAGE shield, in 1970, operated at 25 percent of its original physical locations.

While the period beginning in the late 1960s continued an emphasis on strategic nuclear warfare capabilities to the further deterioration of air defense, it also seriously brought Americans and Soviets to the table for weapons discussion. In 1968, the Strategic Arms Limitation Treaties (SALT) I and II, with their agreements and amendments, set numerical limitations on nuclear weapons, addressed deployment of ABM systems, and restricted development of new weapons technologies. New nuclear missiles included the Tomahawk Cruise, launched from SAC B-52 bombers and from Navy submarines, and the MX-Peacekeeper missiles, designed to destroy silo-hardened missiles. The addition of the short-range attack missile (SRAM) of the 1972-1974 years stimulated major renovation and additions at selected SAC Christmas tree alert aprons of the late 1950s, as did deployment of air-launched cruise missiles (ALCMs) during the Reagan administration of the middle 1980s. During the 1970s ADC largely deactivated air defense systems developed in the 1950s and early 1960s, greatly reducing all radar squadrons and eliminating the offshore radar outposts, antiaircraft emplacements, the ground observer corps, and the early-warning aircraft. ADC, known as Aerospace Defense Command after 1967, lost interceptor squadrons, bases, and personnel to TAC, and by 1979 was no longer a major Air Force command. TAC did add substantial flightline infrastructure during the 1963 to 1980 period at installations where it was a major presence. These structures were all prefabricated steel in type, with most designs originating before 1970 and dependent on repetitive, multi-bay units. In 1972, the U.S. and the Soviet Union signed the Antiballistic Missile (ABM) Treaty banning further territorial defense against ICBMs, in theory making both nations equally vulnerable should attack and counter-attack occur. By 1974, tactical planning focused on surveillance and warning, not defense against manned attack. In late 1975, the single American ABM site, permitted by an attached protocol to the ABM Treaty of the year before, became operational, yet was deactivated after only two months. Nonetheless, the U.S. continued work on large phased-array radars, including the in-progress Cobra Dane on Shemya Island in the Aleutians of 1971-1974.

The 1980s brought the Cold War to its final stages, with major advances in planning, with conclusive treaties, and with dual-nation financial exhaustion. During 1975 to 1980, the Air Force planned and built two large phased-array radars for PAVE PAWS in Massachusetts and California, adding to this surveillance and warning system for submarine-launched ballistic missiles (SLBMs) again during the Reagan buildup of 1983-1988 in Texas and Georgia. These very large radars, coupled with a component of the Safeguard Site in North Dakota and the Eglin and Shemya radars, gave the U.S. a system of seven large phased-array radars. In January 1984 the six remaining SAGE facilities were deactivated. Simultaneously the Air Force upgraded the web of about 65 long- and short-range radars of the DEW Line, making them considerably more sophisticated. Renamed the North Warning System (NWS), the revamped DEW Line included some physical site changes. Another group of upgraded radars collated from the remnants of the original Supremacy Plan and the Pinetree Line, and numbering about 60, continued its role as an active radar fence. The Joint Surveillance System (JSS) took over post-SAGE command and control at seven American and two Canadian locations. In the late 1980s, another air defense system, the Over-the-Horizon Backscatter (OTH-B), added yet another very large radar for early missile attack warning.

After 1983 the American military began work on the Strategic Defense Initiative (SDI), a space-based plan for an ultimate ABM system. The Air Force deployed the MX missile as the Peacekeeper in mid-decade, shortly following the Soviet deployment of its parallel SS-24. Reagan's SDI, as well as the expansion of the PAVE PAWS program, stimulated Soviet arms escalation—inclusive of its own system of large phased-array radars. Both the MX and the SS-24 featured MIRVs, with 10 warheads on each missile. In 1986 the Soviet SS-24 was rail-mobile. Construction for the American Rail Garrison deployment immediately followed, occupying the Air Force during 1987 into 1990, returning to the 1959-1960 ideas of Project Big Star for Minuteman I. During the middle 1980s, also, SAC's program for the B1-B, added major new maintenance facilities and fuel cell docks to the flightlines of selected installations—the first such infrastructure since that designed for the SAC bombers of the 1950s. The continuous military and technological achievements, as well as the extreme costs of the half-century Cold War, the fall of the Berlin Wall, and the political upheaval in the Soviet Union at the close of the 1980s, led to the Strategic Arms Reduction Treaty (START). Signed in July 1991 by the U.S. and the Soviet Union, START stipulated mutual arsenal reduction by 50 percent, and elimination of all MIRVed ICBMs. Rail Garrison was one of the conclusive bargaining chips of the war.

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Chapter 2: Evolution of Key Property Types

Plate 1. F-101Bs on alert at Dow Air Force Base. Butler mobilization hangar. View of 1958-1959. Courtesy of the Air Force Historical Research Agency.

During the Cold War, the evolution of key property types for ADC / TAC fighter and command-communications infrastructure can be analyzed in seven categories. As is also the case for SAC bomber infrastructure, these categories are concentrated during the 1950s. Also like SAC, ADC undertook significant design efforts through a well known architectural-engineering firm at the very outset of the Cold War—during the late 1940s. Not until the early 1960s into the 1970s did TAC sponsor a large program of fighter flightline infrastructure. After about 1962, ADC generally handled its program needs through a revamping of existing infrastructure—coincident with the rise in new TAC building programs for the fighter mission. As a group, TAC structures were more utilitarian, functionally meeting mission needs through wide standardization, repetitive multiples, and few design flourishes.

Discussions below focus on operational buildings and structures, inclusive of runway lengthening and aircraft parking aprons. Not generally addressed is cantonment architecture, such as administrative, engineering, and office buildings; airmen and officer housing; base entertainment and shopping complexes; medical facilities; schools; churches; general aircraft maintenance and repair infrastructure; and generic support units. Jet fighter tie-down pads; engine test cells; and noise suppression structures, including hush houses, are also not included. Unlike SAC, ADC and TAC did not create a Cold War mythology for the command. Notably, its command posts were strongly linked to pre-existing traditions within the communications industry and to federal law specified for such structures since the 1930s. So understated was ADC that its pre-eminently important fighter-interceptor alert hangars of 1951 are of more than one type, and are of unclear lineage—tied not just to ADC, but also to the assumption of the air defense mission by the Air National Guard (ANG). The network of ancillary structures supporting ADC alert, including the special weapons storage facilities required for the MB-1 Genie, quickly became invisible. ADC's real glory came with the command and control web known as the Semi-Automatic Ground Environment (SAGE) at the end of the 1950s. Fundamentally interesting, SAGE had an immediate, first generation precursor—a command and control web fully two-thirds the size of SAGE and historically all but forgotten. TAC was even more understated in its fighter mission than ADC—especially before about 1960. TAC trained fighter pilots and mobilized aircraft, taking on the air defense mission in selected locations. During the early Cold War TAC appears to have used available infrastructure to support its needs. At analyzed TAC installations, TAC employed the SAC basic double-cantilever hangar and, on occasion, several of its wing docks to meet maintenance and shelter requirements. For air defense, TAC appears to have used ADC infrastructure directly. After the middle 1960s—and very heavily during the 1970s—TAC turned to standardized modules, erected in repeated patterns at the flightline. A final note: for the ADC and TAC fighter mission, very rapid changes in jet fighter aircraft between the late 1940s and the early 1960s, including physical changes like aircraft length and height, and, growing sophistication in linkages to the command-communications network, directly affected the associated infrastructure. Change to this degree was not characteristic of the parallel SAC bomber mission.

The categories presented are arranged by property type, and are discussed in an overall chronological format, with a minimum of overlapping years as the analysis moves from one property type to another (Plate 1). Categories are (1) first generation alert hangars, inclusive of four types, 1951-1954; (2) modified first generation, and second generation, alert hangars, 1956-1962; (3) TAC flightline hangars of the 1960s and 1970s; (4) support structures for alert areas, inclusive of ready crew buildings, squadron operations, flight simulators, readiness/maintenance hangars, ready shelters, calibration shelters, armament and electronic structures, and munitions storage, 1951-1962; (5) first generation ADC command and control structures, 1951-1957; (6) second generation ADC command and control structures (SAGE), 1955-1960; and, (7) post-SAGE ADC command and control structures for the Backup Interceptor Control system (BUIC and post-BUIC), 1962-1991.

First Generation Alert Hangars

America post-World War II interpreted the need for air defense differently than it had after World War I: the United States did not anticipate a bombing attack from either Europe or Japan, but it assumed that such an attack would become a future reality from the Soviet Union. The new enemy would strike from a polar route, either through Alaska or the North Atlantic. Air defense soon concentrated on the northwest and the northeast. The dropping of the atomic bomb on Hiroshima and Nagasaki also profoundly altered dynamics. An American nuclear monopoly allowed for a slowness in any air defense planning, with the formal interpretation that the Soviet Union would not possess intercontinental bombing capabilities until the early 1950s. Knowledge that nuclear weapons themselves would likely change the meaning of air defense further restrained any desires to build air defense infrastructure quickly for fear of allotting precious funds to a system obsolete even before it was in place. From 1946 forward, SAC became the premier military arm of the Army Air Forces (AAF) and, from mid-1947, the Air Force. ADC took stock of radar and communications, fighter aviation, and antiaircraft artillery, concentrating on three air defense elements leftover from World War II. At the beginning of the Cold War in 1947, ADC had one-quarter the strength of TAC and one-twelfth the manpower of SAC. Yet ADC, not TAC, received the air defense mission. For that mission, ANG supported ADC: the AAF federally recognized 31 ANG pursuit fighter squadrons in early 1947.[1]

Air defense of the first Cold War years, 1946-1948, was at best tentative. As funding for regular ADC infrastructure remained nonexistent, with only nine cobbled-together radar stations established even by mid-1948; command-communications operated in makeshift quarters; and the few ADC pursuit squadrons continued to use existing hangars and aprons. For a brief period, air defense duties became divided in a practical sense, with decision-making concentrated directly within ADC, and with aircraft operations and information gathering managed jointly by ANG and ADC together. Available American pursuit aircraft were all propeller-driven, although jet fighter technology existed. Pilots and radar crewmen made decisions divorced from effective control and communications. Available World War II

AAF airfields supported these planes, with runways long enough to accommodate ANG F-47 and F-51 aircraft, but lacking the minimum runway length of 7,000 feet required for jet operation. The ANG pursuit squadrons organized and received recognition heavily in the southern, midwestern, and western United States, spread more or less evenly across the nation. Of the 31 original ANG pursuit squadrons, expanded through addition of seven light bombardment squadrons during 1947, only a maximum of 12 physically coincided with the ANG and ADC fighter-interceptor alert locations of 1951. The smaller, distinctly Cold War group were uniformly located in the northeast (as many as six squadrons), the northwest (as many as three squadrons), and the midwest (as many as three squadrons).

The AAF had intended ANG to be the United States air defense force, concentrated in fighter squadrons. During 1945, the command had formalized postwar policies toward its reserve corps, the National Guard, and had initiated an air unit, ANG. The next year, through the National Guard Bureau (NGB), the AAF authorized the design and construction of a Cold War alert hangar. Conflicts in military jurisdiction, and the seeking of independent power, however, encouraged only confused and contradictory relations between the AAF and the NGB, with ANG suffering accordingly. Federal and state interests were also at cross purposes in decisions over who would fund basic installation sites, infrastructure, aircraft, manpower, and training. Finally, ADC and the NGB did not allocate responsibilities for air defense hierarchically, again directly affecting ANG. As a result, ANG grew on paper quickly, but the command's air defense readiness was acknowledged as very poor. ANG funding was severely curtailed in September 1946 through 1947. Support infrastructure for the ANG pursuit squadrons that continued to train during this period is assumed to have been ad hoc, with a liaison hanger designed in early 1948, assumed built. The design for this hangar is unanalyzed, and its numbers are unresearched.[2] The NGB ANG situation continued through 1950.

After mid-1947, the fastest aircraft, and the first with night and all-weather capabilities, were prioritized for the Air Force, with ADC discarding obsolete aircraft, as they were improved, to ANG. ADC, then, had the first jet fighters, and quickly augmented their possession with a rigorous, full-time training program for pilots and ground crew. Even though ADC remained without alert hangars, the command planned where they would be built and how they would function. By 1948, ADC parked alert aircraft at the end of designated runways, with alert crews living alongside their planes in ready shacks and then standardized trailers. ADC called its first formal 24-hour, continuous alert in late March 1948, with air defense focused on the protection of the Hanford atomic energy plant and the Boeing manufacturing sites in eastern and western Washington. It remained for fate to bring circumstances together, stimulating not just authorization for the design of an alert hangar—as had been true for ANG in 1946, but its actual design and construction.

After the initiation of the Korean conflict in June 1950, attention turned sharply to America's air defense fighter squadrons. In August President Truman authorized the Air Force "to destroy aircraft in flight within the sovereign boundaries of the United States which commit hostile acts, which are manifestly hostile in intent, or which bear the military insignia of the USSR, unless properly cleared or obviously in distress." Truman's order effectively gave the Air Force its first tactical, blanket right to shoot.[3] The Air Force expanded its existing fighter-interceptor squadron (FIS) program, while Congress passed the Selective Service Act of 1950 that empowered the President to federalize the available ANG fighter squadrons under formal Air Force jurisdiction. The first 15 ANG fighter squadrons federalized were so recommended due to their possession of adequate support facilities and location in radar-covered areas. By December 1950 the Air Force had provided four of the federalized ANG squadrons with F-80 and F-84 jet aircraft, while the remainder continued with World War II planes. Federalization of the 15 ANG squadrons became official in February 1951, with six more squadrons added in March. At the outset of 1952, the Air Force Directorate of Installations formalized definitive layout standards for ADC's alert apron.[4]

Between late 1951 and 1954, in particular, ADC surveyed multiple municipal airport and Air Force locations for the placement, or relocation, of fighter-interceptor squadrons for the air defense mission. In some cases, ANG squadrons needed new facilities; in others, a World War II runway was too short for the anticipated fighter jets, and constrained by geographic setting against mandatory lengthening.[5] Other more complex siting problems also arose that required using available airfields in conjunction with one another to defend air space. In 1951, ADC desired to place a fighter-interceptor squadron at Offutt Air Force Base near Omaha, due to the presence of SAC headquarters at the installation. Engineering tests at the base revealed a "radar echo" due to the configuration of the immediate terrain. ADC solved the problem by siting a fighter-interceptor squadron at Sioux City, 100 miles to the north of Offutt—in effect making Sioux City the ADC adjunct for Offutt.[6] By the second half of 1953, ADC was actively talking with other military arms—both internal and external to the Air Force—about the possibility of establishing air defense fighter-interceptor squadrons. Examples of this year include discussions for a fighter-interceptor squadron at a Naval Air Station in Seattle; at the Marines' Camp Pendelton near San Diego; at the Army's Phillips Field at the Aberdeen Proving Ground, Maryland; and at several TAC bases in the southeast.[7] ADC also sent its survey teams for potential fighter-interceptor squadron facilities to non-historic military locations, where need was determined very high. One such jurisdiction was the border between southern Oregon and northern California. Here ADC scrutinized the airports at both Medford and Klamath Falls, Oregon, and at Arcata, California. During 1954, the Navy and the Army rejected ADC's request for fighter-interceptor squadrons in the San Diego and Baltimore regions, claiming saturated air space and other logistical problems. Simultaneously, in June, ADC presented arguments for "perimeter defense of the United States," concentrating, like SAC, across the northern tier of the country. At that time, ADC made decisions for fighter-interceptor squadrons at six virgin Air Force installations, then in planning: Glasgow, Montana; Minot and Grand Forks, North Dakota; and, Kinross and K.I. Sawyer, Michigan. ADC included Klamath Falls, Oregon, in its required perimeter needs—with the San Diego issue unresolved.[8]

ADC used four types of alert hangars to support its fighter-interceptor squadrons during the 1951-1955 period.[9] Three of the four could be considered mobilization infrastructure, although only one of the group truly fits this category. ADC commissioned the four types simultaneously, or nearly so, in April to September 1951. The four followed an experimental period of months, from January through March 1951, during which Mills & Petticord, Washington, D.C., produced designs for two preliminary air defense alert hangars. Handled only as a single sheet of drawings in each case, the Mills & Petticord design of January was of 264- (wide) by 66-foot (deep) size, while that of March was enlarged to 298 by 66 feet. The March design had a small rear blast door, and full front overhead door. As in the cases of Mills & Petticord submissions for initial SAC Cold War infrastructure, these hangars were not built, but do clearly relate to the chosen program[10] (Plate 2).

Each of the four types of constructed alert hangars had central alert crew quarters, with two bracketing aircraft pockets on each side for a single squadron, or four pockets on each side for a double squadron. On rare occasion, ADC built a four-pocket hangar with its alert crew quarters at the end of the structure, but this configuration undoubtedly indicates that an eight-pocket hangar was planned from the start (and remained unbuilt to the fully anticipated size). The basic, programmatic air defense alert hangar, across the four types, was uniformly a steel structure bolted to a reinforced concrete pad, sheathed in deeply corrugated siding, with opening front and rear doors for each aircraft pocket. The overall size of a four-pocket hangar varied from 303 to 329 feet wide, 69 to 72 feet deep, and 30 to 35 feet high. Doors for the alert hangars were separately manufactured from the primary hangar structures, with four companies known to have handled four distinct, standardized doors. All ADC and TAC alert hangars employed an alert taxiway and apron, angled at 45 degrees at the end of the runway. Air defense alerts achieved five-minute status for two to eight fighter-interceptors by the close of 1951, with squadrons maintaining another third of their aircraft on three-hour alert. ADC and TAC built the four types of first generation alert hangars steadily between 1951 and 1956.

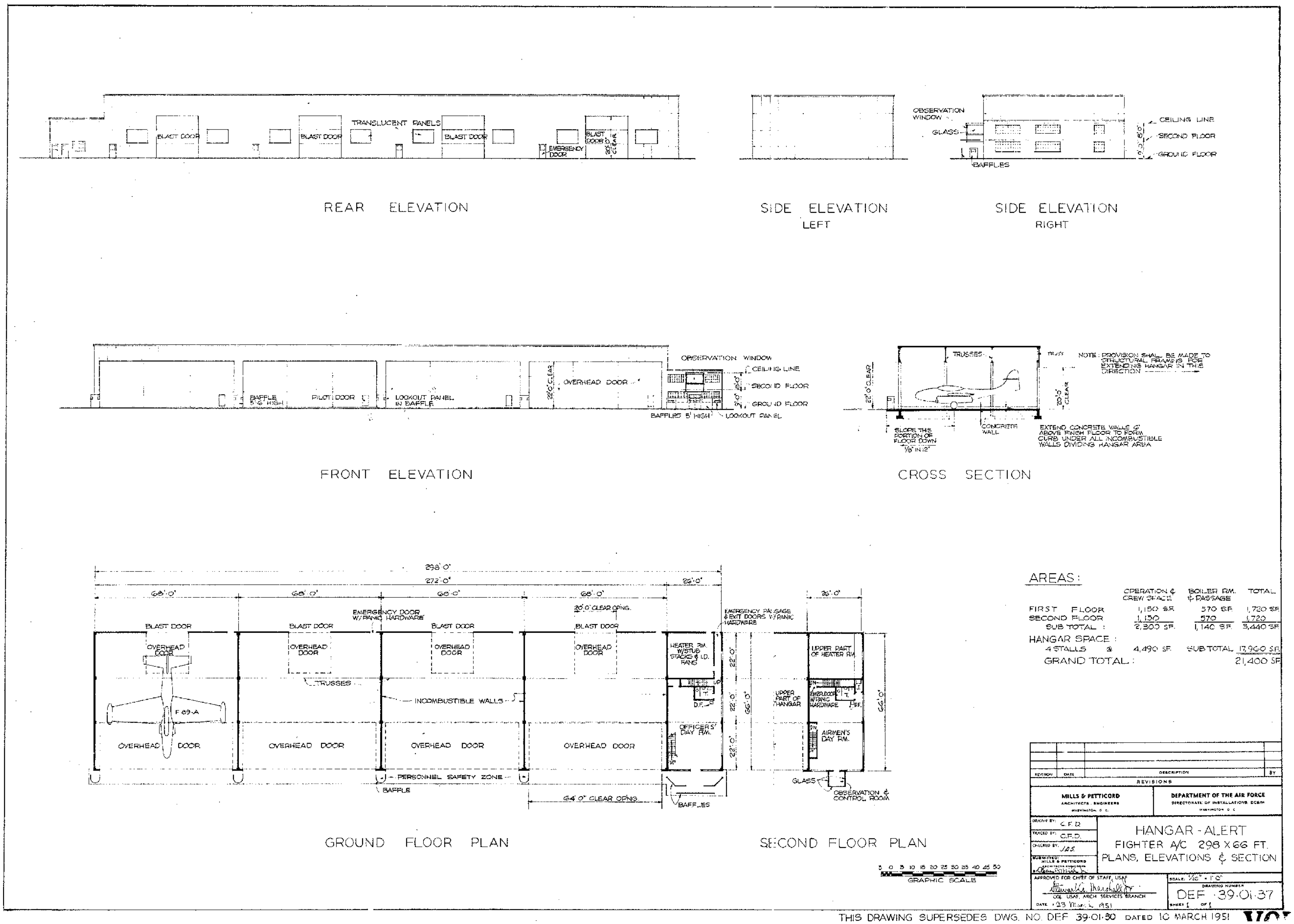

Plate 2. **Mills & Petticord. Design for Alert Hangar, Elevations and Sections. March 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

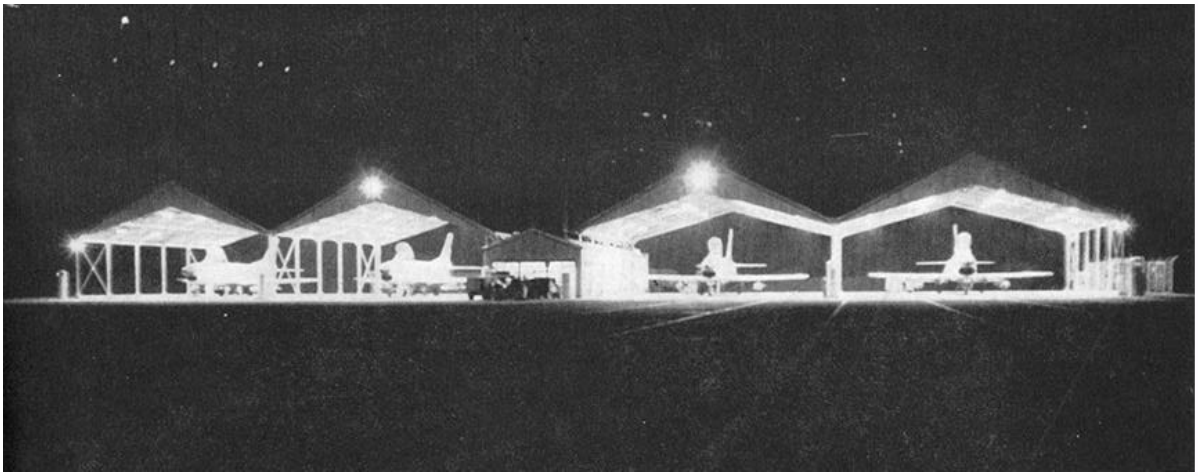

Plate 3. Mobilization alert hangar. Itazuke Air Base, Japan. Reproduced from *A History of the United States Air Force 1907-1957*.

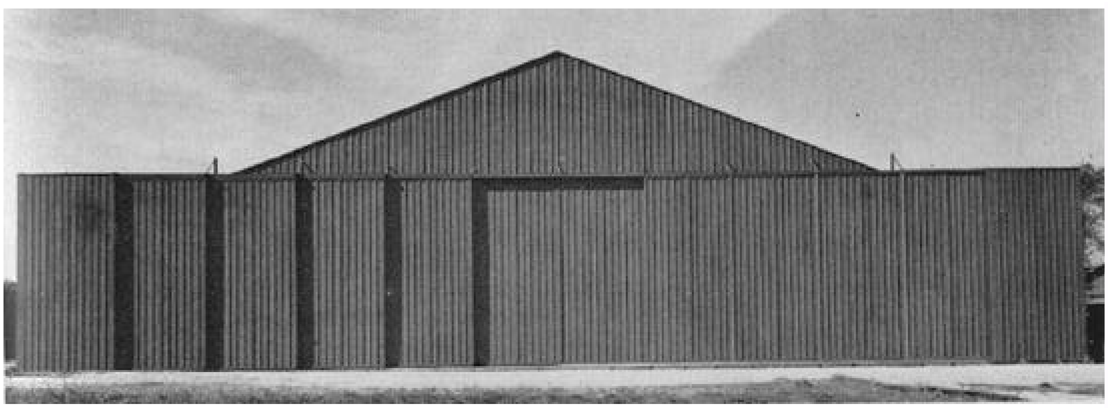

Plate 4. Butler Manufacturing. Prefabricated hangar for the Army Air Forces, with steel doors and roof. Reproduced from *The Military Engineer*. May 1945.

The Overseas, Mobilization Hangar

ADC's mobilization hangar used for alert duty overseas was of prefabricated type, and consisted of four open-shed pockets, with a simple one-story, partially open, ops-crew building in the center. Of steel construction, the hangar featured completely open side walls between the aircraft pockets and at the ends of the structure. Each pocket carried a steeply angled gable, trussed roof, and was sheathed in corrugated paneling, inclusive of abbreviated front and rear paneling to protect the trusswork.[11] At Itazuke Air Base, in Japan, the Air Force mapped the structure as "permanent," although its very spare form and structure come closest to the understanding of mobilization, or semi-permanent, infrastructure (Plate 3). Manufacturer for the overseas alert hangar is as yet unresearched. Nonetheless, the hangar strongly resembles a larger Butler Manufacturing Company hangar of 1945, with center structure reminiscent of the Butler rigid-frame building of this same period. The Butler hangar was manufactured with and without ten moveable doors, sliding into bracketing side pockets[12] (Plate 4). Butler had introduced its rigid-frame building in 1939, with a full line of structures in 1940.[13] During World War II, Butler had manufactured large quantities of steel landing mats, rigid-frame warehouses (Plate 5), experimental housing, and light-weight, easily erected combat hangars. The Navy had ordered over 3,000 rigid-frame warehouses, while the Army Signal Corps had ordered the "dymaxion deployment unit," radical housing designed by architect Buckminster Fuller and manufactured by Butler (Plate 6). The AAF had placed the order for the combat hangars in May 1942.[14] The ADC alert hangar at Itazuke, photographed by the Air

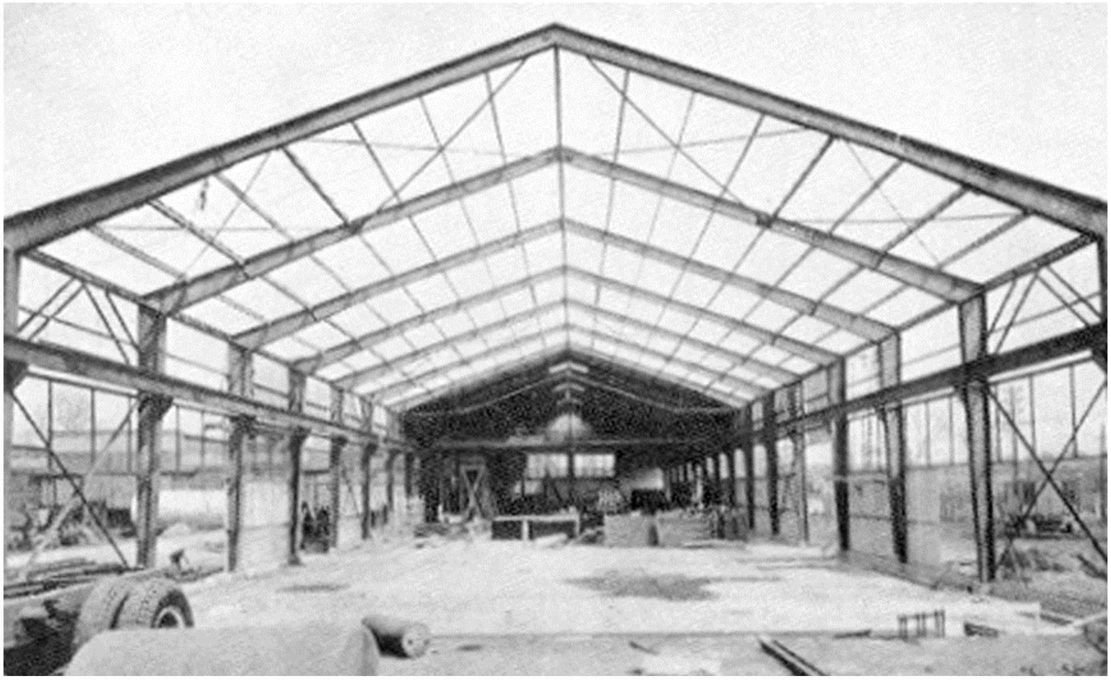

Plate 5. Butler Manufacturing. Rigid-frame warehouse. Early 1940s. Courtesy of the Butler Manufacturing Company.

Plate 6. Buckminster Fuller and Butler Manufacturing. Dymaxion deployment unit. Housing for the U.S. Army. Courtesy of the Butler Manufacturing Company.

Force in about 1956, appears to be open rigid-frame construction, with roof trusswork sheathed rather than exposed as in the Butler hangars of World War II. ADC used an unknown number of these open hangars, primarily outside the continental United States, but possibly also on occasion at selected airfields within the country.

The Gable-Roofed Anomaly

A second type of air defense alert hangar from the early 1950s exists at Langley Air Force Base in Virginia (Plates 7-11). Designed and manufactured by Luria Engineering of New York, a maker of prefabricated steel buildings like Butler, the hangar is steel-framed and gable-roofed. The structure is fully sheathed in corrugated metal paneling. Described as new (and photographed) in mid-1954, the hangar had large-angled, counter-weighted blister doors, front and rear to accommodate the F-94.[15] Baseline drawings for the structure date to 4 September 1951.[16] The blister doors accommodating the longer F-94 likely were a design change from the original Luria drawings (as yet not analyzed). Langley had first supported a 24-hour alert air defense mission through the 48th FIS assigned in 1952, flying the F-84 by 1953. TAC served as the base's fighter command, with its 405th fighter-bomber wing also flying F-84s in 1953.[17] It is possible, although unconfirmed, that the alert hangar used at Langley is a distinctly TAC, rather than ADC, structure. The alert apron is mapped on the opposite side of the runway from its support structures, at about 6,500 to 7,000 feet (where the runway ended in the early 1950s).[18] In 1957 the Air Force planned to move the alert hangar to the new "end of the runway" on the same side of the flightline as the ancillaries. This move, similar to one for an alert hangar at Andrews Air Force Base at this same time, did not occur.

Plate 7. Luria Engineering. Radar-equipped F-94 in the alert hangar at Langley Air Force Base. View of 1954. Courtesy of the Air Force Historical Research Agency.

Plate 8. Luria Engineering. Alert hangar at Langley Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

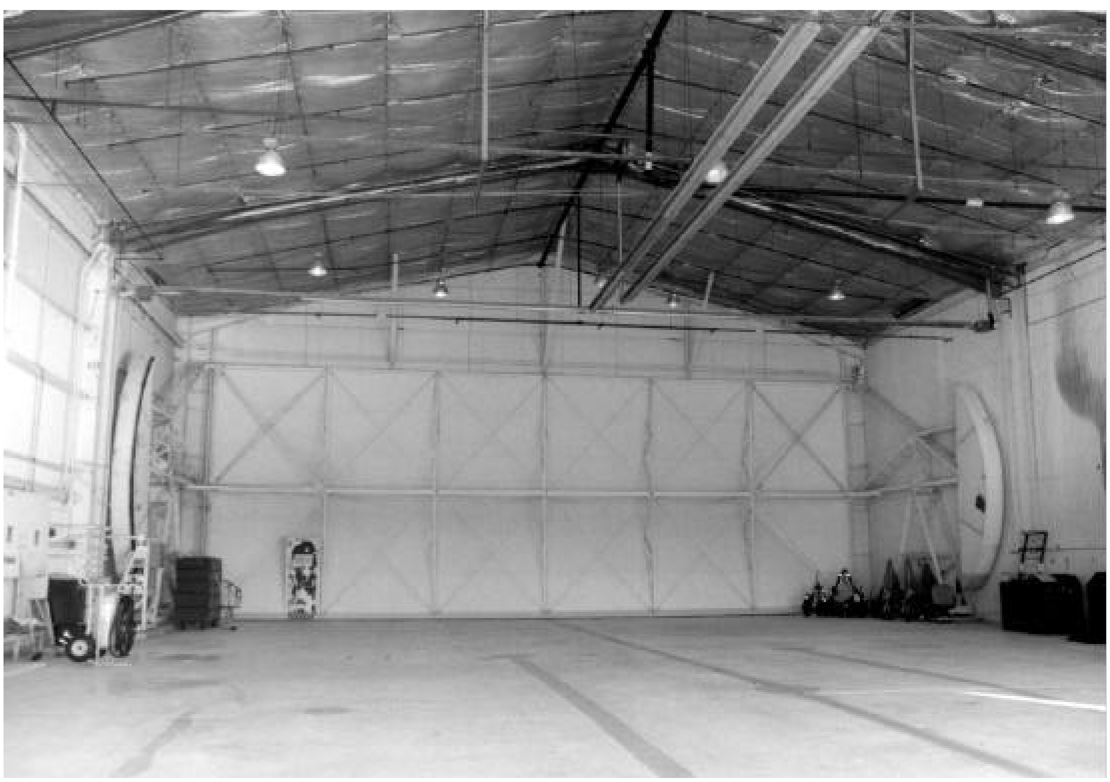

Plate 9. Luria Engineering. Interior of alert hangar aircraft pocket at Langley Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

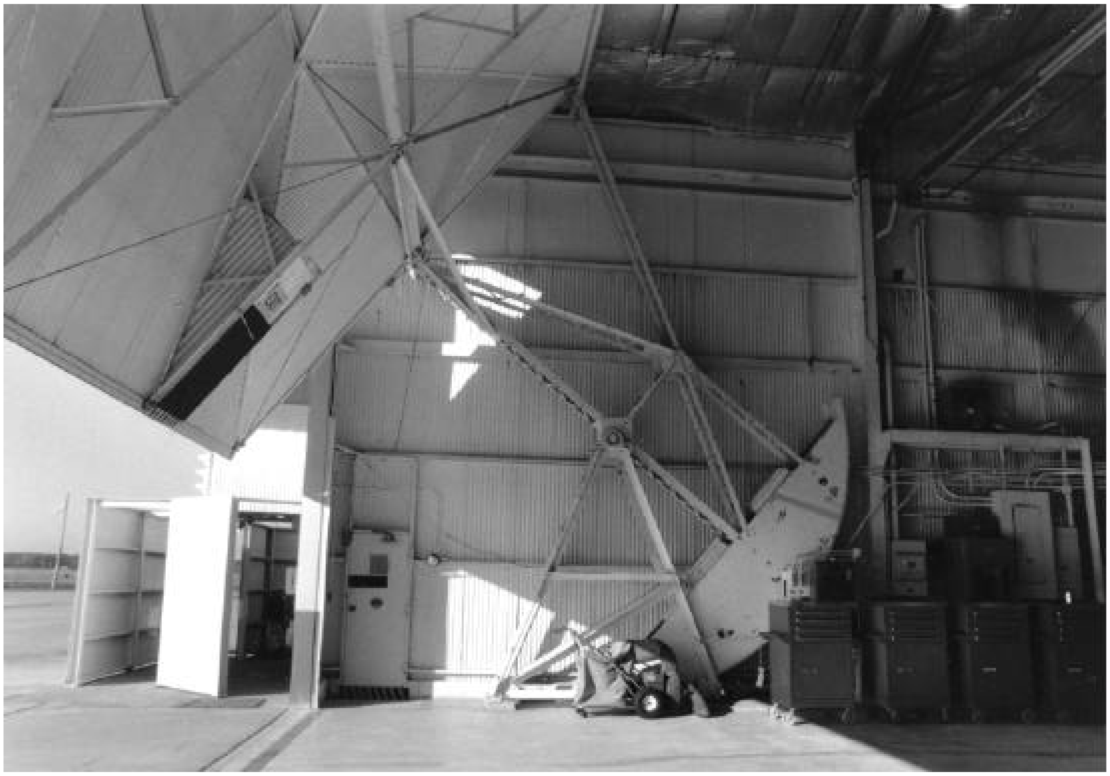

Plate 10. Luria Engineering. Door mechanism for the alert hangar at Langley Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 11. Luria Engineering. Flightline command booth in the alert hangar at Langley Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Primary Buildout: the Strobel & Salzman Hangar

The primary alert hangar was that designed by the New York architectural-engineering firm Strobel & Salzman in April 1951[19] (Plate 12). The total number of these hangars built is unknown, but is likely about 35, based on the number of air defense squadrons active in 1956 and on mapped structural footprints in 1957. (See Table 1, chapter 3.) The hangar measured 303 feet wide, for the basic four-pocket version (inclusive of center, two-story alert crew quarters) and 69 feet deep. Height for open hangar doors was 24 feet, with both front and rear doors opening fully and each having an inset pilot door. Individual aircraft pockets were 68 feet wide. Like the Mills & Petticord prototypical design of January-March 1951, that of Strobel & Salzman was flat-roofed—distinct from the gabled roofs of the other three alert hangars within this first generation group. Engineer Peter A. Strobel consulted with Luria Engineering in the design and engineering for the SAC B-36 wing hangar at this same time, and it is that work that likely introduced him to the Air Force. Continental Steel of Los Angeles manufactured the doors for the hangar. Of unbraced canopy type, with two supporting inside cable systems, the doors are distinctive for the structure[20] (Plates 13-14). In rare instances, the hangar was doubled to eight aircraft pockets, supporting two squadrons on alert at a single installation. Very early Strobel & Salzman hangars included that at McChord Air Force Base in Tacoma, adapted for the base in May-June 1951, and expanded to an eight-pocket hangar almost immediately, in October 1951.[21] As of late 1952, ADC had only five double fighter-interceptor squadrons on alert nationwide: at McChord, McGuire (New Jersey), Otis (Massachusetts), Selfridge (Michigan), and Truax (Wisconsin) (Plates 15-17).

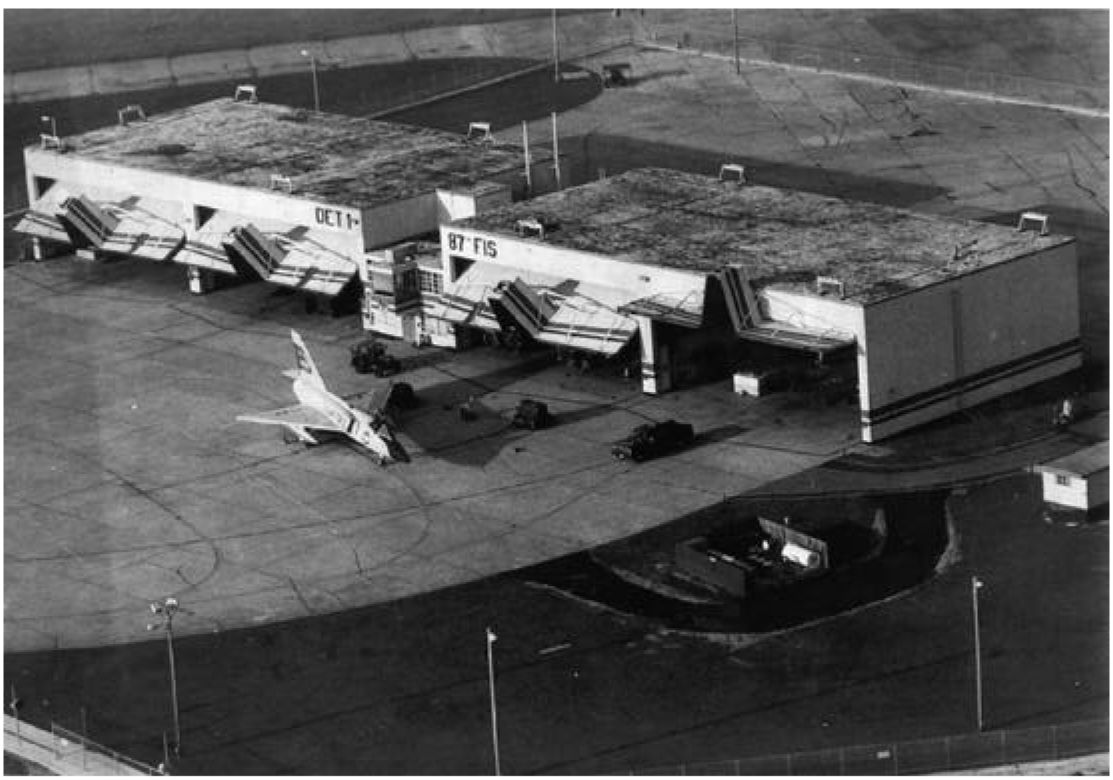

Plate 12. Strobel & Salzman. First generation alert hangar at Charleston Air Force Base. The 87th Fighter-Interceptor Squadron. View of the 1970s. Courtesy of Geo-Marine, Inc.

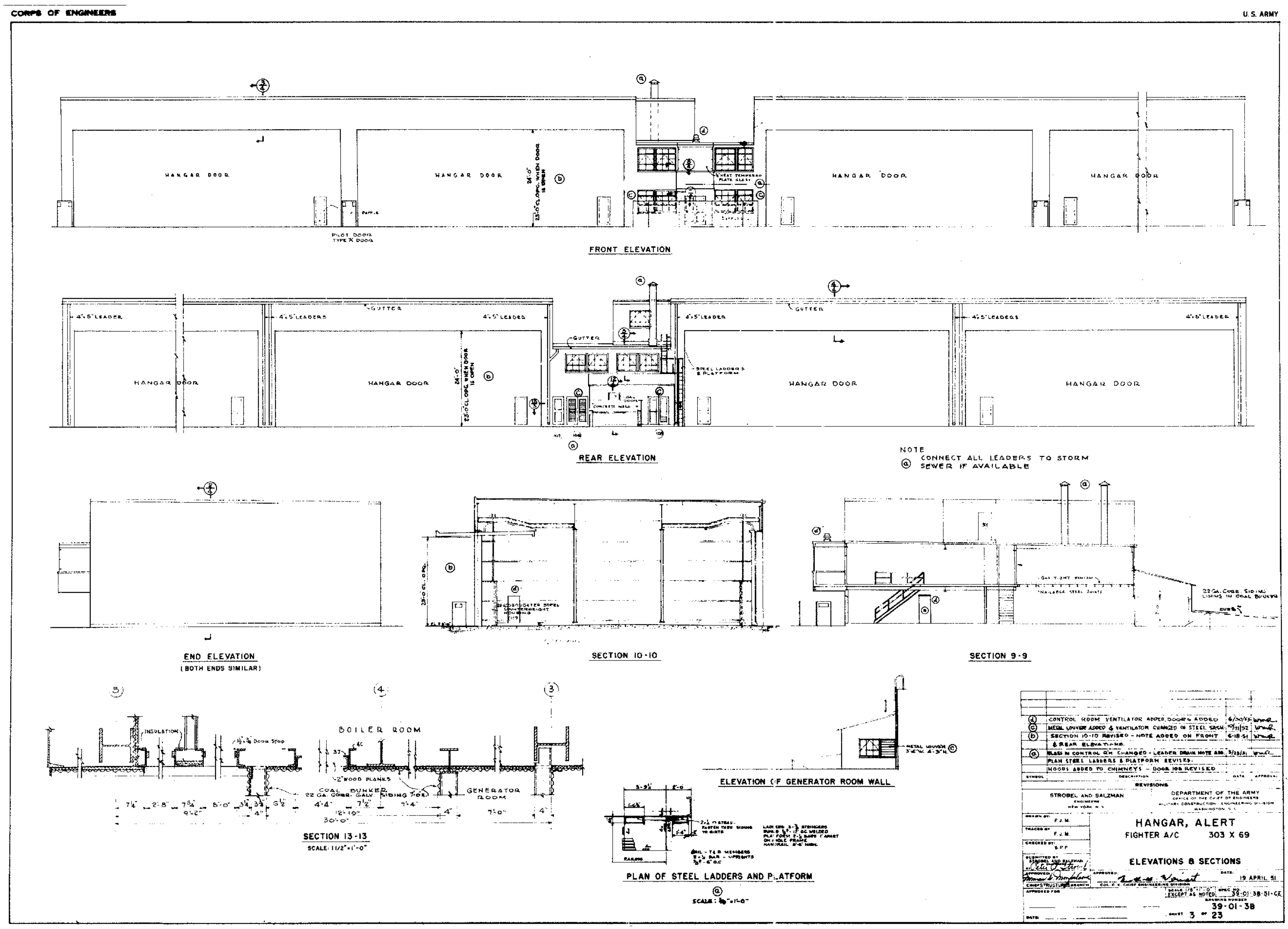

Plate 13. **Strobel & Salzman. Alert Hangar, Elevations and Sections. April 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

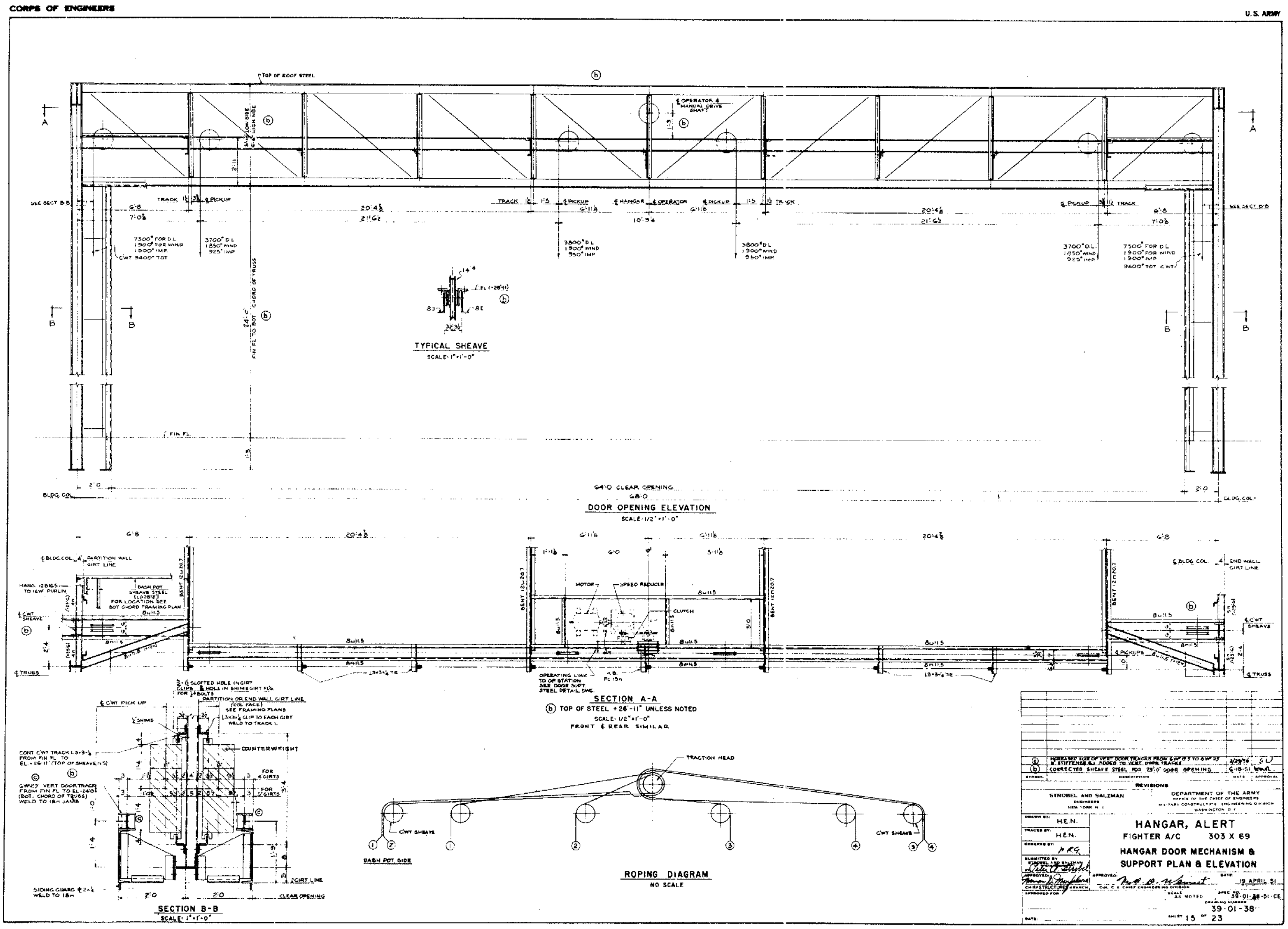

Plate 14. **Strobel & Salzman. Alert Hangar, Door Mechanism and Support Plan. April 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

Plate 15. Strobel & Salzman. Eight-pocket, first generation alert hangar at McChord Air Force Base. Doors modified. Flightline view of 1995. Courtesy of Geo-Marine, Inc.

