COLD WAR INFRASTRUCTURE
FOR STRATEGIC AIR COMMAND:
THE BOMBER MISSION

Prepared for

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Table of Contents

List of Tables

List of Maps

List of Plates

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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
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
CBR	California Bearing Ratio
CIOS	Combined Intelligence Objectives Subcommittee
COC	Command Operations Center
CONUS	Continental United States
DASA	Defense Atomic Support Agency
DNA	Defense Nuclear Agency
DEW	Distant Early Warning System
DoD	Department of Defense
FAA	Federal Aviation Agency
FIAT	Field Information Agency, Technical
HABS	Historic American Building Survey
HAER	Historic American Engineering Record
HB	Heavy Bomber
IBM	International Business Machines
ICBM	Intercontinental Ballistic Missile
IRBM	Intermediate Range Ballistic Missile
JAL	Japan Airlines
JSS	Joint Surveillance System
MB	Medium Bomber
MIRV	Multiple Independently Targetable Re-Entry Vehicles
Mk 17	Mark 17
MLC	Military Liaison Committee
NACA	National Advisory Committee for Aeronautics
NART	Navy Air Reserve Training
NASA	National Aeronautics and Space Administration
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
SAC	Strategic Air Command
SAGE	Semi-Automatic Ground Environment
SALT	Strategic Arms Limitations Treaty
SCC	Super Combat Center
SDI	Strategic Defense Initiative
SLBM	Submarine-Launched Ballistic Missile
SRAM	Short-Range Attack Missile
START	Strategic Arms Reduction Treaty
TAC	Tactical Air Command
TN	Thermonuclear
TWA	Trans World Airlines
USACERL	United States Army Corps of Engineers Construction Engineering Research Laboratories
USAF	United States Air Force
USAFE	United States Air Force in Europe
VVHB	Very Very Heavy Bomber
WACS	White Alice Communications System
WAI	Weidlinger Associates, Inc.
X-1	Expansible, Basic
X-2	Expansible, Intermediate
X-3	Expansible, Ultimate
ZD	Zeiss-Dywidag

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 Butler Manufacturing (Kansas City), Luria Engineering (New York and Bethlehem, Pennsylvania), Armco Drainage and Metal Products (Middletown, Ohio), Detroit Steel Products (Detroit), and, 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 hangars 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.

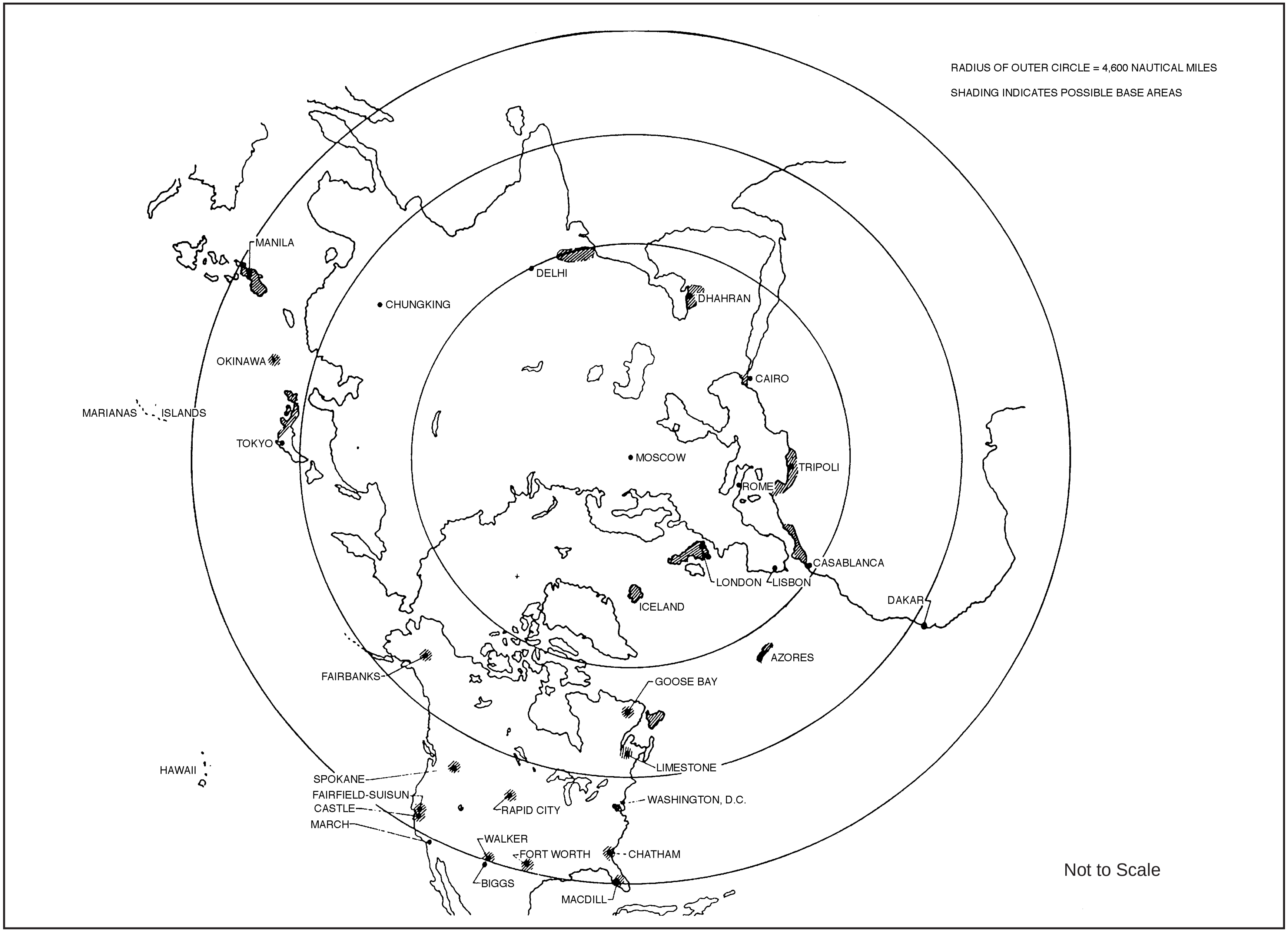
Tiered to Western Electric, the architectural-engineering firm Burns & Roe of New York designed the infrastructure for combat and direction centers, and for accompanying power stations. SAGE allowed a four-fold increase in considered air defense scenarios, and in aircraft-weapons deployment—making it 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. B-36 at Ellsworth Air Force Base. Hangar, midground. Moveable wing docks, left, background. View of 1953. Courtesy of the Air Force Historical Research Agency.

During the Cold War, the evolution of key property types for SAC bomber infrastructure can be analyzed in eight categories. Of note, these categories are concentrated in the period of Curtis LeMay's leadership of SAC, 1946/1947 to 1957, with a subsequent appearance of significant new design and engineering during the Carter, Reagan, and Bush presidencies, 1976-1991. Upon the completion of construction programs begun in the late 1950s, design and engineering for SAC bomber infrastructure is largely static for a full quarter century. After about 1960, SAC reused or adapted many pre-existing structures to accommodate added bomber missions, and did so primarily due to introduced weapons systems—paralleling the exceptionally long life of the B-52 bomber and KC-135 refueling tanker. Discussions below focus on operational buildings and structures, inclusive of runway pavements and aircraft parking apron configurations. 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. On occasion, cantonment architecture built during the Cold War can be directly tied to the bombing mission of SAC, rather than to the Air Force-wide expansion of installation infrastructure in support of a large U.S. military during these years. These latter cases will be included below.

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) the first generation maintenance hangar for the B-36, 1947-1950; (2) the second generation maintenance hangar for the B-36, B-47, and B-52, 1951-1955; (3) prefabricated, mobilization infrastructure, including wing docks and, steel-panel airmen dormitories, 1948-1956; (4) pavement experimentation at selected runways for the B-36 and the B-52, 1948-1956; (5) Q Areas, 1947-1956; (6) alert apron configurations and crew quarters, 1954-1959; (7) first generation headquarters command post, below ground, and the Offutt chapel, 1954-1957; and (8) infrastructure of the late 1970s, and again during the Reagan-Bush years, including a maintenance hangar for the airborne command post; a hangar for the B-1 and aircraft shelters for the B-2; and, the second generation underground headquarters command and control center.

First Generation Maintenance Hangar for the B-36

With the establishment of SAC in March 1946, the aircraft inventory for command's bombardment groups included B-29s, B-17s, and even a few B-25s. Only the B-29 was not obsolete, yet this bomber could not attack intercontinental targets from the continental U.S.—making SAC's long-range bombing capabilities all but nonexistent. Additionally, in May 1946, the Army Air Forces (AAF) gave SAC the responsibility of delivering the atomic bomb. Only one of the command's bombardment units, the 509th at Walker Air Force Base (then Roswell Field) in New Mexico, was trained and ready for the atomic bomb mission. Walker, and Kirtland to the north in Albuquerque, would quickly become the bases around which this mission first centered, although with the move of SAC's headquarters from Andrews to Offutt in 1948 plans for the initial flightline infrastructure associated with this mission shifted to Ellsworth and Loring, in South Dakota and Maine, respectively. Loaded with an atomic bomb, the B-29, soon paired with its updated version the B-50 (with greater speed and longer combat radius), and paralleled by the Soviets through the Tu-4, were the first Cold War bombers. While the B-29, B-50, and Tu-4 were the long-range aircraft that revolutionized air war, the aircraft could only fly the U.S.-Soviet corridor one way, and could not achieve that distance heavily loaded. Hangars and flightline ancillary structures for SAC's B-29 and B-50 carried over from World War II, with the exception of added wing docks immediately before 1950.

SAC commanders, particularly Curtis LeMay who was known for his "single-mindedness of purpose and iron resolution,"[1] realized early that a truly intercontinental bomber, effective in a retaliatory nuclear attack against the Soviet Union, would need considerably more range. The AAF had contracted with a predecessor of Convair, Vultee Aircraft, for the B-36 Peacemaker in 1941. At that time the Army realized that Europe might be lost as a staging ground for combat, and that an aircraft capable of flying a round trip from American continental bases, with aerial refueling, was needed. As Convair developed the very heavy bomber in the immediate post-World War II years, designing the aircraft to carry nuclear payloads and to make the transition from a propeller- to a jet-engine plane, the B-36 was still highly experimental in its primary mission. Driven by six engines, the B-36 came into the SAC inventory in late 1948, with three operational heavy bombardment wings of B-36s available at the close of 1949 (Plate 2). Eleven wings of B-29s and B-50s still constituted the majority of SAC aircraft—from this point forward reclassed as medium, rather than heavy, bombers.

Just before the turn of 1951, supported by the mobilization for the Korean War after June 1950, SAC had 38 B-36s deployed to its bases. Unwieldy planes with a wingspan of 230 feet, a length of just over 162 feet, and a height of nearly 49 feet, the B-36 had an official range of 10,000 miles. Actual range for the bomber was 6,800 to 8,175 miles, with aerial refueling required. When loaded, the B-36 burned fuel at an exorbitant rate. With progressive evolution of the bomb itself, especially from the early atomic bombs of the late 1940s to the thermonuclear devices with sealed detonator pits ("wooden" bombs with an indefinite shelf life) of the middle 1950s, even the jet-modified B-36—with its 10 engines—could only carry a single bomb. The Mark 17 (Mk 17), a thermonuclear bomb of mid-decade, weighed more than 41,000 pounds. The complimentary tanker for the B-36 was the KC-97, a slow propeller-engine aircraft with a range of only 4,300 miles, also derived from the B-29. The B-36/KC-97 pair necessitated runway extensions to a minimum of 10,000 feet, with 40 inches of subsurface construction.[2]

Plate 2. B-36 in flight over Carswell Air Force Base. View of 1953. Courtesy of the Air Force Historical Research Agency.