Plate 16. Strobel & Salzman. Eight-pocket, first generation alert hangar at McChord Air Force Base. Doors modified. Rear view of 1995. Courtesy of Geo-Marine, Inc.

Plate 17. Strobel & Salzman. Four-pocket, first generation alert hangar at Geiger Air Force Base. View of 1955. Courtesy of the Air Force Historical Research Agency.

The Strobel & Salzman firm handled significant Air Force, Army, Marine, and Navy assignments during 1951-1956, with a continuance of Navy work by Willgoos, Strobel, Panero & Knoerle in 1959. Beginning with the Luria collaboration for the B-36 wing hangar in early 1951, Strobel established the firm with his partner Joseph Salzman through a second prominent assignment for the Marine Corps. Strobel & Salzman provided consulting engineering for the Mitchell Mobile Hangar Corporation of New York, parallel to its role with Luria, for a "clamshell" hangar at the Marine Corps Air Station at Cherry Point, North Carolina, completed before July 1951 (Plates 18-19). The Marine Corps hangar opened and closed in two 100-foot equilateral triangular halves, rolling on embedded railroad ties set in reinforced concrete. A maximum separation of 172 feet between the opened halves allowed aircraft to enter and leave the structure, with total opening time only three minutes. When closed, the hangar was self-sufficient and fully protected, with its own power generators. In addition to this prescient ability to function under the understood, foreseen conditions of an atomic Cold War, the hangar was "demountable and could be moved from place to place as war or defense demands might require."[22] The firm's ADC alert hangar only marginally continued this tie to mobilization, serving instead to move the firm toward more traditional, permanent aviation infrastructure. In 1953, Strobel & Salzman completed design for an ADC readiness/maintenance hangar (see below); in 1955, designs for three Army maintenance hangars;[23] in 1956, design for the second generation ADC alert hangar (see below); and, in 1957, design for the ADC ready shelter (see below). During several years after mid-decade Peter A. Strobel left the firm to serve as Commissioner of the Public Buildings Service, the lead federal agency for government building design.[24] Engineer Strobel returned to hangar design at the close of the 1950s with his work on a Navy cable-assisted cantilever truss hangar at Andrews Air Force Base.[25] The Navy hangar became a standard Navy design, paralleling innovative work of the same type in the private aviation sector of the year before.

Plate 18. Strobel & Salzman. Marine Corps hangar. Cherry Point, North Carolina. Reproduced from *Engineering News-Record*. 12 July 1951.

Plate 19. Strobel & Salzman. Marine Corps hangar. Cherry Point, North Carolina. *Engineering News-Record*. 12 July 1951.

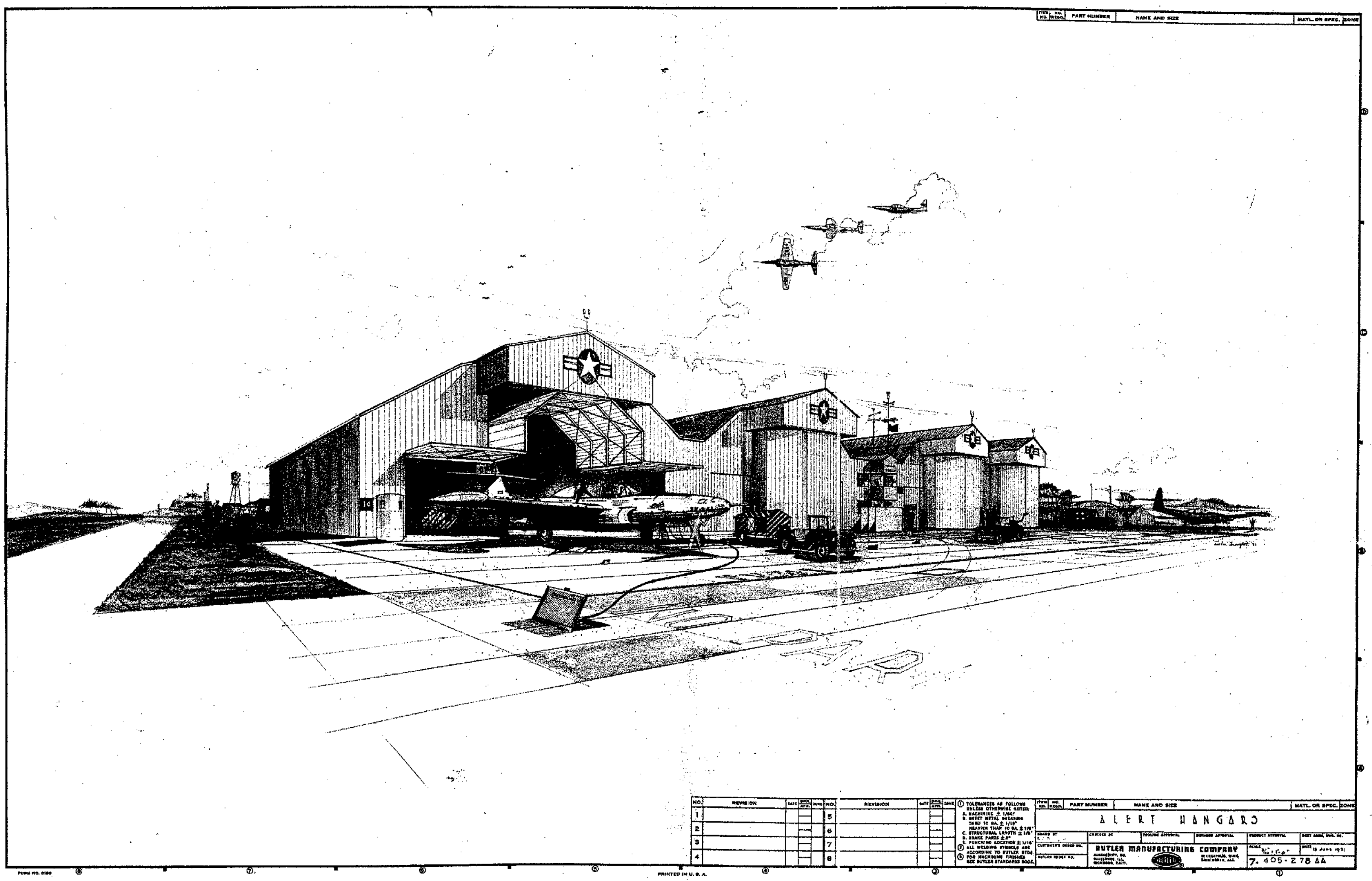

Plate 20. **Butler Manufacturing. Drawing for alert hangar. June 1951. Courtesy of the Butler Manufacturing Company.**

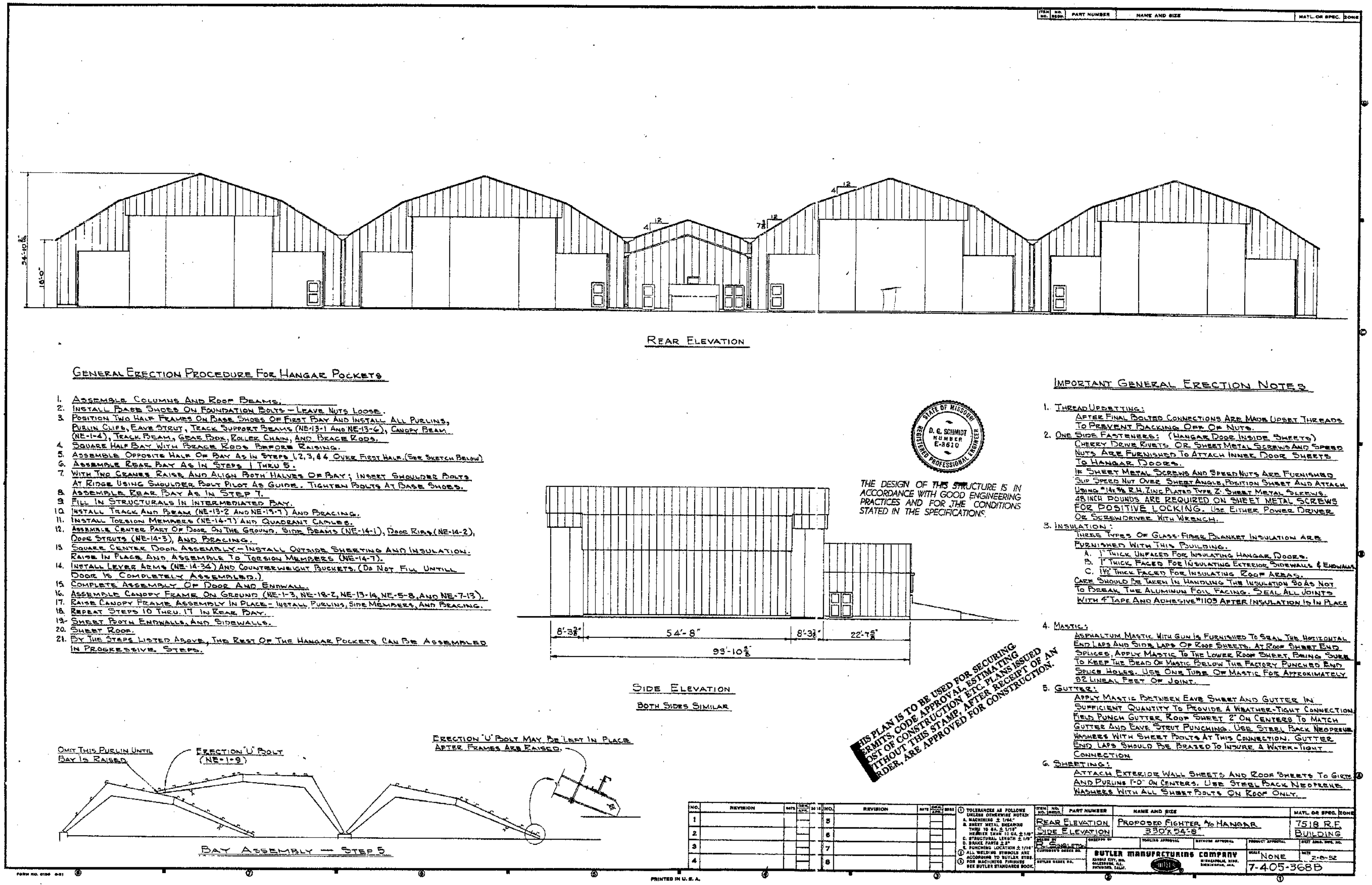

Plate 21. Butler Manufacturing. Rear elevation and bay assembly for alert hangar. February 1952. Courtesy of the Butler Manufacturing Company.

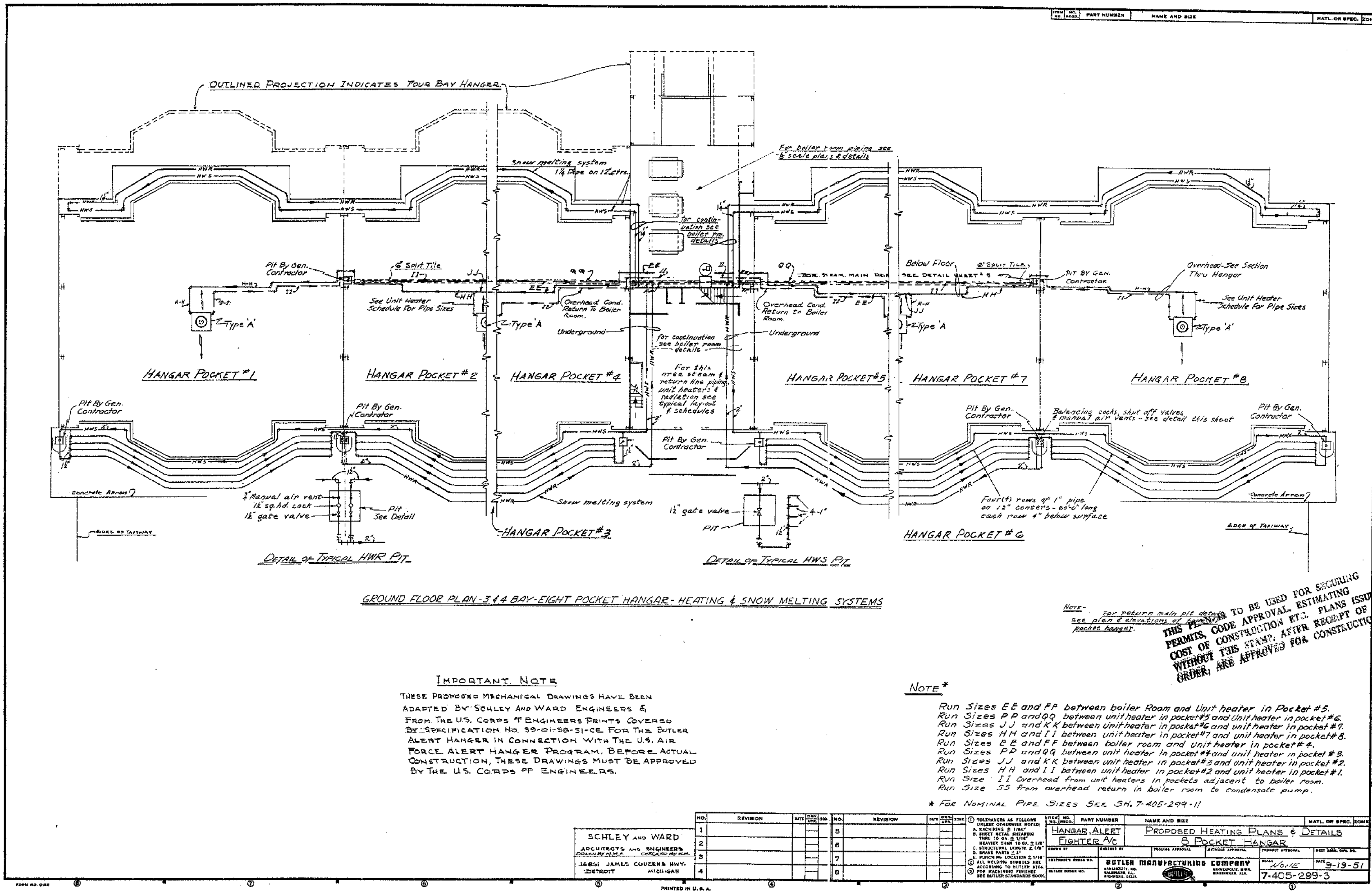

Plate 22. **Butler Manufacturing. Heating plans and details for eight-pocket alert hangar. September 1951. Courtesy of the Butler Manufacturing Company.**

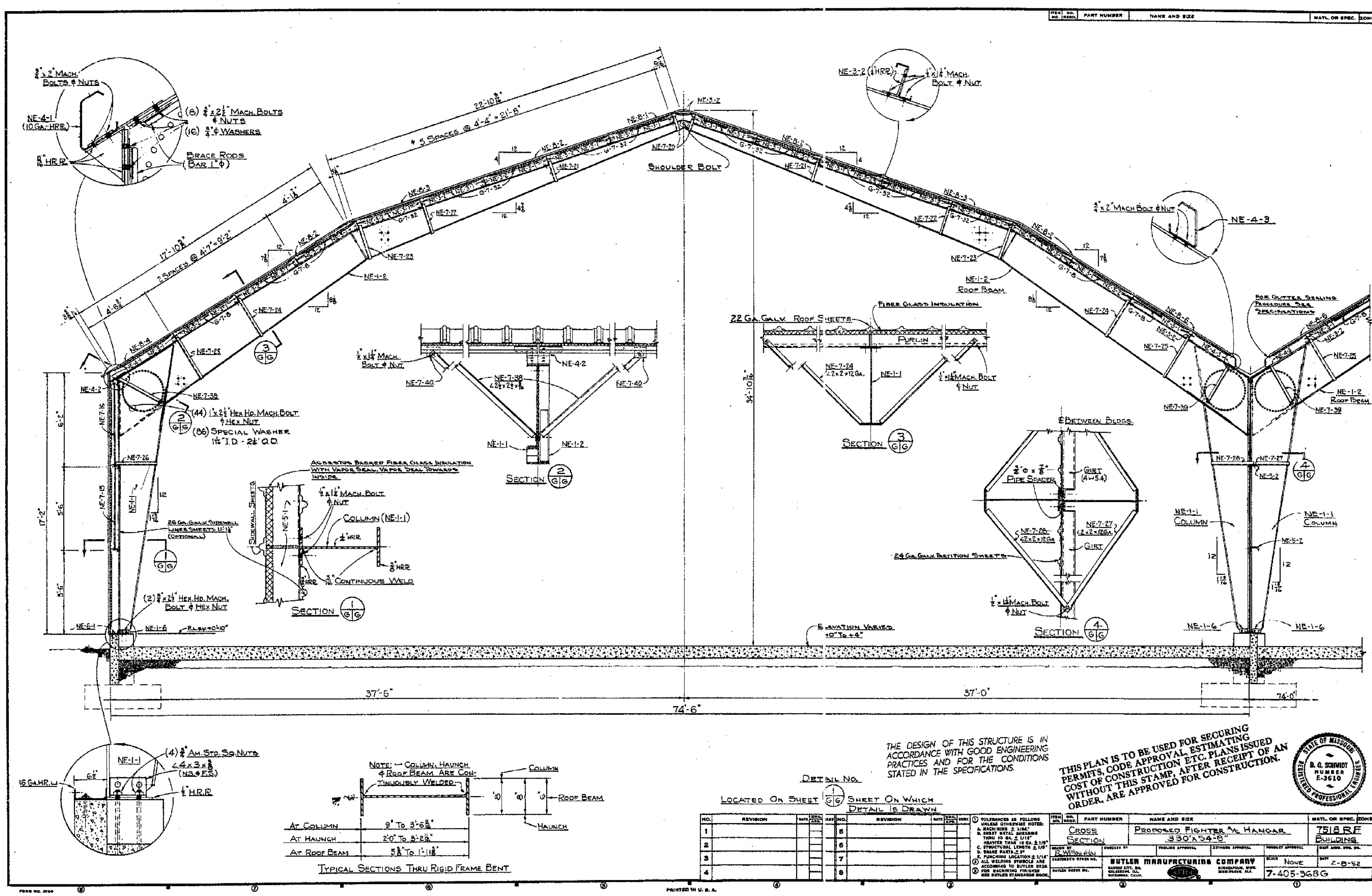

Plate 23. Butler Manufacturing. Alert hangar. Details of rigid-frame system and standing seam sheathing. February 1952. Courtesy of the Butler Manufacturing Company.

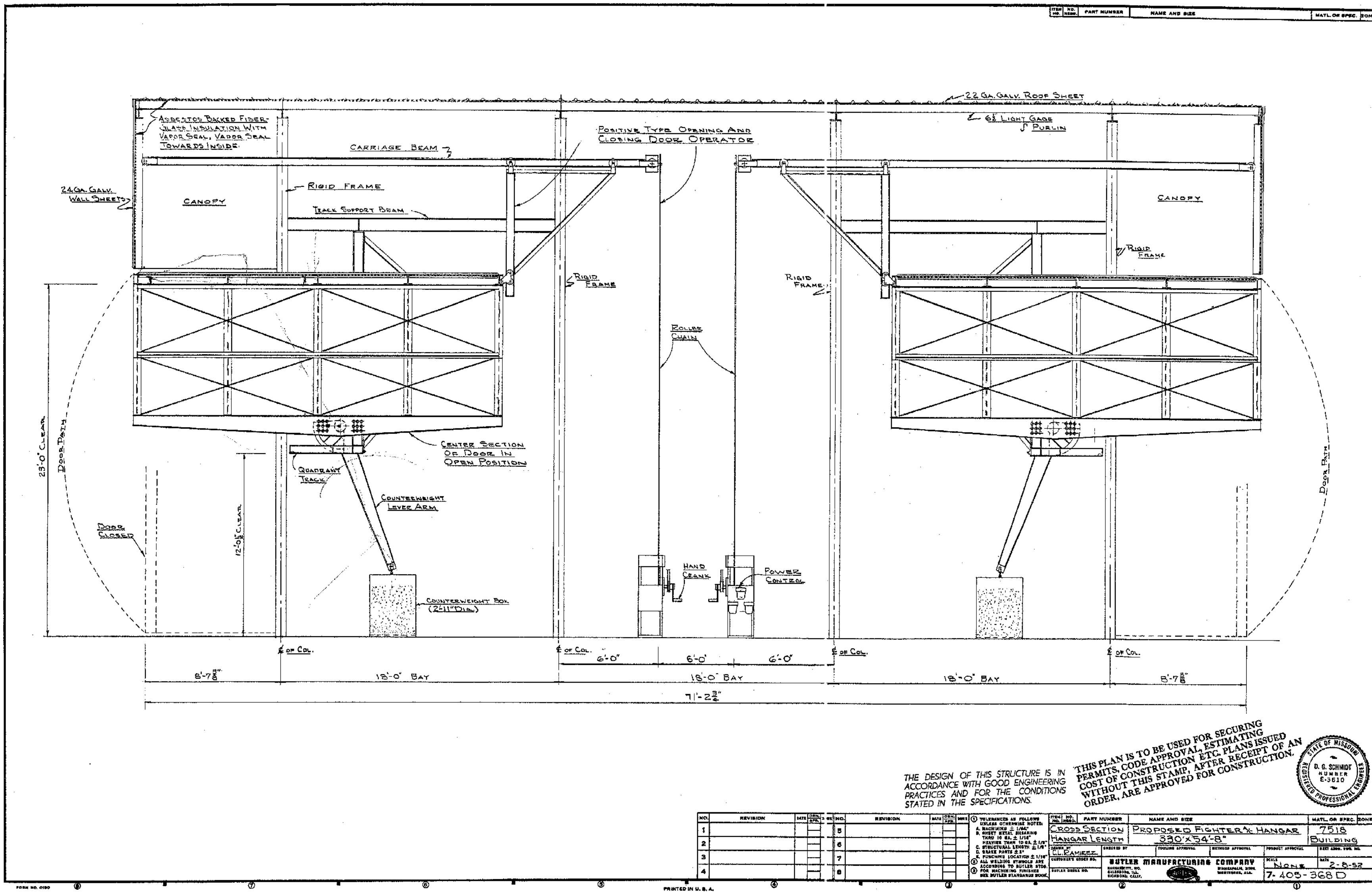

Plate 24. **Butler Manufacturing. Alert hangar. Counter-weighted door mechanism. February 1952. Courtesy of the Butler Manufacturing Company.**

The Butler Alert Hangar

Butler manufactured the final alert hangar of the four types, a hangar sometimes discussed and mapped as a mobilization, or temporary, structure. The hangar had a very distinctive footprint when accurately mapped, but was often misleadingly mapped identically to the Strobel & Salzman hangar. The history and intended use for this particular hangar is somewhat complex. The Corps of Engineers assigned the Butler hangar the identical drawing series number as the Strobel & Salzman alert hangar of April 1951, with the design date for the Butler hangar several months later, in June 1951 (Plates 20-24). Butler engineering data sheets date steadily from mid-March through August 1951.[26] This suggests that the two hangars were intended for simultaneous consideration, and indeed, in at least one case—at Kirtland Air Force Base in New Mexico—plans for both the Strobel & Salzman *and* the Butler alert hangars remain in the civil engineering vault.[27] Butler also designed and load-tested an aluminum version of its alert hangar at its Galesburg, Illinois, plant for Air Materiel Command, planned for construction in the Arctic. This was a special contract of April-May 1951 (Plate 25). Butler built both steel and aluminum hangar test bays in Galesburg in April, following with the full-scale aluminum hangar in May. Air Defense Command sent personnel to inspect the Galesburg test bays, and were closely involved with the project. For this assignment, Butler commented: "It was required that this building be completely transportable by air before assembly, and for this reason aluminum was used in a majority of the design. … [The] large door had to be designed so that it could be opened in 45 seconds by one man. Since the building is to be located in Arctic regions, it was necessary to insulate it completely."[28] The aluminum alert hangar remained unbuilt, but ADC did erect an aluminum readiness/maintenance hangar next to the standard steel Butler alert hangar at Wright-Patterson Air Force Base in Dayton—an event that appears to be unique. (See Plate 30.)

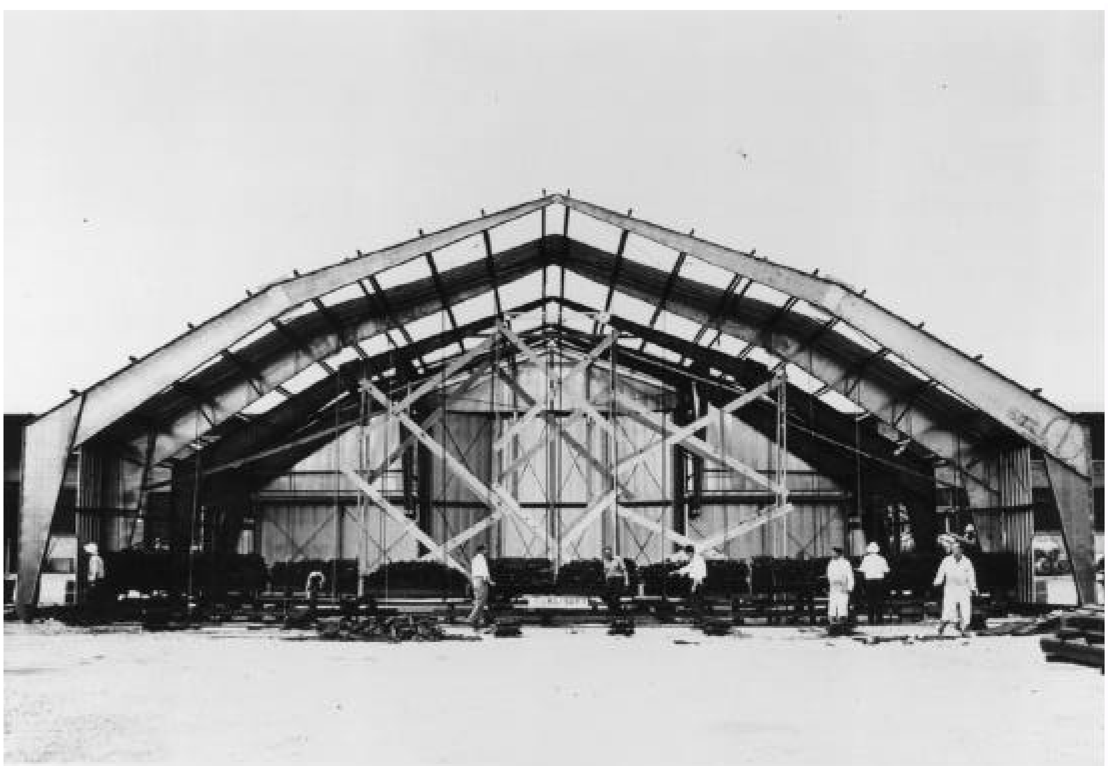

Plate 25. Butler Manufacturing. Aluminum alert hangar designed for the Arctic. Pilot model load test at 85 psf. 25 May 1951. Courtesy of the Butler Manufacturing Company.

The Butler alert hangar was fairly rare, built at about 20 installations, and with about half of these surviving today. These hangars correlate to some of the locations maintained by ANG during the late 1940s, and federalized for Air Force air defense duty in February-March 1951. These locations include at least those for squadrons in Washington, D.C. (Andrews Air Force Base); Portland (municipal airport); Bangor (Dow Air Force Base); Grenier Air Force Base, New Hampshire; Fort Ethan Allen, Vermont; Wilmington, Delaware (New Castle Air Force Base); Madison (Truax Air Force Base); and, Albuquerque (Kirtland Air Force Base). Of further note, the very first 34 locations for 40 ADC alert fighter-interceptor squadrons, as of August 1952, include 18 verified as having had the Butler hangar: Portland; Hamilton Air Force Base, north of San Francisco; Oxnard Air Force Base, north of Los Angeles; George Air Force Base, near San Bernardino; Kirtland Air Force Base; Ellsworth Air Force Base, Rapid City, South Dakota; Truax Air Force Base; O'Hare Airport, Chicago; Scott Air Force Base, east of Saint Louis; Wright-Patterson Air Force Base, Dayton; Griffiss Air Force Base, Rome, New York; Niagara Falls Municipal Airport; Grenier Air Force Base; Ethan Allen Air Force Base; Dow Air Force Base; Otis Air Force Base, Massachusetts; New Castle Air Force Base; and Andrews Air Force Base. The 34 locations also included four verified as having had the Strobel & Salzman hangar: three installations in Washington, and Dover Air Force Base in Delaware. Of the remaining 12 locations, it is certain that two had a hangar that fell into disuse, replaced by a second generation Strobel & Salzman hangar (see below) in 1957 or later. At least two-thirds of the earliest ADC alert hangars, then, were Butler hangars—with the further coincidence between the Butler hangars and sites that were federalized as ANG alert during 1951. The probability is that the Butler alert hangar was the structure most often selected for high-priority erection at the outset of the ADC alert program in 1951-1952, and in a few cases that it continued to be a choice into 1954-1955, especially for locations of sustained alert that had not yet received infrastructure.

The Butler hangar was slightly larger than that of Strobel & Salzman, measuring 330 feet wide by 72 feet deep. Individual aircraft pockets were 74 feet wide. The depth of the hangar was made possible by the counter-weighted, flat-faced clamshell front and rear doors: actual depth without the added space provided by the doors was only 54 feet. As was the case for the Strobel & Salzman hangar, the four-pocket structure was basic, but expansion to eight pockets occasionally occurred. Alert crew quarters were central. The Butler hangar was a rigid-frame structure, descended from rigid-frame structures of the 1940s. A bolted-together and bolted-down structure, it could be erected easily on site; could additionally be moved to accommodate runway lengthening to 8,000, 9,000, 10,000, 12,000 or 13,000 feet during the middle and late 1950s; and, could be disassembled and shipped to a distant location for reuse. The hangar featured double-pitched gable roofs, hinged at the ridge, and directly reflective of the framing system of individual purlins. Sheathing was standing-seam steel siding. The McKee Door Company of Aurora, Illinois, manufactured the flat-faced clamshell doors. (See Plates 20 and 35.) Butler hangars erected at Kirtland and Ellsworth Air Force Bases, in New Mexico and South Dakota, were among the first in the country, with base-specific drawings dating to June 1951.[29] The Air Force did indeed move Butler hangars. At Kirtland the Air Force moved the hangar to accommodate a lengthened runway by 1957 (Plate 26). At the Portland Airport personnel disassembled the hangar, shipped it 150 miles north to McChord Air Force Base in the middle 1980s, with McChord personnel again disassembling it in the early 1990s for shipment to the Navy at China Lake, California. And at Ellsworth, the Air Force moved the hangar from the flightline to another on-base site for a second life as a museum. Engineer Norman W. Rimmer designed the Butler alert hangar, supervising Clyde R. Guder, Roger A. Hield, and Ralph E. Small. The Corps of Engineers had asked Butler to bid on an existing design. Rimmer instead proposed a hangar that reflected the lines of the aircraft. The Air Force tested a single-pocket version of the hangar at Oscoda, Michigan, in early 1951, with Rimmer present. That hangar had a front-opening door, with rear blast panel—suggesting that Butler was working with the Mills & Petticord prototype of March. Oscoda served as an artillery range and cold-weather proving ground, 1940-1952, later becoming the site for Wurtsmith Air Force Base. Following the test, Butler added a rear door to its alert hangar, as did Strobel & Salzman, with hangars in constructions late the same year.[30]

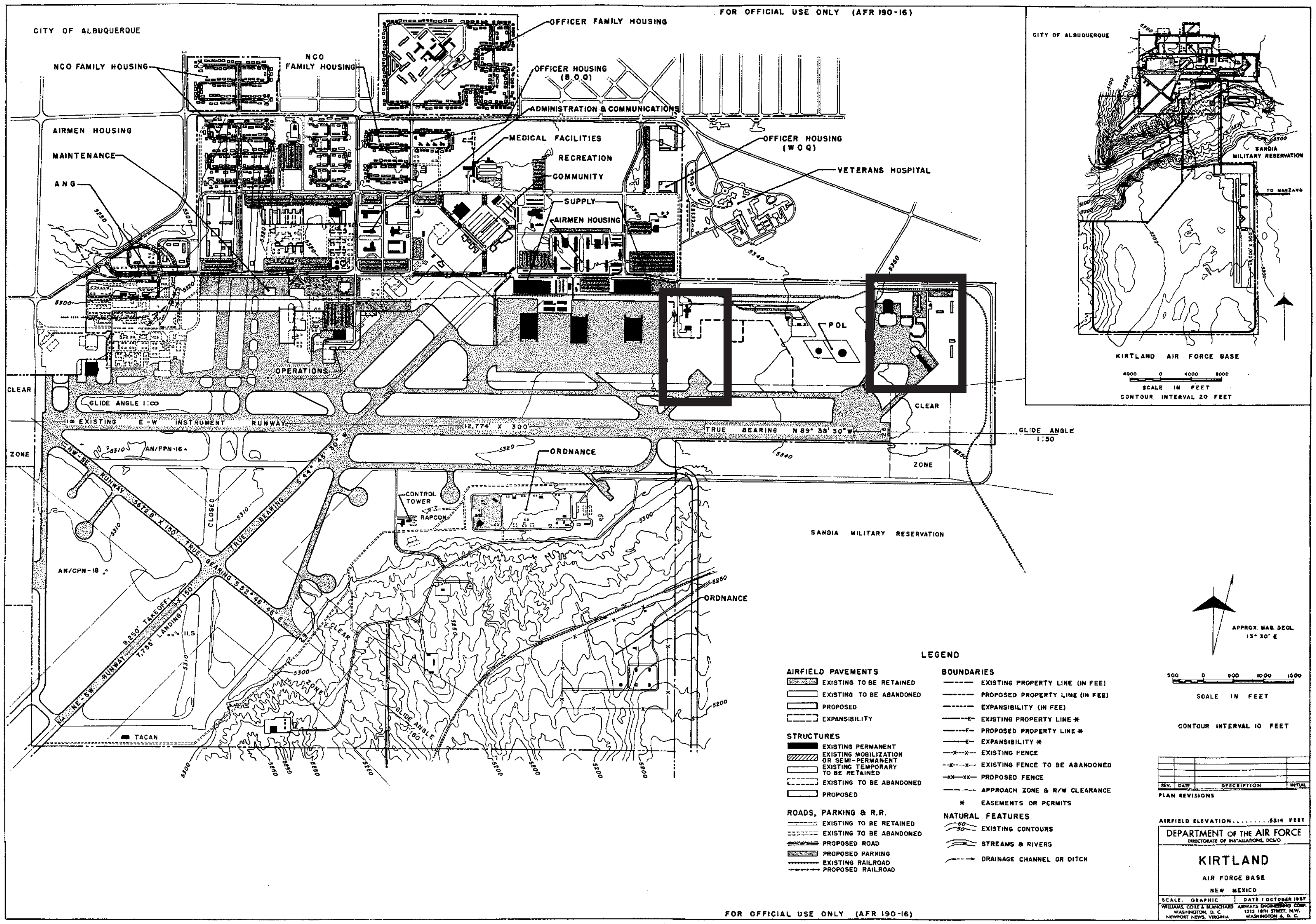

Plate 26. **First (flightline, near center) and second (flightline, right) locations for the Butler alert hangar. Each with support structures shown. Kirtland Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

First Generation Modified, and Second Generation, Alert Hangars

Modifications for the First Generation Hangars

Beginning in 1956-1957, and continuing through about 1960, ADC significantly modified both the Strobel & Salzman and Butler first generation hangars, through the replacement of the front and rear hangar doors. ADC slated this change only for the alert hangars receiving the F-101B, F-102 (F-102B), or F-106 (in development as the F-101A). The F-101 series was a much longer jet fighter, Air Force-approved for development as an interceptor in 1955.[31] The fighter required either entirely new alert hangars, or workable modifications to the existing system. By late 1955, ADC acknowledged that recent design changes for the F-101 and F-102, with the former aircraft lengthened from 67 feet, five inches, to 72 feet, and the latter aircraft from 68 feet, three inches, to 70 feet, eight inches—with increased tail height for the F-102, mandated that no more alert hangars be built unless they could accommodate the F-101 and F-102. "An analysis of existing hangars was made and the Corps of Engineers was instructed to design a 'blister,' or door extension for each of the four (4) types of hangars being used by the Air Force."[32] First plans, in 1956, were for a new hangar, but by 1957 the decision to modify many of the hangars currently in use became the dominant action.[33] In early 1958 the modification project was underway:

> In order to provide for continued use of existing alert hangar facilities to accommodate current and future deployment of latest configuration century series aircraft, a base-by-base evaluation for adequacy of alert hangars in Z.I. has been completed. Criteria drawings and cost estimate necessary to accomplish a selective modification for each installation … have been furnished Headquarters, Air Defense Command.[34]

ADC received its first F-101B in January 1959, with the first fighter-interceptor squadron equipped with the aircraft one at Otis Air Force Base in Massachusetts[35] (Plates 27-29).

Plate 27. Strobel & Salzman. First generation alert hangar modified for the F-101B at the former Duluth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

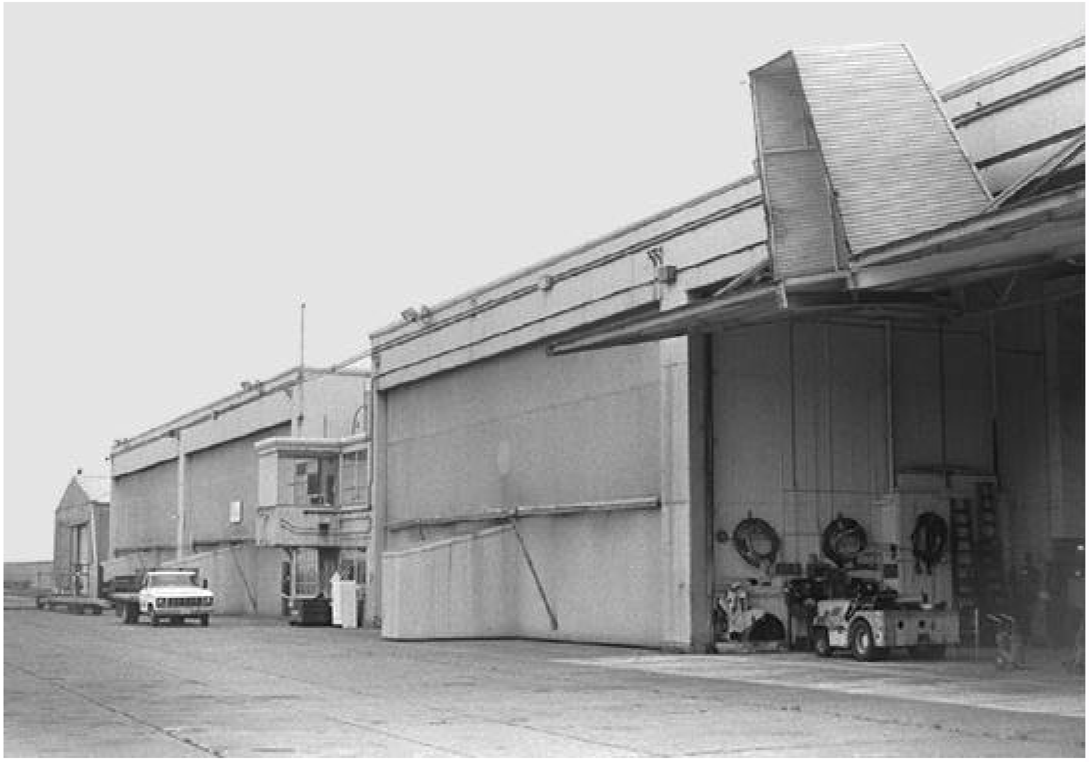

Plate 28. Strobel & Salzman. First generation alert hangar, modified, at the former Paine Air Force Base. View of front door extension, 1996. Photograph, K.J. Weitze.

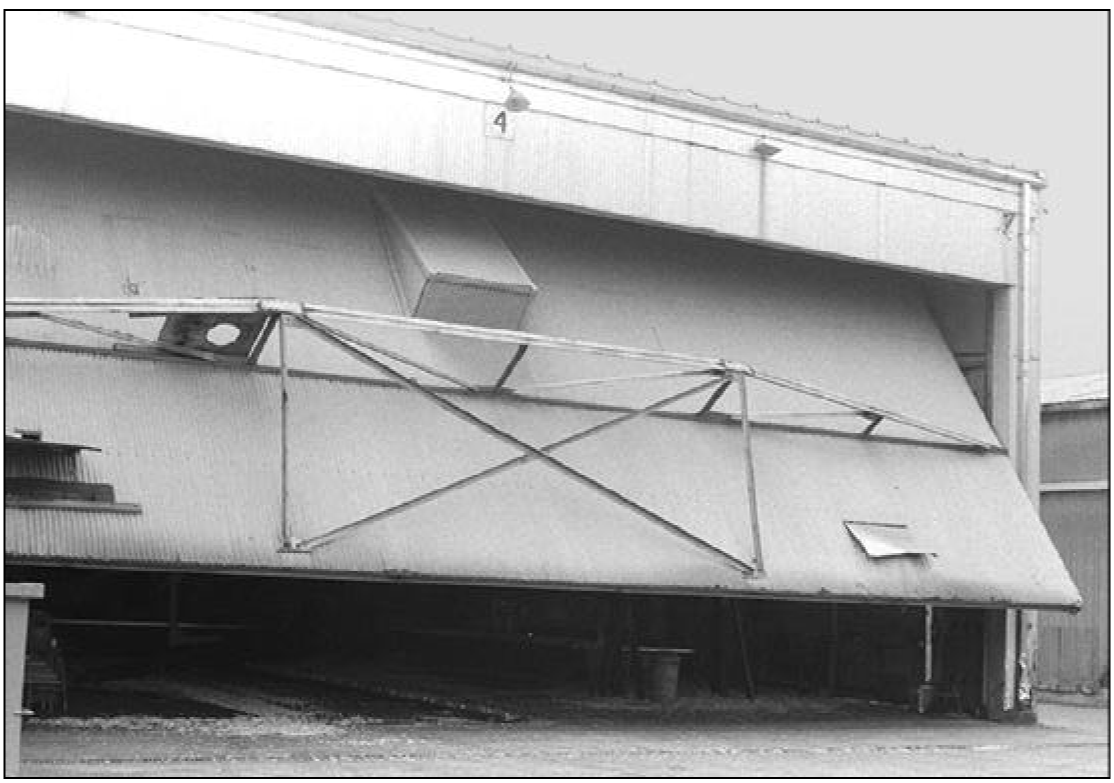

Plate 29. Strobel & Salzman. First generation alert hangar, modified, at the former Paine Air Force Base. View of rear door extension, 1996. Photograph, K.J. Weitze.

For the Strobel & Salzman first generation hangar, the International Steel Company, of Evansville, Indiana, manufactured the new doors. These doors were gravity opening doors, with four supporting cable systems visible from both the front and the rear. The doors featured nose and tail bubbles to accommodate the longer aircraft. In addition, a steel trusswork braced the front doors across their lower edges. (See Plates 16-17.) For the Butler first generation hangar, the Luria Engineering Corporation of New York handled the door replacement project. Luria was then simultaneously handling a large wing hangar program for SAC, and had been designing wing hangars for that command since 1951. The Luria doors were, like those for the Strobel & Salzman hangars, of mismatched front and rear configuration. The new front door featured a simple angled projection, while the rear door was a complex, multi-faced unit—a distended clamshell (Plates 30-35). Door replacement for hangars planned to get the F-101B were underway during 1958-1959. Butler hangars at Kirtland and Ellsworth Air Force Bases, for example, received the modification in late 1958 and late 1959, respectively.[36] ADC did not modify all of its alert hangars. Of note, by the late 1950s, some air defense installations were already slated for excess and only selected squadrons received the newest aircraft and weapons systems. In addition, Congress openly challenged “the entire air defense posture.” Fighter-interceptor squadrons had increased from 40 in 1952 to 55 in 1954, peaking at 65 in 1956. By 1959, the plan was to reduce fighter-interceptor strength from the 62 existing squadrons to only 44 squadrons by 1962-1963.[37] By 1967, only 31 air defense squadrons were operational, becoming 14 by 1970, and six by 1980.[38]

Plate 30. Butler alert hangar. Rear doors. Here reassembled incorrectly after move for new use as museum. Ellsworth Air Force Base. July 1999. Photograph, K.J. Weitze.

Plate 31. Butler alert hangar. Modified front doors. Command booth and crew quarters center. Andrews Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 32. Butler alert hangar. Oblique view of flightline facade. Andrews Air Force Base. 1995. Courtesy of Geo-Marine, Inc.

Plate 33. Butler Manufacturing. Alert hangar at the former Richards-Gebaur Air Force Base. Modified rear doors. View of July 1999. Photograph, K.J. Weitze.

Plate 34. Butler / Strobel & Salzman. Eight-pocket alert hangar at the former Truax Air Force Base. Modified front doors. View of July 1999. Photograph, K.J. Weitze.

Plate 35. Butler Manufacturing. Alert hangar with original doors. Wright-Patterson Air Force Base. View of September 1999. Photograph, K.J. Weitze.

Second Generation ADC Alert Hangar

ADC did proceed with a second generation alert hangar in early 1956. For this structure, ADC made a fundamental change. The basic hangar was to include two aircraft pockets, not four, with centered alert quarters. "The provision for two (2) large hangar pockets in lieu of four (4) smaller aircraft pockets will provide greater flexibility for future aircraft."[39] Strobel & Salzman designed this hangar to supercede its first generation structure, with a set of 22 drawings completed in late January 1957[40] (Plates 36-38). Simultaneously, Strobel & Salzman designed an aircraft shelter for ADC (see below), with each shelter identical in size and design to one of the aircraft pockets of the second generation alert hangar.[41] Each aircraft pocket (or shelter) measured about 106 feet wide by 89.5 feet deep—as compared to the 68-foot width and 69-foot depth of the first generation Strobel & Salzman alert hangar.[42] ADC appears to have erected the second generation Strobel & Salzman alert hangar in the intended two-pocket configuration only in a small number of cases, with an excellent example at Loring Air Force Base in Maine.[43] Loring was taking over the air defense mission from near-by Presque Isle Air Force Base, which was slated for early closure in 1959. At an unknown, but also likely small, number of installations, ADC built the second generation alert hangar in a four-pocket configuration (Plates 39-42). The second generation Strobel & Salzman alert hangar is substantially larger than the firm's first generation hangar, but visually quite similar.[44] In some cases, ADC and TAC also made front and rear door modifications to the second generation Strobel & Salzman hangar—modifications notably different from those for the first generation hangars.

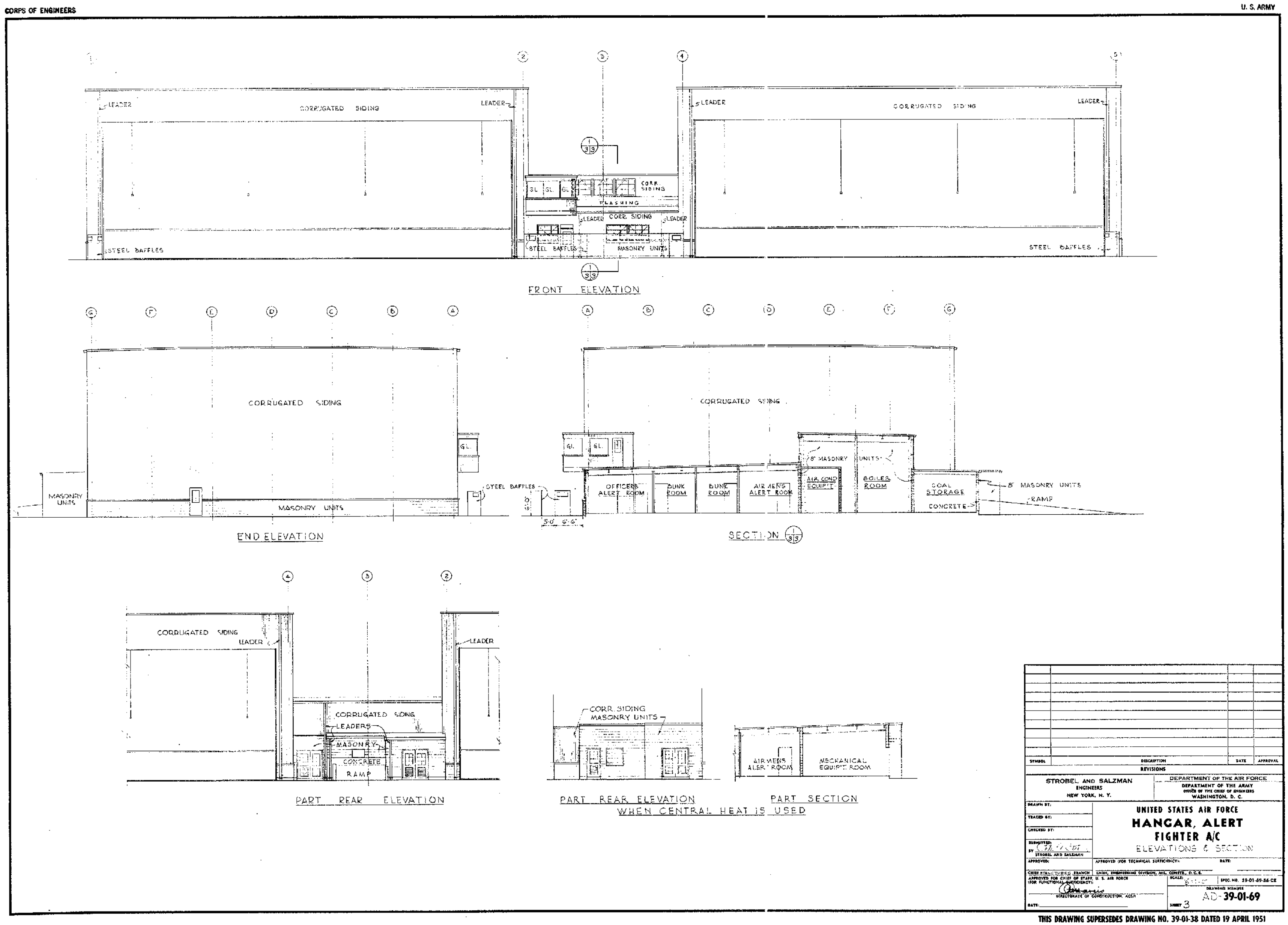

Plate 36. **Strobel & Salzman. Two-Pocket Alert Hangar, Elevations. January 1957. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

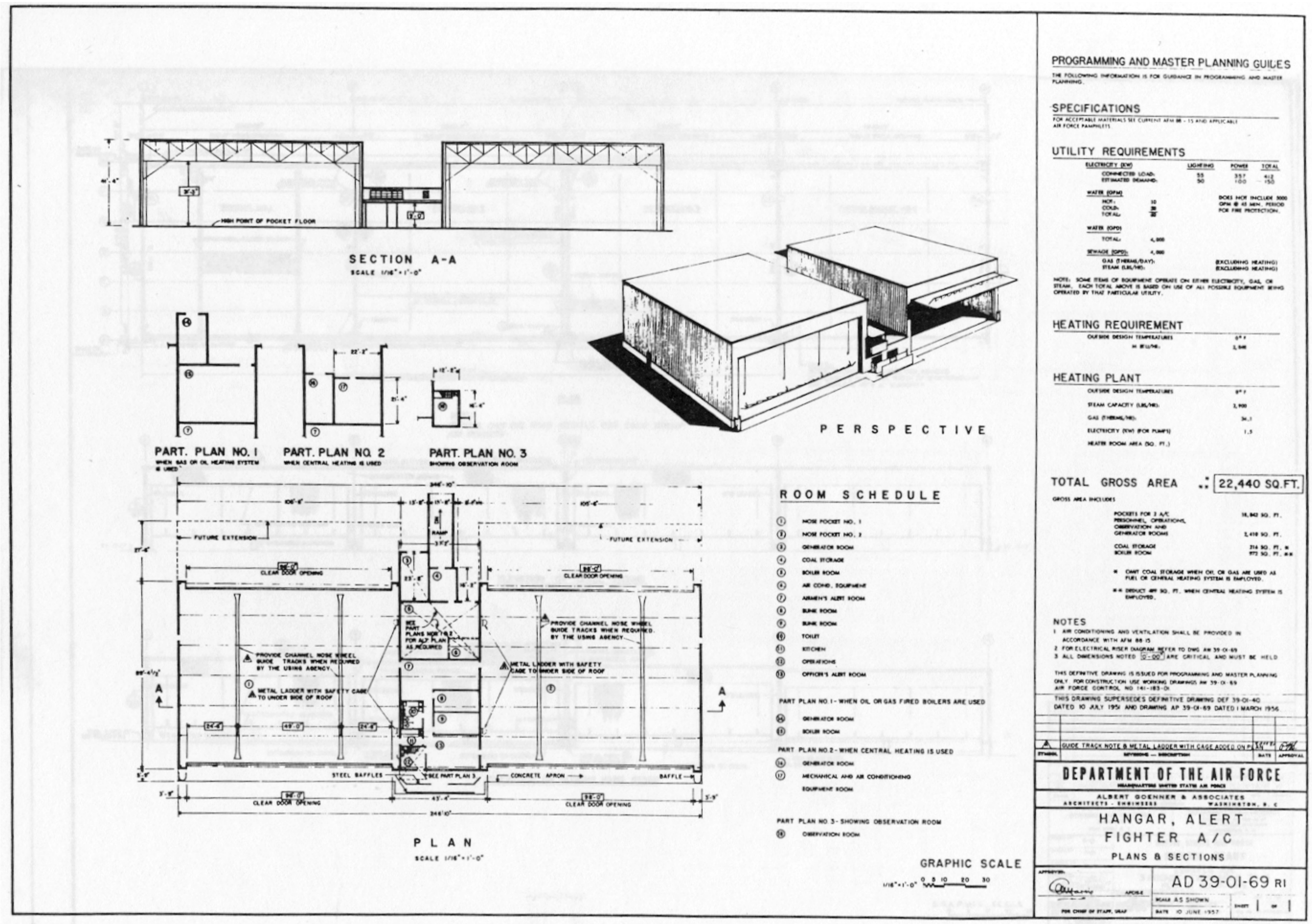

Plate 37. **Strobel & Salzman. Two-Pocket Alert Hangar, Plans and Sections. January 1957. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

Plate 38. Strobel & Salzman. Second generation, two-pocket alert hangar at the former Loring Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 39. Strobel & Salzman. Second generation, four-pocket alert hangar. Davis-Monthan Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

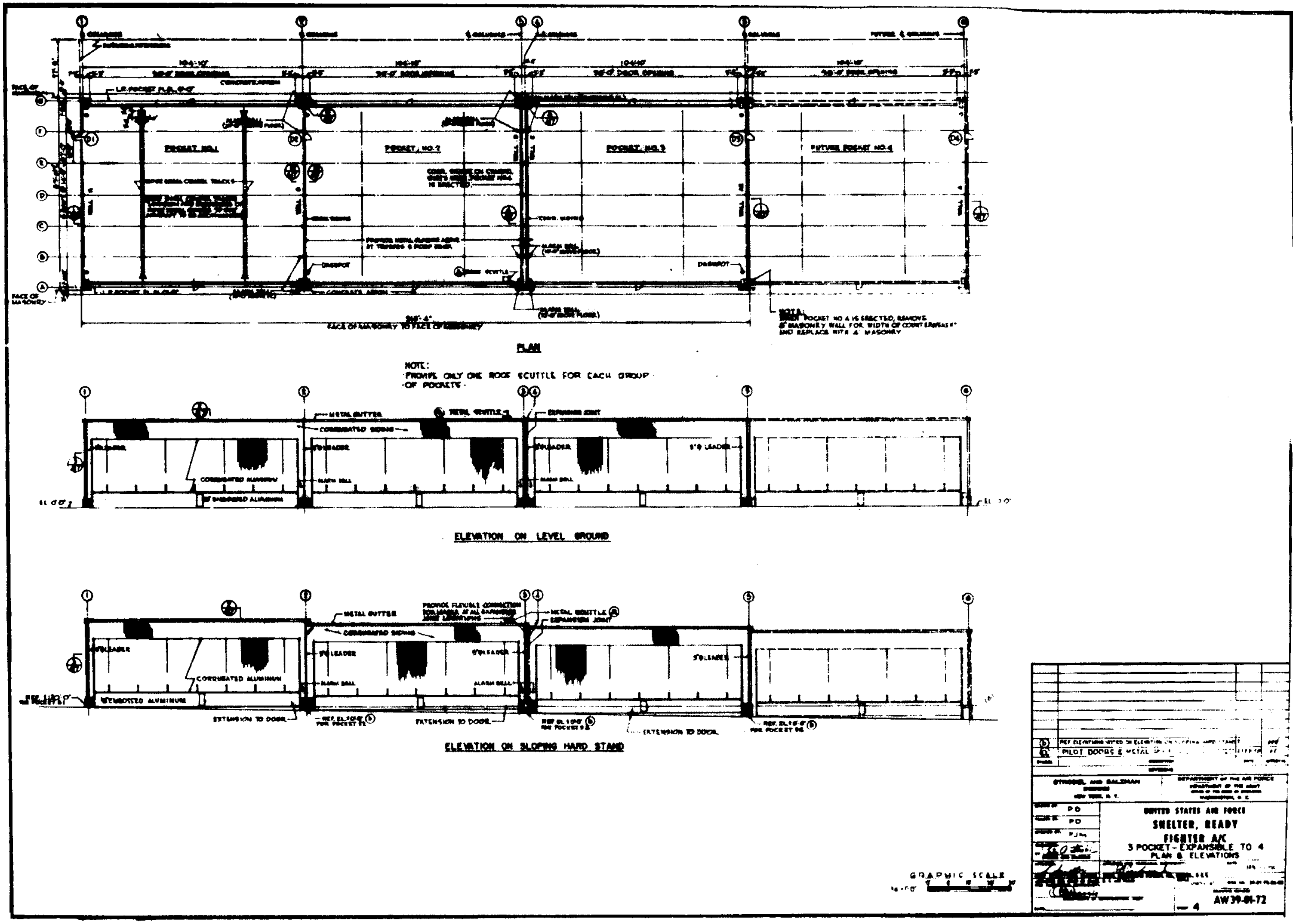

Plate 40. **Strobel & Salzman. Second generation, four-pocket alert hangar. Hangar derived from the basic design for an aircraft shelter. January 1957. Reproduced from** ***Overview of Military Aircraft Hangars*** **(1996).**

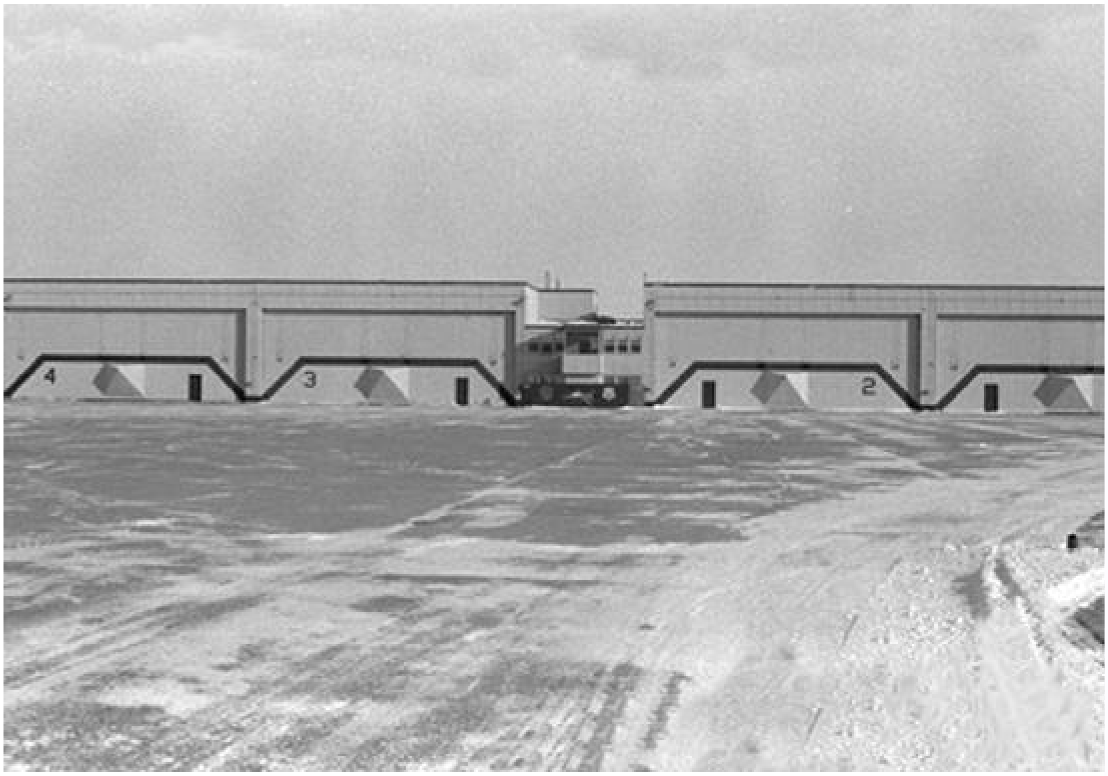

Plate 41. Strobel & Salzman. Second generation alert hangar. Modified front doors. Minot Air Force Base. View of 1996. Photograph, K.J. Weitze.

Plate 42. Strobel & Salzman. Second generation alert hangar. Modified rear doors. Minot Air Force Base. View of 1996. Photograph, K.J. Weitze.

TAC Hangars of the 1960s and 1970s

During the first 30 years of the Cold War, until 1980, TAC's mission was to maintain fighter squadrons in the event that these forces were needed as deterrence in the United States, or for deployment in war. At its earliest Cold War bases, TAC apparently relied on available Air Force infrastructure—adapting it to the needs of the command. The varied situations tended to mask the choice of structures. For example, the TAC headquarters installation at Langley largely supported fighter aircraft but did in fact also support the smaller bombers of the early 1950s (the B-26, the B-45 and the B-50). Langley chose to erect the SAC basic double-cantilever hangar as its key maintenance building for both fighters and bombers. At Seymour Johnson and Shaw, installations in North and South Carolina respectively, TAC also erected the smallest version of the SAC double-cantilever hangar. Seymour Johnson supported SAC as a tenant, but was a key TAC base. Shaw, also an important TAC installation, hosted only the smaller fighter-bombers (the B-57 and the B-66), in addition to its fighters.

The air defense mission was not the direct responsibility of TAC until after the discontinuance of ADC in 1979. Headquarters Air Force no longer was willing to support two fighter commands, and made ADC a subordinate unit of TAC—naming the new entity Air Defense-TAC (ADTAC). Nonetheless, the demise of ADC occurred slowly and steadily during the 1960s and 1970s as the command "gradually lost interceptors, radars, bases, and personnel to TAC."[45] As ADC grew smaller during these two decades, TAC acquired ADC real property, yet also required new infrastructure in support of its growth. The TAC solution of the 1960s was very different from that of either ADC or SAC during the 1950s. In part, it is assumed that TAC's choices reflected a maturity of infrastructure across the Air Force, as well as a channeling of military funding into the missiles and space programs. The result was a turn to generic, fully standardized flightline structures for small aircraft, used in multiple unit configurations, and erected with little or no change from about 1960 to 1977. While the infrastructure recalled the mobilization efforts of 1951 (as seen, for example, in the SAC wing hangars for the B-36), here the structures were not a striving toward solving new problems. Instead hangars were utilitarian, and relied on already mature design programs and engineering.

Two key types of structures were widely erected across TAC installations. One type was a rigid-frame building manufactured by Butler, of at least two distinct roof configurations and aircraft pocket sizes, while the other, not rigid-frame construction, is of yet unresearched origin. The Butler structures were sometimes described as "prefabricated aircraft shelters," but, through the Air Force processing of standardized drawings, almost never retained crediting to Butler, instead often carrying the name of the architectural-engineering firm responsible for that particular series of definitives.[46] The patented rigid-frame system is clearly identifiable in section drawings. Examples of Butler rigid-frame structures used by TAC include the "Aircraft Shelter (Fighter Ready) Inclosed & Open" [1958]; the "Shelter Aircraft Weapons Calibration 'Type A' (Closed & Open Facilities)" [1959], and the "Shelter Aircraft Weapons Calibration Type 'B' (Closed & Open Facilities)" [1959][47] (Plates 43-45). For the latter two shelters, weapons calibration types A and B, Kuljian Corporation oversaw the design of the structures (see below). TAC used these three Butler buildings in several ways: as calibration shelters for fighter-interceptors (inherited from ADC) and as more generic maintenance docks and aircraft shelters. The second key type of structure used across TAC installations was the "Dock Aircraft Maintenance Small Aircraft." This structure appears to date to about 1961, and was suggested for erection in four configurations: types A, B, C, and D. These configurations translated to single-, double-, triple-, and quadruple-unit clusters with a single band of recessing panel doors across a unified façade. Individual units were 96 feet deep and 89 feet, nine inches wide.[48] TAC bases all sustained this latter infrastructure, with Nellis Air Force Base in Nevada a particularly good example of multiple clusters of different sizes. TAC erected these hangars both parallel and perpendicular to the flightline (Plates 46-48).

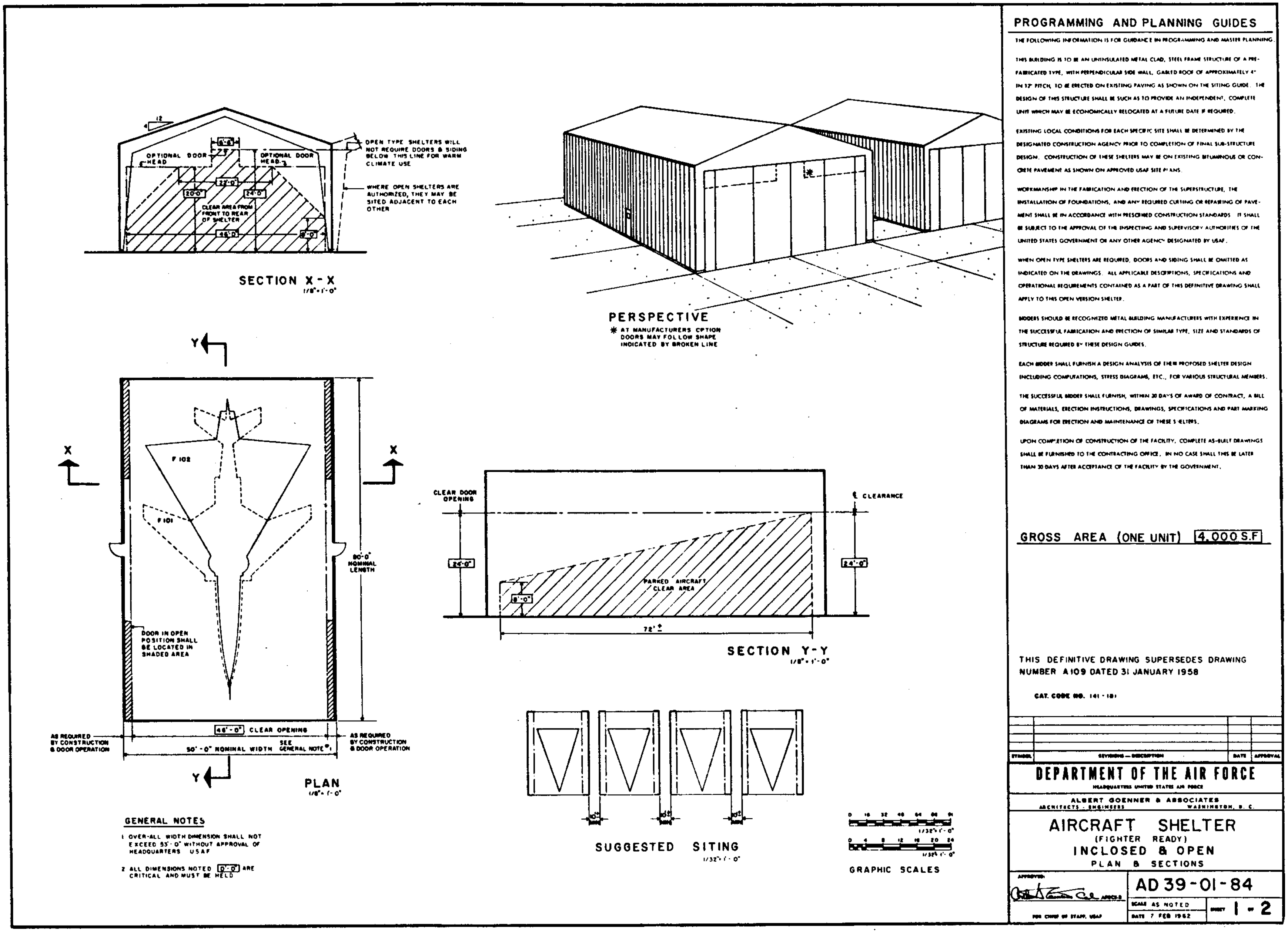

Plate 43. **Butler Manufacturing. Prefabricated ready fighter aircraft shelter, plan and section. 1958. Reproduced from** *Overview of Military Aircraft Hangars* **(1996).**

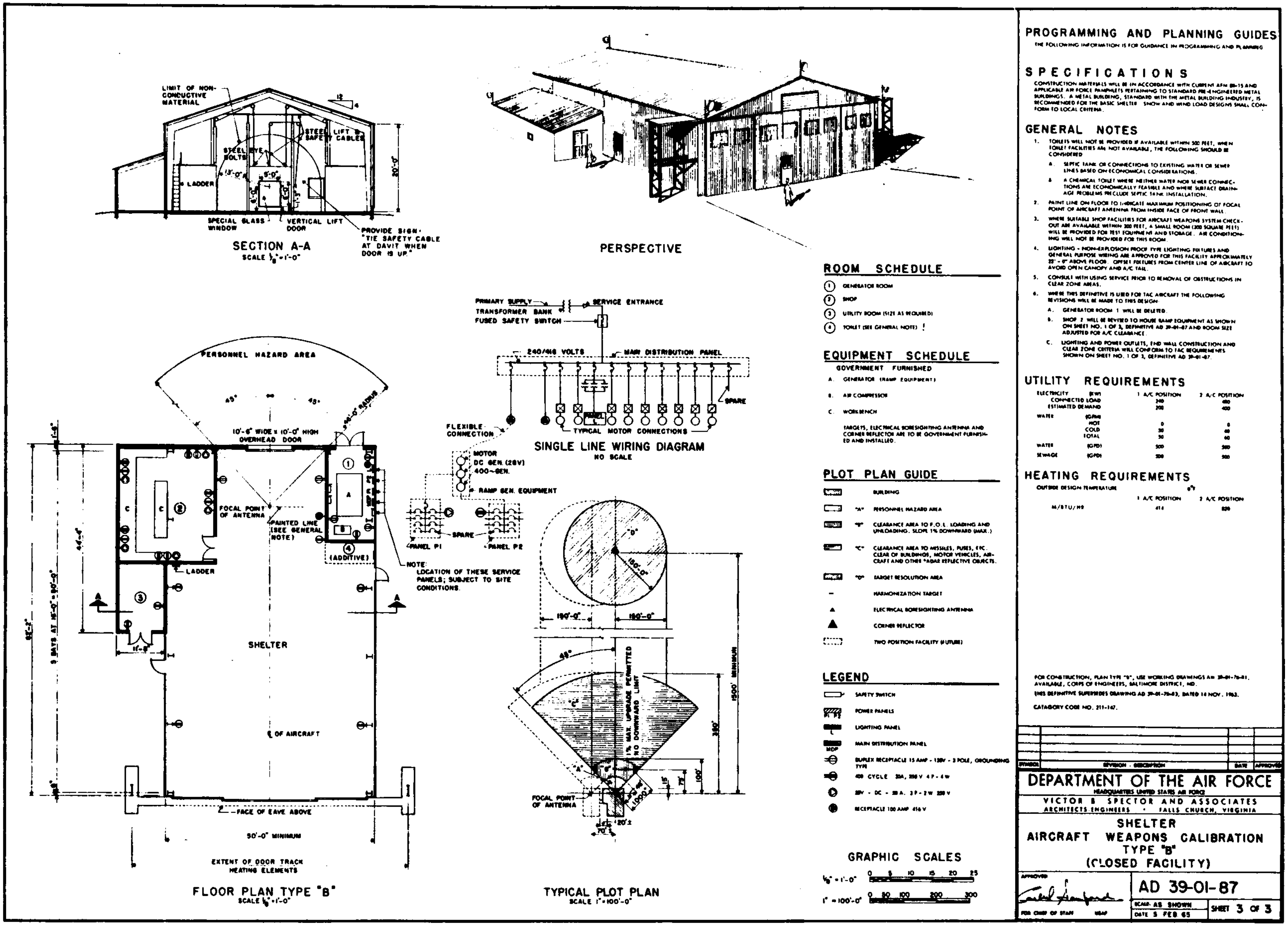

Plate 44. **Butler Manufacturing. Prefabricated ready fighter aircraft shelter adapted by Kuljian Corporation for weapons calibration, type B. 1959. Reproduced from** ***Overview of Military Aircraft Hangars*** **(1996).**

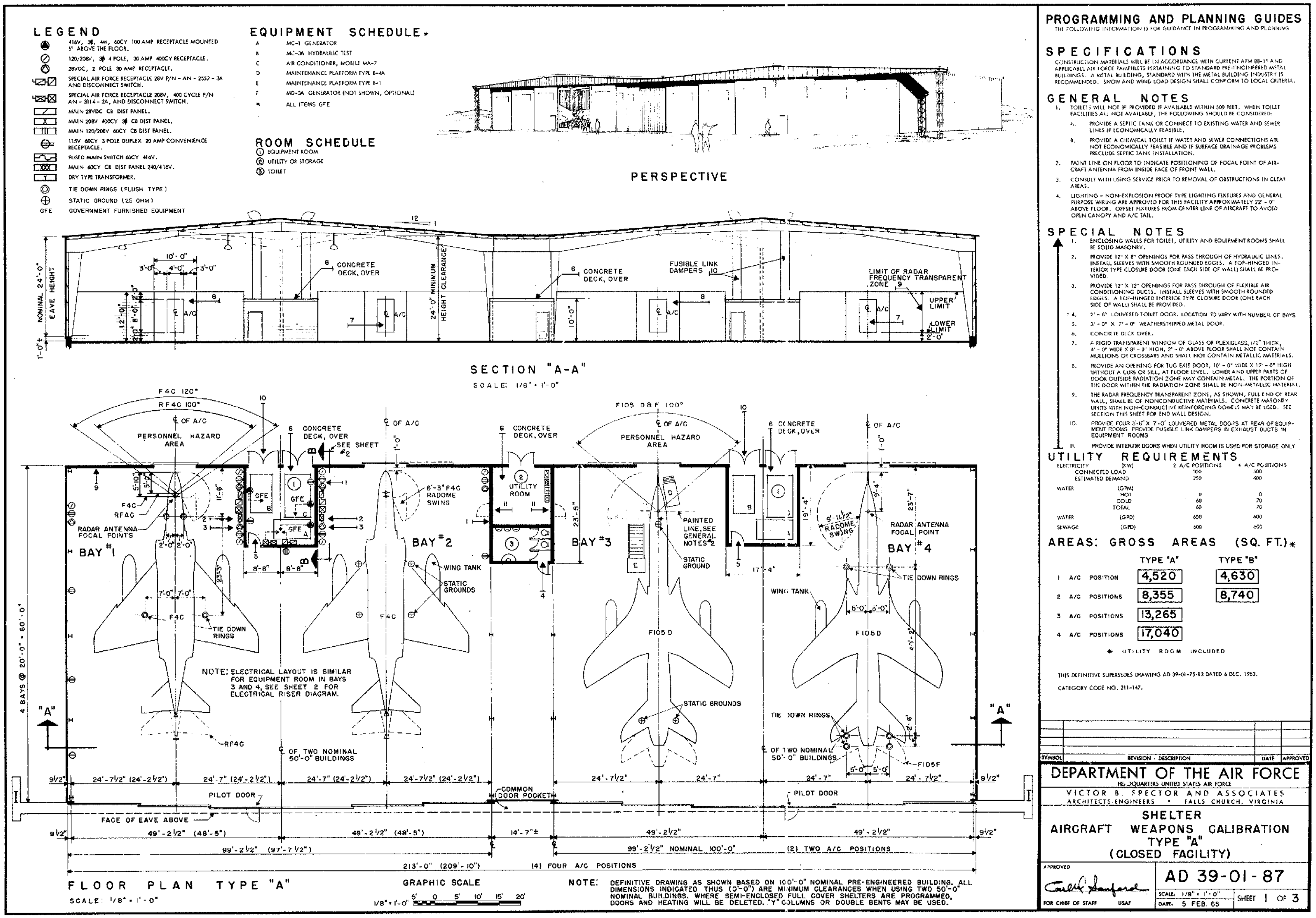

Plate 45. **Butler Manufacturing. Prefabricated ready fighter aircraft shelter adapted by Kuljian Corporation for weapons calibration, type A. 1959. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

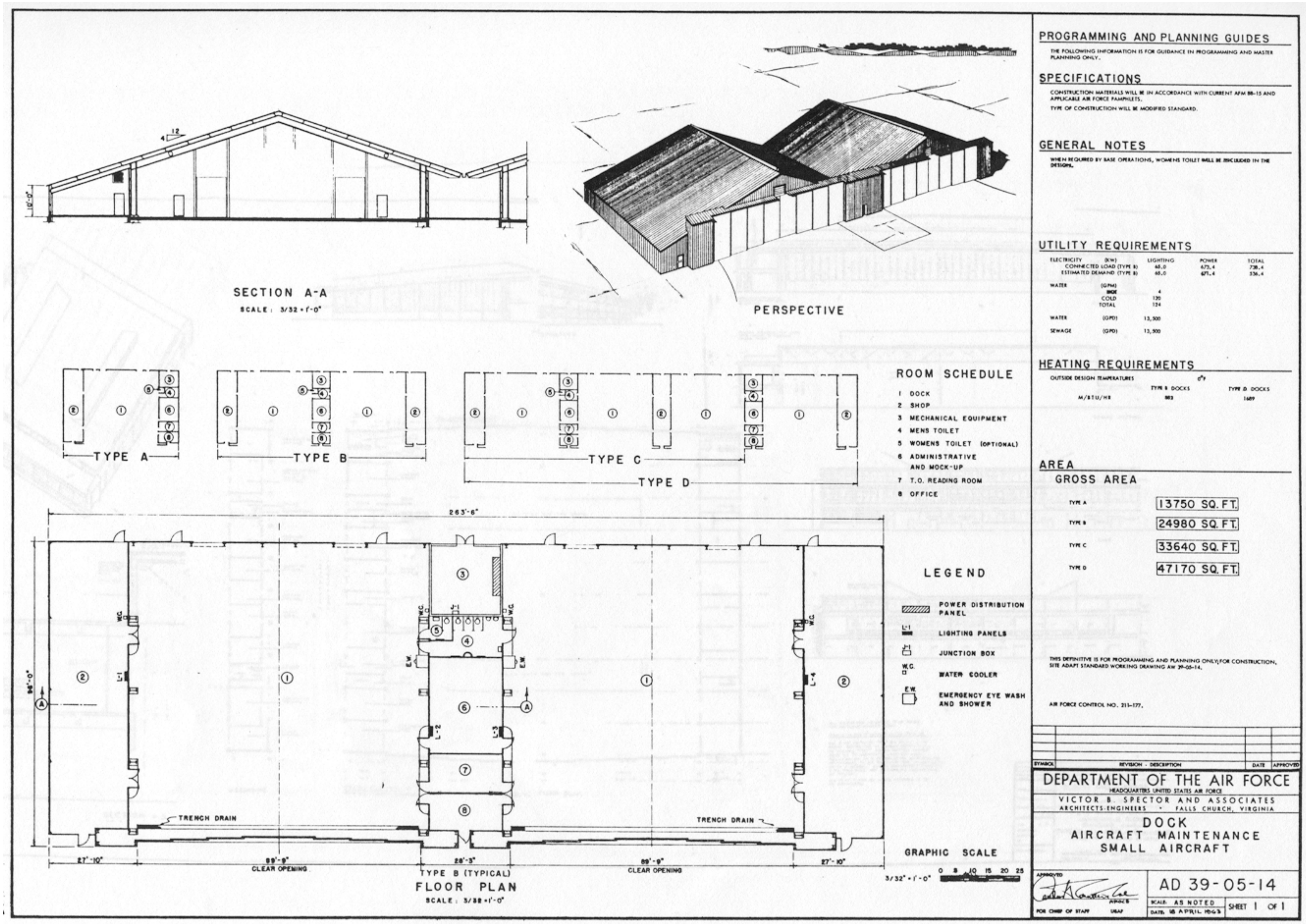

Plate 46. **Tactical Air Command. Small Aircraft Maintenance Dock, Perspective, Elevation and Plan. 1961-1963. Reproduced from** ***Overview of Military Aircraft Hangars*** **(1996).**

Plate 47. Tactical Air Command. Groupings of maintenance docks perpendicular to the flightline. Nellis Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 48. Tactical Air Command. Pair of maintenance docks parallel to the flightline. Nellis Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

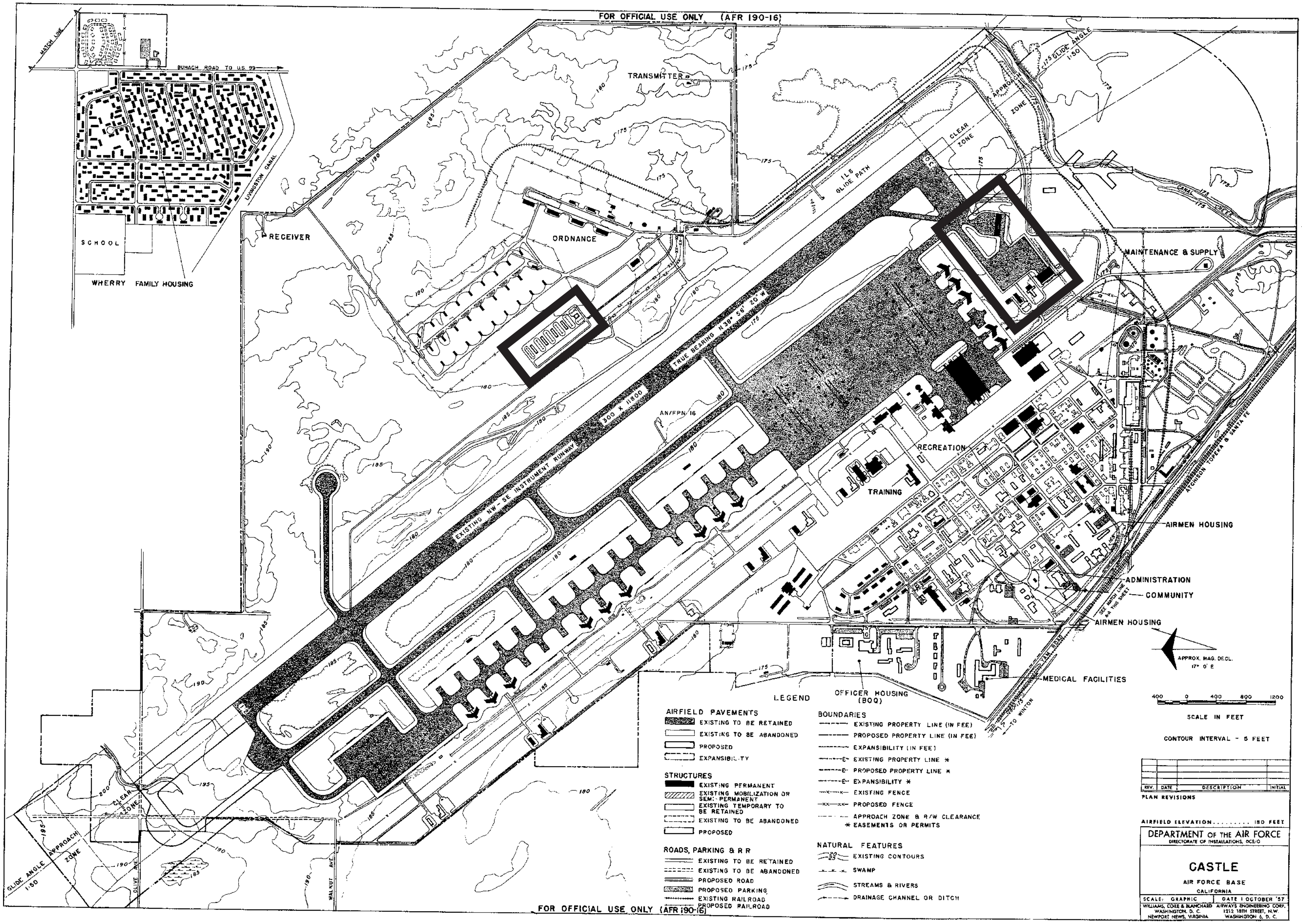

Plate 49. ADC alert area (background right). Alert hangar with support structures. Weapons checkout and storage (background left). Castle Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.

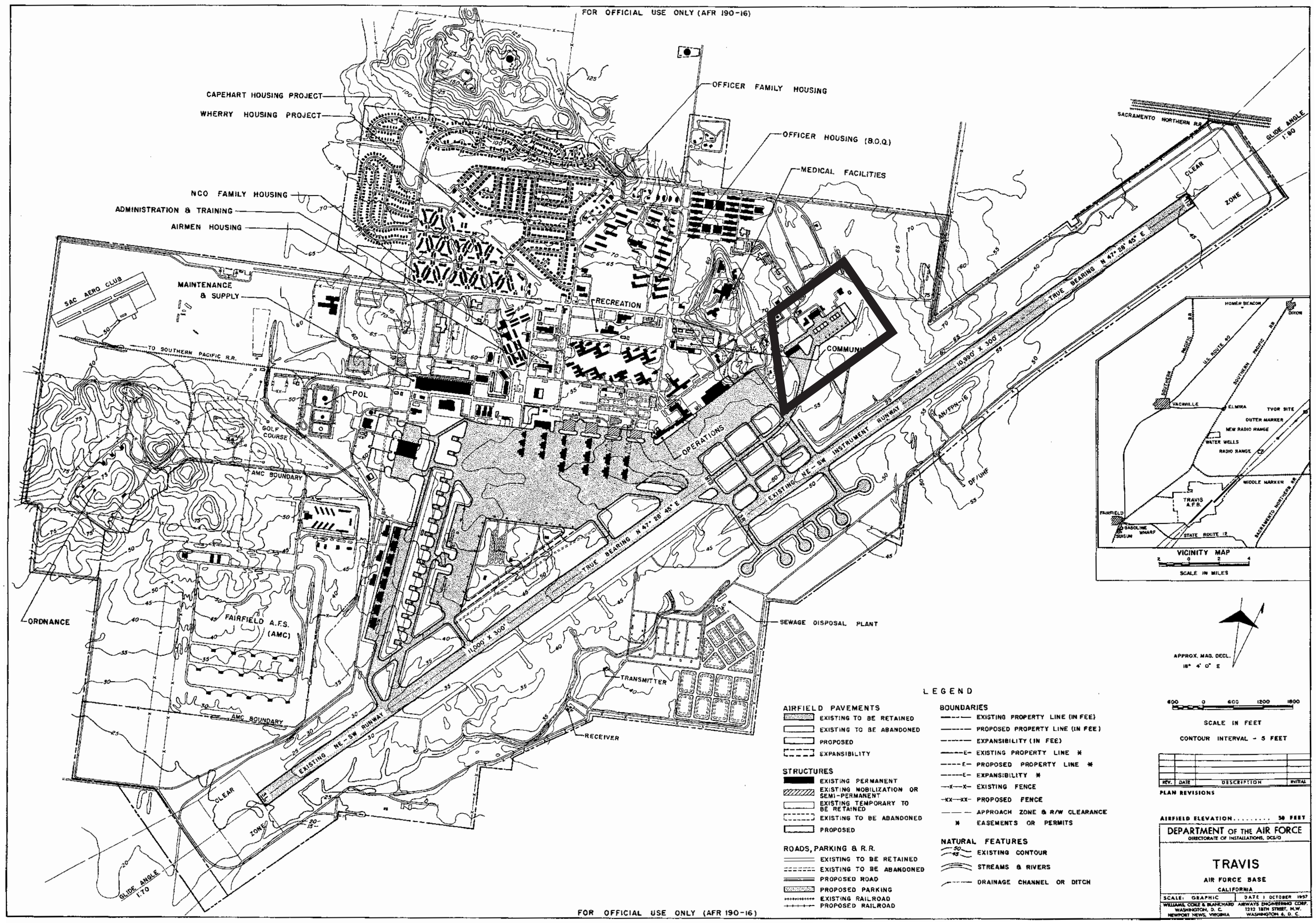

Plate 50. **ADC alert area (miground right of center). Alert hangar with support structures. Travis Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

Support Structures for Alert

A sizeable cluster of supporting structures accompanied fighter-interceptor alert from its inception in 1951 through its maturity in the early 1960s. ADC alert was quite different from SAC alert, even though the commands orchestrated both alerts at the end of an installation's longest runway—and often were present near each other. ADC's alert was a first, and primary, mission for its command from the outset of the Cold War, while SAC's alert grew more slowly in the middle 1950s and did not become formalized until 1959-1960. This situation meant that ADC placed its support structures at the flightline *from the beginning*, near the alert hangar. By the time SAC formalized alert, the command's support was already in place elsewhere along the flightline or on base, particularly in its very large maintenance hangar(s); its nose docks and wing hangars; and its weapons storage areas—with much of that support large-scale and representing a considerable expenditure of real property funds. ADC alert support structures, then, offer an opportunity to read the fighter-interceptor landscape at installations in a quite cohesive way, with a linear evolution typically present that reflects the fast-paced changes in fighter aircraft, weapons, and links to command-communications during the 1950s. From selected physical vantage points (on the ground or from the air), one can see the ADC alert grouping all at one time, in a single viewshed. While not as flashy as SAC alert moleholes and Christmas tree alert aprons, the ADC alert configuration offers considerable information about the role of the air defense fighter-interceptor squadron. Different too from the uniformity of the SAC alert infrastructural web, that of ADC allows a viewer to see the distinctions in mission from installation to installation—what aircraft were where, what weapons were in place, when and how long an alert fighter-interceptor mission was active (Plates 49-50).