The very first SAC Cold War infrastructure, then, attempted to respond to the challenges of the B-36, anticipated in the bomber inventory in 1948-1949, and its accompanying newly atomic world—with its progression of weapons from the Mk 3 and the Mk 4 of the late 1940s through the Mk 91 of less than a decade later.[3] The oversized B-36 required a proportionally large maintenance hangar, much longer, and with a wider span, than almost all of the World War II hangars extant at AAF installations. There was at least one exception, nationwide, that SAC did adapt as a make-shift B-36 maintenance hangar: the 12-acre (522,720 square feet) B-17 engine overhaul-and-repair hangar of 1943, built to house 20 B-17s simultaneously, and the gross equivalent of about three of the largest B-36 double-cantilever hangars of 1951 in square footage—although only housing up to four B-36s.[4] SAC approached the problem of a maintenance hangar for the B-36 both conservatively and with innovation. The architectural-engineering firm selected to design the first generation hangar had established itself through hangar designs for the Navy from 1939 forward on the West and East Coasts, and, tentatively, for the AAF, with hangars at Wright-Patterson and Andrews Air Force Bases (then Wright and Andrews Fields) in Dayton, Ohio, and immediately outside Washington, D.C., during 1942-1945. The construction technology for these hangars, however, was internationally cutting-edge; still considered experimental; and, rapidly achieving increasingly wider spans. Civilian airfields for American cities hosted the technology simultaneously, but were much more cautious in their sponsorship of span width. The first generation SAC B-36 hangars were the largest hangars in the world when built, using a construction understood by practicing engineers to be one of the key paths to the future's wide-spanned spaces.

SAC commissioned what was intended to be a standardized design for the B-36 hangar in early 1947, with a full set of drawings signed and submitted in May[5] (Plate 3). Construction for the two prototype hangars was underway first at Ellsworth Air Force Base (then Rapid City Air Force Base, and, for a brief while in 1948, Weaver Air Force Base) in South Dakota and at Loring Air Force Base (then Limestone Air Force Base) in Maine, in 1948. Design and initiation of construction for the hangar preceded availability of the B-36, but at each location required two full years for completion, a situation aggravated by long, severe winters. The B-36 and its two first generation hangars became functional SAC real property together, at the opening of 1950. Measuring 370 feet by 314 feet, the hangar provided 106,760 square feet of unobstructed floor space (340-foot clear span), with entrance for the B-36s 300 feet wide by 40 feet high. Although not technically planned as a pull-through structure, the hangar was designed with two main doors on each end. The doors had additional center openings of 50 by 20 feet to accommodate the tail assemblies of the bomber; the maximum inside arch clearance was 90 feet above the floor, 75 feet above the springing line. Massive, reinforced concrete subfoundations 20 inches thick supported loads up to 150,000 pounds. The first generation B-36 maintenance hangar serviced two bombers, with each aircraft entering the facility from opposite doors.[6] As illustrated on a Loring master plan of May 1948—at the beginning of actual construction for Ellsworth, SAC planned for clusters of three and four of these B-36 hangars, with taxiways between each individual structure (Plate 4). The clusters were sited adjacent to a major parking apron for the bombers, and, to a separate, rectangular ready apron. The ready apron had immediate access to the main runway of 9,160 feet, with an extension anticipated of half again that length.[7]

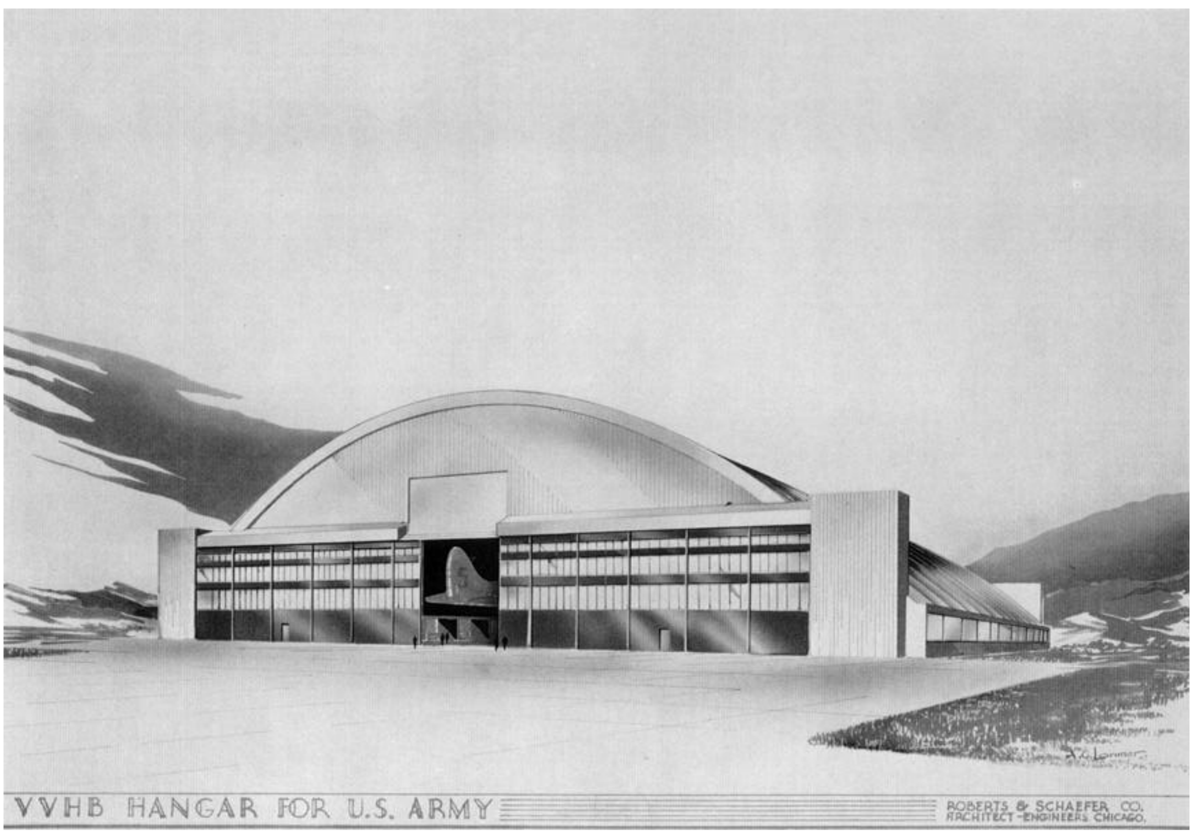

Plate 3. Anton Tedesko, Roberts & Schaefer. Presentation drawing for the SAC B-36 hangar. 1947. Courtesy of the Civil Engineering Archives, Princeton University.

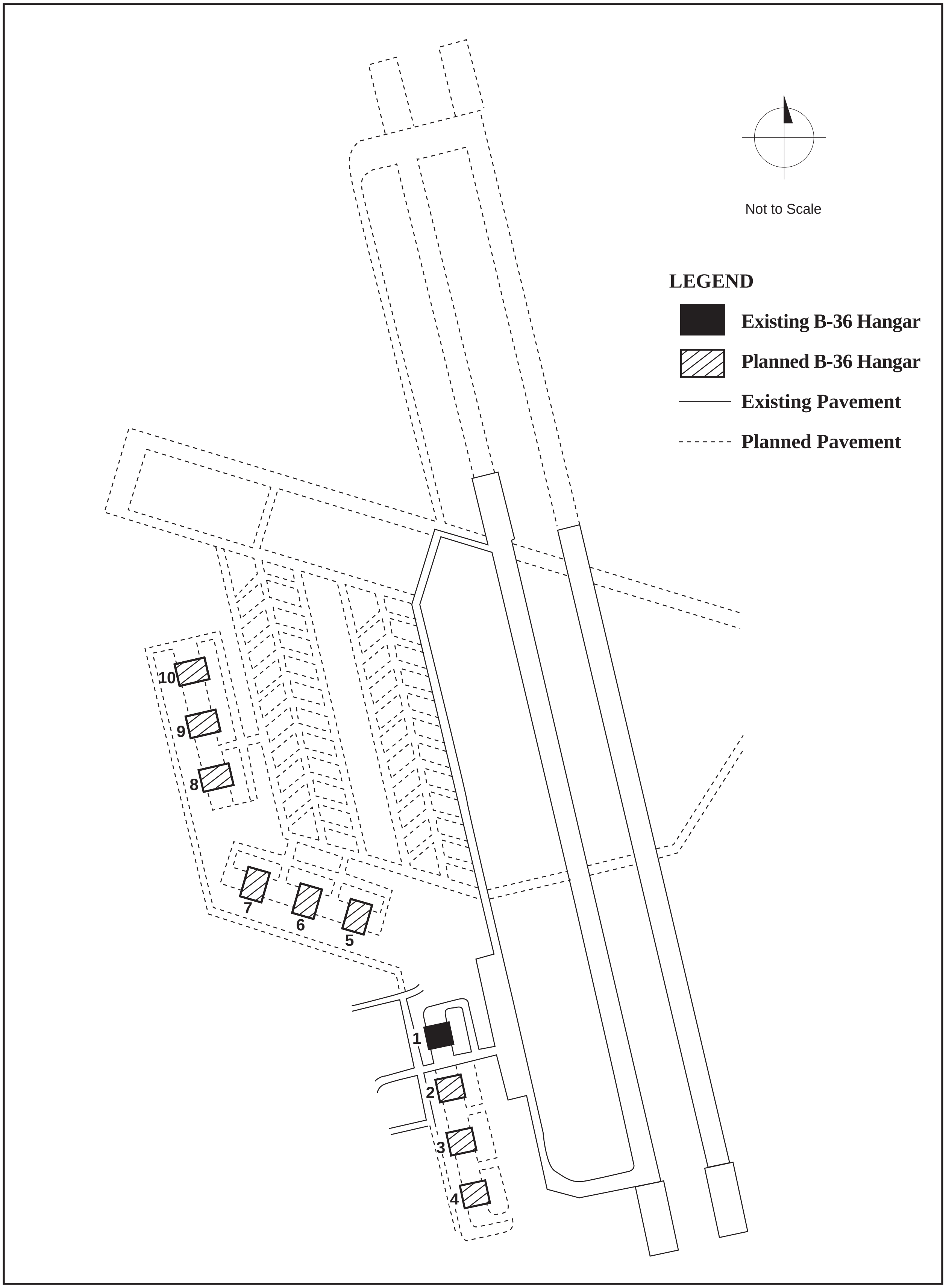

Plate 4. Layout plan for 10 B-36 hangars, Loring [Limestone] Air Force Base. May 1948. Adapted from the original plan held at the National Archives II, Maryland.

Engineer Anton Tedesko, of the Chicago firm Roberts & Schaefer, designed and engineered the first generation B-36 hangar for SAC, drawing upon 20 years of research in thin-shell, reinforced concrete, short-barrel construction. Dr. Tedesko (1903-1994) was born and educated in Vienna, Austria, receiving his first degree in civil engineering in 1926. From 1926 to 1928 he worked in the U.S. as a "detailer and steel designer," then returning to Vienna to assist Ernest Melan, a professor of steel design and construction at the Institute of Technology with whom he would later undertake his doctorate. In Vienna, Tedesko also began his life's work in industrial architecture, hiring with Dyckerhoff & Widmann A.G. [*Aktien Gesellschaft* (joint-stock company)] in Wiesbaden-Biebrich in 1930. Dyckerhoff & Widmann were pioneers in reinforced concrete construction, and were renowned as builders of dams, bridges, and tunnels. Dyckerhoff & Widmann had begun analyses and testing for thin-shell, concrete design during 1922 to 1930, focused through the work of two firm members, engineers Franz Dischinger (1887-1953) and Ulrich Finsterwalder (1897-1989). Tedesko worked for Dyckerhoff & Widmann for only two years—until 1932, but sustained continuous interaction with the firm into the 1940s. In Wiesbaden-Biebrich, Tedesko worked closely with Finsterwalder, in particular, while Finsterwalder and another firm engineer, Hubert Rüsch, finished their analyses on the behavior of shallow, cylindrical, reinforced concrete barrel shells. Tedesko participated in the design for the Great Market Hall in Budapest, the firm's first large-scale shallow barrel shell, under Finsterwalder, as well as being one of the firm's engineers who developed the detailed analysis of the thin shell engineered for a large sulfate works storage facility in Belgium.[8]

The engineers developing and testing the thin-shell, reinforced concrete construction system through Dyckerhoff & Widmann concentrated on aligning theoretical mathematics with practical industrial uses. Dyckerhoff & Widmann had initiated experimentation in 1922 to meet the needs of the Zeiss optical company for a planetarium at the German Museum in Munich, with engineers from both firms participating. This first thin-shell dome was quite small, but featured reinforced concrete only 1.1811 inches thick—which was remarkable for its nearly 52.5-foot diameter. The two lead engineers from Zeiss and Dyckerhoff & Widmann decided to patent the thin-shell system as Z-D, also alternately known as Zeiss-Dywidag [***Z***eiss ***Dy***ckerhoff & ***Wid***mann ***A.G***.] construction. With larger scale projects, the two engineers, Walter Bauersfeld of Zeiss and Franz Dischinger of Dyckerhoff & Widmann, addressed shell behavior under asymmetric loads, stability against buckling, and overall deflections.[9] By the time of Tedesko's hiring at Dyckerhoff & Widmann, the firm was contracting for thin-shell industrial structures in Germany, Lithuania, Rumania, Hungary, Belgium, and Italy, including aircraft hangars, a rolling mill, a plant for processing crude industrial benzene (a petroleum distillate), a coal storage silo, a streetcar repair facility, and several automobile showrooms.[10]

In 1932 Anton Tedesko immigrated to the U.S., joining the Chicago firm of Roberts & Schaefer under a joint agreement with Dyckerhoff & Widmann to promote, design, and supervise construction of ZD structures. Founded in 1896 by Colonel Warren R. Roberts, a civil engineer, as the Warren R. Roberts Company, Roberts & Schaefer originated as a structural design service for the cement, minerals, and grain industries of the upper Midwest. Colonel Roberts had formalized the partnership Roberts & Schaefer in 1904 with a University of Illinois classmate J.V. Schaefer, who at that time worked for LinkBelt in their coal washery department. The company, like Dyckerhoff & Widmann, focused on industrial construction—particularly processing plants and storage facilities for coal, gold, silver, copper, limestone, cement, aggregate, phosphate, salt, potash, lead, antimony, zinc, zinc oxide, and silica sand.[11] The licensing agreement between Dyckerhoff & Widmann and Roberts & Schaefer resulted not just from the natural fit between the two companies, but also directly from an existing connection dating back to the middle 1920s. Engineer John E. Kalinka (born 1888), like Tedesko Viennese and an engineering graduate of the Institute of Technology, had worked in Europe until 1924 as a designer and supervisor for major highway and railway projects, inclusive of long-span bridges. In 1925 he hired with Roberts & Schaefer.[12] Kalinka is thought either to have had a sustained connection to Dyckerhoff & Widmann after his immigration, or, to have been a professional associate known to Tedesko through their university education in Vienna. Kalinka was the conduit for Tedesko between Dyckerhoff & Widmann and Roberts & Schaefer.[13]

Tedesko's joint task for Dyckerhoff & Widmann and Roberts & Schaefer was to sell reinforced concrete long-barrel shell, short-barrel shell, and dome construction in the U.S., with Roberts & Schaefer receiving exclusive American rights to ZD construction after a trial period during which three or four thin-shell structures would be built. Prior to his arrival in 1932, no such structures had been built outside of those by Dyckerhoff & Widmann in Europe, although *Engineering News-Record*, *Western Construction News*, *Construction Methods*, *Transactions of the American Society of Civil Engineers*, and *Architectural Forum* had begun publishing short articles on the innovative technology in 1929-1932. Tedesko immediately authored an article on reinforced concrete shells for the Canadian journal *Concrete and Quarry* in late 1933, with Dyckerhoff & Widmann's Budapest markethall showcased in the international edition of *Architectural Forum* in early 1934.[14]

The Depression in the U.S. at first slowed progress of the German-American ZD enterprise. After being unsuccessful at winning the contract for the German Pavilion at the Century of Progress World's Fair in Chicago, Roberts & Schaefer finally secured a contract for the long-barrel shell Brook Hill Dairy Farm exhibition hall erected for the second season of the fair in 1934. The Brook Hill Dairy Farm hall allowed Roberts & Schaefer to showcase ZD construction, with *Engineering News-Record*, *Concrete*, *Architectural Forum*, and *Architectural Record* all illustrating the building and taking professional note.[15] Brook Hill featured five parallel, elliptical three-inch shells, each spanning 14 feet with a length of 34 feet. The hall is considered the first true multi-span vault in the U.S. Tedesko followed it the same year with the design for a thin-shell dome for the Hayden Planetarium in New York. The dome was 81 feet in diameter and of 77-foot height at its crown. Like the Chicago fair building, the planetarium featured a three-inch thick shell. It also marked the first known collaboration between Tedesko and another engineering firm that would become prominent in designing specialized structures for the Air Force during the early Cold War, Weiskopf & Pickworth of New York.[16] Throughout the remainder of the 1930s Tedesko continued to establish himself as a significant engineer of thin-shell, reinforced concrete construction in the U.S. Prominent commissions included those for the Hershey Sports Arena, in Hershey, Pennsylvania, 1935-1936, a short-barrel shell of three-and-one-half inches thickness spanning 245 feet; auditoriums in Kansas, Wisconsin, Tennessee, Louisiana; another sports arena for Haverford College, Haverford, Pennsylvania; industrial storage buildings in New York and Pennsylvania; a tire plant in Natchez, Mississippi; and an ice skating rink in Washington, D.C.[17]

In 1939 Roberts & Schaefer, still with direct support and collaboration by Dyckerhoff & Widmann, began designing reinforced concrete thin-shell hangars, armories, engineering and repair shops, foundries, and munitions warehouses for the U.S. Army and Navy. Following an international congress for reinforced concrete in Liege, Belgium, held in September 1930 and subsequently published[18], the Nazi military had also initiated the adoption of ZD construction—most notably for a flight training school hangar in Cottbus, Germany in 1933. The Cottbus hangar collapsed several months after it was built due to deflections caused by excessive creep. Dyckerhoff & Widmann had used too few stiffening ribs along the length of the vault (spaced at just over 131 feet), although it had previously designed hangars successfully in Turin, Prague, Great Britain, and Cairo.[19] Although Roberts & Schaefer's first U.S. military commission did not occur until the end of the decade, engineer Ulrich Finsterwalder (Dyckerhoff & Widmann) had actively collaborated with Anton Tedesko (after his arrival at Roberts & Schaefer) in proposing American hangars and engineering shops as early as November 1932, with documented correspondence in German for airfield shops in Portland, Oregon. Similar, but more lengthy, correspondence exists as of July 1939 for Navy seaplane hangars in San Diego, California.[20] During 1937, Eric C. Molke, an engineering graduate of the University of Vienna, also joined Roberts & Schaefer, becoming manager of the Washington, D.C., Roberts & Schaefer office—a position assumed by Tedesko during World War II.[21] In January-February 1940, John Kalinka authored a dramatic article on ZD hangars for *The Military Engineer*, the official journal of the U.S. Army Corps of Engineers, in which he illustrated four single- and multiple-barrel thin-shell concrete hangars recently completed outside the U.S.[22] (Plate 5). At about this same time, Dyckerhoff & Widmann's Franz Dischinger consulted for Organization Todt—the Third Reich's equivalent of the U.S. Army Corps of Engineers. Named for Dr.

Plate 5. Dyckerhoff & Widmann. Thin-shell concrete hangar completed outside the U.S. Reproduced from *The Military Engineer*, January-February 1940.

Fritz Todt, a civil engineer, the organization designed and built the Autobahn, airfields, and fortifications.[23]

From 1939 through World War II, and continuing with the two prototype B-36 hangars for SAC in 1947, Tedesko designed key thin-shell reinforced concrete structures for the U.S. military, running field tests on many to ascertain their structural performance once formwork was removed. His mathematical calculations for the sulfate storage warehouse in Tertre, Belgium, made while with Dyckerhoff & Widmann in 1930-1931, served as a source of tables for later short-barrel structures, and in fact the Tertre structural shell with its strengthening ribs resembles the form and size (a span of just over 144 feet) that the Army hangars of the early 1940s would take.[24] Tedesko's earliest hangars included three for the Army Air Corps at Borinquen Field, Puerto Rico (project cost: $1,100,000); 16 (seaplane, maintenance, electronics testing, radar and flight testing) for the Navy at North Island, San Diego (two: $1,000,000), Philadelphia (one: $1,000,000), Patuxent, Maryland (12: $5,250,000) (Plate 6), and Richmond, Virginia; six for the Army Signal Corps and the Army Air Forces at Wright Field, Dayton, Ohio ($1,125,000) (Plate 7); and two for the Army Air Forces at Andrews Field, Maryland ($400,000).[25] Especially spectacular were groupings of Navy and Army warehouses, each warehouse 182 feet wide and 1,562 feet long, side by side, in Richmond and Norfolk, Columbus and Dayton, and Bayonne, New Jersey, 1940-1943[26] (Plate 8). In all, by July 1946, Roberts & Schaefer—through the work of Anton Tedesko—claimed "28 concrete hangars and six million square feet of concrete warehouses and shops for the Navy, Air Corps and Quartermaster Corps…all in 'Z-D' type construction." The firm noted that:

> The Z-D monolithic reinforced 'Shell Dome' system, pioneered by the Roberts and Schaefer Company, has grown in this country during the last fifteen years from a theory based on mathematical calculations to a complete method of practical concrete construction. It is economical, fast, fireproof, easy to maintain and the completed structures function with high efficiency.[27]

The final event that perhaps convinced SAC that Tedesko's ZD hangars had proved themselves followed in 1945. Fueled aircraft caught fire inside one of five contiguous ZD, 160-foot span, three-and-one-half-inch thick, hangars at Wright Field in Dayton, creating a two-hour inferno so hot that it fused glass. The thin-shell construction, nonetheless, fully contained the fire inside the structure in which it started. Roberts & Schaefer conducted extensive post-fire tests, and were able to repair the structure for less than $50,000.[28] (See Plate 7.) Also in 1945, Roberts & Schaefer built a ZD flight test hangar for General Electric in Schenectady, New York.[29]

Plate 6. Anton Tedesko, Roberts & Schaefer. Hangars for the United States Navy, Patuxent, Maryland. 1942. Courtesy of the Civil Engineering Archives, Princeton University.