The grouping of structures supporting 1950s ADC alert included a ready crew dormitory; squadron operations; a flight simulator; readiness/maintenance hangars; aircraft shelters; electronics and calibration structures; and, weapons checkout and storage. Primary engineering firms responsible for the ADC alert supporting structures were Strobel & Salzman, Kuljian, Weiskopf & Pickworth, and Black & Veatch. ADC introduced each of these buildings in particular time periods, and some categories of real property had specific evolutions over the decade indicative of the assigned aircraft and their weapons. The alert hangar, with its central alert crew quarters, was in all ways the focal structure for the cluster. For the most part, supporting structures were architecturally modest, paralleling the distinctive, but understated, configuration of the alert apron itself. Interestingly, when an early air defense alert installation lengthened its runway to accommodate faster, more sophisticated jet fighters, a double-vision landscape was left behind. In these instances—all with a Butler alert hangar, a discarded alert apron and taxiway, with a complement of supporting structures, remained in situ. ADC then added a second alert taxiway and apron at the extended terminus of the runway; moved the alert hangar to the new location on the flightline; and built a second group of supporting structures at the re-established alert site. Sometimes only the supporting structures are left behind, with original alert apron and hangar completely gone, a case where reading the landscape carefully tells a story otherwise visually missed.

The Readiness Crew Dormitory and Squadron Operations

ADC used a standardized design for a 25-year construction readiness crew dormitory developed in 1951 by a Washington, D.C., architectural-engineering firm, Charles M. Goodman, Associates. The readiness crew backed up the alert crew and provided operations links. By the middle 1950s, most as-built readiness crew dormitories reflected revisions to the original design, but remained based on the evolved standardized design coordinated through the U.S. Army Corps of Engineers for the Air Force.[49] Adaptations by the local architectural-engineering firm in charge of construction for a particular installation were common, although modest, and often reflected choice of materials (stuccoed wood-frame or concrete-block); differing fenestration and heating systems; and inclusion or deletion of an ell wing, basement, or full upper story. Typically, ADC first incorporated its squadron operations that supported alert in the readiness crew dormitory. At some installations ADC built a separate squadron operations building almost immediately, revamping the original squadron operations space in the readiness dormitory to additional airmen housing. Often in the late 1950s, ADC planned to erect a second readiness dormitory, mirroring the first—usually this expansion did not occur. The readiness crew dormitory, with squadron operations incorporated, included a large briefing room on each floor; an intelligence reading room and office; locker and personnel equipment rooms; an aircrew ready room; a mess area and kitchen; and officers and airmen dormitory space. Overall building design reflected that of the 1950s, with flat roofs, banded fenestration, and functional appearance (Plate 51).

Flight Simulator

ADC alert areas typically added a flight simulator between 1952 and 1958. First called the "physiological high altitude building," the simulator dates to mid-1951. A definitive fighter simulator followed in early 1952, with formal revisions for a subsequent design in mid-1955.[50] "The basic plan permits housing of the various types of Simulators and expansion to provide for additional Simulators or expanded to accommodate F-151 trainers."[51] Usually of one-story, concrete-block construction, the structure was small and windowless with flat roof. Continued use of the area for fighter-interceptors, particularly by TAC, typically meant a major high-bay addition and upgrading for later-era aircraft (Plate 52).

Readiness/Maintenance Hangars

Although all readiness and maintenance hangars supporting ADC alert are similar, the hangars underwent a distinct evolution between those built at the outset of the decade and those built toward its close. Three standardized hangar designs of 1951, 1953, and 1955 are present across ADC installations. All were typically steel-frame, sheathed in corrugated steel siding.

The hangar of 1951 is that of Mills & Petticord of Washington, D.C., partnered with Luria Engineering of New York[52] (Plate 53). The 1951 hangars featured both bow-truss and gabled roofs, with lean-to shops lining the sides and rear of the hangar. The bow-truss structure, more clearly linked to hangars of World War II, was of wood-frame construction, and is likely the design of January 1951. A second standardized design, of much different type, superceded the first in July the same year. This final Mills & Petticord hangar featured a low-pitched gable roof and an interior trussed 80-foot cantilever system joined at the ridge line. Depth and width of the hangar clear span was about 116 by 160 feet.[53] At Andrews Air Force Base, outside Washington, D.C., ADC built both hangars side by side during 1952 and 1953. Typically in the early 1950s ADC had one or two readiness/maintenance hangars perpendicular to the flightline in the near vicinity of the alert hangar, and clustered with the other supporting structures.

In mid-1953 Strobel & Salzman refined the work of Mills & Petticord, in a sense continuing the design program begun with their ADC alert hangar of 1951.[54] Characteristics and size of the hangar were identical to that of Mills & Petticord, but interior cantilevered trusswork was of considerably greater sophistication. The design of the façade featured overall unity and modernized, recessing panel doors. Again shops lined the sides and rear of the hangar. The Strobel & Salzman hangar was always built in pairs perpendicular to the flightline (Plates 54-55).

Plate 51. ADC readiness crew dormitory. Grand Forks Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 52. ADC flight simulator (midground left) and readiness/maintenance hangar (midground right). Travis Air Force Base. View, 1995. Courtesy of Geo-Marine, Inc.

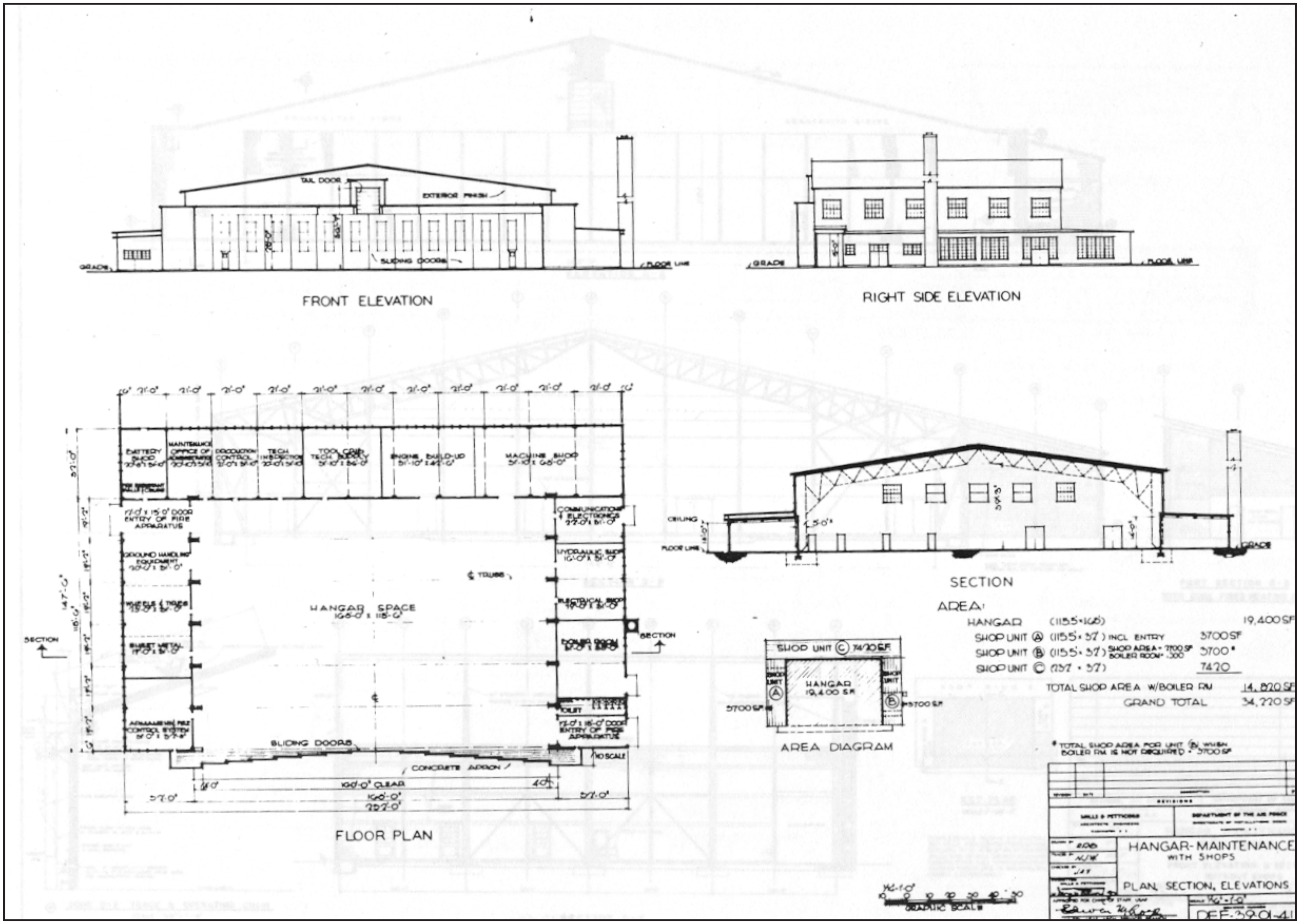

Plate 53. **Mills & Petticord, with Luria Engineering. Maintenance Hangar with Shops. 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

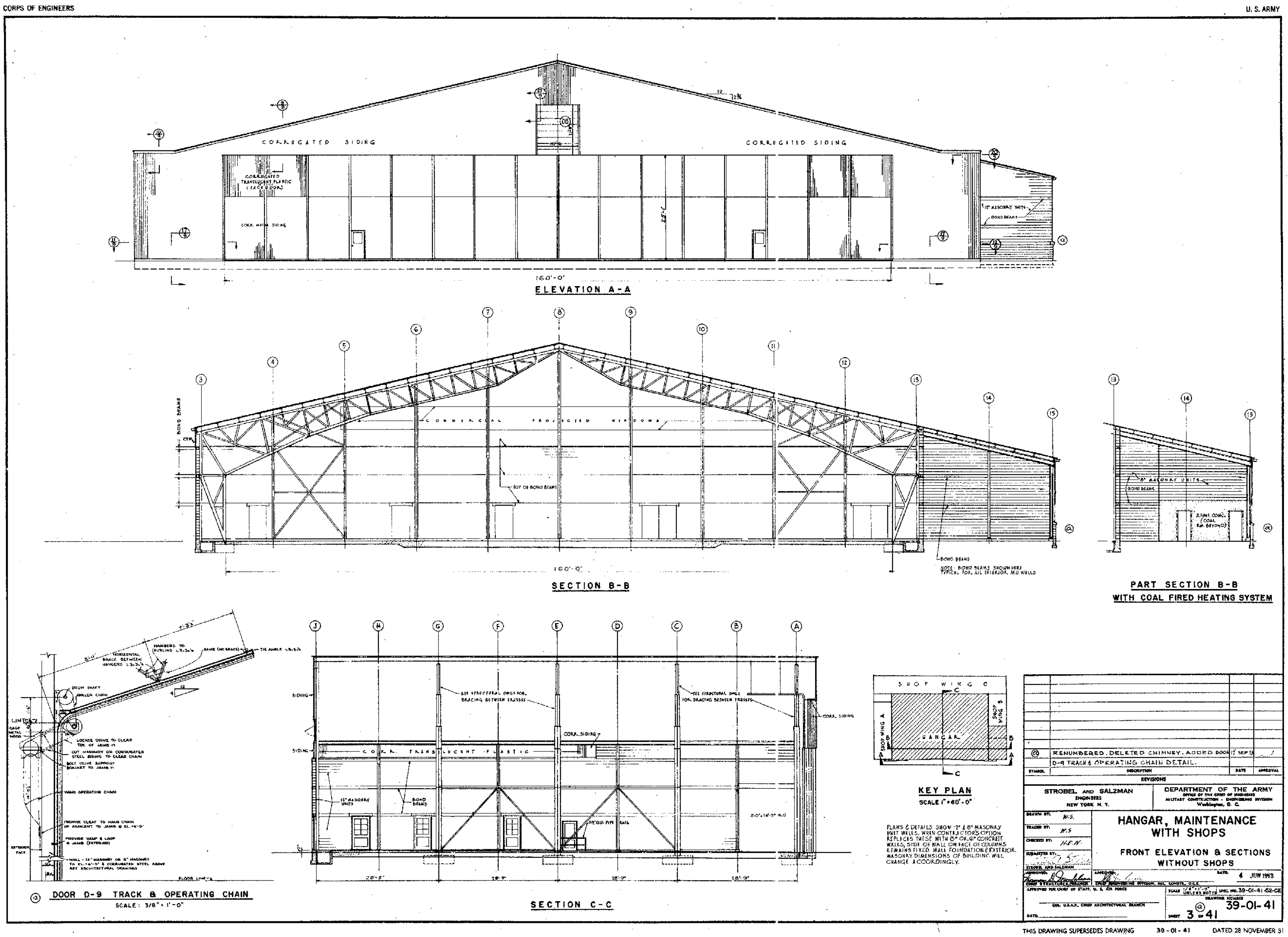

Plate 54. **Strobel & Salzman. Maintenance Hangar with Shops, Elevation and Sections. 1953. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

Plate 55. Strobel & Salzman. Readiness/maintenance hangar, with ready crew dormitory. Travis Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 56. Kuljian Corporation. Readiness/maintenance hangar. Grand Forks Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

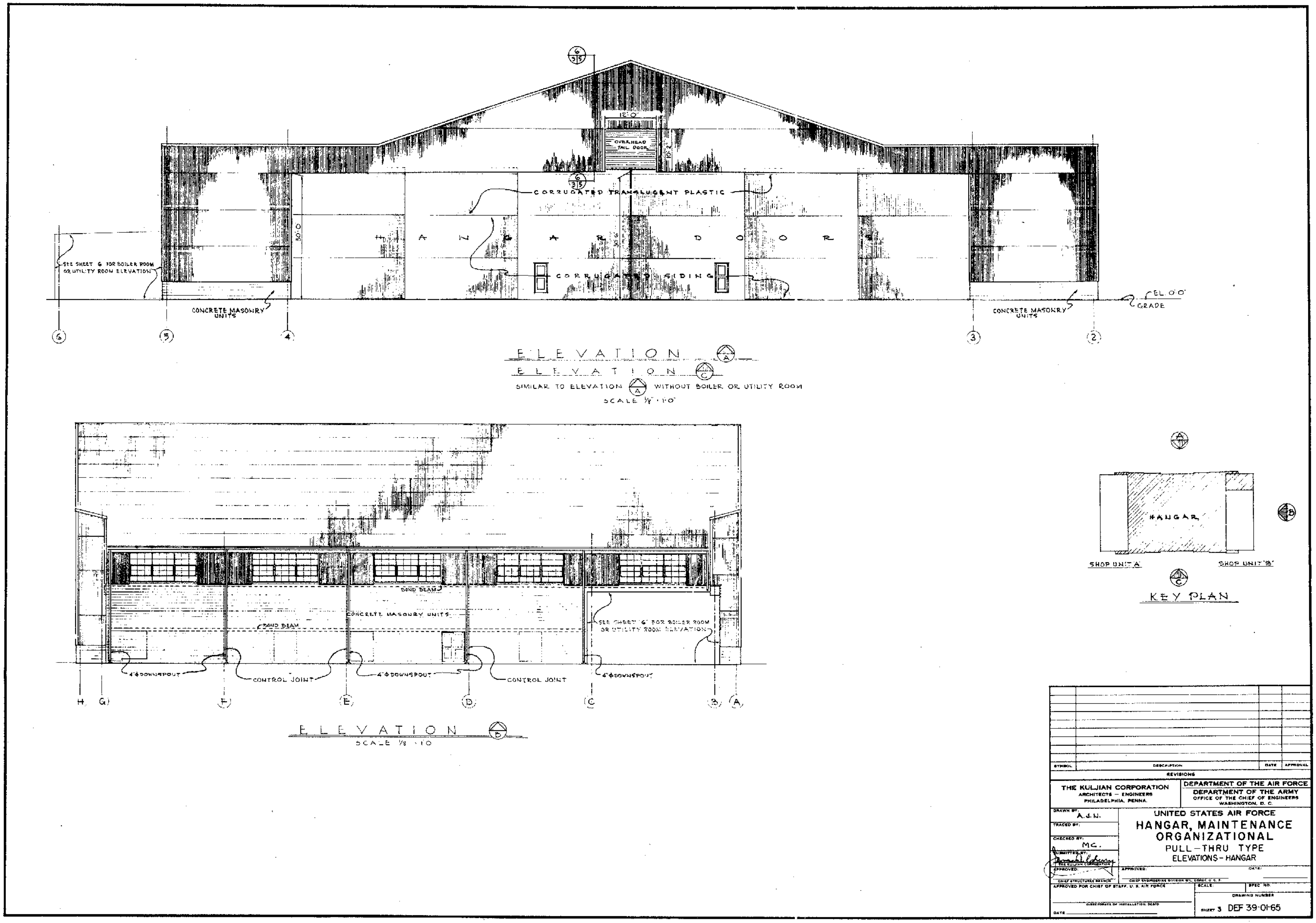

Plate 57. **Kuljian Corporation. Maintenance Hangar Pull-Thru Type, Elevations. 1955. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

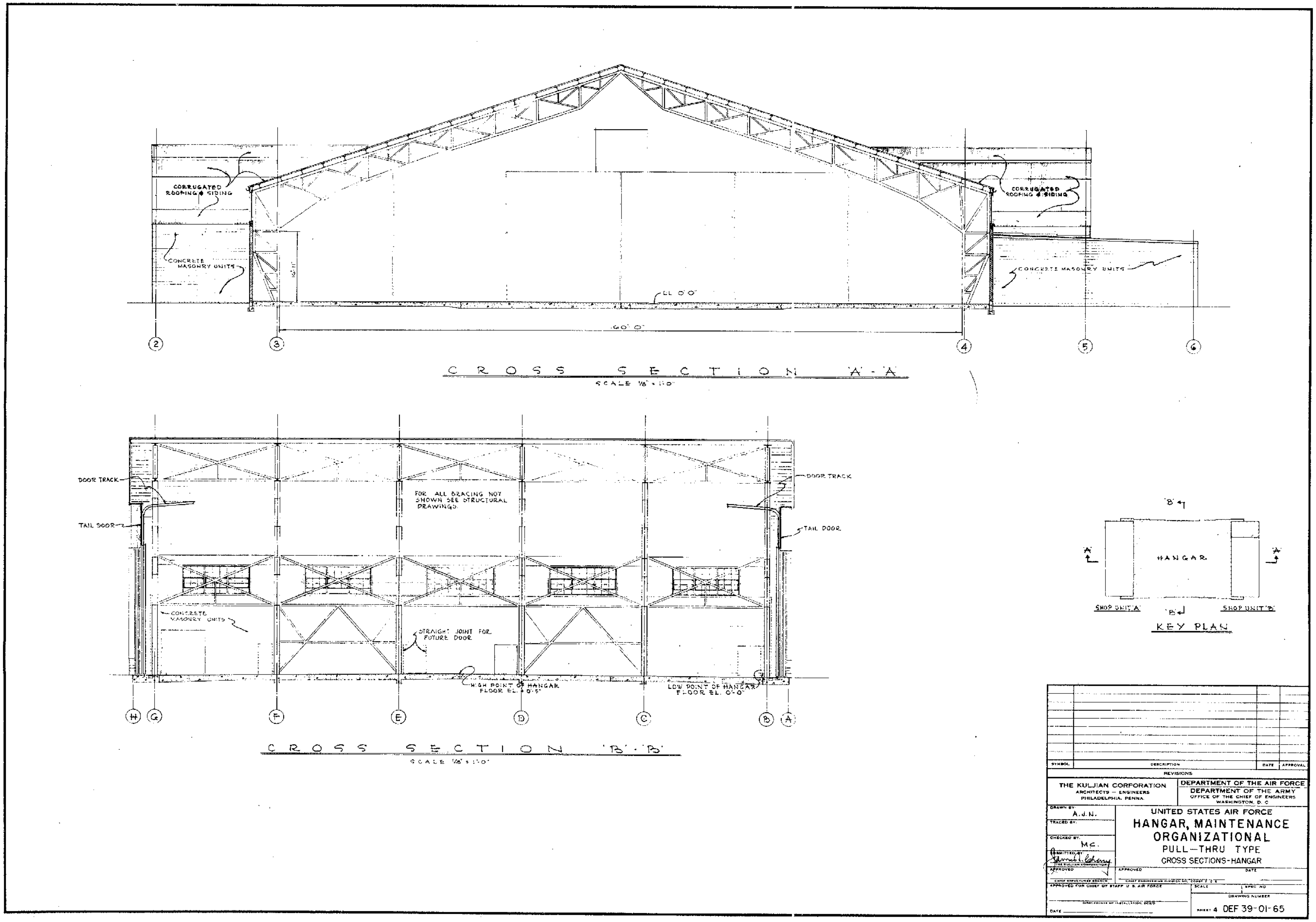

Plate 58. **Kuljian Corporation. Maintenance Hangar Pull-Thru Type, Cross Sections. 1955. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

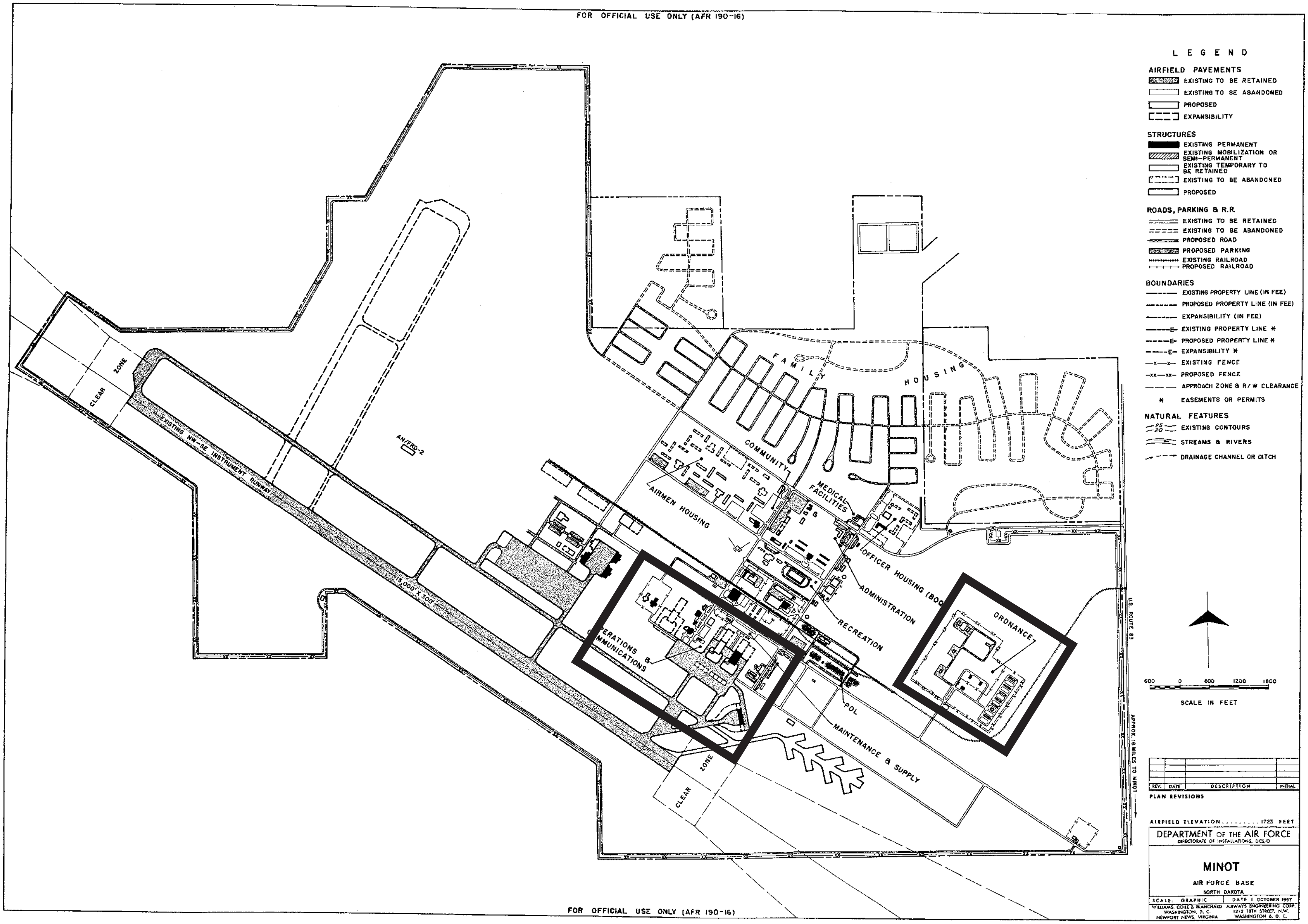

Plate 59. **ADC alert area (foreground center), streamlined for combination with a SAC mission. Collocated ADC and SAC munitions (right). Minot Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

Kuljian Engineering, of Philadelphia, produced the final, third generation readiness/maintenance hangars for ADC in 1955, with final plans for the hangar distributed to installations by July.[55] Again these hangars are always found paired, but are parallel to the flightline and of pull-thru type. Kuljian revised the interior truss system—making it significantly lighter, but maintained the 80-foot cantilever. With rear shops removed, the hangar became about 150 feet long, accommodating the F-101B, F-102, and F-106. Shops lined the sides of the structure, extending laterally from behind the front and rear façade recessing door pockets in a low-slung configuration, lending a maturity of design and function to the hangars not present before[56] (Plates 56-59).

Aircraft Shelters

Strobel & Salzman also designed fighter aircraft shelters for the ADC alert area in January 1957.[57] Like the third generation readiness/maintenance hangars, the aircraft shelters were planned to accommodate the F-101B, F-102, and F-106.[58] ADC added these structures after it began planning and construction for its northern-tier air defense installations across Montana, North Dakota, Wisconsin, and Michigan. During 1956, it became fully apparent that the extreme cold experienced during winters in these regions required "complete cover" for ready aircraft—a situation directly paralleling SAC's need for substantially more wing hangars at its installations across the far north. Shelters were planned to be of "austere type," and "housing two (2) Fighter Aircraft each."[59] Dimensions of the shelters exactly matched those of the aircraft pockets for the second generation Strobel & Salzman ADC alert hangar, designed simultaneously (see above). Shelters were pull-thru, intended for erection in pairs, threes, or fours, side by side in rows, with entrance and egress parallel to the flightline (Plates 60-61).

Plate 60. Strobel & Salzman. Paired aircraft shelters at the former Sioux City Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 61. Strobel & Salzman. Sets of aircraft shelters parallel to the flightline at the former Sioux City Air Force Base. View of July 1999. Photograph, K.J. Weitze.

In mid-1961, ADC also used a prefabricated aircraft shelter "developed on an austere basis."[60] Of 80- by 50-foot, pull-through configuration, the shelter was a rigid-frame Butler building, ordered by TAC in 1958. ADC had also adapted the Butler shelter for weapons calibration shelters needed to service the F-101B (see below) in 1959. By 1971 the Air Force even used a flightline cluster of this multi-purpose shelter to house the SR-71 spy plane at Beale Air Force Base in Northern California.[61] (See Plate 27.)

Electronics and Calibration Structures

ADC added an armament and electronics shop (type B), and weapons calibration shelters, to its alert area immediately following the aircraft shelter. Again planned in 1956 as a component of the new supporting structures needed for the century-series fighter jets,[62] these facilities dated to 1958-1959, with erection into 1962. Kuljian Corporation designed the pair, with weapons calibration shelters (types A and B) each having an open and closed configuration (the four versions variations of one basic design). The "type B" structures were always present together, and were required to support the complex linkage between the aircraft (the F-101B), its weapons system (the MB-1 Genie air-to-air missile), and computerized air defense command-communications (SAGE)—a linkage newly possible in 1959-1960. For the armament and electronics shop (type B), planning was specifically underway in 1958[63] and Kuljian completed preliminary drawings in March 1959, with finalized drawings in early September.[64] The shop was a one-story structure of concrete-block construction.[65] The weapons calibration shelters offer a slightly more elaborate design scenario than did the shop. In 1958, Butler Manufacturing designed a rigid-frame, prefabricated "Aircraft Shelter (Fighter Ready) Inclosed & Open" for TAC (see above) and an "economy type Bomarc Launcher Shelter" for Air Research and Development Command (ARDC).[66] Kuljian used the former shelter as the basic unit of both the types A and B weapons calibration shelters in 1959, a design solution mandated by the Air Force the year before:

> In view of the repetitive requirements of this facility in the FY-60 MCP [1959-1960 fiscal year Military Construction Program], particular

> emphasis was placed on the development of economical design that may be suitable for central procurement of basic steel and doors utilizing standards compatible with the steel building industry.[67]

For the type A structure, Kuljian combined four 80- by 50-foot individual Butler shelters with a small centered utility room between pairs. (See Plate 45.) Kuljian unified the façade to appear as two bays with low-pitched gable facings, while the interior maintained four single, rigid-frame units. For the type B structure, Kuljian employed a single Butler 80- by 50-foot shelter (Plates 62-63). Kuljian enclosed both types A and B with panel doors, recessing into simple, open, truss-supported pockets on each side of the façade.[68]

Plate 62. Kuljian Corporation. Weapons calibration shelter, type B. Minot Air Force Base. View of 1996. Courtesy of Geo-Marine, Inc.

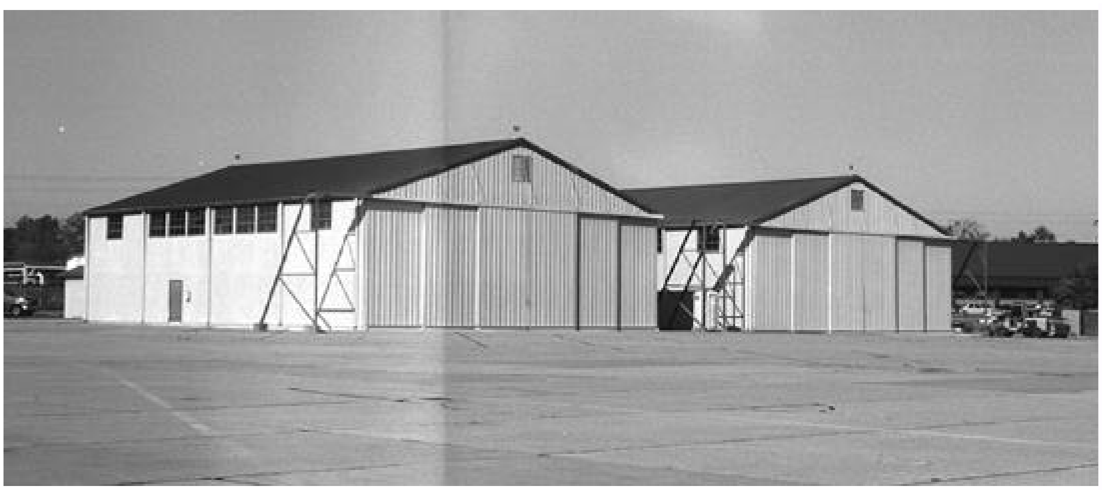

Plate 63. Kuljian Corporation. Pair of weapons calibration shelters, type B. Shaw Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 64. Hardened aircraft shelter at Bitburg Air Base, Germany. View of 1987. Courtesy of the Air Force Historical Research Agency.

Hardened Aircraft Shelters for Overseas

In 1962 the Air Force Directorate of Civil Engineering, in conjunction with other elements of the Air Staff, undertook studies for new, upgraded fighter shelters at overseas bases. Intent was for limited hardness, that is for protection from blast overpressures in the lower ranges. Directed by the Secretary of Defense, the Air Force selected a design for "an earth-mounded structure with doors," primarily chosen for its resistance to fragmentation damage from non-nuclear weapons.[69] During 1963, the Secretary of Defense also authorized construction of a prototype for the overseas shelter at Eglin Air Force Base. The Air Force conducted tests on the Eglin prototype, using increasingly potent traditional weapons, through the close of the year, remodeling with sturdier (steel) doors to achieve near invulnerability unless directly hit. Congress, however, was unsatisfied with the planned $30-million expenditure for the fighter shelters during fiscal year 1964, with the Air Force reducing its recommendations to $20 million for fiscal year 1965.[70] During the second half of 1964, the Air Force continued to improve the prototype shelter at Eglin, fabricating new doors for test in the climatic hangar at the installation and in live napalm bombing on Range 56. The napalm tests were partially destructive to the doors during direct hits, causing another round of improvements. The Air Force planned further napalm and high-explosive tests on the Eglin test range, with the Navy issuing a procurement order for the shelters. The use of the shelters overseas was still not firm, but expectations were for North Atlantic Treaty Organization (NATO) participation in the program.[71] Fighter shelters derived from these initial experiments were in active use for the F-4 at Cairo West Air Base, Egypt, in 1980,[72] and a later version for the F-15 at Bitburg Air Base in Germany in 1987[73] (Plate 64).

Weapons Checkout and Storage

As might be anticipated, weapons checkout and storage structures evolved directly paralleling the evolution of the fighter aircraft and the accompanying weapons systems during the 1950s.

First Generation: Small Arms Storage

At the outset of the decade, ADC usually erected a small arms storage building in the vicinity of the readiness/maintenance hangars. At that time, available fighter-interceptor aircraft were armed with machine guns only (Plate 65).

Plate 65. Small arms storage. ADC alert area. Travis Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 66. Weiskopf & Pickworth. Second generation weapons storage for ADC alert. McChord Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Second Generation: FFARs and GARs

With ADC receipt of the F-86D Sabre during 1953, folding-fin air-to-air rockets (FFARs) replaced machine gun armament. The F-86D interceptor was still experimental during 1953, however, with major engine fires a serious issue. Throughout 1954 and into 1955, a costly modification program continuously removed F-86Ds from the command, but by the end of 1955 ADC had more than a thousand of the Sabres.[74] FFARs required a checkout and assembly building at the flightline. The engineering firm Weiskopf & Pickworth, of New York, designed the building in two stages during 1954 and 1955. The Unit A structure, designed in April 1954, served the checkout and assembly function for the FFAR, and was sometimes built in double configurations. A simple, one-story, reinforced concrete structure, the Unit A building was about 50 feet square and featured an interior divided into a four-bay rocket storage area and a separate section for rocket testing. Walls one-foot thick separated each of the bays, and further segregated the test cell. In September 1955, Weiskopf & Pickworth designed an addition to the checkout and assembly building, Unit B. By this date, guided air rockets (GARs)—such as the Falcon, were planned to replace FFARs. Unit B additions quadrupled the size of the checkout and assembly building for most ADC bases (Plate 66). The GAR additions featured two wings, divided into four rocket storage areas; a test and assembly room; and, a receiving room. Weiskopf & Pickworth established a prestigious practice that continues into the present. Known for solving sophisticated structural problems, the firm is responsible for the engineering specifications for several renowned recent skyscrapers designed by I.M. Pei, inclusive of the Raffles City 72-story hotel in Singapore, among the world's tallest buildings.

Third Generation: The Nuclear-Tipped Genie

ADC considered devising atomic weapons for its fighter-interceptors as early as 1951, paralleling work done at this same time by SAC for its bombers. During the first half of the 1950s, the concept was so advanced that ADC took little action—the challenge of developing a nuclear rocket small enough to be carried by a fighter jet was substantially different than that faced by SAC in developing compatible bombers and nuclear weapons systems. Nonetheless, in early 1955 headquarters Air Force instructed ARDC to convert the F-89D for an ADC nuclear weapon, and the command undertook a crash program. ADC received the resultant aircraft, the F-89J (the Scorpion), beginning in December 1956, just making the deadline of 1 January 1957 set by the National Security Council. On that latter date, ADC placed one F-89J, armed with the MB-1 rocket (also known first as the Ding Dong and then as the Genie), on alert at Hamilton Air Force Base north of San Francisco. By mid-1958 ADC had 268 F-89Js. The fighter-interceptor carried the Genie from 1957 through the close of 1960, thereafter replaced in the air defense inventory by the F-101B and the F-106.[75]

By the middle of 1955, the Air Force had also begun planning for the needed special weapons storage facilities that the Genie mandated. Black & Veatch, of Kansas City, received the contract to develop the Genie storage, and, checkout and assembly structures, delivering preliminary plans to the Army Corps of Engineers. Before the close of the year the Armed Services Explosive Safety Board, and the Armed Forces Special Weapons Project (AFSWP), had approved the plans.[76] Black & Veatch had previously designed and engineered special weapons storage (Q Areas) for SAC, to accommodate the atomic, and then thermonuclear, bomb. The firm had a classified contract, dating back to 1946, and was the only such firm in the world working continuously with the particular challenges of engineering such weapons storage from the outset of nuclear weaponry. ADC planned, and was funded, for these facilities at 12 of its bases as of mid-1955, inclusive of "storage magazines, assembly checkout building, guard gatehouse, chain link fencing, utilities, and necessary security items such as protective alarm devices for structures within the storage area and the alert hangar area." In late July, the Corps of Engineers held a meeting in Kansas City with representatives of all engineering parties associated with the project. For the latter months of 1955 issues focused on the design of the storage magazine, with another meeting in Washington, D.C.:

> Based on the comments of the Armed Services Explosive Safety Board, it was decided to adopt the stall type of building since it was pointed out that delays would occur in using igloos as to real estate, obtaining additional topography, the increased quantity safety distances and the requirements of operational use. Based on the conference decision revised sketches of the storage magazine and typical layout were made.[77]

In mid-October another meeting, with all engineering parties present, occurred in Washington, D.C., followed by similarly-attended meetings at ADC headquarters in Colorado Springs, Colorado, and at the Special Weapons Center in Albuquerque, New Mexico. The Air Force amended the design directive for the project, giving Black & Veatch the authority to finalize its designs in mid-November.[78]

Programming for the planned ADC special weapons storage changed somewhat at the turn of the federal fiscal year 1955, channeling the available funding into nine (instead of the original 12) ADC installations—as construction of the facilities required additional monies. Deferred among the first 12 ADC bases were Truax Air Force Base (Wisconsin) and Youngstown Air Force Base (Ohio), sites with shared municipal airports, and Presque Isle in Maine. The first ADC special weapons storage complex under construction was that at Otis Air Force Base in Massachusetts. ADC programmed for a total of 23 special storage sites for the Genie, with a prioritized plan and beneficial occupancy dates established during 1956. The command estimated the total program cost at 27 million dollars.[79] Black & Veatch submitted their final drawings for the project beginning in May 1956,[80] with construction across ADC following through about 1958. Compounds for the Genie were accessible to the ADC alert area, but were often not sited immediately adjacent. They were sometimes across the flightline at the opposite end of the runway, connected to the ADC area via a perimeter road. Typical compound configuration included the guard station, a checkout and assembly building, and four to five stall-type storage igloos. At selected ADC installations of very high profile in the late 1950s, such as Oxnard Air Force Base north of Los Angeles, the number of igloos was doubled. The design of the igloos featured stall magazines with free-standing, sloped earthen embankments sited between each igloo, and also shielding each side of the checkout and assembly building. At ADC installations receiving the special storage complex after mid-1958, such as Charleston, Grand Forks, and McChord Air Force Bases, no protective berms accompanied the compound. Each igloo contained 30 storage units, designed as offset back-to-back linear groups of 15. Steel overhead doors with upper blowout panels defined the structures. ADC fired only one of the Genies from a fighter-interceptor aircraft in the entire period of the weapon's deployment, and that at the Nevada test ground on 19 July 1957. For the live Genie mission, Operation John Shot, Captain Burford Culpepper flew a backup F-89J into the radioactive blast cloud created by the interceptor missile. His collection of scientific data earned him the Distinguished Flying Cross in 1958.[81] (Plates 67-68).

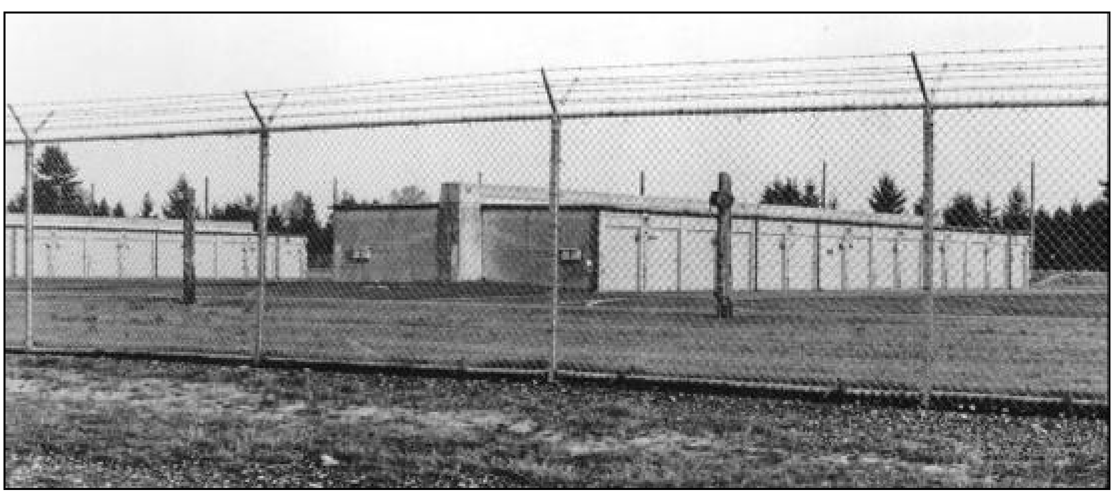

Plate 67. Black & Veatch. Third generation special weapons (Genie) storage for ADC alert. McChord Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

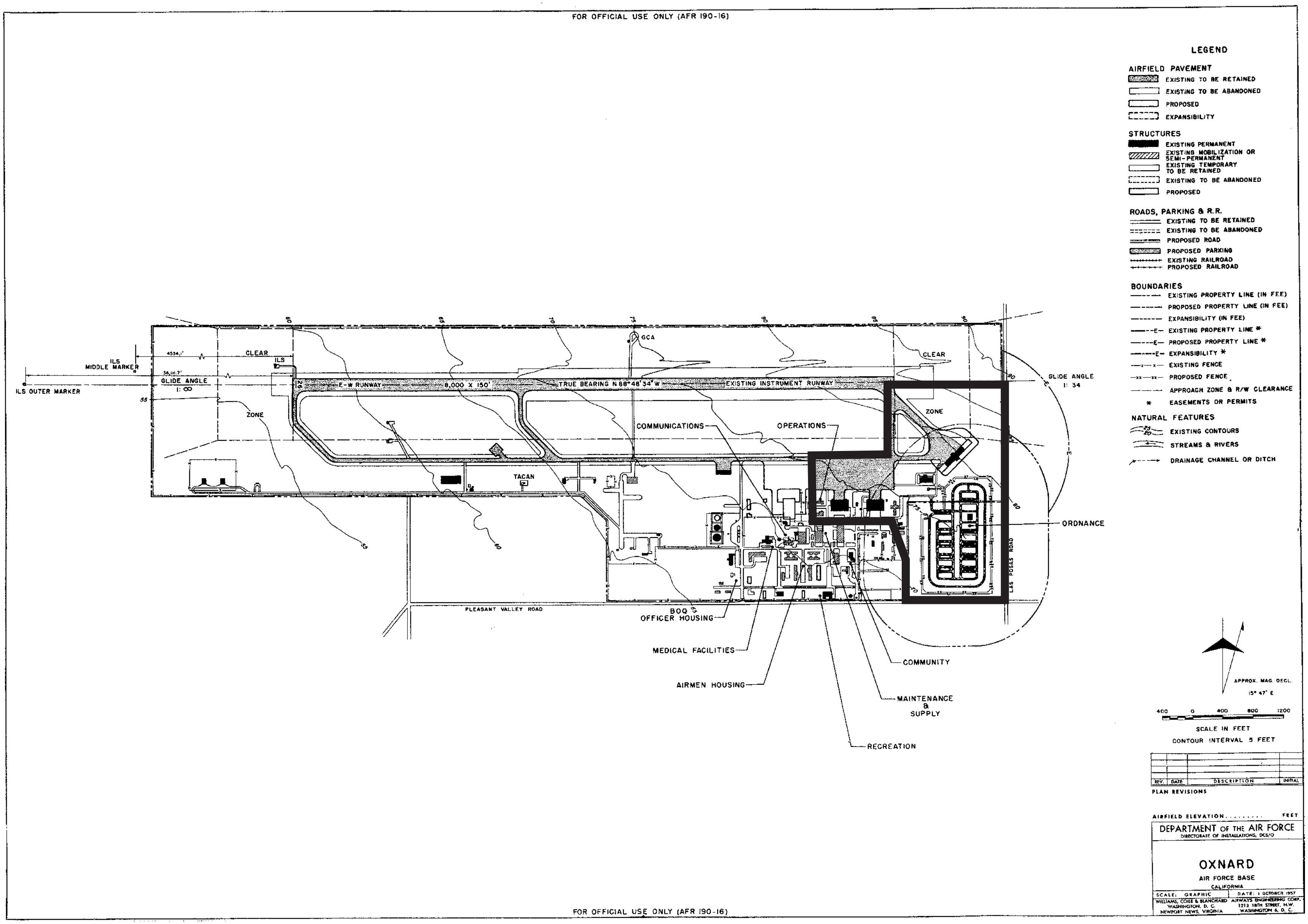

Plate 68. **ADC alert area (miground right). Alert hangar with support structures. Doubled configuration for the special weapons storage area. Oxnard Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

First Generation ADC Command and Control Structures

Following the Communist coup in Czechoslovakia in February 1948 and the Berlin blockade in March, heightened international tensions had stimulated ADC to put forth a more detailed plan for a radar program, calling for the construction of 85 Aircraft Control & Warning (AC&W) stations and 11 command and control centers during 1949 and 1950. The ADC plan bore a striking similarity to one of ANG in 1947. Funding for the radar and command and control web remained unobtainable during fiscal year 1949. The December 1948 creation of Continental Air Command (CONAC) forced the further stretching and pooling of resources for ADC, TAC, ANG, and the Air Reserves, allowing a continued emphasis on SAC. Yet with the Soviet detonation of an atomic device in late August 1949, things changed abruptly. The Air Force commissioned architect-engineers for the system of radars and command and control centers, hiring the Chicago firm of Holabird Root & Burgee in October to design the entire scheme (Plates 69-71). By August 1951, ADC had emplaced only one AC&W radar squadron with modern, permanent equipment, erecting it in conjunction with the first windowless, semihardened command and control operations center at McChord Air Force Base near Tacoma, Washington. At the outset of 1952, 14 more AC&W squadrons were operational, with the remaining 70 AC&W squadrons and 10 command and control centers nearly completed by late the same year at Air Force bases across the nation. Command and control centers as of the close of 1954 were associated with Air Force installations at Duluth (Minnesota), George (Southern California), Griffiss (New York), Hamilton (north of San Francisco), Kirtland (New Mexico), Malmstrom (Montana), McChord (Washington), Robins (Georgia), Selfridge (Michigan), Stewart (New York), and Tinker (Oklahoma). These centers monitored an equal number of air defense divisions. Actual physical siting for the command and control centers was typically on the Air Force base with which it was associated, but in at least two cases the centers were consolidated with off-base AC&W radar stations. An ADC combat operations center at Ent Air Force Base in Colorado, built in 1954, coordinated the network.[82]

Plate 69. Holabird, Root & Burgee. ADC first generation command/control, type 4 station at the former Richards-Gebaur Air Force Base. July 1999. Photograph, K.J. Weitze.