Plate 7. Anton Tedesko, Roberts & Schaefer. Hangars for the Army Air Forces, Wright Field. 1943-1945. View of September 1999. Photograph, K.J. Weitze.

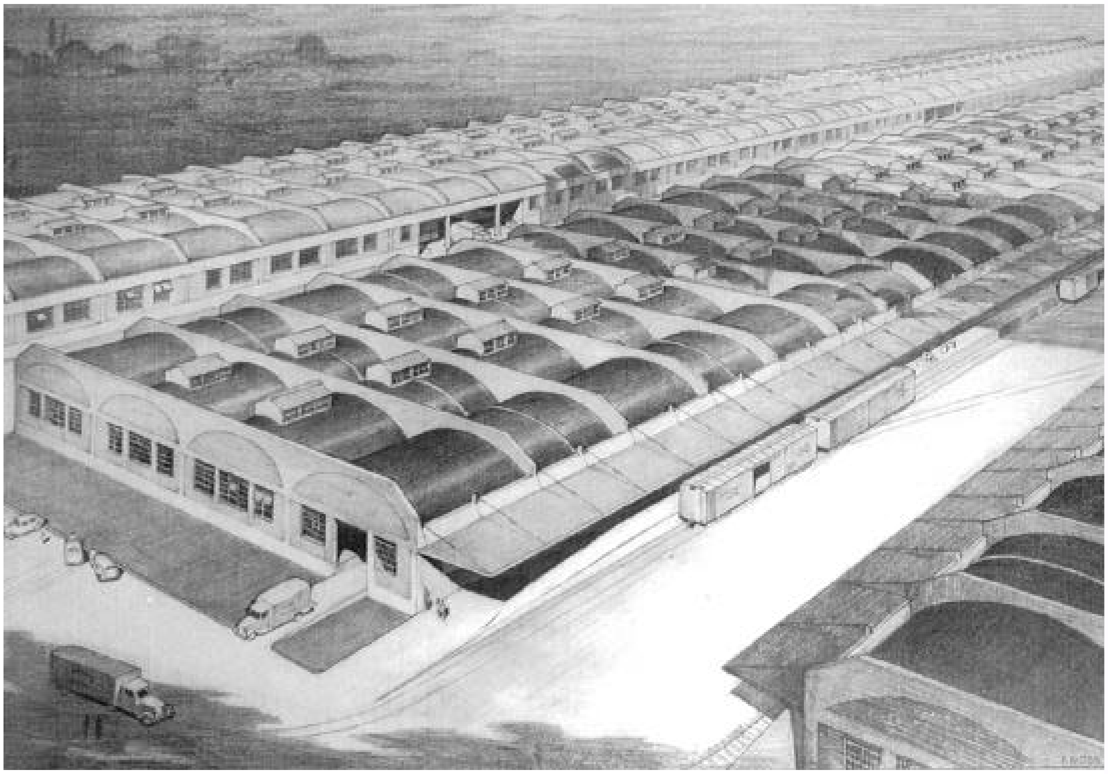

Plate 8. Anton Tedesko, Roberts & Schaefer. Warehouses, United States Army, Columbus, Ohio. 1940. Courtesy of the Civil Engineering Archives, Princeton University.

Prior to the design and erection of the two SAC B-36 hangars at Ellsworth and Loring Air Force Bases in 1948-1949, the longest clear span achieved was the 291-foot span for each of the three Roberts & Schaefer Navy seaplane hangars, built at San Diego and Philadelphia, 1939-1941. Each of these hangars had door openings of 200 feet, as did the three Army Air Corps hangars in Puerto Rico, hangars of slightly smaller dimensions overall.[30] In addition to Tedesko, Roberts & Schaefer engineers Robert Zaborowski and Otto Gruenwald were prominent, and published, spokesmen for the Navy ZD hangars—and soon for those of SAC. Both were Illinois engineers who joined the company in 1941. Zaborowski did take war leave, however, working for the Applied Physics Laboratory at Johns Hopkins University in Baltimore as a supervisor for the selection of materials, designs, and research to develop classified, special Navy ordnance.[31] At the time of the SAC commission in early 1947, the connections between Roberts & Schaefer and the U.S. military were many. The post-World War II situation, in addition to SAC's mission, also focused attention on fireproof construction capable of sustaining as little damage from direct hits as possible. It is unlikely that analysis for atomic blast was overt at this date, although it was immediately known from after-studies of the damage at Hiroshima and Nagasaki that reinforced concrete buildings remained at least as shells in areas where all other structures had vanished. Too, the chief engineer at the Navy's Bureau of Yards and Docks, Arsham Amirikian, was an early advocate of achieving blast-resistant design. Zaborowski's experience working with special weapons for the Navy at the Applied Physics Laboratory during the 1942-1945 period would have further corroborated the desire for reinforced concrete construction. The choice of ZD construction for the first generation SAC B-36 hangar may even have been directly influenced by continuing ties to Roberts & Schaefer's German counterpart, Dyckerhoff & Widmann. During 1947 and early 1948 engineer Franz Dischinger cooperated with the United States Air Force in Europe (USAFE), headquartered in Wiesbadan, to analyze submarine pens in Bremen; to review multiple German reinforced concrete fortifications; and, to design a bunker capable of withstanding a 40-ton bomb. The U.S. Army considered Dischinger one of the top four engineers and technicians—of a group of 160—needed for future American military construction. In February 1948 the U.S. and Britain were actively competing to recruit Dischinger (to the U.S. through

Paperclip), with the Soviets seeking him as well.[32] The SAC B-36 hangar in effect marked a plateau of engineering achievements for the 1930-1947 period, and, looked toward the future.

Tedesko and the Roberts & Schaefer engineers took new strides with the SAC hangars. They changed the designed profile of the hangar from one that had been nearly elliptical with the early 1940s Navy structures to one much closer to a catenary form. The shift allowed the engineers to use more slender supporting ribs, and, as a byproduct of the increasingly sophisticated mathematical knowledge, to achieve a more elegant hangar[33] (Plates 9-11). The SAC hangars at Ellsworth and Loring expanded the previous Roberts & Schaefer clear span by just over 17% to 340 feet. The electrically operated (or "motorized") doors, on railroad trackage, ran across 300 feet at both ends of the hangar. The design increased the door width for entering aircraft by 50%. Inside maximum height also increased, from 80 to 90 feet, allowing work space for the nearly 60-foot tall B-36. Tedesko spaced the strengthening ribs every 25 feet, center to center, with end and even-numbered ribs 20 inches wide, and, odd-numbered ribs 24 inches wide. Even-numbered ribs were each in the middle of a poured section. Roof thickness tapered from six inches at the ribs to five inches, four feet out from the ribs. Wooden timber falsework provided centering and moved on rails, with plans to reuse the expensive and complex falsework repeatedly for successive hangars at an installation. Winch-operated cables as well as tractors pulled and "walked out" the mobile centering, the entire falsework structure called a traveler.[34] Concrete pours required warm, dry weather—which did slow construction, as did a major windstorm of August 1948 that demolished the falsework at Rapid City.[35] Bid price of the SAC hangar at Ellsworth was $1,343,000, or $12.16 per square foot inclusive of utilities. Construction cost as published in the *New York Times* was $1,700,000. Continuing the procedures that had been in place since the first days at Dyckerhoff & Widmann, Roberts & Schaefer built a 12-foot scale model (1:30) of the SAC B-36 hangar for testing at the Fritze Engineering

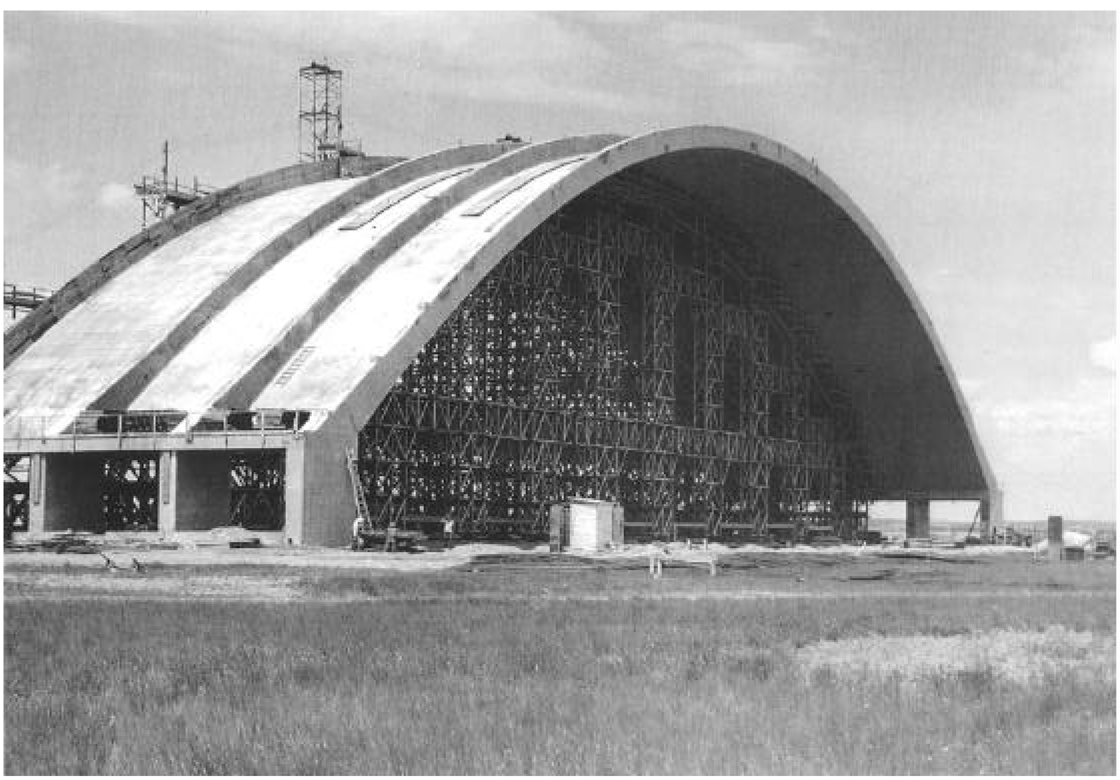

Plate 9. Anton Tedesko, Roberts & Schaefer. Construction, B-36 hangar at Ellsworth Air Force Base, 1948. Courtesy of the Civil Engineering Archives, Princeton University.

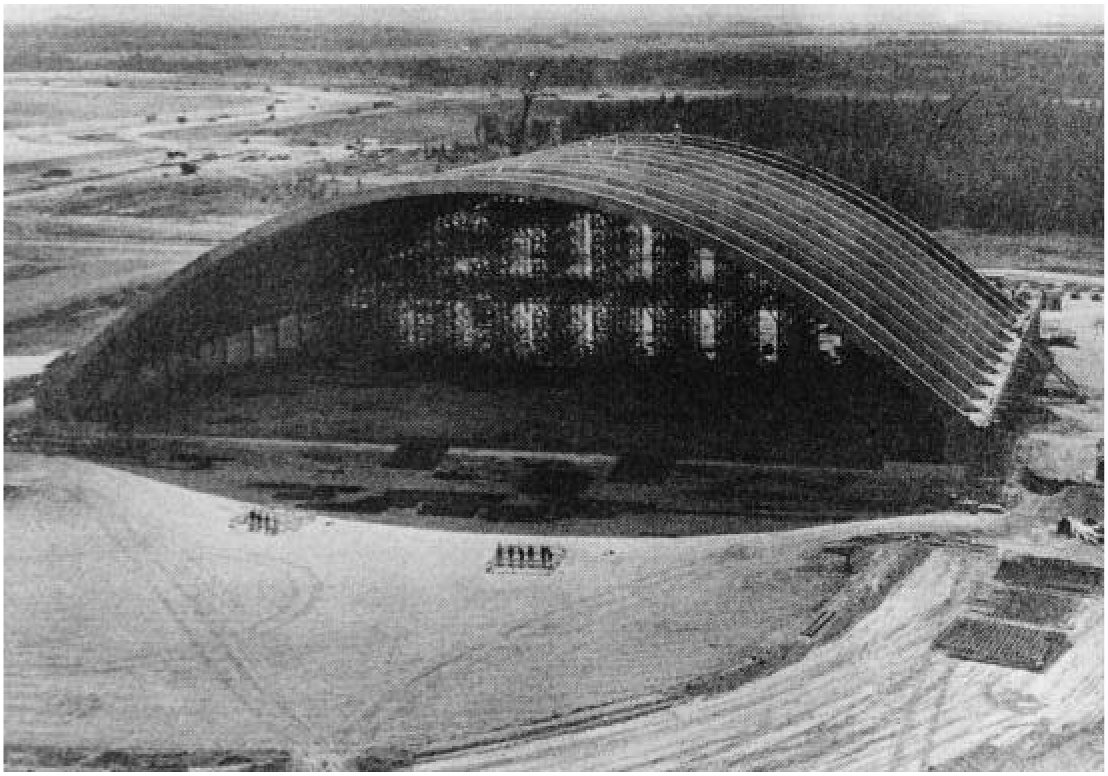

Plate 10. Anton Tedesko, Roberts & Schaefer. Construction, B-36 hangar at Loring Air Force Base, September 1948. Reproduced from *Army Engineers in New England* (1978).

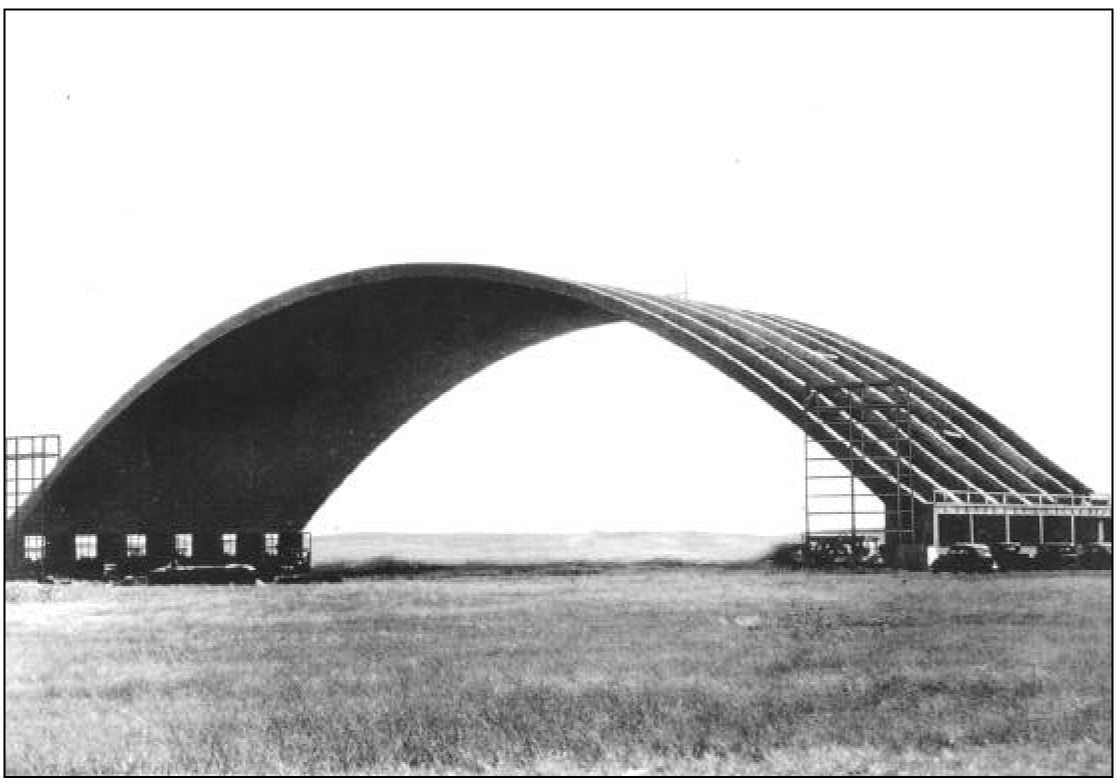

Plate 11. Anton Tedesko, Roberts & Schaefer. Construction, B-36 hangar at Ellsworth Air Force Base. 1948. Courtesy of the Civil Engineering Archives, Princeton University.

Laboratory at Lehigh University. Engineering journals heralded the two SAC hangars throughout 1948 to 1953, including *Civil Engineering*, *Engineering News-Record*, *Journal of the American Concrete Institute*, and *Airports and Air Carriers*[36] (Plate 12). *Reinforced Concrete in Architecture*, an international look at progressive design and engineering published in 1958, also featured the SAC B-36 hangar.

Plate 12. B-36 hangar at Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Thin-shell, reinforced concrete hangars of the early Cold War years also saw advancement for the first time at American civilian airfields. While the two first generation SAC B-36 hangars were in design, Ammann & Whitney—who became competitors of Roberts & Schaefer from the late 1940s forward—completed hangars for American Airlines and TWA at Midway Airport in Chicago (Plates 13-14). Both hangars were double-span structures and were quite conservative. The American Airlines hangar featured a maximum clear span of 257 feet (1947), while the TWA hangar featured a clear span of 270 feet (1948), each smaller than the Navy seaplane hangar in San Diego of 1939-1941. Engineers Othmar Ammann and Charles S. Whitney, like the men at Roberts & Schaefer, were concerned about convincing potential clients of the technology's reasonable cost: for the American Airlines hangar, cost per square foot with utilities was $12.88.[37] Engineers Gruenwald, Molke, and Zaborowski, of Roberts & Schaefer, published cost comparisons for the Ammann & Whitney American Airlines Chicago hangar against their SAC hangar at Ellsworth—with the assumption by both firms that the four hangars in Chicago, South Dakota, and Maine would set the tone of hangar construction both in the U.S. military and at civilian airfields during the 1950s.[38] Swiss engineer Ammann (1879-1965) is best known for his bridge designs in urban New York.[39]

Although SAC did not choose to use the first generation B-36 hangar for its buildout worldwide, primarily due to construction delays and cement shortages, the hangar did see erection in two other guises during 1949-1952. Tedesko designed two hangars for the Ezeiza Airport in Buenos Aires (1949; $2,000,000); a hockey stadium for Quebec (1949: $3,000,000) and a municipal coliseum for Denver

(1951-1952: $2,250,000) (Plates 15-16). The Argentine hangars closely approximated the design, size, and span of the Ellsworth and Loring Air Force Base hangars of 1947-1949, although featured a clear span of only 295 feet. The Quebec and Denver stadia were somewhat more conservative in clear span at 240 and 254 feet, respectively. Not surprisingly, the stadia had a close competitor in a 1950 coliseum designed by Ammann & Whitney in Montgomery, Alabama, with 286-foot span.[40] Roberts & Schaefer designed a final group of seven thin-shell military hangars (each of 160-foot span: $1,750,000 per hangar) during 1951-1956 for the Navy Air Reserve Training (NART) program, with hangars erected in Denver (prototype); Guantanamo Bay, Cuba; Lincoln, Nebraska; Willow Grove, Pennsylvania; Niagara Falls, New York; Camp Lejeune, North Carolina; and Memphis, Tennessee[41] (Plates 17-18).

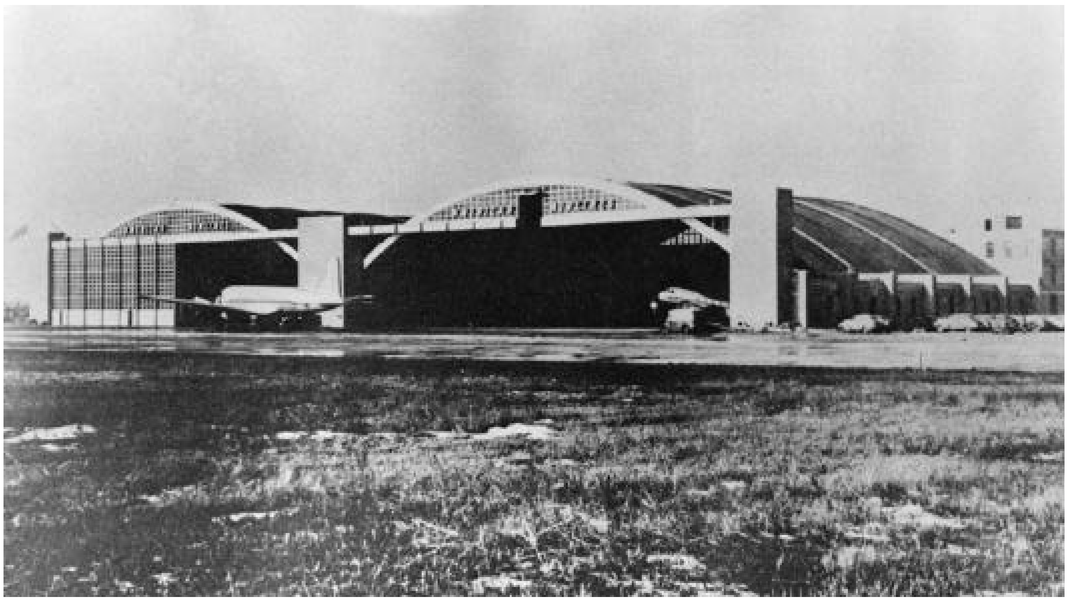

Plate 13. Ammann & Whitney. American Airlines hangar, Midway Airport, Chicago. 1947. Reproduced from *Reinforced Concrete in Architecture* (1958). In use by ATA, September 1999.