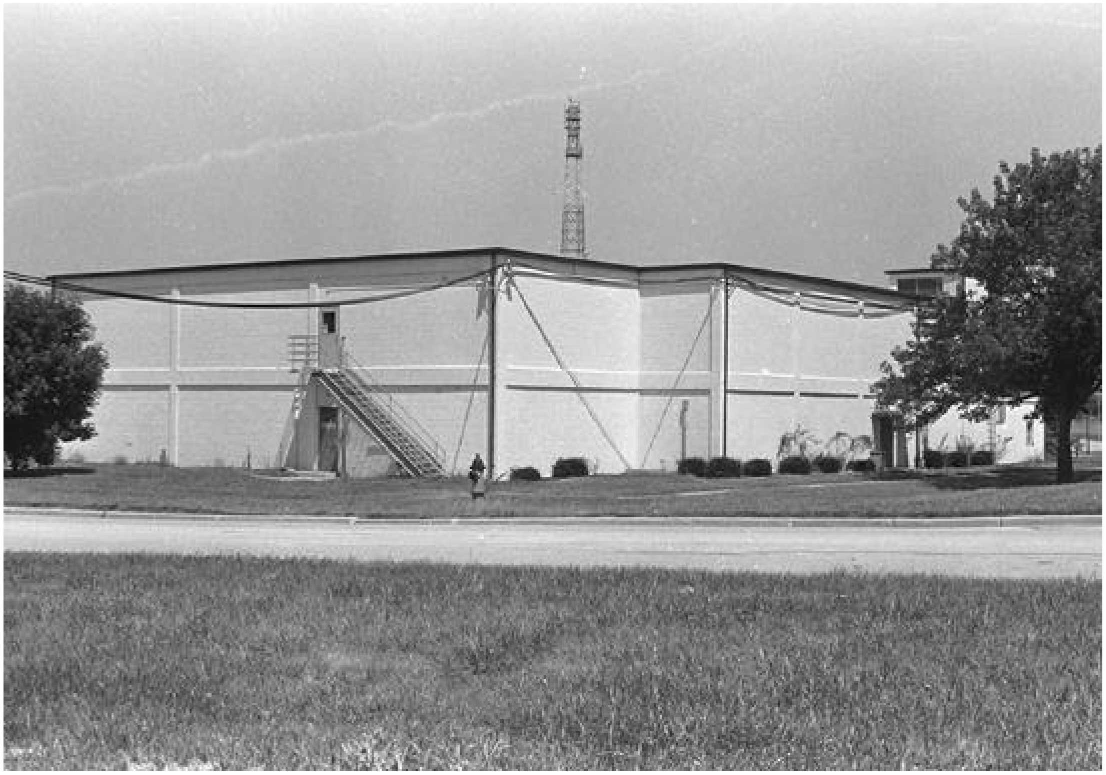

Plate 70. Holabird, Root & Burgee. Pilaster detailing of the ADC type 4 station at the former Richards-Gebaur Air Force Base. July 1999. Photograph, K.J. Weitze.

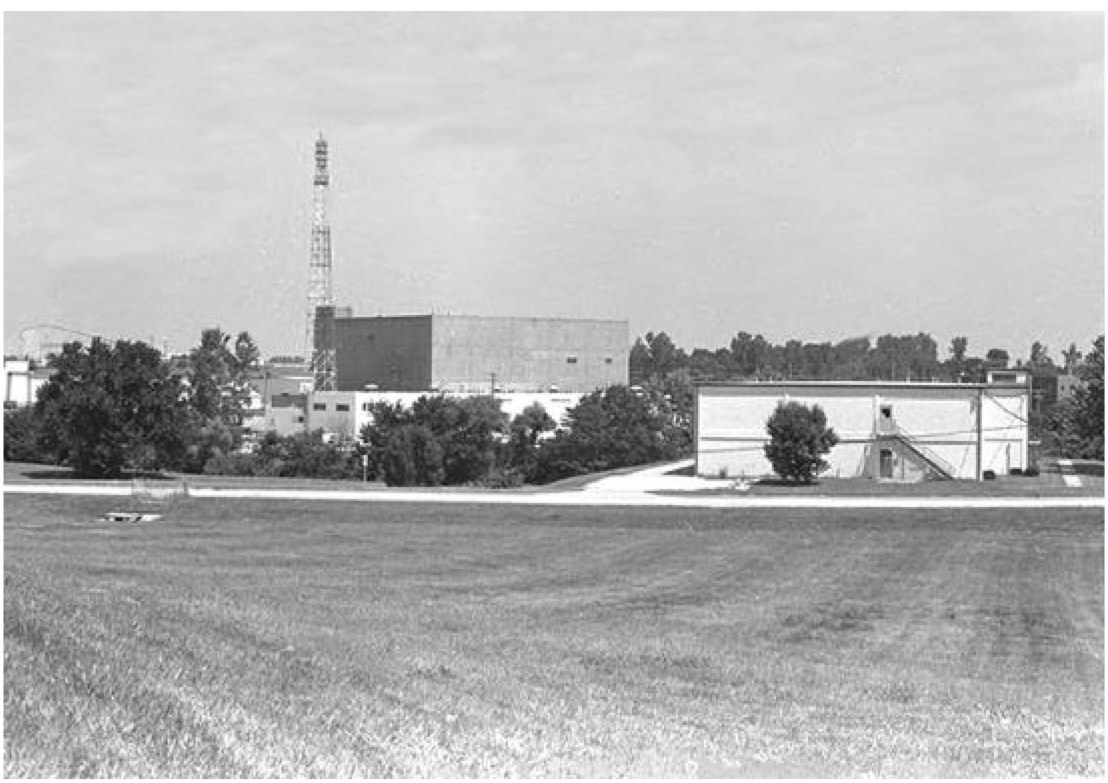

Plate 71. Holabird, Root & Burgee. ADC type 4 station at the former Richards-Gebaur Air Force Base. SAGE center in background. July 1999. Photograph, K.J. Weitze.

This initial air defense web of command and control was a manual system, using the telephone, the teletype, vertical and horizontal plotting boards, and vu-graph overhead projections to keep information from radar stations, as well as from a network of ground observer corps volunteers, up to date (Plates 72-74). From the beginning of the Cold War, the facilities housing command and control—including temporary buildings and structures while the program fluctuated in buildout[83]—focused on its role in "combat operations," conducted in what has since been more loosely termed the "war room." In the large command room, military and intelligence personnel sat at individual stations along a two-tiered set of daises looking down on the changing information on the vertical and horizontal displays.[84] ADC ran multiple air defense alert exercises testing command and control, such as Tailwind of mid-1953 at the Malmstrom air defense center (Plates 75-76):

> It was nearly mid-night, 10 July 53 when the Division was alerted to the Apple Jack Conditions of adjacent air divisions. Both the 31st Air Division to the east, and the 25th Air Division to the west, had picked up unknown aircraft, and it was then that Exercise Tailwind began for the Division.[85]

Plate 72. Ground Observer Corps, 9th Air Division, Spokane, Washington. 1955. Courtesy of the Air Force Historical Research Agency.

Plate 73. Boise Filter Center for the 9th Air Division. (Tiered information gathering: volunteers.) 1955. Courtesy of the Air Force Historical Research Agency.

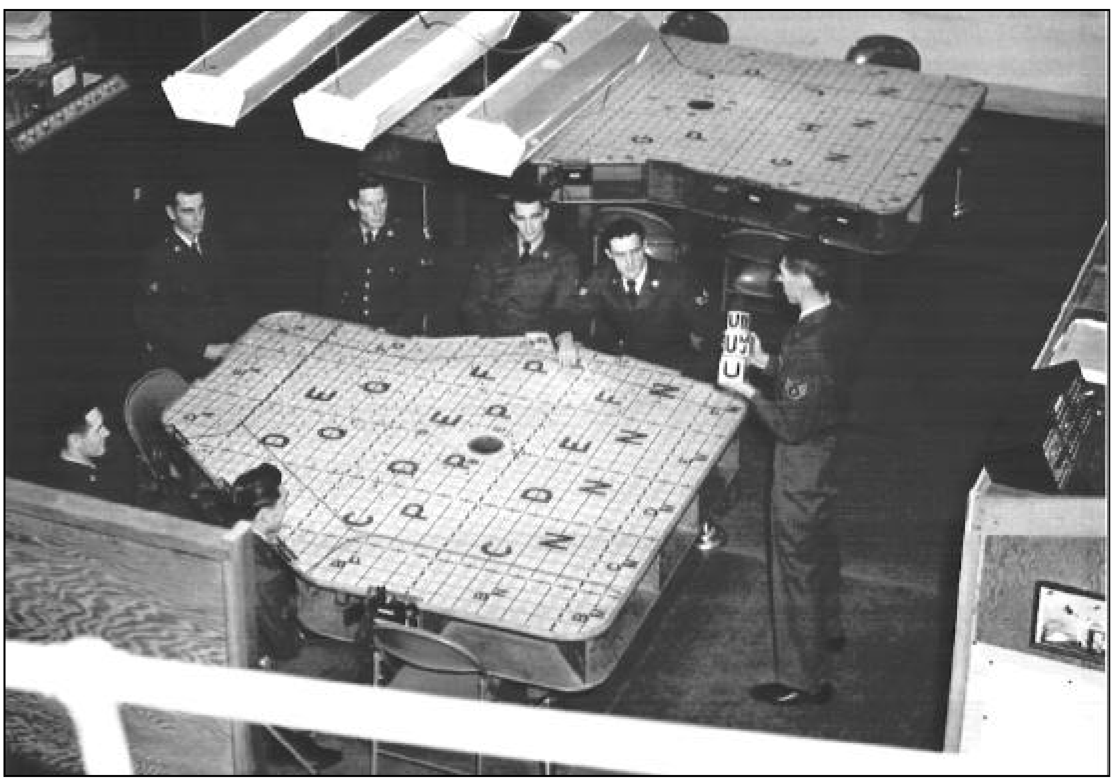

Plate 74. Boise Filter Center for the 9th Air Division. (Tiered information gathering: military analysis.) 1955. Courtesy of the Air Force Historical Research Agency.

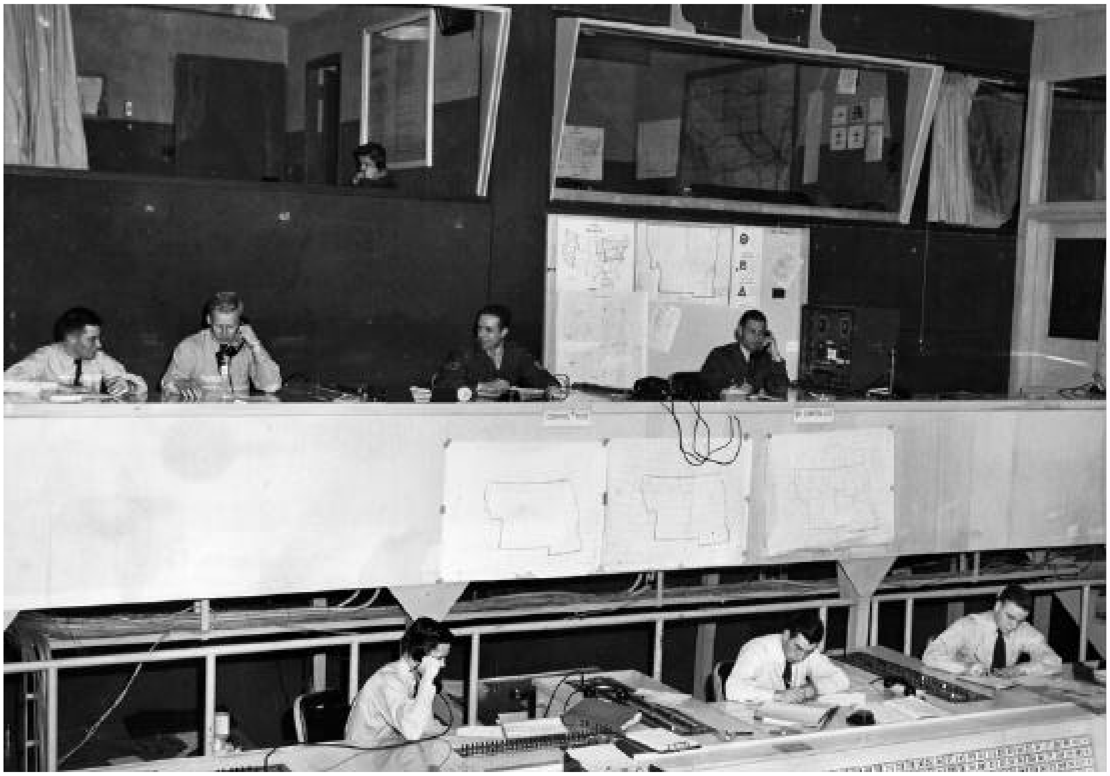

Plate 75. **ADC first generation command/control at Malmstrom Air Force Base. Information analysis during early 1953. Courtesy of the Air Force Historical Research Agency.**

Plate 76. **ADC command/control. Malmstrom Air Force Base. Vu-graph transfer to vertical status board. 1953. Courtesy, Air Force Historical Research Agency.**

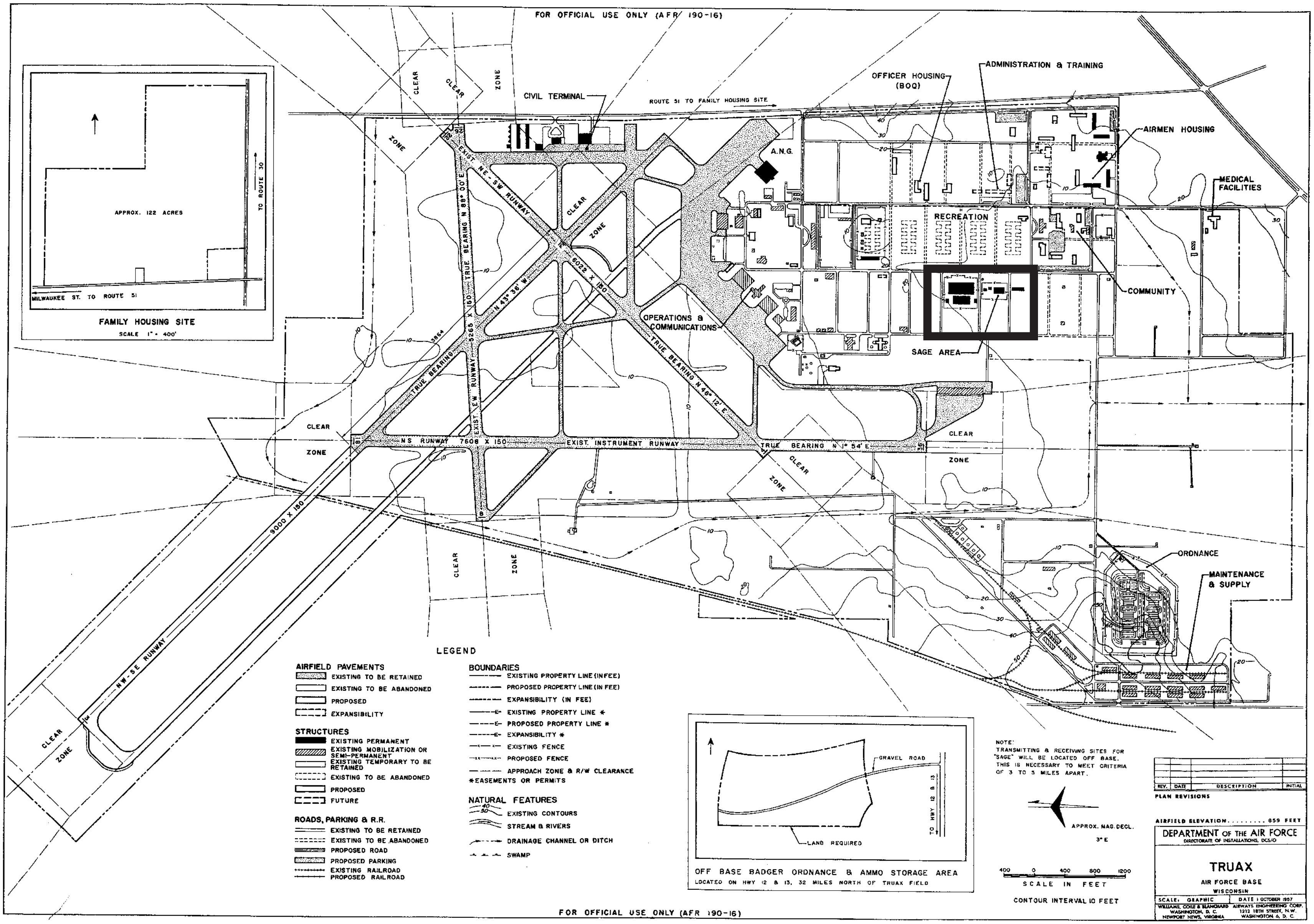

Plate 77. **ADC first generation command/control and SAGE at the former Truax Air Force Base. SAGE combat and direction centers, with power building, left; ADC command/control center, right. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

General terminology for all of these operations, as well as prototypical modeling between ADC and SAC, was quite fluid. ADC, in its very early need to achieve both fighter-interceptor alert and to coordinate that alert with a large network of radars; observers; and command and control, more than once functioned as the understated model for SAC. For example, ADC placed small standing markers on the horizontal status board within its command and control centers during the early 1950s representing the track of a formation of aircraft, with tiny plaques hung on the markers indicating the number of the track, the number of aircraft in the formation, and the formation's status as enemy or friendly. ADC called these markers "Christmas trees," a name which would also adhere to the simple triangular ADC alert apron of 1951, and to the final herringbone configuration of the SAC alert apron of 1957.[86]

As ADC prepared to computerize its command and control operations in 1955-1957, through what would come to be called the Semi-Automatic Ground Environment (SAGE), the command augmented its first 11 command and control centers with an additional five "for a proper span of control."[87] Located at Andrews Air Force Base (near Washington, D.C.), Fort Knox (Kentucky), Larson Air Force Base (Washington), Richards-Gebaur (Missouri), and Truax (Wisconsin), these centers completed buildout for the first generation ADC command and control web. During the transition to SAGE, ADC planned to reduce the number of manual command and control centers in this web to between seven and nine. Certain centers sustained a very long life in a continued air defense role, others became defunct—usually heavily altered at an installation for a subsequent real property use. Today, intact ADC first generation command and control centers are extremely rare, with perhaps the single best example (of about half the buildout sites verified) that at the former Richards-Gebaur Air Force Base in Kansas City, Missouri. As SAGE went in during the 1957-1961 years, it was sometimes collocated directly at the site of a first generation command and control center, such as at Richards-Gebaur and Truax Air Force Bases (Plates 71 and 77).)

The ADC first generation command and control complex typically included a small cluster of structures. Two AC&W operations buildings, described as types 3 and 4 on the Holabird Root & Burgee drawings; a power plant; and one or two radomes, made up the compound. A building at the 85 radar stations channeling information to the 11 command and control centers—the AC&W type 2 station, directly paralleled the types 3 and 4 stations in design, engineering, and program. William Holabird, of Holabird Root & Burgee, signed some of the drawings for October 1949 project. The AC&W types 2, 3, and 4 stations immediately foreshadowed the next generation SAGE command and control facilities. Interlinkage between the first and second generation systems was so continuous, that ADC renovated a selected number of type 2 stations, such as that at Fortuna, North Dakota, for the follow-on system to SAGE, the Backup Interceptor Control (BUIC) system of the early and middle 1960s. The first generation ADC command and control, SAGE, and BUIC were all aboveground structures, semi-hardened through their windowless, reinforced concrete construction. ADC structures were reinforced concrete, column-and-spandrel-beam construction, with double, concrete-block exterior walls. The construction typology for the first generation complex, of course, was prototypical. As understood in its own period, the construction could withstand overblast pressures from as near as a mile away, but nothing from closer detonation proximity or from a direct hit.[88] Targeting at the outset of the Cold War was not accurate, and Atomic Energy Commission (AEC) studies undertaken during the early 1950s at the Nevada test site demonstrated that reinforced concrete-block structures functioned well in blast conditions anticipated from early atomic bombs.

The key structure of the ADC command and control center was the type 4 station,[89] a two-story reinforced concrete column and beam structure, with columns and beams 14 inches thick (Plates 78-80). Double walls built as bay infills between the column-and-beam structure were eight- and four-inch concrete-block (also referenced as "pumice block"), with a two-inch air pocket between the walls. Interior partition walls were also four-inch concrete-block. The six- and three-bay elevations were without fenestration, and exterior pilasters mirrored the column-and-beam structure. A small ventilating shaft articulated one end of the building. The interior plan featured one of the earliest Cold War configurations designed for the

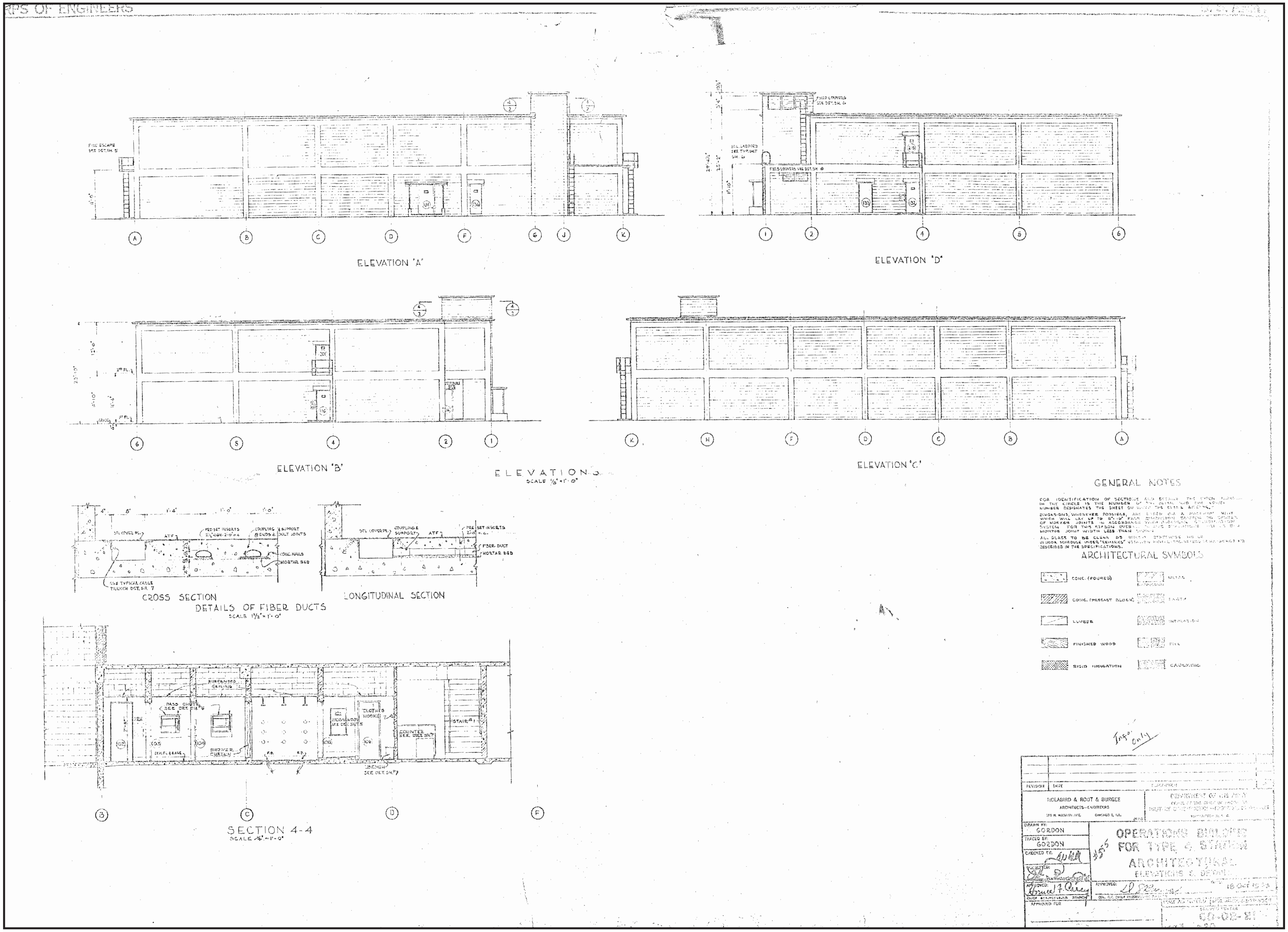

Plate 78. **Holabird, Root, & Burgee. Type 4 Station, Elevations. October 1949. Collection of K.J. Weitze.**

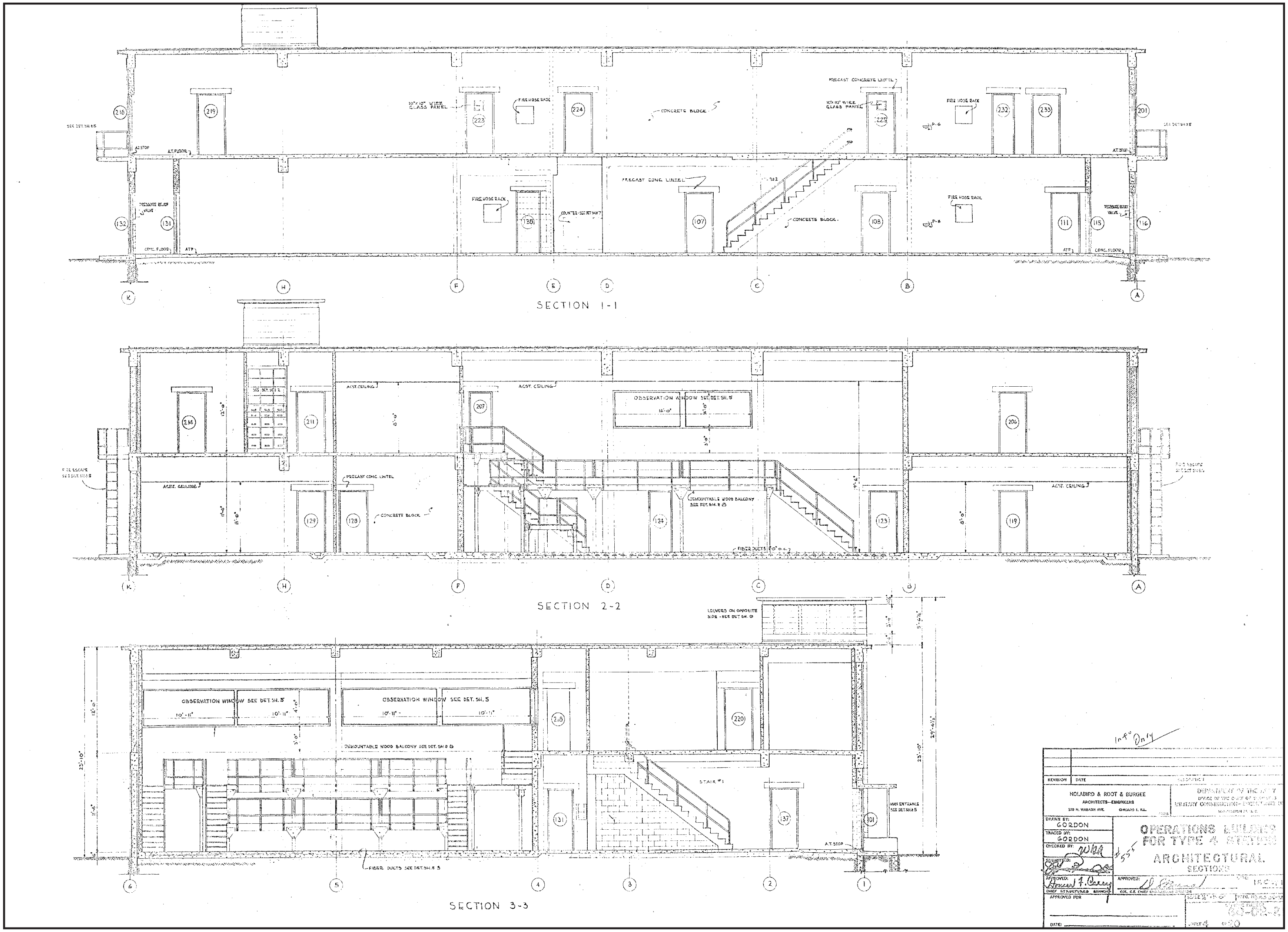

Plate 79. **Holabird, Root, & Burgee. Type 4 Station, Sections. October 1949. Collection of K.J. Weitze.**

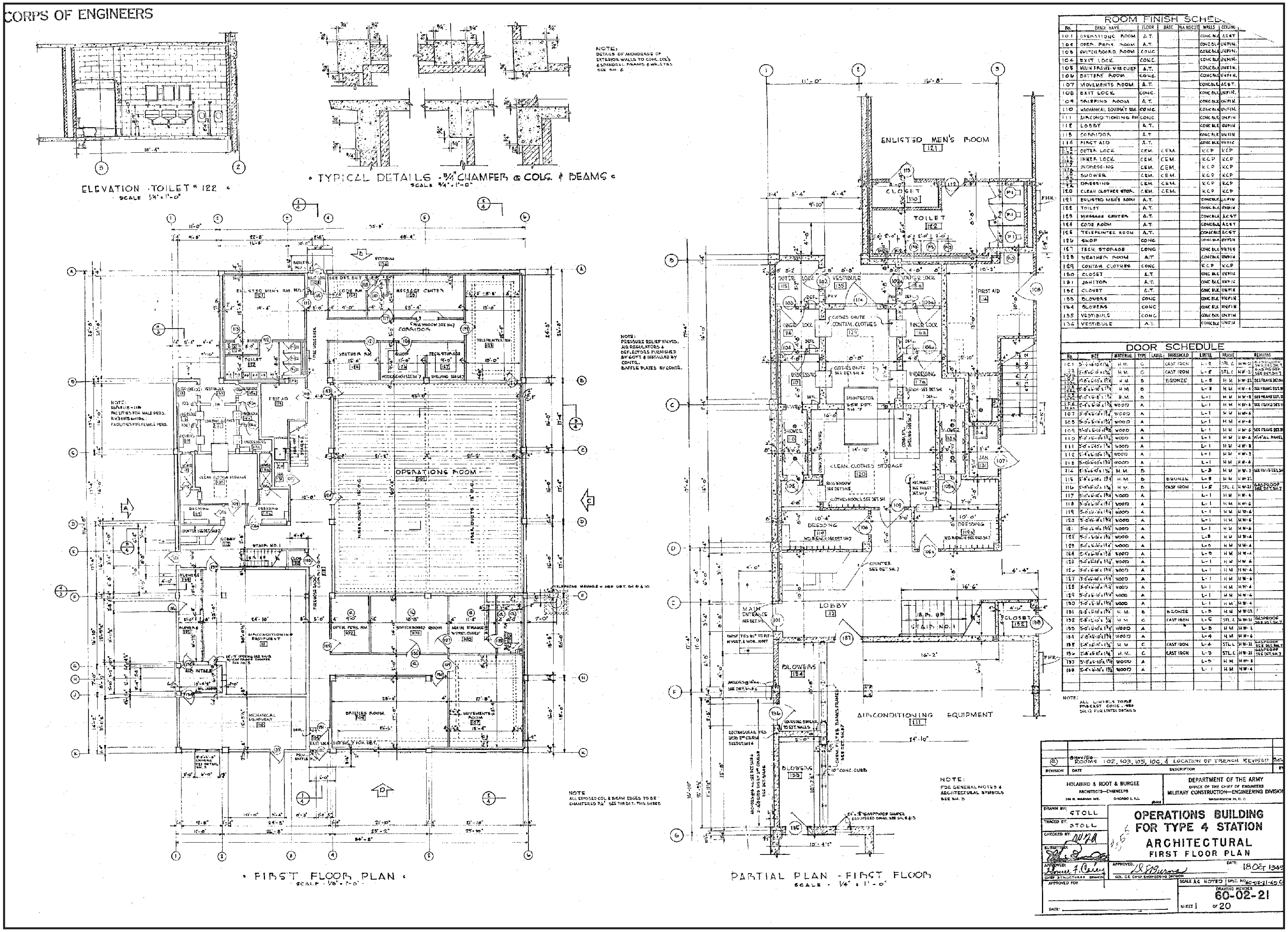

Plate 80. Holabird, Root, & Burgee. Type 4 Station, First Floor Plan. October 1949. Collection of K.J. Weitze.

U.S. military for a secured command and control facility intended to operate during and after a nuclear attack. On the first floor a maze of intricate, cubically arranged dressing rooms, and mechanical equipment rooms, bracketed a small entrance lobby, with stairs to the second floor. The dressing rooms sequentially featured two dressing areas; a clean clothes storage area; two showers; two undressing areas; a contaminated clothes area with disinfector; two inner-lock areas; two outer-lock areas; a vestibule; and an exit. The inner-lock areas and the undressing areas accessed four gas-proof clothes chutes. The entrance lobby led to a bisecting center corridor, with a balcony featuring a bank of observation windows, above, and exit-lock areas at each end. The corridor accessed the operations and first-aid rooms, and two groups of offices. One office cluster included weather and code rooms, a message center, shop space, storage, and an enlisted men's area. The second office cluster included communications rooms; briefing and movements rooms; and the room for operational personnel. The second floor of the type 4 station wrapped around an open area above the operations room, with spatial divisions for combat and intelligence personnel. In the corner of the building, the first floor housed the teleprinter room, while the second floor was devoted to the war room. Special detailing of the type 4 station included gas-proof doors, with small glass panels to visually confirm personnel access to rooms; baffle panels; and, chemical filter banks.

Especially important in the design and engineering for the first generation ADC command and control building were particular construction features. Notable were the reinforced concrete, column-and-beam structure; the double, concrete-block exterior walls; the exterior pilasters; the lack of windows (with hand-operated louvered vents placed very sparingly); trenches for communications cables laid as five feet of gravel, one foot of cement grout, and four feet of concrete; double, concrete-block walls encasing special interior areas, inclusive of the operations room and the mechanical equipment rooms; air-locks; decontamination chambers; and the use of pressurized air. The latter was particularly important, and was a new technology of the 1950s with a keen Cold War role. Pressurized air utilized air conditioning equipment, with two blower rooms prominent in the design of the first generation ADC command and control building. Air conditioning here sustained a positive air pressure on the interior of the structure, appropriately interpreted by the Navy as a useful and readily achieved preventative device against contaminated air when used with air lock entrances, baffles, and filters. The further assumption of the early Cold War was for not just atomic contamination, but combined threat from biological and chemical contamination as well.

> The primary consideration in providing shelter against biologicals and chemical gases is to prevent their entrance into a structure. This may be accomplished by continuously pressurizing—introducing filtered air to maintain a slight positive pressure in the shelter. Thus, if the shelter is reasonably airtight, all minor leaks will be outward.

The Navy referenced this type of Cold War engineering for contamination conditions as "slanting."[90] The command operations center at Ent Air Force Base was also of windowless, concrete-block construction, but is not analyzed here.[91]

The other structures associated with ADC first generation command and control complemented the design and engineering of the type 4 station. The type 2 station, sited at the radar stations and linked to the type 4 station, was of very similar typology. This station also featured an operations (war) room with two-tiered daises overlooking the open area for plotting boards, informational maps and charts; telephone and teleprinter rooms; a message center; a segregated and especially secure crytopgraphic room; mechanical equipment room; and blowers for the ventilation shaft.[92] The power plant was also a reinforced concrete and concrete-block structure, one story in height with flat reinforced concrete roof. The type 3 station was again similar, but much less secured for an attack situation through the inclusion of cement asbestos board panels for some facades—essentially a fire-proofing precaution. It is assumed to have performed a more purely administrative function. The ADC first generation command and control clusters also sustained one or two radars, usually configured as small one-story structures supporting radomes.

The Chicago engineering firm responsible for the first generation ADC command and control clusters, Holabird, Root & Burgee, was best known for its traditional office buildings—and then skyscrapers—from the firm's inception in 1880 through the 1920s. Holabird & Roche, and then Holabird & Root, was among the most prominent American architectural-engineering firms of its time. The founding William Holabird had been trained as an Army engineer at West Point, and the young Holabird & Roche landed the commission for Chicago's Fort Sheridan in 1887. The firm prospered through sons Robert and John Holabird, and with the death of Martin Roche, through the addition of partner John Root in the second decade of the 20th century. Holabird & Root suffered from the crash of 1929, surviving during the 1930s primarily through its pioneering work for Illinois Bell Telephone—work the firm would continue steadily through the 1960s. After World War II, in particular, with the death of the second generation Holabird (John), the firm faced a crisis. At that time, a cousin, William Holabird, and an internal management-oriented employee, Joseph Burgee, became partners in the firm, then named Holabird, Root & Burgee. The firm of this era was not the aggressively well known design leader that it had been (and has been since), but did achieve expertise in construction for communications. With the federal communications legislation of 1934, certain communications structures were to be designed with traditional bomb-proofing taken into account.[93] As such, this particular work by Holabird, Root & Burgee made it the perfect firm to undertake the first semi-hardened design for command and control, that of ADC, appropriate to the new conditions of the early Cold War.[94]

Second Generation ADC Command and Control: SAGE

Immediately following World War II, scientists working in university laboratories were aware that accurate data handling was at the threshold of change. Scientists understood that computer technology, through research started at the Massachusetts Institute of Technology (MIT) Digital Computer Laboratory, could support radar and other communications, interpreting, processing, and disseminating information with new speed. MIT had initiated the development of the Electronic Numerical Integrator And Calculator (ENIAC) during 1945 to assist problem solving at Los Alamos. The Army completed the ENIAC project at the Aberdeen Proving Ground, Maryland, in 1946, for use in the rapid, repeated calculations needed for ordnance tables. At this point, advancement in computer technology shifted to the Princeton mathematics department, where research began on the next generation machine, one required to analyze fusion calculations in the experimental phases of a thermonuclear bomb. At MIT, the Office of Naval Research backed a program to use advancing computer capabilities to analyze aircraft stability. This program resulted in the computer Whirlwind in 1947. MIT soon envisioned that Whirlwind could be adapted to receive radar pulses, and then to calculate aircraft speed, direction, and distance for coordination of the fighter-interceptor air defense mission. MIT proposed testing Whirlwind in this role as a part of the Cape Cod Air Defense System this same year. After courting the Air Force for additional research and development monies, MIT dedicated Whirlwind solely to the Air Force.

In early 1950, General Gordon P. Saville headed efforts to use current scientific research for Air Force ends. General Saville, having previously led special projects for ADC, consulted physics professor George E. Valley of MIT, who advised him of the computer's future role in command, control, and communications, and of progress through Whirlwind. Dr. Valley led a committee, the Valley Committee, to analyze Air Force air defense capabilities. Valley concluded that ADC would be able to destroy only 10 percent of incoming Soviet bombers, under the planned AC&W first generation command and control scenario. He recommended that ADC establish an air defense laboratory at MIT to develop automated equipment to enhance data handling and transmission. The Valley Committee had honed in on the need for continuous wave radars coupled with a digital computer. Up until this time, military computers were analog, as was radar. Valley envisioned taking the data from many small radars and correlating it via computer, a task of converting radar signals into digital radar data. This step necessitated a shift from analog to digital computers, allowing many thousand times more arithmetic calculations per second.[95] Two other study groups immediately followed, that of Project Charles—led out of the University of Illinois, and, that of Western Electric—named the Continental Air Defense System (CADS). During 1950-1951, at the height of the Korean War, RAND and the Weapons Systems Evaluations Group

(WSEG) corroborated the findings of Project Charles, and at the close of 1951 MIT established Project Lincoln. The Air Force funded Lincoln as a joint air defense laboratory for itself, the Army, and the Navy. Air Force Secretary Finletter described Lincoln as the Manhattan Project of air defense.

Project Lincoln represented a major turning point in the unfolding air defense mission. MIT scientists likened the pre-1951 air defense shield to a brainless beast, one commanded only nominally through the regional AC&W centers just beginning to go into place, and then run manually, without sufficient speed. Lincoln Laboratory's long-range mission, then, was to develop a centralized, digital, high-speed air defense system expanded from the interim AC&W network. Scientists anticipated that development of the computer transistor was pivotal. While the laboratory opened the computer research, debate raged within the Air Force as to the appropriate funding emphasis for SAC and ADC. MIT spearheaded another air defense committee, the Summer Study Group of late 1952, to further evaluate American air defense. Through simulated, electronic war games scientists brought forth the imagery of a Maginot Line, inferring that Air Force emphasis on SAC as a retaliatory force was misconceived. SAC responded that it was ADC's planning for air defense infrastructure that was foolish—labeling such a shield a Great Wall of China. While the argument went back and forth, scientists at the Willow Run Research Center at the University of Michigan initiated their own experiments for computerized air defense. Willow Run adapted the Comprehensive Display System (CDS) of the British Royal Navy to American radars, renaming it the Air Defense Integrated System (ADIS). The ADIS project of the University of Michigan was closely affiliated with the research and development for the ground-to-air Bomarc interceptor missile. Also contributing to the advancement of air defense hardware was the Army's Project 414A, SYSNET—an antiaircraft control system.[96] The Air Force studied the two plans for computerized air defense command and control, MIT's Lincoln Transmission System and the University of Michigan's ADIS. The two plans argued for fewer (MIT) and greater (Michigan) command posts, named control centers (MIT) and direction centers (Michigan). Michigan's proposed system primarily addressed Soviet attack by manned bombers, the perceived likelihood. MIT evaluated the future possibility of ICBM threat. The Air Force stipulated that each team approach the air defense problem in these distinctively different ways. In May 1953 the Air Force dropped the Michigan study, giving the go-ahead to MIT to augment its Cape Cod test model for a real military environment. Procrastination nonetheless continued until Soviet detonation of a thermonuclear device in August—after which air defense through automated data handling received unequivocal priority.

The Air Force began calling its future computerized air defense system "semi-automatic" in 1954, in reference to its combined plan for continued reliance on the telephone, coupled with the not-yet-available digital computer. The original "conversion period" between the manual AC&W network, and the semi-automatic Lincoln Transmission System was 1956-1958.[97] MIT physicist Valley recalled in 1985 that the actual name change from the Lincoln Transmission System to the Semi-Automatic Ground Environment (SAGE)—which also occurred during 1954—was quite arbitrary. Valley recounted that when the Air Force set about formalizing a name and acronym for the program, it ran into a dilemma. ADC desired "air defense" in the selected name, but resultant acronyms were justifiably derided. Especially problematic was SAD—the Semiautomatic Air Defense system, or SAD system. As Valley told the story, civilian and military personnel were confined in a conference room one afternoon to definitively find a name that would allow a presentable acronym when arguing for the program's funding before Congress. An attendee of the mandatory meeting, John D. Churchill, had been doodling, drawing stick figures of George Valley, and then in a desultory moment adding his initials, GEV, to the end of SAD. From SADGEV Churchill saw SAGE within the whole, retrofitting a name to the acronym.[98] The official Air Force program name for SAGE was Project 416L.

As SAGE got formally underway, the numbers of planned direction centers grew to 46, with priorities in the corridor from Maine to Virginia. In early 1954, the number had already changed to 42, with two manual centers in the group for coverage of Colorado, Utah, and Wyoming, and with priorities expanded to include Truax Air Force Base in Madison, Wisconsin. In June ADC abandoned the idea of direction centers, in which the command had planned to collocate both air defense sector and subsector responsibilities. The revised SAGE featured both combat centers (sector level) and direction centers (subsector level)—in essence combining the key infrastructure originally suggested by both MIT and the University of Michigan, with the stipulation that the mainframe computer in development also be rethought as two different computers. ADC added plans for nine combat centers to the existing program. After further review by ADC and ARDC, draft SAGE buildout was again downsized in early 1955, to 34 direction centers and eight combat centers. Plans were for operational capability staged over early 1957 through 1960. Minor program changes occurred again before the close of the year, with projected operational dates moved forward into 1962 for the entire system.[99]

Even before the close of 1954, the Air Force negotiated a contract with Western Electric for the first two SAGE sites, still planning for a collocated sector and subsector operations building (the first-conceived direction center) and a power building.[100] The pattern closely followed that of the pre-existing AC&W command and control centers, and in fact, even after ADC decided to build separate combat and direction centers, the plan was to erect SAGE facilities immediately adjacent to first generation command and control clusters wherever possible. The first generation command and control type 3 and 4 stations would then become additional administrative space for SAGE.[101] Although ADC only rarely collocated SAGE with a first generation command and control cluster, when it did occur the effect was striking—allowing viewers to take in two plateaus of air defense infrastructure in a single snapshot of the early Cold War. Two such verified examples are those at the former Richards-Gebaur and Truax Air Force Bases, in Kansas City and Madison, respectively. (See Plates 71 and 77.) SAGE also impacted the AC&W type 2 stations—the radars—through additions (called SAGE annexes) built to house the FST-2, a digital data processing device developed by Burroughs Corporation to transmit data gathered by long-range radars to the mainframe computers of the SAGE direction centers.[102] SAGE building construction was underway in 1955, with the first three direction centers in progress at McGuire Air Force Base (New Jersey), Stewart Air Force Base (New York), and Fort Lee (Virginia).[103] Before mid-1956, direction centers at Topsham Air Force Station (near Brunswick NAS, Maine) and Fort Custer (Michigan) were going up, as well as the combination combat and direction centers at Syracuse Air Force Base (New York) and Truax Air Force Base (Wisconsin)[104] (Plates 81-84).