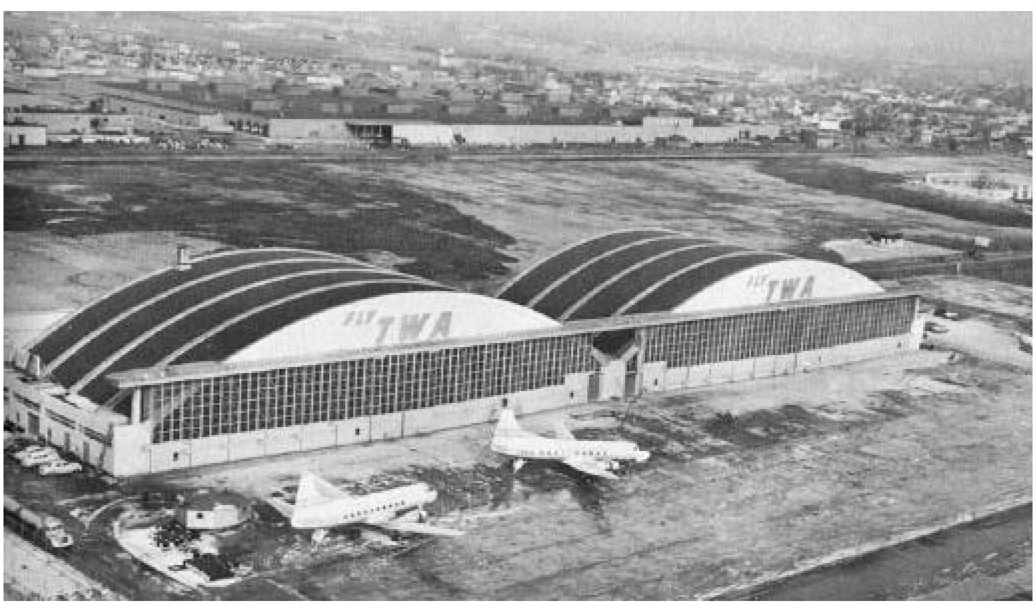

Plate 14. Amman & Whitney. TWA hangar, Midway Airport, Chicago. 1948. Reproduced from *American Building Art of the Twentieth Century* (1961). In use by Southwest Airlines, September 1999.

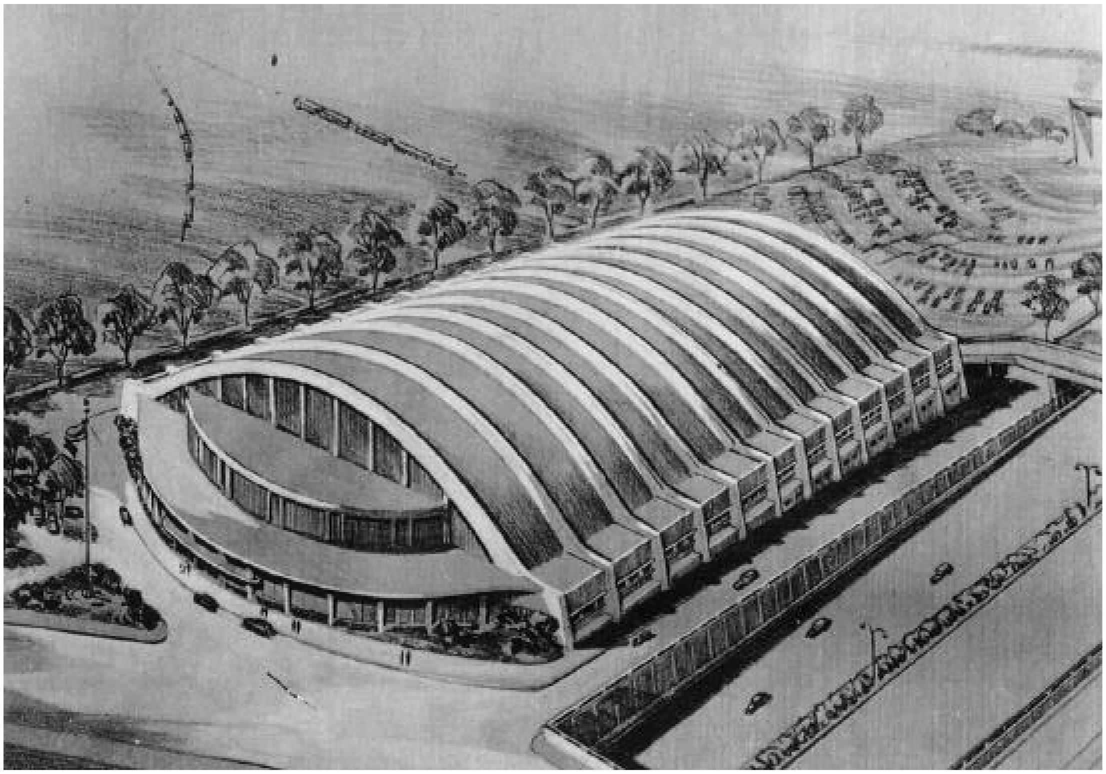

Plate 15. Anton Tedesko, Roberts & Schaefer. Ink wash drawing for the Denver Coliseum. 1951-1952. Courtesy of the Civil Engineering Archives, Princeton University.

Plate 16. View of the Denver Coliseum. View of July 1999. Photograph, K.J. Weitze.

Plate 17. Anton Tedesko, Roberts & Schaefer. Prototype NART hangar, Buckley Field, Denver. 1951. Courtesy of the Civil Engineering Archives, Princeton University.

Plate 18. Anton Tedesko, Roberts & Schaefer. NART hangar, Lincoln, Nebraska. View of July 1999. [Today in use by the Nebraska ANG.] Photograph, K.J. Weitze.

At the close of the Navy hangar program, in 1956-1958, Roberts & Schaefer executed one final set of arched reinforced concrete hangars for the Army Corps of Engineers. The Corps described these hangars as "concrete" and "precast concrete," with clear spans of 220 feet and length of 152 feet (Plates 19-20). Pull-through maintenance hangars, these do derive from the World War II – early Cold War thin-shell hangar, but appear to be an alternate design to an identically sized steel hangar built for joint ADC-SAC use after buildout of the second generation double-cantilever SAC bomber of 1951. The Air Force intended these hangars to accommodate either fighters (such as the F-101B) or B-52 bombers.[42] By the mid-1950s the Air Force commissioned thin-shell barrel arches only rarely—but in at least two cases, with stunning results. At Larson Air Force Base in Moses Lake, Washington, Boeing built a $5.8 million-hangar to accommodate eight B-52s or KC-135 tankers, 1954-1957. Featuring a three-inch thick shell of alternating low- and high-bay barrels, the hangar was 1,068 feet long and 372 feet wide, with clear spans of 217 feet. Seattle engineering firm Worthington & Skilling executed the design.[43] In 1957-1958, Roberts & Schaefer again designed thin-shell construction for the Air Force at Olmsted Air Force Base in Middletown, Pennsylvania, near Harrisburg. Two large warehouses featured ribless shells consisting of 16 units, each measuring 200 by 200 feet.[44] After 1955, Anton Tedesko went on to become a consultant to Air Force headquarters for the next 15-year period, focused on the engineering challenges for domed, reinforced concrete underground launch control centers for the intercontinental ballistic missile (ICBM) and on those for space vehicle launch platforms.[45]

Second Generation Maintenance Hangar for the B-36, B-47, and B-52

SAC selected the thin-shell, reinforced concrete hangar for the B-36 in early 1947, in all probability based upon the known success of the construction technology for World War II Navy hangars; the behavior of the hangar, as-built for the AAF, through an intense fire at Wright-Patterson Air Force Base in 1945; and, the established relationship of Anton Tedesko with the U.S. military through the Roberts & Schaefer office in Washington, D.C. Secondarily, with an awareness that the Soviet Union would soon possess the capability of reaching the American continent through a force of Tu-4s, SAC leadership may have already had some concerns about achieving the structural ability to survive at least traditional bombing with contained damage. SAC, however, could not have predicted the level of post-World War II private sector demands on the cement industry, with the ensuing shortages, nor could the command have comprehended the full impact of immediate post-World War II federal funding cutbacks. With the outbreak of the Korean conflict in mid-1950, a number of planning parameters changed. It was clear by this date that actual erection of the thin-shell B-36 hangar was likely to be time-consuming, without ease of procuring construction materials.

At Loring in May 1948, SAC had anticipated 10 thin-shell hangars, built one after the other—an arrangement that would have accommodated 20 B-36s, two per maintenance hangar. (See Plate 4.) By August 1950, the Loring construction program did not specify the projected number of hangars, but instead recorded that 10 additional B-36s required hangars at an overall estimated facilities cost of five million dollars.[46] While what is immediately noticeable is the 50% reduction in number of bombers to be in maintenance at any one time, what is also pertinent is the lack of enumeration for the planned hangars. Not only had federal funding constrictions pulled in the anticipated infrastructure for the bombers, but the program was being rethought. The thin-shell hangar was not a flexible-use hangar for the B-36: it could accommodate two bombers, and only two bombers, in a nearly rigid manner. In 1950 aircraft were changing, with a need to accommodate not just the B-36, but the B-47 (which entered SAC inventory in late 1951) and in a few years the B-52 (in SAC inventory in mid-1955), with a probable mixed use at some installations. In late 1950 SAC required an "expansible" heavy bomber hangar. With Korea, the command also needed hangars that could go up more like mobilization infrastructure.

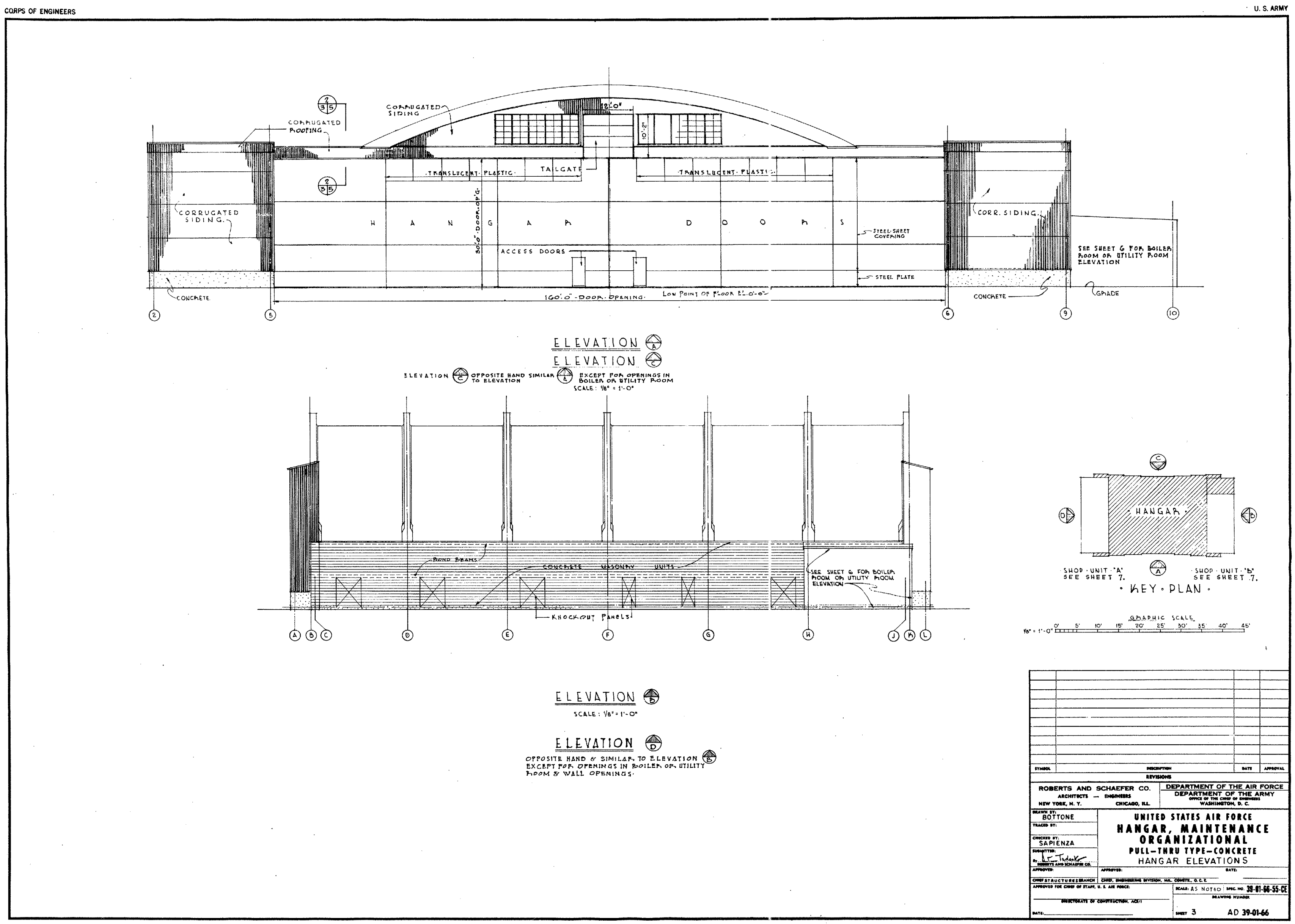

Plate 19. **Anton Tedesko, Roberts & Schaefer. Pull-Thru Hangar, Elevation. 1956-1958. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