Initial planning for computerized air defense had looked at the idea of placing SAGE in the existing first generation AC&W type 4 stations, soon discovering that the computer equipment was simply too large and specialized for the 1949-designed buildings (Plates 85-86). Air defense strategists for the late 1940s air defense centers had assumed that only a certain number of combat scenarios could be handled per center, thus placing the air battle at the division (sector) level. With the AN/FSQ-7 Combat Direction Central, as ADC called the SAGE computer after 1954, a four-fold increase in considered air defense situations and weapons deployment was made possible. It then became desirable to shift the air battle to the wing (subsector) level. A more comprehensive portrait of an attack, with higher decision making, occurred in the combat centers, with the AN/FSQ-8 installed therein as a modification of the AN/FSQ-7. The dual direction-combat center SAGE program necessitated redrawing the air defense sector boundaries. The very first "direction center" was actually a test complex at the Lincoln Laboratory outside Boston, responsible for the Experimental SAGE subsector.

Plate 81. **Burns & Roe. Aerial view of SAGE direction center and power building at Topsham Air Force Station, Maine. 1958-1959. Courtesy, Air Force Historical Research Agency.**

Plate 82. Burns & Roe. SAGE combat (left) and direction (right) centers at Syracuse Air Force Station. September 1956. Courtesy, Air Force Historical Research Agency.

Plate 83. Burns & Roe. SAGE combat and direction centers under construction at Syracuse Air Force Station. May 1956. Courtesy, Air Force Historical Research Agency.

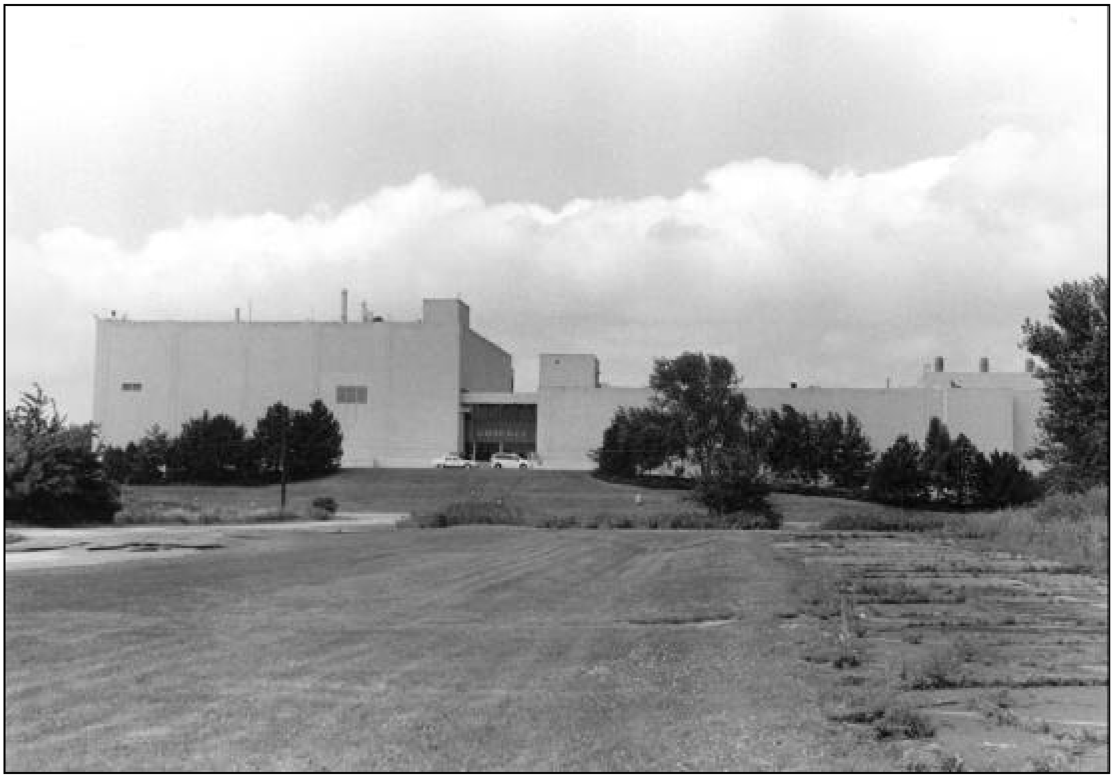

Plate 84. Burns & Roe. SAGE combat (left) and direction (right) centers at the former Truax Air Force Base. View of July 1999. Photograph, K.J. Weitze.

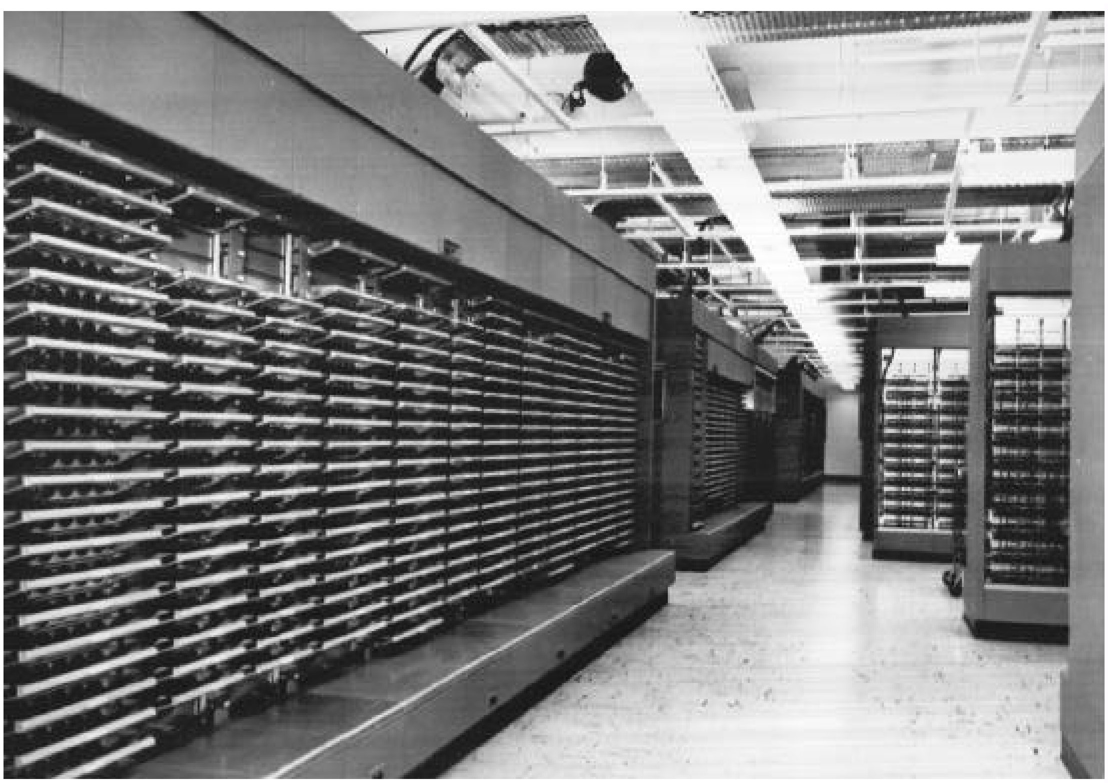

Plate 85. SAGE computer equipment (IBM AN/FSQ-7) at Topsham Air Force Station, Maine. 1958-1959. Courtesy, Air Force Historical Research Agency.

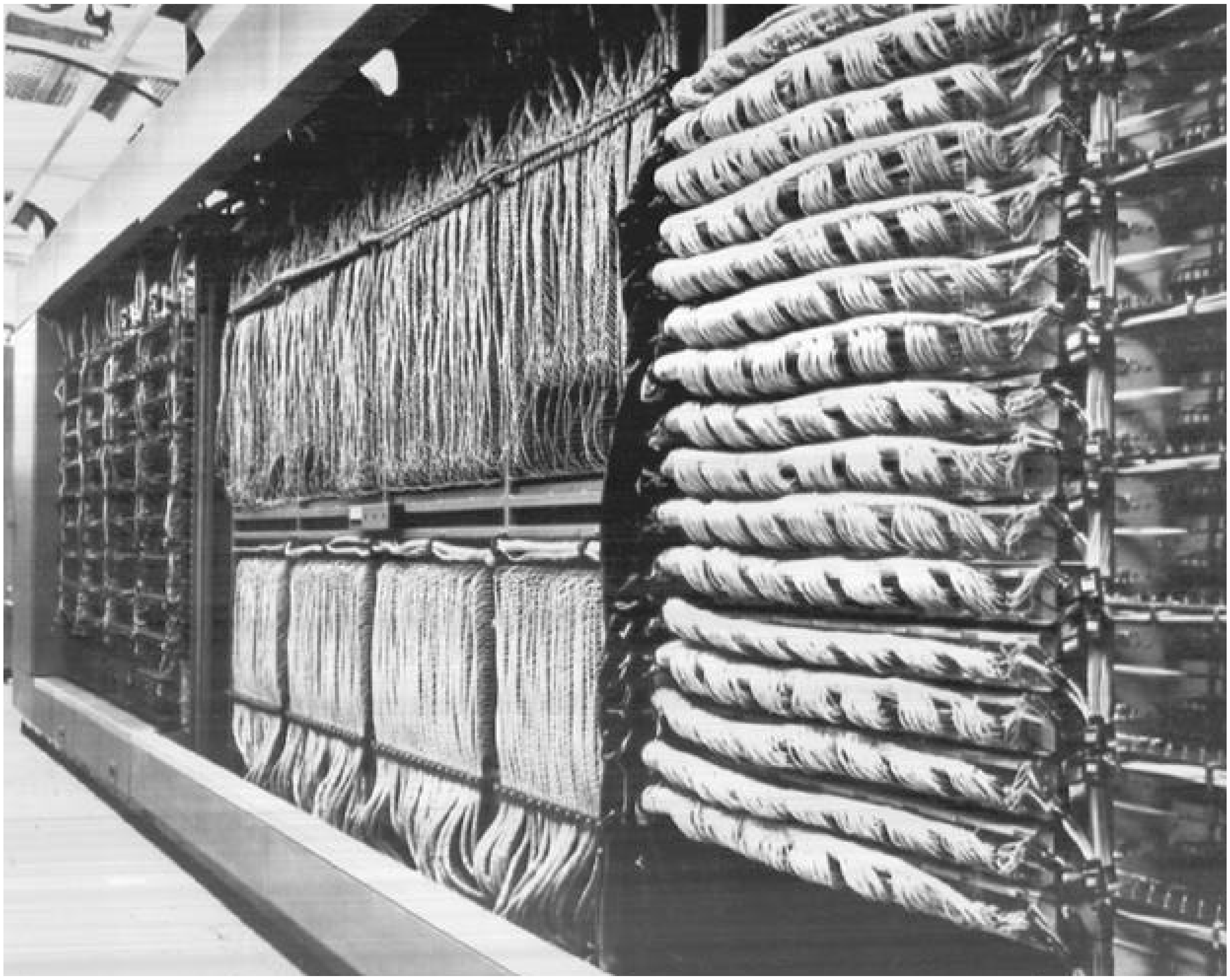

Plate 86. SAGE computer equipment (IBM AN/FSQ-7) at Topsham Air Force Station, Maine. 1958-1959. Courtesy, Air Force Historical Research Agency.

ADC initially considered making the SAGE complexes hardened facilities, below ground, but soon concluded that aboveground, shock-resistant and contamination-proof, reinforced concrete buildings were preferred. Judgments concerning probable first-strike targets—the SAC bases, major population centers and industrial / nuclear weapons compounds—made it reasonable to assume that the prohibitive funding required for placement underground would be better used for strategic capabilities. Designed by the New York firm of Burns & Roe, with Western Electric, direction centers were initially planned as four-story buildings; combat centers as three-story buildings; and power buildings, required for both direction and combat centers, as one-story. Original design featured two variations, one for separately sited combat and direction centers, each with its own power building; and a second for a combined combat-direction center, with attached power building. As funding for the program shrunk, and ideas for the network changed, ADC built only three combat centers instead of eight. ADC erected each of these with a direction center immediately adjacent. (For example: if buildout had continued as originally planned, ADC's San Francisco Air Defense Sector would have supported a combat center, with power building, at Hamilton Air Force Base just north of San Francisco, and, a direction center, with power building, at Beale Air Force Base north of Sacramento. ADC intended fully free-standing combat and direction centers only for this kind of geographically split scenario.) In one instance, that at Minot Air Force Base, North Dakota, construction was well along for the originally planned combat-direction center complex, when ADC downgraded the cluster to a direction center only—leaving a physical structure looking like one thing, when it was another. At Minot also, the four-story "direction center" had its first level below ground, as did the "combat center," making building heights three and two stories, respectively.[105]

Issues of blast-resistant construction—hardening—become complex by the middle and later 1950s. Nuclear weapons were sufficiently improved from those developed at the outset of the decade, with more advanced structures testing and analysis, that the intent of engineers in the SAGE buildings is not yet clear. The framework of SAGE buildings was a system of square, two-foot, four-inch reinforced concrete columns, with massive mushroom capitals and three-foot, four-inch square bases, set in 30-foot square bays. Exterior walls, flooring, and roof were also reinforced concrete, varying in thickness from 10 inches to about one foot. As originally designed, ADC planned that both the combat and direction centers be about 150 feet square and 75 feet high (with interior floors of varying height). The power building was to be 110 feet square, 21 feet high, and connected to either the direction or combat center by a bay 100 feet by 22 feet. For the combined combat-direction center (that built at Syracuse, Truax, and McChord Air Force Bases), a one-story building, framed for two additional stories, connected the individual centers, of 150- by 30-foot dimensions. Its power building was a stepped one-story structure, varying in height from 25 to 15 feet, and of 220- by 150-foot dimensions[106] (Plates 87-88.) Burns & Roe engineered the exterior walls for the SAGE buildings as a system of eight-foot square panels, with alternating panels featuring horizontal and vertical, closely placed, steel reinforcing bars.[107] In addition, about 12—or approximately half—of the SAGE centers built out for the program had an exterior finishing that featured foundation-to-roof vertical ribbing, configured as shallow stepped pilasters. The remainder, completed during the second half of the program, had a final cement coat that made the alternating square patterning visible. While the pilastered patterning first appears to be decorative, strongly recalling the Moderne of the 1930s, it was actually an engineering detail tied to hardening. In a New York telephone building engineered in 1953-1954 for protection against nuclear blast and radiation, reinforced concrete exterior walls "were designed as flat plates and were stiffened with pilasters on column lines." Reinforcing steel bars for the New York structure were hooked to "assure adequate anchorage at their ends," and for added strength to resist blast loads.[108] The alternating eight-foot square wall panels were also most probably a feature tied to this issue.[109] (See Plates 82-83.)

Issues of survivability had grown increasingly more sophisticated by the date of construction for SAGE, including not just nuclear blast overpressures (partially understood at the outset of the decade), but also the radiation penetration of gamma rays and energized neutrons. Questions of construction arise for SAGE, and like related questions surrounding the first generation ADC command and control buildings, can only be superficially addressed here. In regards to blast effects, by 1958-1959 scientists and engineers understood blast from a one megaton nuclear explosion to moderately damage windowless, reinforced concrete structures one mile from ground zero. Overpressure effects from nuclear explosions could be matched by those from traditional high explosives, but those of nuclear weapons lasted longer. Scientists and engineers also knew that small structures could be crushed by blast, and that rectangular structures presenting their smaller face to direction of the shock front would also sustain considerable damage due to notable differential loading between the front and back faces of the building.[110] It is reasonable to assume that the square configuration of SAGE direction and combat centers was deliberate. The thickness and composition of the concrete was also of note in the hardening of aboveground buildings from this period, as was the amount and placement of the steel reinforcing.[111] Concrete walls effectively shielded interiors, with walls of six-inch thickness reducing penetration of gamma rays by 50 percent (and walls of 10-to12 inches being optimum).[112] In addition, an inch-and-a-half of steel had the same shielding potential as six-inches of concrete, and outer-layer shielding was more important than what was behind it. The problem of radiation via energized neutrons offered more complexities, as these particles passed right through heavy masses like thick concrete walls, unless the concrete mix featured additives such as iron punchings, colemanite, or boron salts. Thickness of concrete did matter, and did offer a partial radiation shield, but the mixture of the concrete was very important. "Specially heavy concrete may be as effective in thinner layers, 7 inches being roughly equivalent to 10 inches of normal concrete."[113] The official *SAGE Operational Plan* of March 1955, known as the project's Red Book, specifically stated that the program's structures were "designed to be shock-resistant and contamination-proof."[114]

Plate 87. SAGE power building. McChord Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

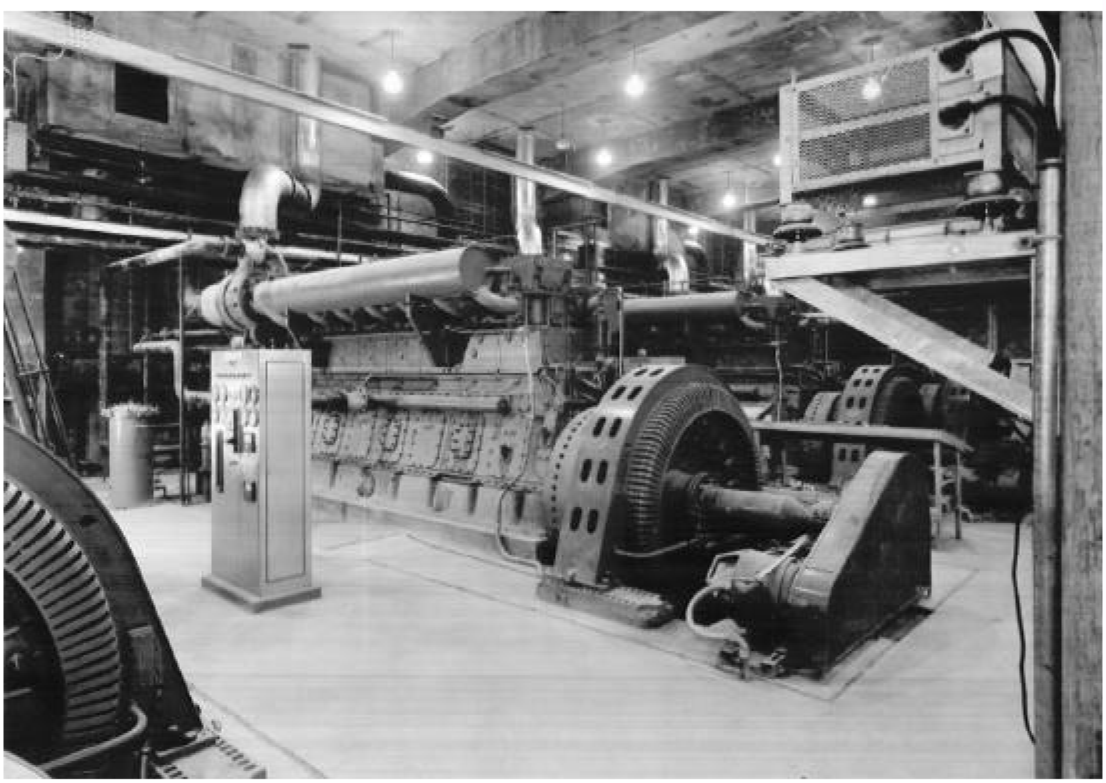

Plate 88. Worthington diesels in the SAGE power building. Syracuse Air Force Station. September 1956. Courtesy, Air Force Historical Research Agency.

Burns & Roe, founded by Ralph C. Roe in 1932, established itself as a noteworthy engineering firm through the design of innovative power plants. The firm pioneered engineering for nuclear power plants, facilities for advanced energy technologies, and aerospace projects, including first-of-a-kind structures. Burns & Roe additionally is known for processing uranium ore and for handling military chemical munitions. For the Department of Defense, the firm has carried forward work for computer centers, communications and electronics networks, radar systems, missile support and testing facilities, vacuum chambers, wind tunnels, and specialized research and development.[115] Western Electric, heavily tied to Sandia Laboratories at the time of the SAGE commission, and in conjunction with American Telephone and Telegraph, hired Burns & Roe for SAGE.

ADC's second generation command and control network, SAGE, was first and foremost a communications challenge. As had been true for the first generation facilities of 1949-1955, SAGE depended very heavily on the telephone, and required an unusually large volume of service. Telephone rates were a substantial cost for SAGE, as was its time-consuming review by the Federal Communications Commission and connected tariff issues.

> It was estimated that 55 per cent of the SAGE business would be handled by the Long Lines Division of AT&T and 15 per cent by independent telephone companies. As a result of this Air Force suggestion, AT&T petitioned the Federal Communications Commission for establishment of a lower "bulk rate" which would apply to customers who used a large volume of communications. SAGE and the broadcasting networks were two such customers who came immediately to mind. AT&T estimated that approval of the bulk rate would save SAGE $14 millions a year.

Coupled with the complex issues of the telephone linkages, were those of producing the computers still in design. By mid-1956, Lincoln Laboratory acknowledged that it was deeply behind its planned schedule, and even though the first SAGE sites were under construction, delays and increased costs were by this date certain to push operational capabilities forward by several years.[116]

As of early 1957, costs for SAGE were escalating out of control, even with the approval for a bulk telephone rate by the Federal Communications Commission. After major divisiveness in Congress, the Department of Defense directed SAGE construction suspended, directly affecting planned work for the direction centers at Malmstrom, Minot, and Luke Air Force Bases. By the close of the year, the project was again active, with these direction centers funded and ones added for Beale, Stead, Norton, K.I. Sawyer, and Larson Air Force Bases. ADC had accepted work at eight SAGE sites as completed by 1958.[117] The Department of Defense, in a memorandum to the Secretary of the Air Force, requested a formal policy change for the implementation of SAGE construction in February 1958. The policy removed the Air Force from direct supervision of construction, replacing the agency with the more traditionally utilized Corps of Engineers. Up to this point in the project 12 SAGE sites were completed: McGuire Air Force Base, Stewart Air Force Base, Syracuse Air Force Station, Fort Lee, Topsham Air Force Station, Fort Custer, Truax Air Force Base, Grandview Air Force Base [Richards-Gebaur Air Force Base], Gunter Air Force Base, Duluth Air Force Base, Grand Forks Air Force Base, and McChord Air Force Base.[118] These SAGE facilities have the pilastered exterior finishing; those coming afterwards, under Corps management, do not (Plate 89). The direction center at Grand Forks may represent a transition, with its exterior walls still having the pilaster treatment but also revealing the eight-foot square paneling. (See Plate 106.)

Plate 89. Burns & Roe. SAGE direction center at the former Sioux City Air Force Base. View of July 1999. Photograph, K.J. Weitze.

As planned in 1955, McGuire Air Force Base in central New Jersey, became the initial operational SAGE complex in mid-1958, covering the New York air defense sector with a direction center. In August 1958 the “direction center” for the Experimental SAGE Subsector closed, with personnel moved to ADC bases and to the computer software design group, Systems Development Corporation (SDC), affiliated with RAND in Southern California. Almost immediately, in January 1959, direction and combat centers began operation at Syracuse Air Force Station, the first combined SAGE facility to come on line. The Syracuse center played a critical role in final tests for the system after closure of the Experimental SAGE Subsector. At this time the North American Defense Command (NORAD) and ADC initiated the realignment of the manual air division boundaries to the SAGE configuration, simultaneously phasing out the first generation ADC command and control centers. Yet changes in the projected methods of Soviet attack, due to the probability of a shift to the intercontinental ballistic missile (ICBM) by the early 1960s, nearly eclipsed the sophistication of troubled SAGE. During 1959 the Joint Chiefs of Staff authorized hardening of the NORAD command operations center, then at Ent Air Force Base in a first generation ADC concrete-block structure. NORAD planned new facilities for construction in Cheyenne Mountain, outside Colorado Springs. This underground combat operations center had been in design since 1956, with the original proposal modeled directly on the combined above- and below ground headquarters for SAC at Offutt Air Force Base, and subsequently changed for the Cheyenne Mountain scheme.[119] With hindsight, eight of the SAGE facilities were analyzed as highly vulnerable—due to their siting on enemy-targeted SAC bases. In an attempt to rectify the situation, ADC planned briefly for 10 Super Combat Centers (SCCs). To be built 300 to 500 feet underground, the SCCs were to receive a new, smaller, transistorized IBM computer, capable of handling five to seven times more data. The growing sophistication of the Soviet nuclear threat, and the horrific costs of below ground hardened construction—especially construction for sites like those of Whitehorse Mountain, New York, and Kennesaw Mountain, Georgia,[120] precipitated cancellation of the SCC program, along with that of the remainder of the unbuilt SAGE facilities, in March 1960.[121]

At the end of 1961, ADC command and control had assumed a mixed configuration. Spacing them evenly across the nation, ADC placed combat centers at Syracuse Air Force Station (Syracuse, New York: Syracuse Air Defense Sector); Truax Air Force Base (Madison, Wisconsin: Chicago Air Defense Sector); and McChord Air Force Base (Tacoma, Washington: Seattle Air Defense Sector), operational as of December 1958, September 1959, and May 1960. To provide SAGE combat center capabilities "in the central and western portions of the U.S. where no combat centers exist due to previous program changes" [including elimination of planned SAGE combat centers for the region and the also-planned SCCs], ADC established "remote combat centers" at Hamilton and Richards-Gebaur Air Force Bases during 1960-1961. ADC achieved these remote combat centers through renovation of the first generation command and control facilities ["the existing manual block houses"] already at these bases.[122] By 1961, ADC had reduced the 16 first generation command and control centers to six—excluding those converted to SAGE combat center status, as it had anticipated in 1953. These six, at Stewart Air Force Base (New York); Truax Air Force Base (Wisconsin); Duluth Air Force Base (Minnesota); Malmstrom Air Force Base (Montana); Larson and McChord Air Force Bases (Washington), remained as key administrative sites, but relinquished their command and control roles.

At buildout, ADC operated SAGE direction centers, governing their respective air defense sectors, at Topsham Air Force Station, Maine (Bangor sector); Stewart Air Force Base and Syracuse Air Force Station, New York (Boston and Syracuse sectors); McGuire Air Force Base, New Jersey (New York sector); Fort Lee, Virginia (Washington, D.C. sector); Gunter Air Force Base, Alabama (Montgomery sector); Custer Air Force Station and K.I. Sawyer Air Force Base, Michigan (Detroit and Sault Saint Marie sectors); Truax Air Force Base, Wisconsin (Chicago sector); Duluth Air Force Station, Minnesota (Duluth sector); Sioux City Air Force Station, Iowa (Sioux City sector); Richards-Gebaur Air Force Base, Missouri (Oklahoma sector); Grand Forks and Minot Air Force Bases, North Dakota (Grand Forks and Minot sectors); Malmstrom Air Force Base, Montana (Great Falls sector); Luke Air Force Base, Arizona (Phoenix sector); Stead Air Force Base, Nevada (Reno sector); Beale and Norton Air Force Bases, California (San Francisco and Los Angeles sectors); Camp Adair, Oregon (Portland sector); and, McChord and Larson Air Force Bases, Washington (Seattle and Spokane sectors) (Plates 90-91). ADC managed a twenty-third direction center, that at Goose Bay, Canada, the only SAGE complex never to be automated. The Richards-Gebaur direction center functioned primarily for program testing and operator / maintenance training. In 1962, this function shifted to the direction center at Luke Air Force Base in Arizona. ADC deactivated selected SAGE direction centers as early as 1963-1965, in the steady transition toward a reliance on standing alert ICBMs and their underground hardened command and control. ADC deactivated both the Grand Forks and Minot SAGE centers in 1963, as Minuteman went operational; a similar situation characterized SAGE decommissioning at Larson Air Force Base in Washington. The focal feature of a SAGE center was its duplex computers. These IBM machines generated 200 different displays every two-and-one-half seconds, with 65,000 computations per second required to achieve these informational fields. In addition to these advances, SAGE adapted a slow-motion video technique that provided a continuous radar picture digitally transmitted over telephone lines.

As the SAGE system became operational, direction center by direction center, its automation drew respect from ADC staff, although many manual procedures continued until the sophisticated computers were better understood (Plate 92). The Bangor Air Defense Sector wrote at length about SAGE during 1958 and 1959, describing its mechanisms in relation to their daily routine and complimenting the digital processing device, the AN/FST-2, as "near-magic." SAGE linked together a dozen radars automatically, allowing the direction of many more weapons than previously possible. As a plane entered the Bangor sector, long-range radars first picked up its image, sending this information along with "ground, cloud and sea clutter" to the AN/FST-2 at an AC&W radar station. This device in turn segregated out the aircraft image, translated it into a digital message and transmitted the message by telephone line to the SAGE direction center. Gap-filler radar followed a similar process, using the AN/FST-1. The direction center computer, the AN/FSQ-7, received information from both radar systems, next decoding and converting it to the x-y coordinates needed for locational mapping at a situation console in the SAGE mapping room.

Plate 90. Burns & Roe. SAGE direction center at the former Richards-Gebaur Air Force Base. Power building at rear (left). View of July 1999. Photograph, K.J. Weitze.

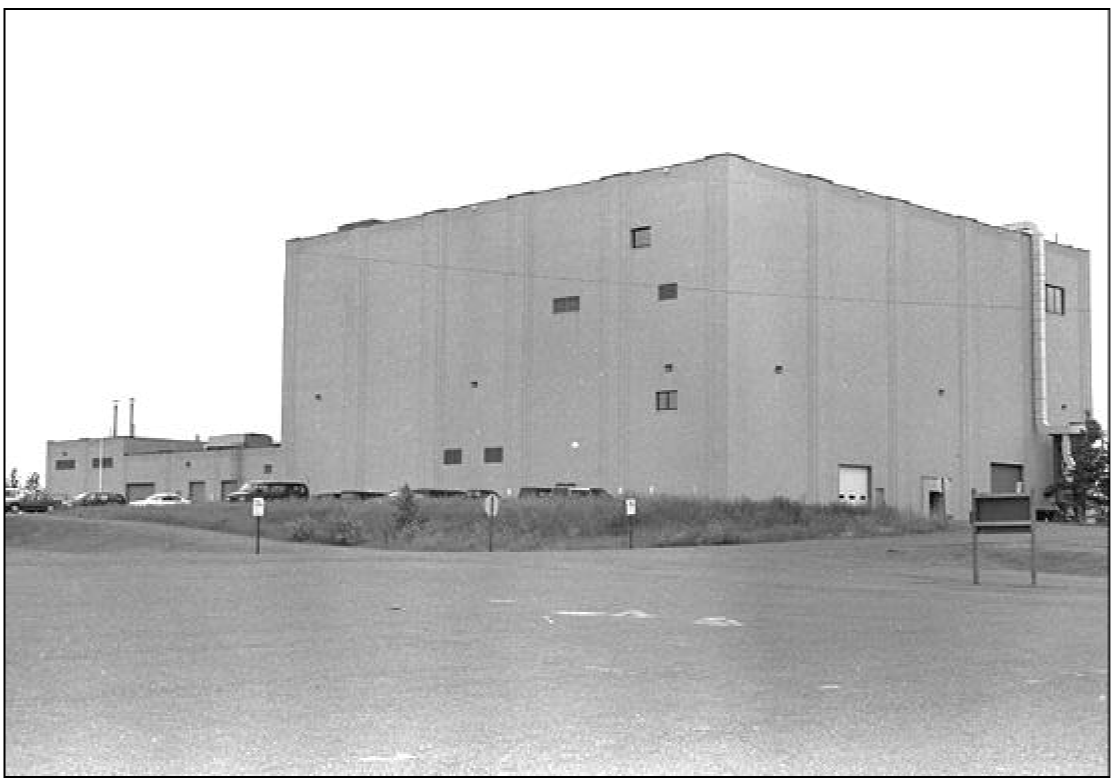

Plate 91. Burns & Roe. SAGE direction center and power building at the former Duluth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 92. War room in the SAGE direction center at Topsham Air Force Station. 1959. Courtesy, Air Force Historical Research Agency.

The console created a tracking image in a photo-electric tube mounted above it. The track was simultaneously displayed in the SAGE identification room for correlation with posted flight plans. (Plans had already reached the direction center via teletype, punched out on an IBM card manually.) While these procedures went forward, the computer system constantly updated information on the original radar image. If the tracking did not match known flight information in one minute, then the system forwarded its image to the SAGE weapons (war) room. There, the ADC director assigned the track on his console to a weapons director, who in turn used an automated weapons assignment display to illustrate possible interception points. Calculating distances and time for fighter-interceptor response to the unknown aircraft, the weapons director selected the squadron with the quickest theoretical scramble capabilities; scrambled the fighters; and assigned the scramble to one of five interceptor directors. The chosen interceptor director received his assignment as an alarm, with imagery on his console. Once the fighters were airborne, the interceptor director's computer managed the interception problem and guided the interceptor path, while the director correlated any additional friend-or-foe information. The fighter pilots received datalink instructions on their aircraft radars. After the interception, computers calculated the vectoring to return the fighters to their home base.

By the early 1960s, however, ADC already perceived problems with SAGE in its role as a shield against incoming Soviet bombers. Simulated attacks, run as exercises by SAC, varied the numbers and flying altitudes of hostile aircraft. In its final exercise for SAGE, an ADC-SAC category III evaluation reiterated that SAGE could cope with a Soviet bomber attack *under favorable conditions*. If the enemy attempted to confuse radars through electronic countermeasures such as "sweep, spot, barrage jamming and bundle chaff;" if weather conditions produced too much extraneous data; if incoming bombers flew below 10,000 feet; or, if enemy penetrations exceeded more than 50 simultaneous penetrations per air defense sector, SAGE could not guarantee the safety of the country. In particular, SAC discovered that bombers attacking from a seaward position and flying very low, below 1,000 feet, could essentially avoid all detection. Cold War technologies developed so fast, that even as ADC addressed this knowledge, the ICBM brought much more impressive concerns to the forefront, and SAGE, sophisticated as it was, witnessed its own accelerated obsolescence.

Third Generation ADC Command and Control: BUIC and Post-BUIC

By 1965, ADC assumed that a Soviet first strike would be ICBM in character, but would likely be followed by a second bomber strike, and would require a combined bomber and ICBM retaliation. To accommodate a third generation command and control, after the aborted initial design and engineering work for the super combat centers, and to support and disperse air defense command and control, ADC built BUIC. In a sense, this system paralleled what SAC hoped to achieve with its dispersed alert program of nearly the same time. ADC command and control centers were important targets for a Soviet strike: the more of them there were, and the more widely they were dispersed, the more likely that the air defense system could function if partially destroyed. In addition, by the early 1960s much smaller computers, with enhanced capabilities, were available to handle the air defense challenge—making the large infrastructure of SAGE replaceable by something more modest. All of these factors combined with budgetary constraints. ADC chose to meet the situation through modification of existing Holabird, Root & Burgee type 2 stations at AC&W radar sites. Although this infrastructure dated to 1949, it had been engineered as hardened for its time and offered 85 different locations from which to configure BUIC. AC&W radar stations were disassociated physically from other military installations, and thus did not already occupy target locations. First plans were to backup SAGE, with 30 AC&W radar stations receiving computers. In early 1962 ADC analyzed the type 2 stations as able to "survive a blast," but with fallout protection needed. ADC planned to accomplish the latter through additional "shielding of those portions of the operations power and communications buildings where constant attendance is required." ADC added independent power stations for the locations where it did not exist.[123]

ADC alternately named its third generation command and control centers NORAD Automated Control Centers (NACCs) or NORAD Control Centers (NCCs). Like SAGE, BUIC came on line in stages and with multiple planning scenarios for the selected locations and the numbers of centers. BUIC I was manual, operational in 1962-1963 at 27 former AC&W radar stations. At the end of this period, only 16 of the 23 SAGE centers functional at buildout in 1961, were still on line.[124] ADC planned the physical renovations of the type 2 stations for BUIC II, in construction during 1962-1965. Anticipated cost for the remodeling was about $100,000 per AC&W site, with a focus on the "Radiological Shielding."[125] Again, precise engineering for the shielding is as yet unresearched, but can be minimally interpreted as evolved from efforts made for the first and second generation ADC command and control centers. For BUIC II, ADC added reinforced concrete, two-foot thick, "fallout protection" walls encasing the first generation type 2 station with an air space of perhaps four to six feet between the outer and inner (original) building. Additionally, ADC removed the innermost four-inch concrete-block wall surrounding the operations room in the type 2 station, replacing it with a continuous metal "R.F." (radiation field) shield. The command also raised the floor in the operations room, laying the metal radiation shield over the original concrete floor, pouring another two inches of concrete above the shield, and creating an air space of one foot, three inches through the addition of small columns and laying a false floor above this.[126] By 1966, when the 14 final BUIC IIs were all on line, including a training facility, only 13 SAGE centers remained operational. The BUIC system was still in transition, however, with the recent issuance of criteria for BUIC III in mid-1965. BUIC III had stopped conversion of the AC&W type 2 stations at about mid-program (buildout planned for 30-31 facilities). For BUIC III work continued, with more additions to the type 2 stations, increasing the spatial capacity of BUIC II through a distinct three-room structure added along its side. The final BUIC III addition was approximately the size of the original type 2 station of 1949—itself encased and shielded for BUIC II. Construction for BUIC III occurred in 1968.[127]

ADC operated only six of the original 23 SAGE centers by 1970, with 12 BUIC III facilities a part of the overall air defense system that year.[128] The SAGE shield maintained centers at Syracuse Air Force

Station, New York (combat and direction centers); Fort Lee, Virginia (direction center); Goose Air Base, Ontario (manual direction center); Malmstrom Air Force Base, Montana (direction center); Luke Air Force Base, Arizona (direction center); and McChord Air Force Base, Washington (combat and direction centers). Beginning in 1969, early warning radar technology also began to alter the nature of air defense systems. Large phased-array radars, the first operational at Eglin Air Force Base in the Florida panhandle in 1969, greatly enhanced the capacity of the U.S. radar network. Often evaluated as basic infrastructure for an antiballistic missile system, these radars will be configured as a complete system of 10 facilities in 2000, with discussions currently underway to further augment the system with battle management radars and emplacement of 100 antimissile interceptors at two sites in Alaska and the northern United States.[129] In January 1984, the six remaining SAGE centers were deactivated, replaced through the Joint [U.S.-Canadian] Surveillance System (JSS) at eight locations in the continental U.S., Alaska, Hawaii, and Canada.[130] (See Table 3, chapter 3.)

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[1] The basic discussion presented here is derived from Karen J. Weitze, *Inventory of Cold War Properties: Andrews, Charleston, Dover, Grand Forks, McChord, Scott, and Travis Air Force Bases* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, 1996). Information and analysis is substantially refined from the original presentation, however, with significant added material. Documentation in the 1996 study is not repeated here, where items are not modified or further footnoted.

[2] National Guard, “Hangar for Liaison Type Plane,” drawing series no.39-01-01, 16 February 1948. Index card for six drawings, 105mm collection, held in Box 7, Standard Drawings, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[3] J.T. Jockel, *No Boundaries Upstairs: Canada, the United States, and the Origins of North American Air Defence, 1945-1958* (Vancouver: The University of British Columbia, 1987), 36-37.

[4] Headquarters, USAF, *History of the Directorate of Installations, 1 January 1952 – 30 June 1952,* Plans Division section: 8-9.

[5] Headquarters, USAF, *History of the Directorate of Installations, 1 January 1953 – 30 June 1953,* Planning and Programming Division section: 7-8, 11, 13.

[6] “Authorizing Construction at Air Force Installations,” House of Representatives, 82nd Congress, 1st Session, Report No.1084, 1 October 1951, 2.

[7] Headquarters, USAF, *History of the Directorate of Installations, 1 July 1953 – 31 December 1953,* Planning and Programming Division section: 9-10, 14-15, 17-18.

[8] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 January 1954 to 30 June 1954*, Planning and Programming Division section: not paginated; multiple references.

[9] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 July 1955 to 31 December 1955*, 75.

[10] Mills & Petticord, “Hangar—Alert, Fighter A/C,” drawings no.39-01-30, and no.39-01-37, 10 January 1951 and 10 March 1951. Index cards, 105mm collection, held in Box 9, Superceded Drawings, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia. The 105mm microfiche for drawing no.39-01-37 survives.

[11] Alfred Goldberg, *A History of the United States Air Force, 1907-1957* (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1957), 191.

[12] Walter G. Hiner, “Combat Airplane Hangars,” *The Military Engineer* 37, no.235 (May 1945): 187.

[13] Butler Manufacturing Company, *Business in the Butler Tradition 1901-1987* (Kansas City, Missouri: Butler Manufacturing Company, 1987), and, Butler company history posted on the internet web site www.butlermfg.org, 5 February 1999.

[14] Butler Manufacturing Company, *Butler in World War II* (Kansas City, Missouri: Butler Manufacturing Company, ca.1945).

[15] Tactical Air Command, *405th Fighter-Bomber Wing History, 1 July to 31 December 1954*, Appendix E, photograph.

[16] The civil engineering vault, Langley Air Force Base, holds the drawings for the Luria alert hangar of 1951, and are to date the only reference source for analysis of this structure.

[17] R. Blake Roxlau, Karen Lewis, and Katherine J. Roxlau, *A Baseline Inventory of Cold War Material Culture at Langley Air Force Base*, volume II-14 of *A Systemic Study of Air Combat Command Cold War Material Culture* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, August 1997), 17-18.

[18] USAF, Directorate of Installations, "Langley Air Force Base," *Master Plans*, October 1957. Information on the engineering firm and date for the alert hangar drawings confirmed through a telephone conversation with personnel in the civil engineering vault, Langley Air Force Base.

[19] Strobel & Salzman, "Hangar, Alert, Fighter A/C," drawing series no.39-01-38, 19 April 1951. In the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[20] Strobel & Salzman, "Hangar, Alert, Fighter A/C: Hangar Door Mechanism & Support Plan & Elevation," drawing series no.39-01-38, 15 of 23, 19 April 1951.

[21] Karen J. Weitze, *Inventory of Cold War Properties: McChord Air Force Base* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, October 1996), 57.

[22] "New Marine Corps Hangar is Open and Shut Case," *Engineering News-Record* 147, no.2 (12 July 1951): 42.

[23] "Hangars, Army Aviation Facilities," drawing series no.39-01-60, 39-01-62, and 39-01-64, January 1955, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[24] "Partner Runs Firm as Strobel Runs PES," *Engineering News-Record* 153, no.5 (29 July 1954): 76.

[25] Willgoos, Strobel, Panero & Knoerle, "Aircraft Maintenance Facilities NAS Hangar Building," drawing series no.39-01-40, 3 November 1959, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[26] Norman W. Rimmer, *Eave Alert Hangar: Engineering Data* (Kansas City, Missouri: Butler Manufacturing Company, March-August 1951).

[27] Karen J. Weitze, site visit, Kirtland Air Force Base, December 1998.

[28] Butler Manufacturing Company, *Load Test 70-13 Aluminum Rigid Frame Arctic Alert Hangar, United States Air Force, Wright-Patterson Air Force Base, Contract No. AF33(038)-20305, Date of Test May 25, 1951* (Kansas City, Missouri: Butler Manufacturing Company, 1951).

[29] Butler Manufacturing Company, "Alert Hangar, Fighter A/C," June 1951 [Kirtland Air Force Base], and June-August 1951 [Ellsworth Air Force Base], drawings held in the respective civil engineering vaults at the installations.

[30] Norman W. Rimmer, interview with Karen J. Weitze, at Butler Manufacturing, Kansas City, 17 September 1999; H.H. Arnold, Major General, "Report on Study of Possible Locations for a Suitable Proving Ground for Aircraft Armament." 19 April 1939, in "Eglin Field," 1939-1940; Air Defense Command, History 121st Fighter-Interceptor Squadron 1 April 1952 – 30 June 1952, 6-11.

[31] 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, 1991), 283.

[32] *History of the Assistant Chief of Staff, Installations, 1 July 1955 to 31 December 1955*, 75.

[33] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 January 1957 to 30 June 1957*, 60-61.

[34] Headquarters, USAF, *History of the Directorate of Installations, 1 January 1958 – 30 June 1958*, 71.

[35] Aerospace Defense Command, *An Overview of ADC Weapons 1946-1972*, 50.

[36] "Alert Hangar, Door Modifications, Butler Type," 7 October 1958, Kirtland Air Force Base, and, "Mod 708, Hangar, Alert," 21 August 1959, Ellsworth Air Force Base. Drawings held in the civil engineering vaults at the respective installations.

[37] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 January 1959 to 30 June 1959*, 59.

[38] Schaffel, *The Emerging Shield*, 270-271.

[39] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 January 1956 to 30 June 1956*, 58-59; index cards, 105mm collection, held in Box 8, Definitive Drawings, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[40] Strobel & Salzman, "Hangar, Alert, Fighter A/C," drawing series no.39-01-69, 29 January 1957, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[41] Strobel & Salzman, "Shelter, Ready Fighter, A/C," drawing series no.39-01-72, 29 January 1957, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[42] Karen J. Weitze, *Inventory of Cold War Properties: Grand Forks Air Force Base* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, October 1996), 65.

[43] James A. Lowe, David P. Staley, and Katherine J. Roxlau, *A Baseline Inventory of Cold War Material Culture at Loring Air Force Base*, volume II-16 of *A Systemic Study of Air Combat Command Cold War Material Culture* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, August 1997), C-18.

[44] Strobel & Salzman, "Shelter, Ready Fighter, A/C, 3 Pocket—Expansible to 4: Plan & Elevations" drawing series no.39-01-72, date not legible. In Julie L. Webster, Michael A. Pedrotty, and Aaron R. Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars: A General History, Thematic Typology, and Inventory of Aircraft Hangars and Associated Buildings on Department of Defense Installations*, Draft (Champaign-Urbana, Illinois: U.S. Army Corps of Engineers Construction Engineering Research Laboratories [USACERL], March 1996).