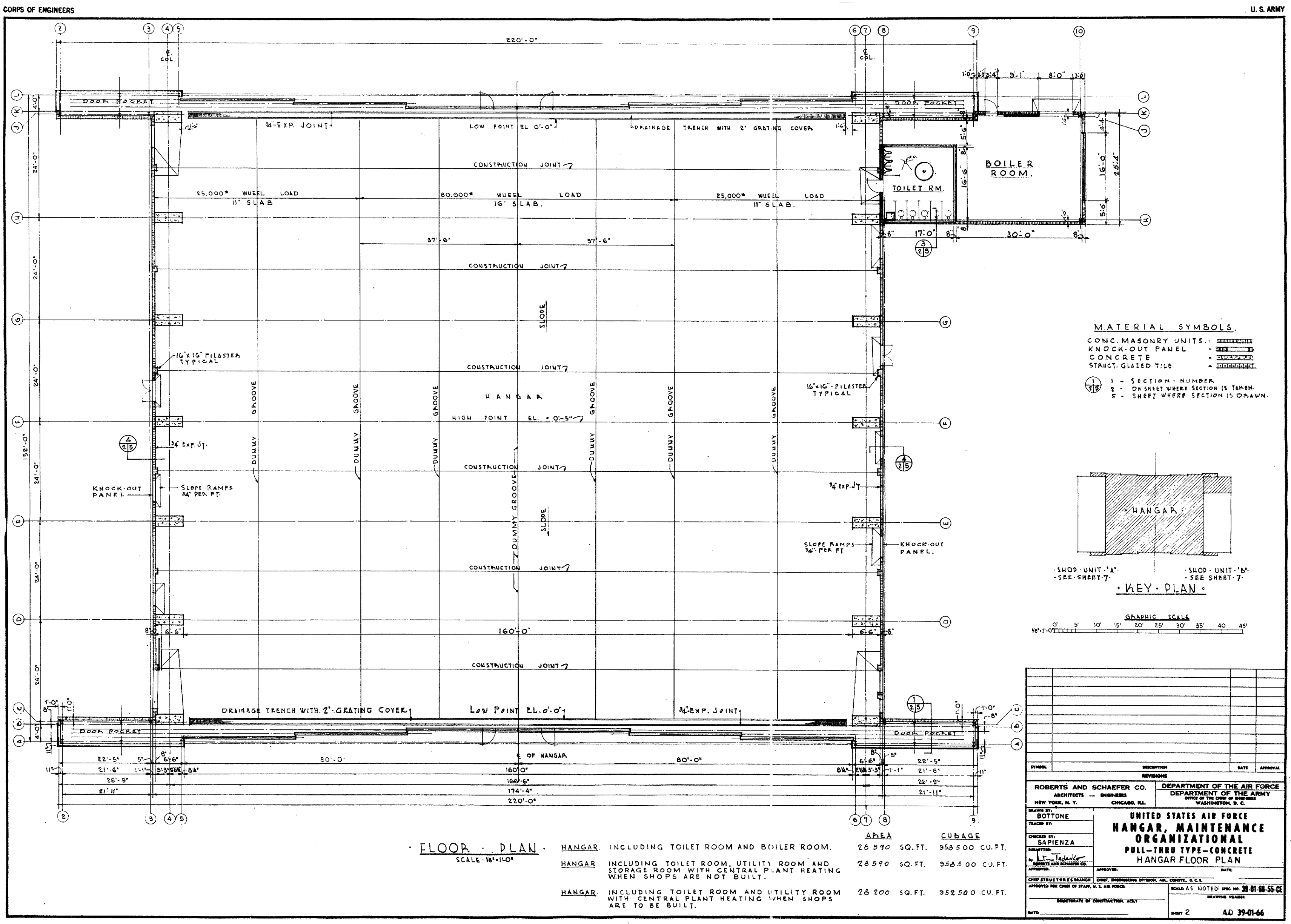

Plate 20. Anton Tedesko, Roberts & Schaefer. Pull-Thru Hangar, Plan. 1956-1958. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.

As of at least the autumn of 1950, SAC had developed other plans for the program of B-36 maintenance hangars it needed across the U.S., and at selected leased bases internationally. The command turned to a steel double-cantilever hangar, rejecting further buildout in reinforced concrete. The source of this shift, as important as it is, remains only partially uncovered. As of the existing research, analysis suggests that the War Department—and subsequently, the Air Force, at the Air Staff level—had architectural-engineering consultants addressing key structures problems continuously from 1943 into at least the 1970s. As an example, in 1943-1944 the Chemical Warfare Service in conjunction with the National Research Defense Committee (NDRC) gathered together two recently immigrated German architects, Eric Mendelsohn and Konrad Wachsmann, and a Czech architect, Antonin Raymond, with appropriate building experience in Japan, to design, with exacting supporting specifications, German and Japan incendiary test structures at Dugway Proving Ground in Utah, and at the Air Proving Ground associated with Eglin Field in Florida.[47] One of these men, Wachsmann, in association with another expatriate, Paul Weidlinger, developed and patented a system called the mobilar truss in 1944-1945. The two engineers proposed that the truss be used as a cantilever frame composed of steel tubes connected by hinged joints, arranged in a two-dimensional grid of shallow Warren trusses tied together by struts in the horizontal plane. Wachsmann and Weidlinger proposed the cantilevered frame to extend outwards in four directions from two centered steel trussed bents.[48] At the outset of 1954, the office of the Air Force Assistant Chief of Staff, Installations, documented that Dr. Wachsmann was just completing a contract "for an unusual hangar design," for which he had executed a set of drawings, a report, and a model.[49]

Like Wachsmann and Tedesko, Weidlinger worked extensively for the U.S. military, especially in an advisory capacity at the uppermost levels. Hungarian Paul Weidlinger had arrived in the U.S., via Bolivia, in 1943. As an engineer of international reputation, Weidlinger pursued both steel and reinforced concrete structural design—not unlike Anton Tedesko at this same time. He published a long article in *Pencil Points* in August 1943 analyzing reinforced concrete structural systems,[50] and as of 1949 the New York and Princeton firm Weidlinger Associates, Inc. (WAI) began its international rise as one of the undisputed leaders in designing long-span steel structures—most notably for airports; above and below ground structures hardened for conventional and nuclear blast; and computer analysis of structures' ability to resist blast. Paul Weidlinger worked with Raymond & Rado (a partnership of Antonin Raymond's in the 1950s, 1960s, and 1970s) for comprehensive services in the design and engineering of Lajes Air Force Base in the Azores during the middle 1950s, a project in which Roberts & Schaefer was also involved significantly. WAI undertook structural work with Burns & Roe for the Bomarc launcher shelter in 1957; an analysis of limits for steel blast-resistant aircraft shelters for RAND also in 1957; prototypical design of a nuclear blast resistant alert shelter for SAC's B-58 in 1959; blast analysis for SAC's control center at Offutt in 1961; numerous analyses for the Defense Nuclear Agency (DNA)—the successor to the Armed Forces Special Weapons Project (AFSWP)—during the 1970s and 1980s; multiple assignments for hardened air defense command and control structures at U.S. overseas bases during the Reagan years; and, post-Cold War, structural evaluations related to nuclear blast effects for Russian storage facilities, as well as for the Peacekeeper Rail Garrison alert shelter.[51]

The Wachsmann and Weidlinger design of 1944-1945 for a spaceframe cantilever hangar is the likely source for the steel double-cantilever hangar that SAC selected as its second generation maintenance hangar for its large bombers of the early-to-middle 1950s. Actual evolution toward the double-cantilever hangar of 1951, a project of the Kuljian Corporation in Philadelphia, is, however, clouded.

Both military and civilian clients for the wide-span hangar of the late 1940s typically considered design solutions in reinforced concrete *and* in steel. First choices, as exemplified by the Ellsworth and Loring B-36 hangars, and by the American and TWA hangars at Midway Airport in Chicago, were reinforced concrete. Yet even as early as 1947, the military had commissioned at least one wide-span steel arch hangar: the electronics test hangar for the Navy at Patuxent, Maryland. A 300-foot hingeless, welded truss arch structure, the hangar was the design of the Navy chief of engineering, Arsham Amirikian.[52] By 1949, a prototypical hinged arch steel hangar had also seen acceptance and was in construction for the New York Port Authority at the New York International Airport in Queens (Idlewild). Perhaps not surprisingly, this hangar was a Roberts & Schaefer design. While the Port Authority commissioned the project as set of two contiguous hangars, the Authority augmented its original intents with a third contiguous structure (Plate 21). Achieved clear span for each of the three hangars was 300 feet, with an interior centerline height of 75 feet as well as front and rear motorized, side-panel doors. The nearly six million dollar triple-hangar drew heavily upon the basic achievements of the B-36 hangar of 1947, yet featured a slightly shorter clear span and interior height. Engineering and architectural journals published analyses of the New York triple-hangar, considering it to be the first example of the initial phase in what became the rapid evolution of steel arched and cantilevered wide-span hangars during the 1950s.[53] Of note, here, the New York hangars accommodated civilian aircraft that did not approach the length of the B-36 until 1960, nor achieve its wing span. The B-36 could have used these hangars (width, length, and height)—but only allowing a single plane per hangar (three bombers total). SAC's double-cantilever hangar of 1950-1951 immediately carried the progress of wide-span hangars to its next design plateau.