[45] Schaffel, *The Emerging Shield*, 274.

[46] A case where Butler is referenced as the underlying source is at Beale Air Force Base (California) in the drawings held for the SR-71 shelters of 1971: "Prefab Aircraft Shelter Traced from Butler Mfg Company NR 153058." The shelter dates to 1958, in its baseline design.

[47] Webster, Pedrotty, and Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars*, 1996. These shelters originated as drawing series no.39-01-84 (which had superceded A109 of 31 January 1958); no.39-01-75; and no.39-01-76 (August 1959).

[48] Webster, Pedrotty, and Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars*, 1996.

[49] Detailed lineage of the readiness crew dormitory is not pursued here, but the appropriate drawing series is noted: no.30-11-08 (9 June 1954) and no.30-11-09 (27 March 1956). See the index for definitive drawings, Box 8, for the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[50] See the indexes for superceded and definitive drawings series no.28-12-01 (21 June 1951), no.28-14-03 (18 January 1952), and no.28-13-102 (20 May 1955), for the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[51] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 January 1955 to 30 June 1955*, 30.

[52] These hangars are credited to Luria Engineering on the drawings held at Andrews Air Force Base, while Mills & Petticord is the firm responsible for the standardized Army Corps of Engineers drawings of January and July 1951. Mills & Petticord also handled the first designs for an ADC alert hangar in January-March 1951, with this design rejected by ADC and superceded through the final April-June selection of the Strobel & Salzman, and Butler prefabricated, hangars. See, drawing series no.39-01-33, no.39-01-39, and no.39-01-41, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[53] Mills & Petticord, "Hangar—Maintenance with Shops," drawing series no.39-01-39 and no.39-01-41, 31 July 1951, in Webster, Pedrotty, and Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars*, 1996.

[54] Strobel & Salzman, "Hangar Readiness, with Shops," drawing series no.39-01-41, 4 June 1953, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[55] *History of the Assistant Chief of Staff, Installations, 1 January 1955 to 30 June 1955*, 30-31.

[56] Weitze, *Inventory of Cold War Properties: Grand Forks Air Force Base*, 1996, 65-66. See, Kuljian Corporation, "Hangar Maintenance Organizational Pull-Thru Type," drawing series no.39-01-65, 1955, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[57] Strobel & Salzman, "Shelter, Ready Fighter, A/C, 3 Pocket—Expansible to 4: Plan & Elevations" drawing series no.39-01-72, date not legible [but confirmed as 31 January 1957 in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.] In Webster, Pedrotty, and Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars,* 1996.

[58] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 July 1956 to 31 December 1956*, 62.

[59] *History of the Assistant Chief of Staff, Installations, 1 January 1956 to 30 June 1956*, 59.

[60] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 July 1961 to 31 December 1961*, 37-38.

[61] "Beale AFB, California: Prefab Aircraft Shelter Traced from Butler Mfg Company NR 153058," drawing held for SR-71 real property, civil engineering drawings vaults, Beale Air Force Base.

[62] *History of the Assistant Chief of Staff, Installations, 1 July 1956 to 31 December 1956*, 62. Both the armament and electronics shop and the weapons calibration shelters underwent programmatic design in 1956, with one or two sheets of drawings. Responsible engineering firm is undiscovered. See, "Armament & Electronics Shop," drawing series no.35-60-10, 12 October 1955; "Shelter Aircraft Weapons Calibration (Open Facility)," drawing series no.39-01-75, 14 December 1956; and "Shelter Aircraft Weapons Calibration (Inclosed Facility)," drawing series no.39-01-76, 14 December 1956, in the index of definitive and superceded drawings, Boxes 8 and 9, for the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[63]Headquarters, USAF, *History Directorate of Installations 1 July 1958 to 31 December 1958*, 71.

[64] Kuljian Corporation, "USAF Armament & Electronics Shop—Type 'B'," drawing series no.35-60-09, 20 March and 9 September 1959, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[65] Weitze, *Inventory of Cold War Properties: Grand Forks Air Force Base*, 1996, 62-63.

[66] *History Directorate of Installations, 1 January 1958 – 30 June 1958*, 64. The Bomarc shelter may also be derivative from the generic Butler shelter of 1958; this possibility is not researched herein.

[67] *History Directorate of Installations 1 July 1958 to 31 December 1958*, 70. Congressional budget cuts hit the Air Force particularly hard for infrastructure as of July 1958. See, "Ax Hits Military Construction," *Engineering News-Record* 161, no.5 (31 July 1958): 24.

[68] Kuljian [with Butler Manufacturing], "USAF Aircraft Weapons Calibration (Open Facility)," drawing series no.39-01-75, 5 August 1959, and, "USAF Aircraft Weapons Calibration (Enclosed Facility), drawings series no.39-01-76, 5 August 1959, in the 105mm collection, U.S. Army Corps of Engineers, History Office, Humphreys Engineering Center, Fort Belvoir, Virginia.

[69] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 July 1962 – 31 December 1962*, 33.

[70] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 July 1963 – 31 December 1963*, 33, 43-44.

[71] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 July 1964 – 31 December 1964*, 34.

[72] United States Central Command, *The United States Military in North Africa and Southwest Asia Since World War II*, January 1988, 28.

[73] United States Air Force in Europe, Headquarters, 36th Tactical Fighter Wing, Seventeenth Air Force, *History of the 36th Tactical Fighter Wing 1 July – 31 December 1987*, volume 1.

[74] Aerospace Defense Command, *An Overview of ADC Weapons 1946-1972*, 39-42.

[75] *Ibid*, 26.

[76] *History of the Assistant Chief of Staff, Installations, 1 July 1955 to 31 December 1955*, 73.

[77] *Ibid*, 65-67.

[78] *Ibid*, 67.
[79] *History of the Assistant Chief of Staff, Installations, 1 July 1956 to 31 December 1956*, 51-52.
[80] Black & Veatch, "Ammunition Storage—ADC Type: Storage Magazine," drawing series no.AW33-13-01, May 1956, with modifications through at least drawing series no.AD33-13-20, August 1957, and revisions through October 1957; and, Black & Veatch, "Ammunition Storage—ADC Type: Assembly & Check-Out Building," drawing series no.AW35-53-01, May 1956, with modifications through at least drawings series no.AD35-69-04, September 1959.
[81] Air Defense Command, *Historical Record of the 412th Fighter Group for the period ending 31 December 1958*.
[82] Air Materiel Command, Headquarters, *History of Air Materiel Command January – June 1951*, volume 1, 288; David W. Shircliffe, *NORAD's Underground COC: Initial Requirement to Initial Operation 1956-1966*, Historical Reference Paper no.12 (NORAD, Directorate of Command History: January 1966), 1-8.
[83] Continental Air Defense Command, Headquarters, "Control and Combat Center Developments," *Air Defense of Alaska 1940-1957*, Historical Reference Paper No. Two, 24-25.
[84] Air Defense Command, Headquarters 29th Air Division (Defense), *Historical Report 29th Air Division (Defense) Great Falls Air Force Base, Montana, 1 January through 30 June 1953,* volume II: supporting documents.
[85] Air Defense Command, *Historical Report 29th Air Division (Defense) Great Falls Air Force Base, Montana, 1 July through 31 December 1954*, 22-31.
[86] Woodford Agee Heflin (ed.), *The United States Air Force Dictionary* (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1954), 113.
[87] North American Air Defense Command, *Fifteen Years of Air Defense*, Historical Reference Paper No.5, December 1962, 25.
[88] David B. Parker, "The Atomic Battlefield," *The Military Engineer* 42, no.289 (September-October 1950): 344-348.
[89] Holabird, Root & Burgee, "Operations Building for Type 4 Station," drawing series no.60-02-21, 18 October 1949. Held in the civil engineering vault at McChord Air Force Base.
[90] Tom R. Johnson, Commander, Civil Engineer Corps, United States Navy, "Providing A-B-C Defense in Construction Design," *The Military Engineer* 45, no.304 (March-April 1953): 104-107.
[91] Shircliffe, *NORAD's Underground COC*, 1966, 1, 6.
[92] Holabird, Root & Burgee, "Operations & Maintenance Bldg. For Type 2 Station: Architectural First Floor," drawing series no.60-02-23, 11 October 1949. Held in the civil engineering vault at Minot Air Force Base, in 1996. Planned for removal with the excessing of the radar station property.
[93] The Federal Communications Commission authored the landmark legislation of 1934, requiring reinforced concrete buildings for certain communications structures. The relevance of the engineering to Cold War, and to contemporary terrorist, conditions has even been noted by popular novelist Tom Clancy. See *The Sum of All Fears* (New York: Berkley Books edition, 1992), 757.
[94] Werner Blaser (ed.), *Chicago Architecture: Holabird & Root 1880-1992* (Basel: Birkhäuser Verlag, 1992).
[95] Primary discussion for the development of SAGE is taken from Weitze, "Planning Toward Computerized Command and Control" and "The Infrastructure of SAGE," in *Inventory of Cold War Properties*, 1996. Additional SAGE presentation is derived from Weitze, "Development of the Supercomputer and the Large Scientific Mainframe," in *PAVE PAWS Beale Air Force Base: Historic Evaluation and Context* (Sacramento: KEA Environmental, Inc., for Air Combat Command, February 1999).
[96] Charles J. Smith, Historical Division, Electronic Systems Division, Hanscom Field, Air Force Systems Command, *History of the Electronics Systems Division, January – June 1964: SAGE – Backgrounds and Origins*, December 1964, 88.
[97] *History of the Assistant Chief of Staff, Installations, 1 January 1954 to 30 June 1954*, Construction Division section: Special Projects Branch (unpaginated).

[98] George E. Valley, Jr., "How the SAGE Development Began," *Annals of the History of Computing* 7, no.3 (July 1985): 224-225.
[99] Richard F. McMullen, *The Birth of SAGE 1951-1958*, Air Defense Command Historical Study No.33, 21-40.
[100] *History of the Assistant Chief of Staff, Installations, 1 July 1954 to 31 December 1954*, Directorate of Construction section (unpaginated).
[101] Air Defense Command, Headquarters, *Operational Plan Semiautomatic Ground Environment System for Air Defense* (Ent Air Force Base, Colorado: 7 March 1955), 59.
[102] McMullen, *The Birth of SAGE 1951-1958*, 72; *History of the Assistant Chief of Staff, Installations, 1 Januuary1955 to 30 June 1955*, Directorate of Construction section, 27; *History of the Assistant Chief of Staff, Installations, 1 July1955 to 31December 1955*, 74.
[103] *Ibid*, 27-28.
[104] Air Defense Command, *Operational Plan Semiautomatic Ground Environment System for Air Defense*, 7 March 1955, 59-72.
[105] Karen J. Weitze, "Architectural Inventory and Evaluation of Cold War Properties at Minot AFB," in Maynard B. Cliff, Duane E. Peter, and William David White, Jr., *Minot Air Force Base Cultural Resources Management Plan* (Plano, Texas: Geo-Marine, Inc., for Air Combat Command, September 1996), H-8, H-9.
[106] Air Defense Command, *Operational Plan Semiautomatic Ground Environment System for Air Defense*, 7 March 1955, 59-72.
[107] Burns & Roe, drawings for SAGE, held in the civil engineering vault, Minot Air Force Base.
[108] Frederick S. Merritt (ed.), "Telephone Building Made Blast-Resistant," *Engineering News-Record* 152, no.22 (3 June 1954): 43-44, 48.
[109] See the complete set of *Historical Records* for the 23 Air Defense Sectors of SAGE, held at the Air Force Historical Research Agency, Maxwell Air Force Base, Montgomery, Alabama, 1957-1962.
[110] Peter Weiser, Space Technology Laboratories, Inc., "Survivability," in Kenneth Brown and Peter Weiser (eds.), *Ground Support Systems for Missiles and Space Vehicles* (New York: McGraw-Hill Book Company, Inc., 1961), 385-386, 388-389, 392.
[111] Merritt, "Telephone Building," *Engineering News-Record*, 3 June 1954, 44.
[112] *Ibid*.
[113] Harold L. Brode, physicist, RAND, "Weapons Effect," in *Ibid*, 359-360.
[114] Air Defense Command, *Operational Plan Semiautomatic Ground Environment System for Air Defense*, 7 March 1955, 8; John F. Jacobs, "SAGE Overview," *Annals of the History of Computing* 5, no.4 (October 1983): 329.
[115] Burns and Roe, internet web site at www.roe.com, 9 February 1999.
[116] McMullen, *The Birth of SAGE 1951-1958*, 54-56.
[117] Headquarters, USAF, *History of the Directorate of Installations, 1 July 1957 to 31 December 1957*, 47-48.
[118] Headquarters, USAF, *History of the Directorate of Installations, 1 January 1958 – 30 June 1958*, 36-37.
[119] Shircliffe, *NORAD's Underground COC*, 1966, 3.
[120] Headquarters, USAF, *History Directorate of Civil Engineering 1 July 1959 – 31 December 1959*, 21.
[121] Headquarters, USAF, *History Directorate of Civil Engineering 1 January 1960 – 30 June 1960*, 14-16.
[122] Headquarters, USAF, *History Directorate of Civil Engineering 1 July 1960 – 31 December 1960*, 13; Headquarters, USAF, *History Directorate of Civil Engineering 1 January 1961 – 30 June 1961*, 19.
[123] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 January 1962 – 30 June 1962*, 11-12.
[124] Schaffel, *The Emerging Shield*, 1991, 270-271.
[125] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 July 1963 – 31 December 1963*, 15-16.
[126] U.S. Army Corps of Engineers, Omaha District, "Ops Bldg Alterations and Add'n: Fortuna Air Force Station, North Dakota," 31 March 1964. Personal collection of K.J. Weitze.

[127] Headquarters, USAF, *History of the Directorate of Civil Engineering, 1 July 1964 – 31 December 1964*, 35-36; Wilscam & Mullins, Omaha, "BUIC III Facilities: Fortuna Air Force Station, North Dakota," 15 April 1968. Personal collection of K.J. Weitze.
[128] Schaffel, *The Emerging Shield*, 1991, 270-271.
[129] Michael R. Gordon, "U.S. Asks Russia to Alter Treaty on Missile Defense," *New York Times*, 17 October 1999, 1, 14.
[130] Weitze, *PAVE PAWS Beale Air Force Base*, February 1999, 20.

Chapter 3: Character-Defining Features and National Register Integrity

Each of the key property types for the ADC / TAC air defense mission, inclusive of subcategories for those property types, can be further refined with respect to character-defining features and issues of historic integrity. Focus here is on the fighter and command-communications infrastructure supporting the historic air defense mission of the Cold War. For the purposes of Air Force real property management, and with regard for existing federal historic preservation legislation, character-defining features are presented below as derived from the criteria for the National Register of Historic Places. Integrity—that sense of historic wholeness a structure, building, or group of structures and buildings can convey to an interested audience—is also discussed here. Integrity can mean different things to different people, and as intended below is based upon years of interpretation for National Register properties, and potential properties, across the United States. Analysis implicitly takes into account the seven aspects of integrity presented in the Register: location, setting, materials, design, workmanship, feeling, and association.

Presentation below is intended to offer guidelines for real property managers across the Air Force, and specifically for those managers within Air Combat Command (ACC) whose installations have benefited from varying levels of Cold War architectural-engineering inventory since the inception of the Department of Defense Legacy Resource Management Program in 1991. Discussions of character-defining features and National Register integrity are directly tied to the seven property type categories set forth for the air defense (fighter and command-communications) mission in chapter 2. Analysis can be taken to more detailed levels, but should always consider the points made here. All buildings and structures understood as eligible for the National Register have physical features, as well as associative values, that support an interpretation of significance in American history. In assessing possible Register eligibility, and especially in making decisions about property management, it is helpful to know what it is about a particular building or structure that is key to telling its story. For example, how can managers hope to assess issues of necessary maintenance, renovation, and additions (expansion for new military missions; new aircraft), with regards to an important historic structure, without first understanding what is truly noteworthy about that building historically? How can recordation projects, such as those under the Historic American Buildings Survey (HABS) and the Historic American Engineering Record (HAER), appropriately document a structure and its setting for the Library of Congress archives without first achieving a level of information that clearly relates physical features to historic importance? Not even the best photographer can capture what he is not looking for, unless by accident.

The history sought here is also of a very particular kind: Air Force infrastructure offers an opportunity to examine major engineering achievements of the mid-20th century; to illuminate the complex and fast-paced military missions of ADC and TAC during the first 15 years of the Cold War; and, to interpret the evolution of early jet aircraft. ADC and TAC, overall, had more understated infrastructure during the Cold War than did SAC, and as a result had no real public imagery or ties to a kind of Hollywood myth-making. The command and control infrastructure for ADC, however, was quite complex and multi-generational, and offers a look at cutting-edge developments in computer technology as well as designing for aboveground hardening during the early Cold War. In addition, fighter alert infrastructure for ADC—inclusive of its specific renderings at many airfields—offers a way of seeing military tactical planning that is often present, but obscured, in the voluminous records housed at the installations; at the National Archives in Washington, D.C.; and, at the Air Force Historical Research Agency at Maxwell Air Force Base, Montgomery, Alabama. For military officers, historians, and analysts studying at the Air University, also at Maxwell, an understanding of past building and airfield programs can further serve to sharpen analytic abilities and hone thinking for the future.

First Generation Alert Hangar

Character-defining features of the four types of alert hangar supporting the air defense mission at the outset of the Cold War are focused on the structures' abilities to convey the urgency and challenges of mobilization. ADC commissioned its alert hangar as (1) an overseas type for true mobilization; (2) two versions that were also prefabricated structures that could be shipped easily and erected with unskilled labor, but were more finished, enclosed structures; and, (3) a final version that was permanent. In fact, the three versions built in the United States were all hangars that became permanent. The chief difference in the selection of a mobilization hangar (Butler or Luria) rather than the buildout hangar (Strobel & Salzman) appears to be based on the extreme urgency of the first months of the air defense mission after the outbreak of the Korean War. The very first alert hangars, sited at installations of the highest initial priority, were Butler hangars—although the Butler hangar was also occasionally erected into the middle 1950s. The Luria alert hangar is particularly rare, and may be tied to the specific TAC fighter-bomber alert mission of the early 1950s.

Another challenge of the first ADC and TAC alert mission was the need to accommodate jet fighter aircraft, both in the steady lengthening of runways at the earliest installations sustaining the air defense mission and in the physical changes to the dimensions of the planes themselves. ADC and TAC are confirmed as having moved, or planned to move, the Butler and Luria alert hangars to a second site at an installation, after runway lengthening. The Strobel & Salzman hangar was never disassembled and moved. Design changes in the series of fighter jets also uniformly required front and rear door modifications for those alert hangars receiving next generation aircraft during the late 1950s. ADC supported a limited number of double-squadron alerts during the 1950s. In these instances, an eight-pocket hangar, with a proportionally larger alert apron, can be anticipated. Eight-pocket Butler hangars are very, very rare (with a verified case at the former Griffiss Air Force Base in New York), while eight-pocket Strobel & Salzman hangars are also unusual (with a highly intact example at McChord Air Force Base in Washington). Occasionally one will find a combination Butler-and-Strobel & Salzman eight-pocket hangar. Examples include hangars at New Castle, Delaware, and Madison, Wisconsin (the former Truax Air Force Base).

Key character-defining features include:

- a triangular concrete alert apron accommodating four to six fighter jets;
- a taxiway angled at 45 degrees from the end of the primary (longest) runway;
- steel structure, sheathed in steel paneling;
- rigid-frame construction [Butler];
- four- or eight-pocket configuration;
- centered alert crew quarters, bracketed by two or four aircraft pockets on each side, and characterized by a protruding all-glass flight operations booth;
- corrugated exterior steel paneling [Luria; Strobel & Salzman];
- standing-seam exterior steel paneling [Butler];
- multi-gable roof, with aircraft pockets individually gabled [overseas; Luria];
- multi-faceted gable roof, with aircraft pockets each having a double-pitched gable roof [Butler];
- flat roof [Strobel & Salzman];
- doorless aircraft pockets [overseas];
- front- and rear-opening aircraft pocket doors [Butler; Luria; Strobel & Salzman];
- counter-weight mechanisms for aircraft pocket doors [Butler: McKee manufacture; Luria: Luria manufacture];
- unbraced canopy aircraft pocket doors [Strobel & Salzman: Continental Steel manufacture];
- bolted and hinged construction [Butler];
- prefabricated components for moveable structure [overseas; Butler; Luria]; and,

- associated ancillary structures supporting the alert air defense mission, including a readiness crew dormitory; squadron operations; flight simulator; readiness/maintenance hangar(s); aircraft shelters; electronics shops and weapons calibrations shelters; and munitions checkout, assembly, and storage structures.

Historically, ADC and TAC often left each of the four alert hangars unpainted. Although it is rare to come across the hangar in this condition today, it is the condition most evocative of the structure's original, mobilization character. Examples where the hangar remains in its original, unpainted state include the Butler hangar at the former Richards-Gebaur Air Force Base in Kansas City, and the Strobel & Salzman hangars at the former Paine and former Walker Air Force Bases in Everett, Washington, and Roswell, New Mexico, respectively. As such, low-key, neutral paint schemes are those closest to the unpainted sheathing of the as-built hangar, while brightly colored schemes, especially when using contrasting door colors, are non-historic. Structures painted with the graphics of the fighter-interceptor squadron (FIS) assigned to the hangar, often found during the 1960s and later, are acceptable alterations to the original design. Resheathing of the alert hangars is possible in situations of extreme damage or deterioration. In such cases, it is advised that renovation and repair of eligible National Register hangars follow the original lines of the structures—particularly the roof lines.

ADC and TAC always erected air defense alert hangars at the end of the primary (longest) runway, on a simple triangular concrete alert apron at the end of a short taxiway angled at 45 degrees. In some cases, a hangar may be found today in the same configuration (angled taxiway and alert apron), but not at the terminus of the primary runway. This situation indicates that the historic runway was shorter, and, at the time of erection for the alert hangar, ended at that point. It is quite possible to find abandoned alert aprons and taxiway remnants at an installation where the Air Force lengthened the runway, and moved the alert hangar either to the new terminus on the same side of the runway; to the new terminus, but across the runway at the same end; or, to the opposite end of the runway, either side of its terminus.

The air defense alert program was large and widespread, with buildout for the hangars estimated at about 35 Strobel & Salzman first generation hangars; 20 Butler hangars; and a very small number of Luria and Butler overseas hangars (Table 1). These alert hangars can be found well beyond current Air Force installations—at former bases that now function as municipal and county airfields in particular. Degree of change to be anticipated varies significantly, with hangars sometimes pristine and sometimes highly altered, without correlation to active use or military ownership. It is more likely than not one will come across these hangars with very little alterations, however, and that one can expect a high degree of integrity in many instances. The most frequent alteration is the extension of the front and rear aircraft pocket doors: these changes are standard in type, and are a contributing feature to the hangars—rather than a loss of integrity—for the 1950s. When integrity has suffered, it is equally likely to be associated with modifications to the doors: newly cut vehicular and personnel doors detract from historicity (Plates 93-94).

ADC reduced the number of squadrons on alert steadily over the 1960s and 1970s. Often the alert mission shifted from ADC to the Air National Guard (ANG) and TAC during these decades as well. In cases where ANG has sustained an alert mission into the present, exterior modifications are still often few. Interior changes to the centered alert crew quarters are to be expected, unless the structure sits in complete abandonment from an early period. Potential National Register eligibility for air defense alert hangars, like potential eligibility for SAC alert crew quarters (moleholes) and their associated aprons, will often be installation-specific. Importance of the alert at a given base varied, as did the assigned aircraft, weapons systems, and length of sustainment. One way of determining the level of mission is to assess the accompanying support structures at the alert area on the flightline. The presence of munitions storage facilities and weapons calibration shelters, in particular, indicate levels of historic importance.

Table 1

Air Defense FIS Alert Hangars

	Northern Tier	East Coast	West Coast	Mid / South	Overseas	Total	Sited with AC&W / SAGE	Sited with SAC Alert
FIS Locations in 1952 with Hangars by 1954	16	8	6	6	N/A	36	15	14
October 1957	25	9	7	8	2	51	16	25
Double Squadrons 1957	7	4	1	1	0	13	6	8
Expansion Planned 1957	3	0	2	0	0	5	3	3
New FIS Location Planned 1957	4	2	1	0	10	17	0	3
Planned for Genie Storage 1957	22	8	4	4	0	38	13	23
December 1957	22	10	10	7	7 (Canada/ North)	56	13	27
Air Force Property August 1999	7	8	2	3	N/A	20	5	11

Plate 93. **Addition of four pockets (1954-1955) to Butler original hangar (1952). New Castle (Delaware) Air National Guard. Front view, March 1999. Photograph, K.J. Weitze.**

Plate 94. **Addition of four pockets (1954-1955) to Butler original hangar (1952). New Castle (Delaware) Air National Guard. Rear view, March 1999. Photograph, K.J. Weitze.**

Door modifications to the alert hangar indicate the presence of certain aircraft. Together, the number, combination, and buildout of supporting ancillary structures for the air defense alert strongly reinforce the setting, feeling, and association aspects of National Register integrity, as well as aid in documenting the particular air defense alert mission at an installation. Air defense alert facilities are significant primarily for their mission, not for their design or engineered structure.

First Generation (Modified) and Second Generation Alert Hangars

Character-defining features of the first generation alert hangar as modified for the F-101B are identical to those for the original first generation hangars, with the exception of changes made to the front- and rear-opening aircraft pocket doors. Door modifications for the overseas hangar are not researched (the original hangar had no doors), while those for the Luria hangar are assumed to be intact at Langley Air Force Base, Virginia—also, unanalyzed for this study. For the Butler hangar, Luria Engineering manufactured the replacement doors, while for the Strobel & Salzman hangar, International Steel handled the changeout.

ADC sponsored a second generation alert hangar simultaneously with its modification of the first generation hangars in place on flightlines. The command only built these hangars (1) where needed at a completely new Air Force installation after 1956-1957 [as at Minot Air Force Base in South Dakota]; (2) in cases where the air defense alert mission was added to a base to replace a similar mission at a nearby installation in closure during the late 1950s and early 1960s [as when Loring took on the mission from Presque Isle]; and (3) in instances where an early alert hangar had deteriorated while the air defense alert mission was inactive, and a hangar was required to support a revived mission (under ANG or TAC) [as at Davis-Monthan Air Force Base in Arizona]. The second generation hangar, also designed by Strobel & Salzman, was a larger structure than the original hangars of 1951, but visually very similar. It accommodated the longer F-101B without need to modify the aircraft pocket doors. (Although the Air Force did modify doors at selected installations subsequent to the hangar's erection—but never in a standardized program requiring new doors as had been the case for the first generation hangar). Character-defining features of the second generation ADC alert hangar are identical to those for the first generation, and first generation, modified, Strobel & Salzman hangars, with the addition of specific features associated with size, configuration, and aircraft pocket doors. When ADC built a two-pocket (instead of four-pocket) alert hangar, the centered crew quarters were only one story in height, rather than two stories.

Key character-defining features include:

- larger overall hangar size;
- individually longer, wider, and taller aircraft pockets, with pockets identical in dimension to those of Strobel & Salzman-designed aircraft shelters designed at this same time (see below);
- configuration as two- and four-pocket hangars (not as eight-pocket hangars);
- and, vertical ribbing, and sometimes lower small-truss, horizontal, bracing for front and rear aircraft pocket doors.

General issues of National Register integrity are the same as discussed above for the first generation alert hangar (Plates 95-96).

Plate 95. Strobel & Salzman. ADC alert hangar. Altered front doors. Travis Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 96. Strobel & Salzman. ADC alert hangar. Altered rear doors. Travis Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

TAC Hangars

Character-defining features of the TAC flightline hangars built during the 1960s and 1970s are focused on the rise of TAC as a fighter command during these decades, while ADC was in simultaneous decline. Air Force construction during this period was mature, highly standardized, and constrained by rising costs associated with the missile and space race. TAC flightline infrastructure of this period relied heavily, if not nearly entirely, on prefabricated structures, erected in varying patterns of multiples, while non-cantonment supporting structures were nondescript. Two steel prefabricated shelters, in particular, served as the mainstay of TAC hangars. One of these structures was a Butler rigid-frame building, while the other is of unresearched manufacture.

Key character-defining features include:

- steel structure, sheathed in corrugated steel paneling;
- rigid-frame construction [Butler];
- basic aircraft shelter unit 80 feet deep by 50 feet wide [Butler];
- moderately pitched gable roof [Butler];
- low-pitched gable roof, with unified horizontal façade [non-Butler structure];
- center-opening pocket doors;
- free-standing, or, joined as multiples [Butler and non-Butler];
- individual facades with horizontal emphasis, or, a single façade across multiple individual shelters [Butler and non-Butler];
- movable for relocation [Butler];
- and, parallel or perpendicular placement at the flightline in clusters of one, two, three, four, and five shelters.

The later-era TAC fighter infrastructure at the flightline is not related to air defense of the continental United States, but rather supports the general growth of the command and its needed presence for fighter deployment overseas in conflicts like those in Southeast Asia and the Middle East. Generally, the hangars have sustained minimal modifications, due to their continuous use. Basic shelter designs date to 1958-1961, but erection of these shelters as TAC hangars is steady through the 1970s.

In most cases, it is unlikely that these shelters will be evaluated as potentially eligible for the National Register. Exceptions may exist where noteworthy concentrations of the hangars are present—such that the overall TAC flightline landscape presents itself as a unified whole through the patterned clusters either parallel or perpendicular to the runway, and clearly evokes a strong picture of the fast rise of this fighter command and the Air Force-wide reliance on prefabricated, standard modular units for new construction during the middle decades of the Cold War.

Support Structures for Alert

Dependent to the alert hangar and sited near it, the typical grouping of support structures found at the flightline for air defense alert is large. These support structures contribute strongly to our ability to see the past—and to sense the urgency of this 1950s mission. A typical cluster of ancillary structures includes a readiness crew dormitory; a squadron operations building (often combined in a single building with the dormitory); a flight simulator; one or two readiness/maintenance hangars; clusters of two, three, and four aircraft shelters, erected in parallel rows; an electronics shop; a weapons calibration shelter; and three generations of weapons checkout, assembly, and storage structures. Not all of these buildings are likely to be found at any given installation—although in cases of extended, high-priority air defense missions, most will be present. Some of these structures change little over the decade of the 1950s (dormitories); others go through distinct multiple generations (readiness/maintenance hangars and munitions storage). Still others within the alert group are aircraft, weapons-system, and time-period specific: when present, these structures indicate a precise date of construction and associated air defense mission. Most often the support structures are together at the flightline, although in cases where ADC has moved a Butler alert hangar to accommodate an extended runway, split clusters can exist—or double clusters—although each group will be evocative of a particular frame of years within the 1950s.

Key character-defining features include:

- simple 1950s design detailing, including flat, or nearly flat roofs, with minimal overhangs, wall treatments, and fenestration [dormitories; flight simulators; squadron operations];
- windowless, modest size [flight simulators of the early part of the decade; first generation weapons checkout and storage];
- windowless, larger size, multi-bay unit construction [second and third generation weapons checkout, assembly and storage];
- reinforced concrete or concrete-block structure [dormitories; squadron operations; flight simulators; electronics shops; all generations weapons checkout and storage];
- steel-frame (very rarely, wood-frame for first generation) construction [readiness/maintenance hangars];
- moderately pitched gable roof, with interior truss system (very rarely, bowed wood truss for first generation) [three generations of readiness/maintenance hangar];
- center-opening, recessing pocket doors [readiness/maintenance hangars];
- attached side and rear shops [first and second generation readiness/maintenance hangars];
- attached side shops only [third generation readiness/maintenance hangars];
- pull-thru [third generation readiness/maintenance hangar; aircraft shelters];
- flat roofed [aircraft shelters];
- steel rigid-frame [weapons calibration shelters];
- modular [weapons calibration shelters];
- prefabricated [weapons calibration shelters];
- earthen bermed [third generation weapons checkout and storage];
- isolated, secure siting, with manned checkpoint entry [third generation weapons checkout and storage];
- and, grouping at the flightline near the alert hangar [all structures except the third generation weapons checkout and storage].

The air defense alert program represented a very sizable web of infrastructure across the United States. In all cases, the support structures were hierarchically dependent upon the presence of an alert hangar—with most hangars being either the Butler or Strobel & Salzman types. Supporting infrastructure did not vary by type of alert hangar. As a landscape, that associated with the alert mission (inclusive of the alert hangar) has much to tell about tactical air defense planning and its evolution during the decade of the 1950s: what was valued the most; when the perceptions and tactical planning changed; where defensive weapons were nuclear and where they were traditional; what installations hosted both ADC/TAC and SAC alerts; and, where alert was brief and where it was sustained. Nonetheless, very few clusters of supporting structures will be evaluated as eligible for the National Register—and none without the intact presence of the primary alert hangar. Air defense alert areas will be significant where they offer a cohesive district (in Register terms), and where they are individually little altered, with the setting largely intact. Intrusions by later-era, unrelated buildings; removal of the alert apron; substantial change in viewshed between structures; and makeovers to the exteriors of any of the individual structures will affect the character of the grouping—which was relatively spare and isolated (as a secured area) during its period of Cold War importance.

First Generation Command and Control

Character-defining features of the ADC first generation command and control centers are focused on the structures' very early engineered design for nuclear, chemical, and biological protection; and on the structures' interior programmatic plan for receiving and evaluating the multi-sourced communications links necessary for directing military defense under conditions of sustained attack. These structures are very rare today. At buildout only 16 existed nationwide, with a secondary supportive web at 85 Aircraft Control & Warning (AC&W) radar sites. The ADC first generation command and control centers were among the very earliest Air Force structures designed for Cold War combat. Designed and engineered by the Chicago firm Holabird, Root & Burgee, the command and control centers date to 1949—and are the only ADC infrastructure of the Cold War before 1951. (SAC's parallel initial Cold War infrastructure is that of the thin-shell, concrete maintenance hangar for the B-36, designed and engineered in mid-1947 by Viennese engineer Anton Tedesko of Roberts & Schaefer.) And although the ADC first generation command and control centers date to 1949, the Air Force delayed their construction until after the outbreak of the Korean War in mid-1950, sustaining a much greater support for SAC than for ADC during the late 1940s. These command and control structures included two primary buildings, known as type 3 and type 4 stations during the 1950s; a power station; and, typically, several radomes. ADC built them at major Air Force installations and at small, but critically located, Air Force stations sited at municipal airfields. The secondary network supporting the 16 command posts were known as type 2 stations during the 1950s, and were always collocated with AC&W radar compounds.

Key character-defining features for the main command and control building (type 4 station) include:

- reinforced concrete column-and-beam structure, with oversized columns and thick beams;
- flat, reinforced concrete roof (thick);
- double concrete-block exterior walls, with intervening air space;
- four-inch thick interior concrete-block walls;
- heavily protected communications cable trenches;
- exterior pilasters (reinforcing strengthening);
- windowless;
- outer- and inner-lock rooms;
- air baffles and chemical filter banks;
- pressurized interior air system (air conditioning);
- ventilation shaft (tower);
- clean- and contaminated-clothes areas (sequential dressing areas), with disinfector;
- decontamination showers;
- gas-proof clothes chutes;
- communications, code equipment, and message rooms;
- two-story, open central operations room with balcony glassed-in observation cubicles;
- war room;
- and, associated administrative building (type 3 station), power plant, and radomes.

Type 2 stations at the AC&W radar sites were very similar to type 4 stations, but were one story structures.

ADC first generation command and control centers only rarely survive today without heavy alterations. The second generation command and control system, the Semi-Automatic Ground Environment (SAGE) replaced this very early system, and was the centerpiece of command and control for ADC during the 1960s—a situation that accelerated the obscurity of the first system and quickly made it forgotten. The prototypical nature of the ADC first generation command and control centers for the design and engineering of SAGE direction and combat centers is extremely important, as is the actual engineering for protection from nuclear overblast pressures and contamination, as understood in 1949. A select number of the 16 first generation command and control centers were co-sited with SAGE after 1957, and this situation enhances the significance of both first and second generation configurations. The correlation between siting for the ADC first generation command and control and that for the Butler fighter-interceptor alert hangar is also of note. The ADC first and second generation command and control centers, both those associated with AC&W and SAGE, were sometimes additionally sited at installations with SAC alerts—making those installations especially attractive Cold War targets (Table 2).

Table 2

Air Defense Command First Generation Command and Control

	Northern Tier	**East Coast**	**West Coast**	**Mid/South**	**Total**
Locations	7	2	3	4	16
Sited With SAGE	5	0	★1	1	7
Butler Alert Hangar Present	4-5	1	2	2	9-10
FIS Alert 1959	7	1	3	2	13
Collocated With SAC Alert	4	1	★1	0	6
Air Force Property August 1999	1	2	★1	2	6

★ Location could also be interpreted as Northern Tier

Plate 97. Holabird, Root & Burgee. ADC first generation command/control, type 4 station. McChord Air Force Base. Altered. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 98. Holabird, Root & Burgee. ADC first generation command/control, types 3 and 4 stations. Andrews Air Force Base. Altered. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 99. Holabird, Root & Burgee. ADC first generation command/control at the former Truax Air Force Base. Altered. View of July 1999. Photograph, K.J. Weitze.

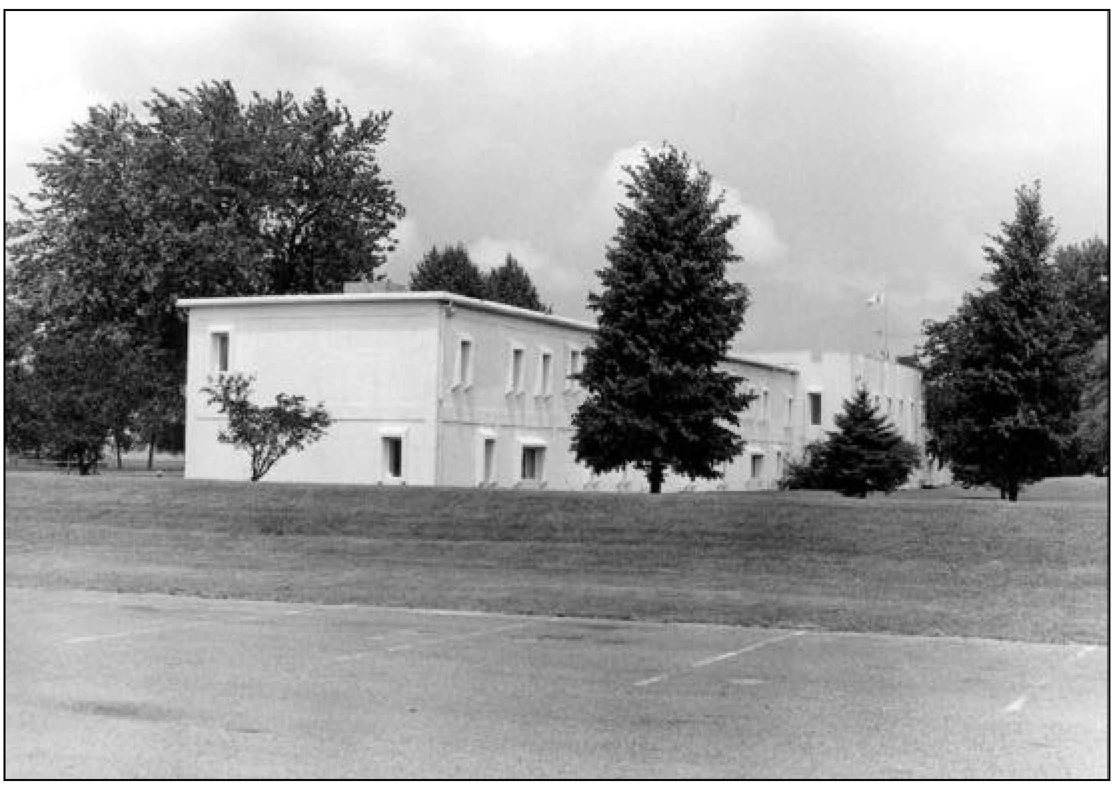


Plate 100. Holabird, Root & Burgee. ADC first generation command/control at the former Truax Air Force Base. Altered. View of July 1999. Photograph, K.J. Weitze.

Plate 101. Holabird, Root & Burgee. Type 4 station at the former Truax Air Force Base. Altered. Pilaster detailing remains. View of July 1999. Photograph, K.J. Weitze.

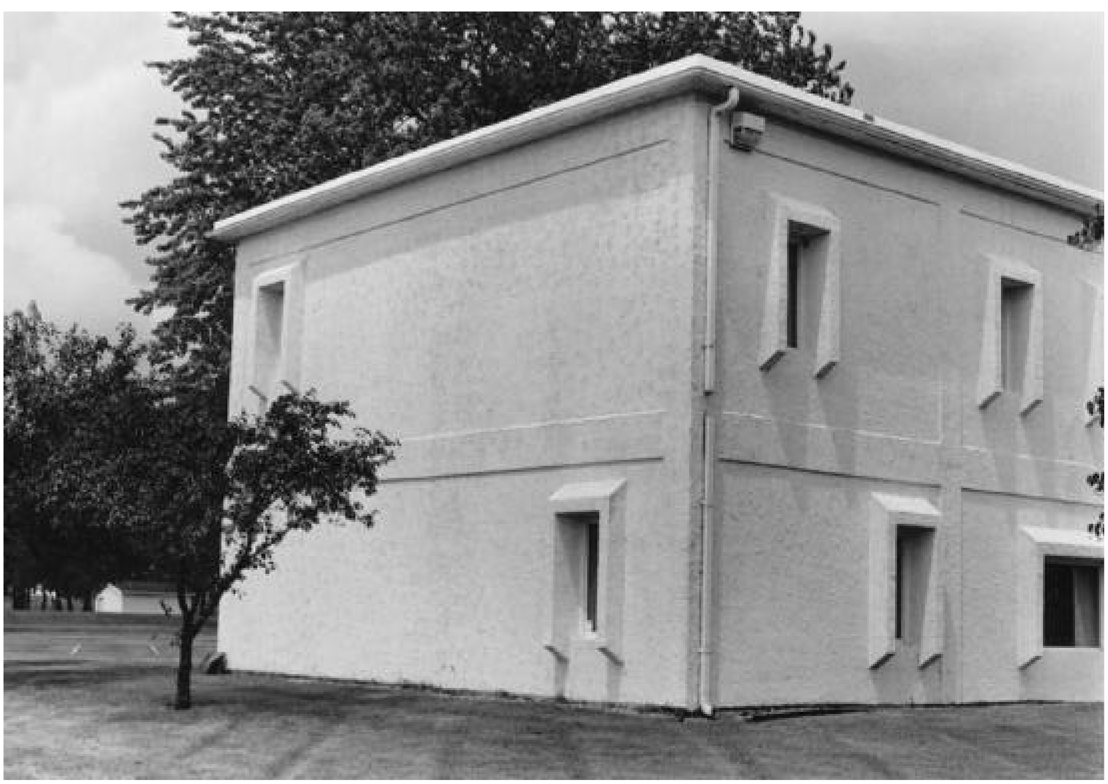


Plate 102. Holabird, Root & Burgee. Type 3 station at the former Truax Air Force Base. Altered. Pilaster detailing remains. View of July 1999. Photograph, K.J. Weitze

ADC first generation command and control centers are austere structures when viewed from outside, and can be anticipated to be highly altered on their interiors. That at the former Richards-Gebaur Air Force Base in Kansas City is very, very rare—perhaps unique—in its pristine integrity, and offers an unusual opportunity to interpret both generations of ADC command and control at a single location, due to the adjacent siting of a SAGE direction center. More typical are the ADC first generation command and control centers at McChord, Andrews, and the former Truax Air Force Bases in Washington, Maryland, and Wisconsin. At McChord, the first command and control center erected by ADC, one can still interpret the underlying type 4 station, but National Register integrity is nonetheless completely lost (Plate 97). At Andrews the three extant structures from the compound—the types 3 and 4 buildings and the power plant—are all but unrecognizable (but are indeed present) (Plate 98). At Truax the most physically complete set of structures remains, yet only as encased by a single-building renovation incorporating the types 3 and 4 buildings, and two radome bases (Plates 99-102). Here too a SAGE complex is a neighboring compound, one of only three combination direction and combat centers, with connected power station. While the grouping at Truax offers an opportunity to study the air defense configuration of a large two-generation cluster of command and control structures, it sustains no integrity in terms of the National Register. Perhaps of further interest, no remnants of the ADC first generation command and control structures exist at former Hamilton (north of San Francisco), George (east of San Bernardino, Southern California), Kirtland (Albuquerque), and Duluth (at the Canadian border in Minnesota) Air Force Bases, locations verified as supporting this infrastructure either directly or at a regional AC&W radar station.

All evaluations and management of the ADC first generation command and control centers, then, should be executed very carefully, with the likelihood of National Register eligibility where integrity is sustained.

Second Generation Command and Control: SAGE

Designed and engineered through the partnered efforts of Western Electric and Burns & Roe, the SAGE program was the premier Cold War air defense effort sponsored by ADC, and like all such efforts undertaken by both ADC and SAC was firmly tied to communications planning during the period's first years. A command and control system that bridged the manual world of the telephone and teletype to the later 20th century world of the increasingly sophisticated computer, SAGE really began with the efforts of scientists, mathematicians, and physicists—concentrated at MIT and within the Army and Navy laboratories of World War II. While historians have written a great deal on the development of the computer and radar equipment that made SAGE communications (and hence Air Force command and control) possible, little has been done to assess the buildings in which the program operated. Perhaps most importantly, almost all ties between SAGE and the ADC first generation command and control types 2, 3, and 4 stations have been lost. Both in terms of programmatic layout (what military and communications functions were where), and in terms of engineering an aboveground structure sufficiently hardened to survive nuclear war conditions of the 1950s, the links between the ADC first and second generation command and control networks are very important. Both systems were webs, spread out across the United States. For the first, 16 command centers defined the system; for the second, 23. Much more research and analysis needs to be undertaken for SAGE construction—and especially for its continuous evolution from similar construction for federal communications structures (telephone and television) first seriously begun in the middle 1930s after the passage of legislation by the Federal Communications Commission. SAGE, and its ADC first generation precursor, is also strongly tied to similar telephone and computer communications centers built by the Army, not surprisingly first built at the outset of the 1950s.

Key character-defining features include:

- reinforced concrete column-and-beam structure, with oversized columns (two times the size of those in the first generation types 2 and 4 stations);
- flat, reinforced concrete roof (thick);
- probable specially mixed concrete, inclusive of additives such as iron punchings, colemanite, or boron salts;
- exterior reinforced concrete walls, 10 inches to one foot in thickness;
- exterior walls designed and engineered as eight-foot square panels, with heavy alternating vertical and horizontal reinforcing steel bars;
- knock-out panels;
- exterior full-height steel reinforcing, configured as pilasters;
- windowless;
- configuration as a massive block, with square footprint;
- three- (direction center), four- (combat center), and one-story (power plant with mezzanine) height;
- inclusion of an independent power plant on site, without exception;
- pressurized interior air system;
- communications, code equipment, and message rooms;
- two-story, open central operations room with balcony, glassed-in, observation cubicles;
- war room;
- and, in selected instances (but uniformly planned) siting adjacent to the ADC first generation command and control types 3 and 4 stations (the latter typically with a small power plant and radomes).

SAGE compounds usually survive today. Their massive construction and large size make the direction and combat centers, and power plants, unlikely candidates for demolition. Like the ADC first generation command and control centers that preceded them, SAGE centers are found not only on Air Force bases, but also as key elements of small Air Force stations historically affiliated with municipal airports—and in a few cases as Air Force stations collocated with Army and Navy installations. A number of SAGE centers are no longer Air Force property, resultant from both excessing and closure beginning as early as the 1960s. SAGE itself began to go offline almost as soon as the system was fully finished, due to the implications of ICBM warfare (Table 3). (SAGE was a system focused on early warning against Soviet bombers, and tactical direction of fighters and weapons systems in response to those bombers.) By the middle 1960s, the ADC third generation command and control, BUIC, was also coming on line.

Table 3

Air Defense Command Second and Third Generation Command and Control

	SAGE Under Construction / Built	BUIC I/II/III	DEW Radars	Gap Fillers	Long-Range Radars, U.S., including AC&W	Long-Range Radars, Canada
1955	3/0	N/A	N/A	N/A	N/A	N/A
1956	7/0	N/A	N/A	N/A	106	35
1957	12/0	N/A	58	44	115	35
1958	12 completed 1 operational	N/A	58	75	135	32
1959	5 operational	N/A	64	114	157	32
1960	13 operational	N/A	64	90	153	34
1961	19 operational	N/A	68	95	147	31
1962	20 operational (23 at buildout)	N/A	68	95	152	31
1963	16	27 (I)	40	86	144	34
1964	15	Transition I/II	40	92	147	35
1965	15	Transition I/II	40	89	142	35
1966	13	14 (II)	40	86	137	35
1967	13	12 (II)	40	68	137	33
1968	11	12 (III)	40	17	125	30
1969	10	12 (III)	33	16	93	30
1970	6	12 (III)	33	0	79	30
1971	6	12 (III)	31	0	71	28
1974	6	1 (III)	31	0	80	25
1981	6	1 (III)	31	0	42	24

Plate 103. Burns & Roe. SAGE combat center at the former Truax Air Force Base. Windows added in place of knockout panels. View of July 1999. Photograph, K.J. Weitze.

Plate 104. Burns & Roe. SAGE combat (left) and direction (right) centers. Altered. McChord Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 105. Burns & Roe. SAGE direction center at the former Duluth Air Force Base. Altered. View of July 1999. Photograph, K.J. Weitze.

Plate 106. Burns & Roe. SAGE direction center. Minor alterations only. Grand Forks Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Typically, SAGE direction and combat centers today are substantially altered. Knockout panels have been converted to irregularly placed windows on the side façade (Plate 103); additions and decorative exterior renovation attempt to make the block buildings less severe for adaptation to the private sector or to later-era Air Force use (Plates 104-106). Sometimes, SAGE buildings can be found in a near-historic condition, but these cases are rare. A particularly good example is the SAGE direction center at the former Larson Air Force Base in eastern Washington, now Moses Lake Airport. Larson was a key early base for both ADC and SAC, but it was also an installation closed early—in the 1960s.

Evaluations of National Register integrity for SAGE direction and combat centers should focus on the exterior features as built. The centers are significant for a relatively brief period of time, typically for their design and engineering during 1955-1957, their construction 1957-1961, and their useful life as a program through the 1960s. (Although six of the SAGE centers remained active from 1970 through 1984.) Interior integrity can be anticipated as lost for SAGE centers.

Third Generation Command and Control: BUIC and Post-BUIC

The final ADC command and control system was that of BUIC, begun in the early 1960s and on line by mid-decade. By this period, computers were much more sophisticated, faster, and smaller. Tactical concerns had shifted with the advent of ICBM warfare: the United States lost the advantage of geographic isolation and anticipated nuclear war on its own soil. Active discussion focused first on a final web of ADC command and control centers below ground, but that idea proved far too costly and time consuming. Instead, ADC decided to convert the type 2 stations at the radar sites of its first generation command and control for contemporary computers, further hardening the buildings—particularly against radiation. Buildout for BUIC I, II, and III varied between about 30 and 14 for the different phases of the program, and operated in tandem with those SAGE direction and combat centers sustained on line.

Key character-defining features include:

- most features of the original type 2 stations (see above);
- addition of two-foot thick, reinforced concrete "fallout protection" walls encasing the station;
- an air space of between four and six feet between the fallout protection walls and the original outer concrete-block walls of the type 2 stations;
- removal of the inner concrete-block walls of the type 2 stations;
- addition of a continuous metal radiation shield in place of the original inner walls;
- raising of the floor in the operations room by about 18-20 inches, with placement of a continuous metal radiation shield over the original concrete slab with a covering layer of two inches of poured concrete;
- and, for the BUIC III system, a reinforced concrete, three-room addition to the encased type 2 station of BUIC II, approximately doubling the square footage of the renovated structure.

Assessment of potential National Register significance and integrity is not undertaken here. Architectural historians and Air Force real property managers have largely overlooked the BUIC program, with most excessed AC&W radar stations evaluated solely as associated with their initial construction and use *for radar*, 1949 forward. The type 2 station is a single structure within a grouping of 50-70 buildings at the AC&W stations, and as such has typically been missed in historic evaluations—both in its role within the ADC first generation command and control web, and in those cases where ADC adapted the structure for BUIC II and III during the 1962-1969 years.

Chapter 4: Real Property Management of Historic ADC and TAC Infrastructure

Following are one-page summaries, installation by installation, for adaptation to current Air Combat Command (ACC) real property management. The summaries are brief, and are intended to correlate information present in the baseline inventories of 1995-1997 prepared by Mariah Associates, Inc., with the context for ADC and TAC fighter and command/control infrastructure presented in chapter 2, and with the overview of character-defining features and National Register integrity presented in chapter 3. In a number of instances, information in the baseline studies is partial, with included photographs also not comprehensive. Nonetheless, the Mariah volumes do offer sufficient information to provide the guidelines given herein. In most cases, cultural resource managers at the installations should be able to fill in missing information for specific structures predicted to be present, and to complete (or revise) assessments of Register integrity. Fieldwork for the baseline inventories occurred four to five years ago, generally, and may need to be revisited by Air Force cultural resource managers for updating an assessment of integrity.

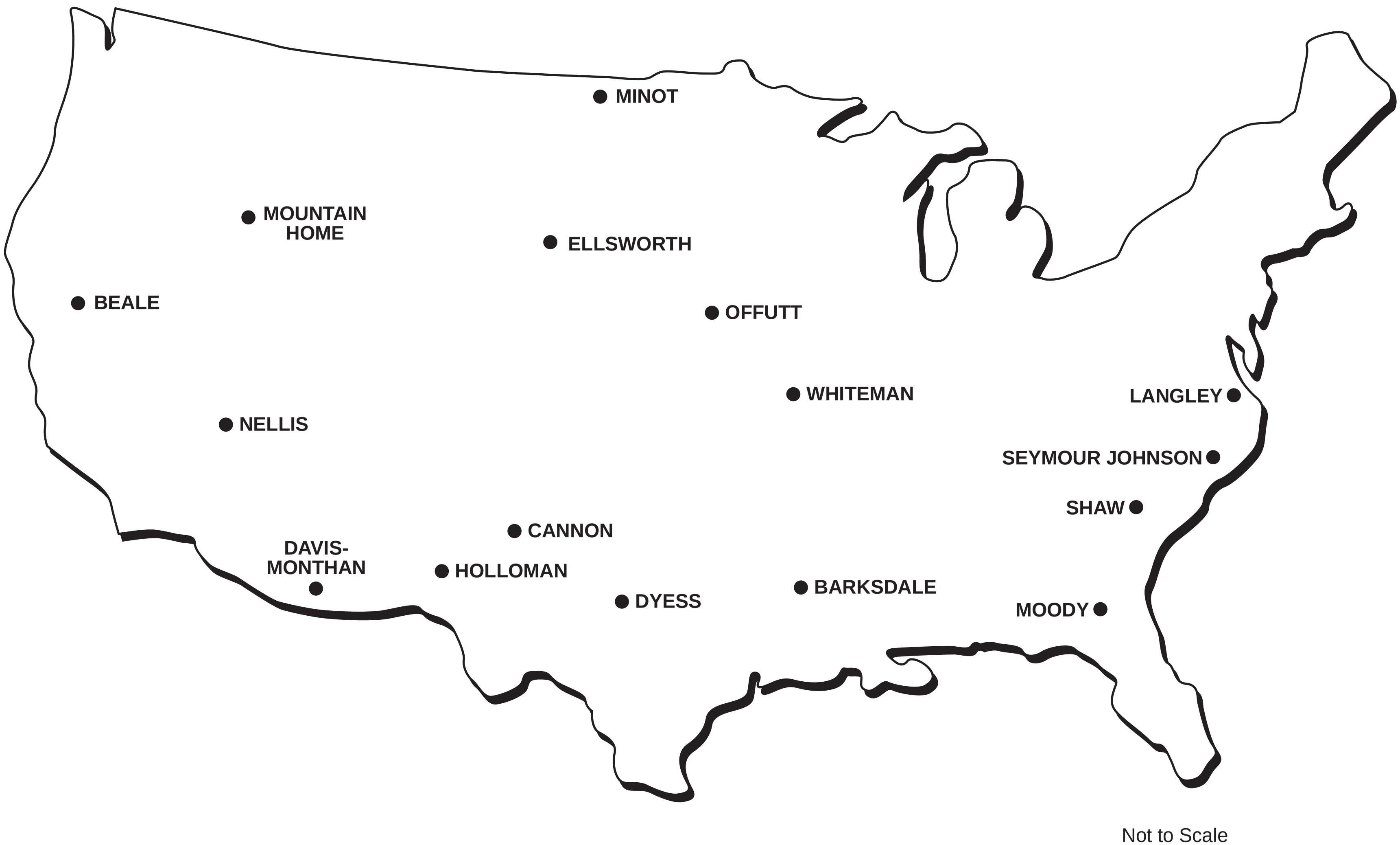
Addressed here are the installations under jurisdiction of ACC as of mid-1999 (Map 2). Those bases closed or transferred to other Air Force commands since the Mariah inventories took place are not included in the real property summaries. Most of these installations do have comparable historic infrastructure. Air Force real property managers for Air Mobility Command (AMC), Air Force Reserve Command (AFRC), and Air Education and Training Command (AETC), may wish to review the information offered here—as well as that in chapters 2 and 3—for pertinence to installations under their jurisdiction.

Current Continental United States (CONUS) ACC installations are those of Barksdale (Louisiana), Beale (California), Cannon (New Mexico), Davis-Monthan (Arizona), Dyess (Texas), Ellsworth (South Dakota), Holloman (New Mexico), Langley (Virginia), Minot (North Dakota), Moody (Georgia), Mountain Home (Idaho), Nellis (Nevada), Offutt (Nebraska), Seymour Johnson (North Carolina), Shaw (South Carolina), and Whiteman (Missouri).

Installations included in the baseline Mariah study, but not included in the summaries that follow, are Castle (California: closed); Fairchild (Washington: ACC to AMC); Griffiss (New York: closed, with a portion to AFRC); Homestead (Florida: closed, with a portion to AFRC); Howard (Panama: transferring to the Government of Panama at the end of 1999); K.I. Sawyer (Michigan: closed); Little Rock (Arkansas: ACC to AETC); Loring (Maine: closed); MacDill (Florida: ACC to AMC); McConnell (Kansas: ACC to AMC); and Pope (North Carolina: ACC to AMC).

Information for each installation focuses on historic names; aircraft; missions; infrastructure; integrity; potential NRHP eligibility; and issues of note. Historic names for a base can be confusing for researchers—so are provided here. Aircraft tell us what infrastructure an installation was *likely* to have had: *when* the aircraft were received reflects the priority of the mission within ADC and TAC. (Are the assigned fighters ones that are being phased out? New inventory?) The remaining five items address real property management directly, and are self-explanatory. Summaries analyze only infrastructure associated with the historic ADC and TAC air defense mission of the Cold War, as discussed in chapters 2 and 3. For TAC it should be noted that generic maintenance hangars and flight simulators, in particular, are almost always present for the early Cold War—for those decades before the command took on the air defense mission in a substantive way. Often TAC reused existing World War II hangars and planned to adapt structures more specifically designed for SAC or ADC. These sometimes went unbuilt.

Many of the current ACC installations also host parallel historic SAC infrastructure associated with the bomber mission. Air Force real property managers are encouraged to cross reference information presented in this chapter with that offered in chapter 4 of the companion volume, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission.*



Map 2. **CONUS Air Combat Command Installations Current as of August 1999.**

Barksdale Air Force Base
Vicinity of Bossier City, and, Shreveport, Louisiana

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Barksdale Air Force Base*, volume II-1 of *A Systemic Study of Air Combat Command Cold War Material Culture* (July 1997)

Historic Names:	Barksdale Field (1933-1947) Barksdale Air Force Base (1948 to present)
Cold War Fighter Aircraft:	None
Missions:	No Cold War fighter missions
Infrastructure:	No ADC or TAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

Beale Air Force Base
Vicinity of Wheatland, Marysville, and Yuba City, California

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Beale Air Force Base*, volume II-2 of *A Systemic Study of Air Combat Command Cold War Material Culture* (October 1997).

Historic Names:	Camp Beale (1942-1947) Beale Air Force Range (1948-1951) Beale Air Force Base (1951 to present)
Cold War Fighter Aircraft:	None
Missions:	No Cold War fighter missions
Infrastructure:	No ADC or TAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

Cannon Air Force Base
Vicinity of Clovis, New Mexico

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Cannon Air Force Base*, volume II-3 of *A Systemic Study of Air Combat Command Cold War Material Culture* (June 1997).

Historic Names:	Portair Field (1920s) Clovis Municipal Airport (1930s) Clovis Army Air Field (1942-1947) Clovis Air Force Base (1947) [Deactivated 1947-1950] Clovis Air Force Base (1950-1957) Cannon Air Force Base (1957 to present)
Cold War Fighter Aircraft:	P-51 (1951-1953) F-86 (received 1953) F-100 (received 1957) F-111 (received 1969)
Missions:	Proficiency in Fighter-Bomber Operations Training with Conventional and Nuclear Weapons Global Deployment
Infrastructure:	TAC Prefabricated Hangars [non rigid-frame / multiples] Butler Enclosed Shelters [rigid-frame / singles]
Integrity:	TAC Prefabricated Hangars: intact Butler Enclosed Shelters: intact
Potential NRHP Eligibility:	TAC Prefabricated Hangars: unlikely (generic) Butler Enclosed Shelters: unlikely (generic)
Other:	TAC presence at Cannon is not tied to an air defense mission. The command was able to reuse two existing World War II hangars for maintenance. Like other TAC installations, Cannon planned for new maintenance hangars of the 3rd generation Kuljian type in 1957: these were not built.

Davis-Monthan Air Force Base
Vicinity of Tucson, Arizona

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Davis-Monthan Air Force Base*, volume II-5 of *A Systemic Study of Air Combat Command Cold War Material Culture* (July 1997).

Historic Names:	Davis-Monthan Field (1927-1940) Tucson Air Base (1941) Davis-Monthan Field (1941-1947) Davis-Monthan Air Force Base (1948 to present)
Cold War Fighter Aircraft:	F-86A (1953) / F-86D (1954-1959) F-101B (1960-1964) F-4C (1964-1971) A-7D (1971-1976) A-10A (1976 to present) F-16 (1973 to present)
Missions:	ADC Alert (1953-1964) TAC Fighter-Bomber Training (1964 to present) ADC/ANG Alert (1973 to present)
Infrastructure:	1st Generation Alert Hangar (Butler) 2nd Generation Alert Hangar Alert Support Structures (readiness crew dormitory; readiness/maintenance hangar [1]; flight simulator; 1st generation weapons storage; 2nd generation weapons storage; 3rd generation Genie storage; weapons calibration shelter; electronics shop type B) TAC Prefabricated Hangars [non rigid-frame / multiples]
Integrity:	1st Generation Alert Hangar (Butler): removed 2nd Generation Alert Hangar: intact Alert Support Structures: unassessed TAC Prefabricated Hangars: intact
Potential NRHP Eligibility:	1st Generation Alert Hangar (Butler): none 2nd Generation Alert Hangar: possible Alert Support Structures: unassessed TAC Prefabricated Hangars: unlikely (generic)
Other:	Davis-Monthan supported a Butler hangar, including modifications for the F-101B. (Photograph, base directory, 1964.) The current supply and equipment warehouse (Building No. 1246) may be the remains of this hangar, reconstructed down the flightline, with the Butler rigid-frame reconfigured. Also, alert support structures are particularly complete, as a group, and should be assessed with the 2nd generation alert hangar as a possible NRHP district.

Dyess Air Force Base
Vicinity of Abilene, Texas

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Dyess Air Force Base*, volume II-6 of *A Systemic Study of Air Combat Command Cold War Material Culture* (June 1997).

Historic Names:	Tye Army Air Field (1942) Abilene Army Air Field (1943-1947) [Deactivated 1947-1952] Abilene Air Force Base (1953-1955) Dyess Air Force Base (1956 to present)
Cold War Fighter Aircraft:	None
Missions:	No Cold War fighter missions
Infrastructure:	No ADC or TAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

Ellsworth Air Force Base
Vicinity of Rapid City, South Dakota

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Ellsworth Air Force Base*, volume II-7 of *A Systemic Study of Air Combat Command Cold War Material Culture* (August 1997).

Historic Names:	Rapid City Army Air Base (1942-1946) [Deactivated 1946-1947] Rapid City Air Force Base (1947) Weaver Air Force Base (1948) Rapid City Air Force Base (1948-1953) Ellsworth Air Force Base (1953 to present)
Cold War Fighter Aircraft:	F-86 (?) F-89J
Missions:	ADC Alert (from 1951 to at least 1960)
Infrastructure:	1st Generation Alert Hangar (Butler) Alert Support Structures (readiness crew dormitory; readiness/maintenance hangar [2]; flight simulator; 2nd generation weapons storage; 3rd generation Genie storage)
Integrity:	1st Generation Alert Hangar (Butler): lost Alert Support Structures: unassessed
Potential NRHP Eligibility:	1st Generation Alert Hangar: moved off flightline as museum Alert Support Structures: primary hangar removed; several structures heavily altered
Other:	The history and inventory for the alert complex at Ellsworth is particularly confused in the baseline study. The hangar is no longer at the flightline; the grouping incorporates pre-existing structures; and, several of the support structures built in the 1950s are adapted for later uses. For example, the Air Force renovated the readiness crew dormitory (Building No. 606) in 1965 as the alert quarters for PACCS, also remodeling two support structures, Building Nos. 608 and 609. The alert grouping at Ellsworth was one of the first in the country: its readiness/maintenance hangars were reused World War II hangars already on site (Building Nos. 601 / 605: 1942).

Holloman Air Force Base
Vicinity of Alamogordo, New Mexico

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Holloman Air Force Base*, volume II-10 of *A Systemic Study of Air Combat Command Cold War Material Culture* (October 1997).

Historic Names:	Alamogordo Bombing and Gunnery Range (1941) Alamogordo Army Air Field (1941-1946) [Deactivated 1946, briefly] Alamogordo Army Air Field (1946) Alamogordo Air Force Base (1947-1948) Holloman Air Force Base (1948 to present)
Cold War Fighter Aircraft:	F-4 (received 1968) A-10 (?) F-117
Missions:	TAC Fighter Training TAC Rapid Mobilization and Global Deployment TAC Alert
Infrastructure:	TAC Alert Hangar TAC Prefabricated Hangars (non rigid-frame / multiples)
Integrity:	TAC Alert Hangar: unassessed TAC Prefabricated Hangars: intact
Potential NRHP Eligibility:	TAC Alert Hangar: needs more information - possible TAC Prefabricated Hangars: unlikely (generic)
Other:	Information and photographs for the TAC alert hangar are inconclusive. The arrangement—as a three-pocket hangar—is unusual, as is its date of erection, ca.1976. TAC alert, as distinct from ADC or ANG alert, is also unresearched with regards to its use of infrastructure. Possible support structures (or lack of) remain unaddressed. In addition, hangars typically used as ADC readiness/maintenance, 2nd and 3rd generations (Strobel & Salzman and Kuljian), are present at Holloman [Building Nos. 500 and 1080] in generic use.

Langley Air Force Base
Vicinity of Hampton, Virginia

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Langley Air Force Base*, volume II-14 of *A Systemic Study of Air Combat Command Cold War Material Culture* (August 1997).

Historic Names:	Langley Field (1915-1947) Langley Air Force Base (1948 to present)
Cold War Fighter Aircraft:	FP-80 (received 1946) A-26 (received 1946) F-86 (received 1949) F-84 (1951-1954) F-94 (1954-1957) F-102 (1957-1960) F-100 (late 1950s) F-106 (1960-1981) F-15 (received 1981)
*Missions:	TAC Reconnaissance ADC / TAC Alert
Infrastructure:	Alert Hangar (Luria) Alert Support Structures (readiness crew dormitory; readiness/maintenance hangar [1]; flight simulator; 1st and 2nd generation weapons storage)
Integrity:	Alert Hangar (Luria): intact Alert Support Structures: unassessed
Potential NRHP Eligibility:	Alert Hangar (Luria): strong Alert Support Structures: unassessed
Other:	The Luria alert hangar may be one of a kind, and at the least is very, very rare. Air Force intent was to either move, or replace, the hangar in 1957-1958—siting the alert across the runway at its extended terminus. The move did not occur, and as a result the original siting is intact. The hangar remained in active air defense use from the early 1950s through 1994, an unusually long and continuous mission, and especially noteworthy given its sustained original location (indicative of a short, 6500-foot early 1950s runway). In addition, the support structures are sited across the runway, and as such are an excellent example of this type of split location from the alert hangar itself. Support structures are not inventoried.

* TAC fighter-bomber missions, with their use of the more typically SAC double-cantilever hangar and fuel systems maintenance docks, are addressed in the companion volume of this study, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission.*

Minot Air Force Base
Vicinity of Minot, North Dakota

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Minot Air Force Base*, volume II-19 of *A Systemic Study of Air Combat Command Cold War Material Culture* (August 1997).

Historic Names:	Minot Air Force Base (1957 to date)
Cold War Fighter Aircraft:	F-106 (1960-ca.1985) F-15 (ca.1985-1988)
Missions:	ADC (1960-1979) / TAC (1979-1988) Alert
Infrastructure:	2nd Generation Alert Hangar Alert Support Structures (readiness crew dormitory; squadron operations; flight simulator; readiness/ maintenance hangar [2]; aircraft shelters [4]; 3rd generation MB-1 Genie storage; weapons calibration shelter; electronics shop type B) SAGE Direction Center
Integrity:	2nd Generation Alert Hangar: minor door alterations Alert Support Structures: mixed SAGE Direction Center: lost
Potential NRHP Eligibility:	2nd Generation Alert Hangar: unlikely Alert Support Structures: none
Other:	No issues.

Moody Air Force Base
Vicinity of Valdosta, Georgia

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Moody Air Force Base*, volume II-20 of *A Systemic Study of Air Combat Command Cold War Material Culture* (July 1997).

Historic Names:	Moody Field (1941-1946) [Deactivated 1946-1951] Moody Air Force Base (1951 to present)
Cold War Fighter Aircraft:	F-89 (1951-1956) F-94 (1951-1956) F-86 (received 1957) F-4 (ca.1975-1987) F-16 (received 1987)
Missions:	Interceptor Pilot and Crew Training Training for Tactical Readiness
Infrastructure:	TAC Prefabricated Hangars [non rigid-frame / multiples]
Integrity:	TAC Prefabricated Hangars: unassessed
Potential NRHP Eligibility:	TAC Prefabricated Hangars: unlikely (generic)
Other:	Moody Air Force Base is an excellent example of TAC's understated position with regards to flightline infrastructure during the first decades of the Cold War. As an active, very early TAC installation, Moody reused three existing World War II hangars for fighter maintenance during the 1950s, planning to erect three parallel readiness/maintenance hangars in 1957 (likely the 3rd generation Kuljian hangar). Moody also planned for a weapons calibration shelter, an armament and electronics shop, and an expanded flight simulator. All of these structures remained unbuilt.

Mountain Home Air Force Base
Vicinity of Mountain Home, Idaho

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Mountain Home Air Force Base*, volume II-21 of *A Systemic Study of Air Combat Command Cold War Material Culture* (July 1997).

Historic Names:	Mountain Home Army Air Base (1942-1943) Mountain Home Army Air Field (1943-1945) [Deactivated 1945-1947] Mountain Home Air Force Base (1948-1949) [Deactivated 1949-1951] Mountain Home Air Force Base (1951 to present)
Cold War Fighter Aircraft:	RF-4C (1966-1971) F-4D (1968-1971) F-111 (received 1971) EF-111 (received 1982) F-15 (received 1991) F-16 (received 1991)
Missions:	TAC Reconnaissance Operations TAC Fighter Training TAC Electronic Countermeasures Support Forces Air Intervention Composite Wing OTH-B Radar
Infrastructure:	OTH-B Radar Building [supportive of early warning]
Integrity:	OTH-B Radar Building: intact
Potential NRHP Eligibility:	OTH-B Radar Building: possible
Other:	Although TAC's presence at Mountain Home additionally supported such structures as hangars and flight simulators, the only air defense mission was that associated with early warning through the late Cold War radar (OTH-B).

Nellis Air Force Base
Vicinity of Las Vegas, Nevada

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Nellis Air Force Base*, volume II-22 of *A Systemic Study of Air Combat Command Cold War Material Culture* (August 1997).

Historic Names:	Western Air Express Airfield (1926-1941) Las Vegas Airfield / McCarran Field (1941) Las Vegas Army Gunnery School (1942) Las Vegas Army Air Field (1943-1947) [Deactivated 1947-1948] Las Vegas Air Force Base (1949-1950) Nellis Air Force Base (1950 to present)
Cold War Fighter Aircraft:	F-105 (received 1958) F-4 (received 1966) F-110 / F-15 / A-10 / F-117A (in test?)
Missions:	Fighter Advanced Pilot, Crew, and Weapons Training [Inclusive of nuclear/biological/chemical, 1954-1956] Training for Air Defense Capabilities Red Flag Exercises (U.S. Military and NATO)
Infrastructure:	LOLA (Live Ordnance Loading Area) Lines TAC Prefabricated Hangars [non rigid-frame / multiples] Butler Enclosed Shelters [rigid-frame / multiples] Red Flag Direction / Combat Center Soviet Threat Simulators [including early warning]
Integrity:	LOLA Lines: unassessed TAC Prefabricated Hangars: intact (26 pockets) Butler Enclosed Shelters: intact Red Flag Direction / Combat Center: unassessed Soviet Threat Simulators: unassessed
Potential NRHP Eligibility:	LOLA Lines: unassessed TAC Prefabricated Hangars: probable district Butler Enclosed Shelters: unlikely (generic) Red Flag Direction / Combat Center: strong Soviet Threat Simulators: possible / likely
Other:	Nellis possesses an unusual number of TAC prefabricated hangars, erected in groupings of two to five, sited parallel and perpendicular to the flightline. The excellent representation, 1961-1977, is a candidate for a NRHP district. Research should also address the Red Flag center and its ties to ADC command and control (esp. SAGE); Green, Blue, Gold, Copper, Maple, Lobo, and Silver Flag Exercises; and, the Soviet Threat Simulators (including air defense radars) on range.

Offutt Air Force Base
Vicinity of Bellevue and Omaha, Nebraska

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Offutt Air Force Base*, volume II-23 of *A Systemic Study of Air Combat Command Cold War Material Culture* (October 1997).

Historic Names:	Fort Crook (1888-1946) Offutt Field (1924-1947) Offutt Air Force Base (1948 to present)
Cold War Fighter Aircraft:	None
Missions:	No Cold War fighter missions
Infrastructure:	No ADC or TAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

Seymour Johnson Air Force Base
Vicinity of Goldsboro, North Carolina

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Seymour Johnson Air Force Base*, volume II-26 of *A Systemic Study of Air Combat Command Cold War Material Culture* (July 1997).

Historic Names:	Seymour Johnson Field (1941-1946) [Deactivated 1946-1949] Seymour Johnson Field (Municipal Airport: 1949-1952) Seymour Johnson Air Force Base (1953 to present)
Cold War Fighter Aircraft:	F-86 (received 1956) F-102 (received by 1959) F-105 (received 1962) F-15E (received 1988)
Missions:	ADC (1956-1965) / ANG (1979-1989) Alert *TAC Fighter Training Exercises
Infrastructure:	1st Generation Alert Hangar Alert Support Structures (readiness crew dormitory; squadron operations; flight simulator; readiness/ maintenance hangar [1]; 2nd generation weapons storage) TAC Prefabricated Hangars [non rigid-frame / multiples]
Integrity:	1st Generation Alert Hangar: intact Alert Support Structures: unassessed TAC Prefabricated Hangars: unassessed
Potential NRHP Eligibility:	1st Generation Alert Hangar: possible Alert Support Structures: unlikely TAC Prefabricated Hangars: unlikely (generic)
Other:	Although the alert support structures are not inventoried, the grouping is an unlikely NRHP grouping. The cluster includes a makeshift readiness hangar; several of the support structures are altered.

* TAC also supported a basic double-cantilever hangar and a cluster of three miscellaneous wing docks (that were likely surplus) from about 1954. Although these structures were designed explicitly for SAC, they were in use for a fighter mission at Seymour Johnson. See the companion volume of this study, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission.*

Shaw Air Force Base
Vicinity of Sumter, South Carolina

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Shaw Air Force Base*, volume II-25 of *A Systemic Study of Air Combat Command Cold War Material Culture* (July 1997).

Historic Names:	Shaw Army Air Field (1941-1947) Shaw Air Force Base (1948 to present)
Cold War Fighter Aircraft:	P-61 (1946-1947) P-51 (received 1946) RF-80 (received 1952) RF-84 (received 1954) RF-101 (received 1957) RF-4C (received 1965) F-16 (received 1981) A-10 (received ca.1994)
*Missions:	TAC Reconnaissance TAC Reconnaissance Training TAC Fighter Readiness
Infrastructure:	TAC Prefabricated Hangars [non rigid-frame / multiples] Butler Enclosed Shelters [rigid-frame / multiples]
Integrity:	TAC Prefabricated Hangars: intact Butler Enclosed Shelters: intact
Potential NRHP Eligibility:	TAC Prefabricated Hangars: unlikely (generic) Butler Enclosed Shelters: unlikely (generic)
Other:	TAC infrastructure at Shaw is only minimally related to the air defense mission (through its focus on reconnaissance).

* TAC supported a basic double-cantilever hangar at Shaw Air Force Base for its fighter mission. See the companion volume of this study, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission*.

Whiteman Air Force Base
Vicinity of Knob Noster, Missouri

Information based upon photographs and text in *A Baseline Inventory of Cold War Material Culture at Whiteman Air Force Base*, volume II-27 of *A Systemic Study of Air Combat Command Cold War Material Culture* (August 1997).

Historic Names:	Sedalia Army Air Field (1942-1946) [Deactivated 1946-1951] Sedalia Air Force Base (1951-1955) Whiteman Air Force Base (1955 to present)
Cold War Fighter Aircraft:	None
Missions:	No Cold War fighter missions
Infrastructure:	No ADC or TAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

Chapter 5: Recommendations

Recommendations for the management of real property that historically supported the ADC and TAC fighter and command/control missions of the Cold War (1949-1991) are discussed below with reference both to the current ACC installations, and with regard to such infrastructure across the Air Force. Generally, tabulations comparing potentially significant historic and contemporary real property associated with the ADC / TAC fighter and command/control missions indicate that the Air Force today owns approximately 30 to 40 percent of the total such property it owned historically, and that this percentage is actively declining as bases close. In addition, major commands within the Air Force are managing a changing real property mix, with historic infrastructure affected as it is reassigned from one major command to another.

Assessments of possible future Air Force actions are further complicated by the knowledge that the process of closing or excessing Air Force real property has been moving forward since the late 1950s—that is, from the end of the first period reflective of the war. Bases began to fall out of the system as strategic and tactical needs evolved. Many of these installations still exist as local or regional airfields, often with a military presence through the Air National Guard (ANG). In these cases, ANG is almost always managing the fighter-interceptor hangar and its supporting ancillaries, often using the infrastructure as it was intended historically and always holding the original engineering drawings. When a continuous air defense mission has existed at an installation, through ADC, TAC, and/or ANG, the likelihood of also finding maintenance manuals for the hangar; historic plans and photographs; and long-time personnel, is also high. Examples of this phenomenon are the contemporary ANG missions at McChord in Washington, Kirtland in New Mexico, Charleston in South Carolina, and Andrews in Maryland. In other cases, a local aero club is using the flightline alert facilities, and is maintaining the structures in a low-key manner. A nearly opposite situation characterizes the multi-generational ADC command/control structures. These structures, when found at private airfields, are as often as not heavily altered.

The distribution of historic ADC and TAC fighter and command/control infrastructure of the Cold War is also on the cusp of substantial, new major change, as local and regional airfields of long standing (which were once key air defense bases) are themselves responding to the pressures of a strong economy and growing U.S. population. Examples include shifts completely away from aviation, as well as pressures to intensify that original function. At the former ADC base of Oxnard in Southern California, a community college has converted a major portion of the property to campus use—including placing picnic tables in the midst of former storage bunkers for the nuclear-tipped Genie tactical missile. A major university research facility has substantially renovated the second generation command and control building (the Semi-Automatic Ground Environment [SAGE]) at the Duluth airport. While former Air Force bases do occasionally sustain both fighter and command/control infrastructure in an unaltered state—such as at Larson in eastern Washington and Richards-Gebaur in Missouri, this situation will become increasingly unusual. Airfields like Larson (now Grant County Airport) are more and more frequently the diversion airports for their urban counterparts (Seattle-Tacoma) during extended bad weather, and are currently meeting the needs of large airlines that use their facilities for maintenance. Grant County Airport is also under current consideration as one of 17 possible launch-and-landing locations for a commercial space shuttle. At the former Richards-Gebaur relatively recent closure has yet to affect a highly intact Butler alert hangar, or two generations of command and control, but Kansas City Southern Railway is actively in the process of converting the site into an intermodal facility for North American Free Trade Association (NAFTA) goods. The period for the dormant survival of relatively unaltered historic ADC and TAC infrastructure at these former installations is about to end—just at the time changes internal to the Air Force are having much the same affect on existing historic real property owned by the government.

Recommendations focus on (1) broad remaining inventory issues at the 16 current CONUS ACC installations pertinent to the historic ADC / TAC fighter and command/control air defense missions of the

Cold War; (2) particularly important real property documents and drawings issues at these same installations (supportive of the existing historic infrastructure); (3) major inventory and recordation issues for the historic ADC / TAC real property types (discussed in chapter 2) across the Air Force; and (4) Air Force-wide challenges in the future management of historic ADC / TAC engineering and real property documents—especially drawings and master plans currently housed in installation civil engineering vaults.

Current ACC Installations: Issues of Inventory

Fighter-Interceptor Alert Hangars

Inventory for the two generations of fighter-interceptor alert hangar is confused at several of the current CONUS ACC installations. For the most part, base cultural resource managers can correct this situation. At Davis-Monthan, a Butler hangar pre-existed the second generation Strobel & Salzman hangar that remains today. At Ellsworth, the Air Force has moved its Butler hangar off the flightline for use as an aviation museum. At Langley, the Luria hangar is minimally inventoried. In this case, the hangar is very rare, with drawings extant in the base civil engineering vault. More supporting documentation for its inventory is warranted.

A final atypical fighter-interceptor alert hangar exists at Holloman Air Force Base. A TAC alert hangar, this structure dates to about 1976. Photographs of the hangar are inadequate in the existing inventory. As the structure is outside the documented sequence of first and second generation alert hangars designed during the 1951-1956 years, it is suggested that additional supporting documentation is needed.

Support Structures

ACC has no substantive inventory for the support structures typically clustered adjacent to the alert hangars at the flightline. Based on the existing inventory photographs, many of these ancillaries appear to be altered. Installation cultural resource managers at Davis-Monthan, Ellsworth, Langley, and Seymour Johnson may wish to verify location; building (real property) number; dates of construction; and original use for these support structures. Support structures have been inventoried at Minot Air Force Base in a cultural resource management plan of 1996. The probability of support structures attendant to the 1970s alert hangar at Holloman is unknown.

Command and Control

No first or second generation inventory issues exist at current CONUS ACC installations. Nonetheless, the Red Flag Direction / Combat Center at Nellis Air Force Base sustains a related air defense mission. Inventory for the Red Flag infrastructure at Nellis, including that for Soviet threat air defense simulators, should be augmented, with information tied to SAGE.

Current ACC Real Property: Issues of Documents and Drawings

ACC may choose to make copies of representative drawings for ADC and TAC Cold War structures interpreted as significantly portraying the fighter and command/control missions of 1949-1991. As such a task is large, and subject to the lapse of time for organizational planning, the task here is prioritized. Only the critical, endangered, rare, or problematic drawings are discussed below.

Fighter-Interceptor Alert Hangars (1951-1959)

Representation for the four types of first generation alert hangar is mixed. Drawings for the most common hangar, that of Strobel & Salzman, exist as 105mm microfiche at the History Office of the U.S. Army Corps of Engineers at Fort Belvoir, as do drawings for the firm's second generation hangar.

Drawings for the Butler and Luria hangars are rare, and need to be collated as a complete set, while drawings for the overseas mobilization hangar are as yet undiscovered. Finally, ACC should augment this set of drawings with individual sheets illustrating the standardized front and rear door modifications made during the middle 1950s to accommodate the longer fighter aircraft then entering the inventory. One set of complete originals should be archived, with copies replacing originals in the pertinent civil engineering vaults.

Installations likely to have full or partial sets of fighter-interceptor alert hangar drawings include Davis-Monthan, Ellsworth, Langley, Minot, and Seymour Johnson. The historic presence of a Butler hangar at Davis-Monthan and Ellsworth make drawings a possibility at these bases, but the relative rarity of the Butler drawings overall suggests that only selected drawings may remain. The hangar at Ellsworth was one of the very first erected in the country. The Luria hangar at Langley is verified as having a complete set of drawings filed in the base civil engineering vault. The TAC alert hangar at Holloman, again, remains undocumented, with no assessment for drawings.

TAC Flightline Hangars (1961-1977)

Drawings for the standardized TAC hangars are assumed to be available in multiples. However, no inventory exists referencing these drawings, and some type of baseline check should be undertaken. Drawings for TAC hangars can be anticipated at Cannon, Davis-Monthan, Holloman, Moody, Nellis, Seymour Johnson, and Shaw Air Force Bases. Due to the number and positioning of the TAC hangars at Davis-Monthan and Nellis, these installations, in particular, may have complete collections of drawings.

Support Structures (1951-1962)

Drawings for support structures exist at multiple active installations across the Air Force. It is not anticipated that those surviving in the civil engineering vaults on ACC bases will best represent the typical cluster of ancillaries associated with the alert mission, although this could be verified by the cultural resource managers at Davis-Monthan, Ellsworth, and Langley. Support structures at Minot are inventoried, with discussion of drawings in the installation cultural resource management plan.

Air Force-Wide: Issues of Inventory and Recordation Across Real Property Types

A much more comprehensive issue exists addressing the most effective method of inventorying, and in some cases recording, the best examples of the key ADC and TAC real property types associated with the commands' Cold War fighter and command/control missions for air defense. In many cases, the best solution may be to look at a property type—such as the alert hangar or command and control—and assess what is significant about its buildout program as a whole. From this point, one can then address where the likely examples are; where they may remain in a least altered state; where they were supported by apron and flightline configurations historically; and where they existed with special site adaptations. It may also be pertinent to assess the earliest built within the overall program, and those associated with critical and/or extended Cold War missions. Assessment across the Air Force is strongly advised for historic ADC infrastructure, in particular, due to the wide dispersal of this property across major commands today.

Most important are mobilization alert hangars (Butler, Luria, and overseas types); the first generation command and control types 2, 3, and 4 stations (Aircraft Control & Warning [AC&W] command sites); the second generation command and control facilities (SAGE); and the third generation command and control facilities (the Backup Interceptor Control [BUIC] system).

For two property categories then—mobilization alert hangars and three generations of command and control—some level of more comprehensive, Air Force-wide profile may assist ACC and other major commands in making appropriate and non-repetitive decisions regarding National Register determinations; selections for Historic American Buildings Survey (HABS) and Historic American Engineering Record (HAER) documentation; and active interpretation. Of major research potential is the engineering for early blast resistant construction and its historic ties to Federal Communications Commission regulations from 1934 forward; to similar work undertaken by the Navy and the Army; to on-site testing at the Nevada Proving Ground for nuclear weapons damage; to the development of engineering standards for infrastructure specific to ground-launched missiles; and to the work of selected engineering firms specializing in such construction during the first decades of the Cold War. In the case of the evolving sophistication of blast resistant construction—hardening—the standing structures are very important, as are existing drawings and any related specifications. Research at the headquarters Air Force level is likely warranted.

A more general, but very useful, tool would be a succinct context for Air Force base closure and excessing, from 1959 to date. Knowing what bases existed when, with sketches of their historic missions and associated aircraft, would provide useful information that could be correlated with historic master plans illustrating ADC and TAC infrastructure. Such a tool would be most appropriate in understanding and assessing the buildout of a very large program, like that of the fighter-interceptor alert, across both time and geography.

Also suggested is contacting selected historic engineering firms responsible for the key ADC infrastructure of the 1949-1962 period. In rare cases engineers who worked on the project may be alive to contribute to a HABS / HAER profile. Where specialized issues existed, such as those described above, this type of contribution would be invaluable. Historic photographs and other documents may also remain in the appropriate engineering offices.

Finally, oral interviews with individuals who worked in the structures historically (such as aircraft maintenance crew), or who have engaged in specialized repair of key features (such as the complex door opening mechanisms for the ADC alert hangar) may also be pertinent. A number of these former men are retired, but could likely be reached systematically through the Air Force Historical Research Agency. The latter group are known to active installations that sustain maintenance on such structures today, and through magnets for aircraft maintenance personnel—like Boeing in Seattle.

Air Force-Wide: Issues of Documents and Drawings

Although numerous challenges could be mentioned here, the urgent issue facing the Air Force is the archiving of its historic engineering drawings now held in the civil engineering vaults at active installations. These documents are oversized, fragile, awkward to store, and exist in a range of completeness from single sheets to full drawings sets. Most often when a building is torn down, and sometimes even when it is substantially remodeled, the original drawings are thrown out. Such is also the case when a base is closed or excessed. Although it is unreasonable to archive all historic drawings, it is critical that the existing situation be changed so that we do not lose rare records that may exist in no other form.

It is suggested that some type of interim policy be adopted for archival storage of drawings most endangered, and that the Air Force actively seek a long-term, permanent solution. Possibly such a solution is storage at the National Archives II in Maryland, or, at the Air Force Historical Research Agency in Alabama. In both cases, the centrality of the storage site is important, as is its access and relation to documents already archived at both locations. The Air Force Historical Research Agency additionally offers its immediate collocation with the Air University. The problem of original drawings is immense and will require careful consideration of the funding, personnel, and physical facilities required to accomplish the task over time and in perpetuity. Care will need to be taken in the selection of any device used to copy drawings for the future, as such devices become obsolete and inaccessible to the very researchers they are intended to aid. (For example, today there exist substantial difficulties in using the

105mm microfiche of drawings stored in the History Office of the U.S. Army Corps of Engineers at Fort Belvoir. The Corps considered the actual drawings too large to store, and maintains no originals today.) Archival storage of, and sustained access to, these important documents is perhaps the single largest issue facing ACC in its assessment of Cold War material culture.

Bibliography

The bibliography offered here focuses on pertinent Air Force literature and documentation, and is organized to facilitate further research on topics related to those presented in this study. First sources are general and real property in character. Second sources are focused on Air Force and U.S. Army Corps of Engineers documents. Not included are history and engineering references of non-military type, as well as articles from engineering journals. These items can be found in their complete citations in the chapter endnotes.

Particularly important to any analysis of Air Force historic real property are documents held at the Air Force Historical Research Agency at Maxwell Air Force Base in Montgomery, Alabama. The Air Force Historical Research Agency serves as the primary repository for all Air Force records below the policy level and maintains truly excellent holdings, exclusive of engineering drawings. Numeric coding specific to the Air Force Historical Research Agency is added for each entry below to make any requests for these documents as efficient as possible. Associated dates need to accompany each code.

Also key is the History Office for the U.S. Army Corps of Engineers at the Humphreys Engineering Center, Fort Belvoir, Virginia. Held here are hand-annotated indexes for the superceded, standardized, and definitive drawings for many of the buildings commissioned for ADC and TAC during the Cold War. The responsibilities for design, engineering, and construction for the Air Force is complex during the 1947-1960 years, but when buildout consisted of multiples erected across the United States, or overseas, typically the Corps managed construction. While the Corps has filed the drawings by original number, it should be noted that gaps in sequencing are common and many drawings are lost. Drawings do not exist as originals, but rather as 105mm microfiche. In a number of important cases, the only remaining evidence of the early evolution of a key ADC and TAC Cold War structure is found on the Corps index cards. To aid researchers, the drawing number is provided, when known.

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