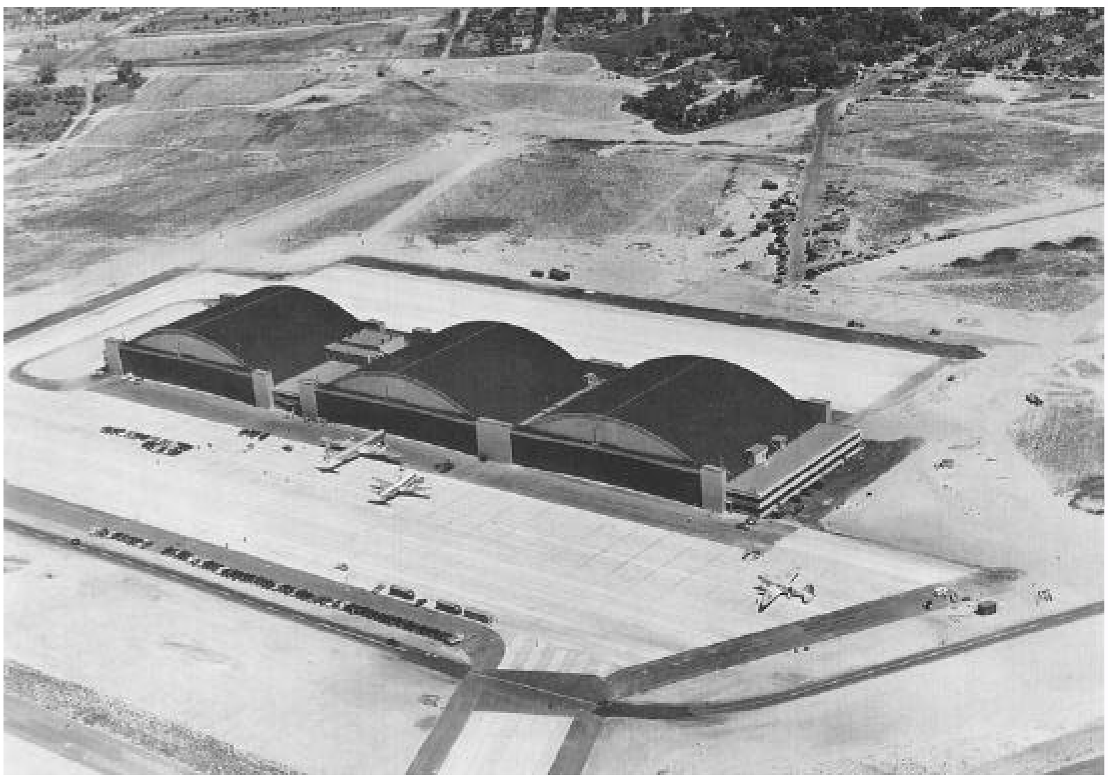

Plate 21. Anton Tedesko, Roberts & Schaefer. Hangars, New York Port Authority, Idlewild Airport. 1949. Courtesy of the Civil Engineering Archives, Princeton University.

The Architectural and Engineering Division of the Air Force Directorate of Installations does not mention the SAC double-cantilever hangar in its written activities summaries until the start of 1953.[54] Yet signed drawings for a version of the hangar exist as of January-February 1951, with one double-cantilever structure under construction by April. A revised version of the initial hangar exists as of late August 1951, with a second transitional double-cantilever hangar under construction by autumn. The final, adopted programmatic double-cantilever hangar is in design as of October 1951, with Air Force buildout underway in 1952. During the hiatus between 1949 and 1952, SAC authorized design and construction of wing hangars by Luria Engineering. After the second generation SAC bomber maintenance hangar was in place, such docks would augment the hangar across Air Force installations, but during the early 1950s SAC intended that the structures literally function in lieu of a more permanent maintenance hangar.[55] The Washington, D.C., engineering firm of Mills & Petticord—who had handled a variety of standard structures for the Air Force in the late 1940s—is the firm responsible for the January-February 1951 design for a double-cantilever hangar. The Mills & Petticord master drawings for this structure no longer exist, but are referenced in a U.S. Army Corps of Engineers card file and in a single drawing by Mills & Petticord for the revised design of August[56] (Plate 22). What is unknown is whether or not the Air Force provided Mills & Petticord with design and engineering parameters for the hangar. The latter situation is the case for the final double-cantilever hangar of October.

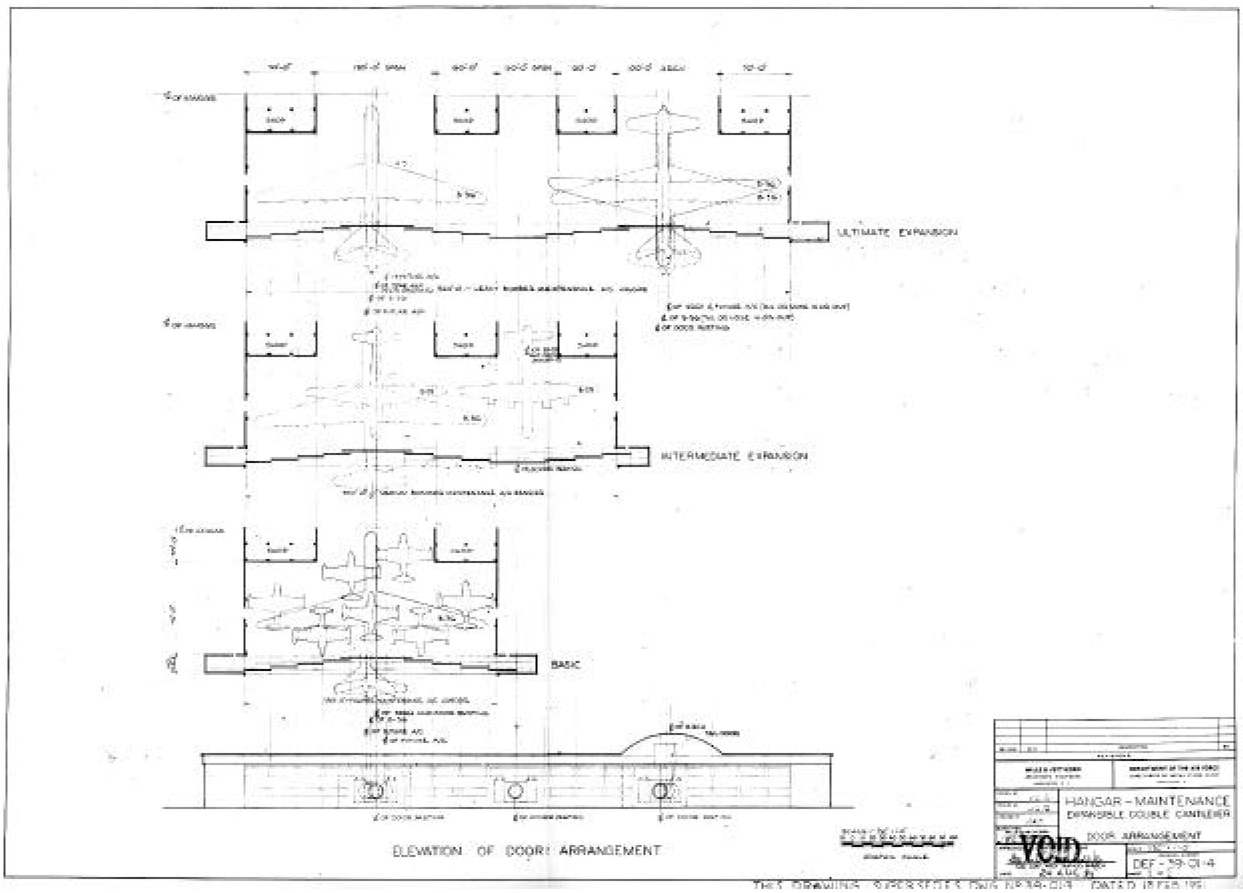

Plate 22. Mills & Petticord. Double-Cantilever Hangar, Plan and Elevation. August 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.

Wachsmann and Weidlinger's double-cantilever hangar was futuristic for 1945-1950, with a then-unachievable, planned cantilever of 192 feet.[57] The Mills & Petticord revised hangar of August 1951 featured pairs of trussed transverse cantilevers of 92 feet, projecting toward the front and rear of the hangar from the edges of 70- and 60-foot square steel-frame, reinforced concrete encased, shop towers centered on the interior of the side walls and at intervals across the center of the hangar in the expanded versions. Straight-chord trusses of 70 and 60 feet spanned between the cantilevered trusses longitudinally, front to rear, with longitudinal trussed arches of either 100 or 120 feet carried on the 92-foot cantilevered transverse trusses to allow for the height of SAC bombers. The arched trusses projected above the flat exterior roofline of the hangar, allowing for about a 60-foot interior maximum height. The hangar featured motorized doors on two facades, expansible for three basic sizes, with the January-February series slightly smaller in footprint than those of the August series. The three versions of the hangar in August, unexpanded, were 250 by 250 feet, 350 by 250 feet, and 600 by 250 feet in footprint. The expansible versions were of slightly different size to allow future additional construction with a minimum of actual modification required for the existing hangar (for example, the medium bomber hangar was 370 by 250 feet and the heavy bomber hangar was 540 by 250 feet). At its largest size, the Mills & Petticord August 1951 hangar could handle six B-36s, and could be expanded.[58] This first design for the second generation SAC maintenance hangar, then, was already a marked improvement in aircraft capacity over the Roberts & Schaefer thin-shell hangar of 1947. It also planned for a more flexible use and allowed for changing aircraft dimensions.

The original Mills & Petticord SAC maintenance hangar of January-February 1951—for which no signed Mills & Petticord master drawings are extant—is annotated by dimension for each of the basic, medium bomber (B-47), and heavy bomber (B-36) versions in the Corps card file for superceded definitive drawings. The dimensions of the Mills & Petticord expansible medium bomber hangar of early 1951 are matched in a double-cantilever hangar under construction at Kirtland Air Force Base in late April 1951. The existing drawings at Kirtland are signed by the responsible site contractor for the hangar, Pacific Iron and Steel of Los Angeles. Both the existing hangar itself, and the April 1951 plans, sections, and elevations, indicate that Mills & Petticord's original double-cantilever design approached the cantilever idea with more conservatism than in their final version of August. The Kirtland SAC hangar is a double-cantilever design, employing paired transverse trussed bents, with longitudinal straight-chord trusses and trussed arches. The three interior shop towers are 60 by 100 feet, supporting transverse cantilevers of only 66.5 feet. One side of the hangar is further enclosed for lean-to shops. The Kirtland double-cantilever hangar, built for the B-47, is the first known example of the SAC steel double-cantilever hangar anywhere, and may be unique[59] (Plates 23-24).

As of late April also, however, SAC authorized a second double-cantilever hangar for one of its bases beginning construction in French Morocco: Nouasseur. The Nouasseur hangar is documented by its footprint on maps of late 1951 as either a B-36 hangar (580 by 244 feet) or an expansible B-36 hangar (560 by 244 feet), and had foundations under construction by late autumn. The Air Force inspection report of December describes this structure as "the Pacific Iron and Steel Company Hangar Building," indicating that it was likely at least *planned* from one of the Mills & Petticord designs.[60] The Nouasseur SAC hangar in fact may be either the Mills & Petticord hangar of January-February 1951, the firm's hangar of August 1951, or, one of the first built from the final Kuljian Corporation designs for the SAC bomber maintenance hangar—if SAC delayed construction past the foundations until early in 1952. The first six B-36s arrived at Sidi Slimane, another SAC base built in French Morocco, in early December 1951, completing their 5,000-mile training flight from Carswell Air Force Base in Fort Worth, Texas. Of note, both Kirtland and Nouasseur had atomic bomb storage sites, Q Areas, at their installations (Plates 25-26).

Just as SAC had chosen not to follow through with the Roberts & Schaefer thin-shell maintenance hangar for the B-36 designed by Tedesko, the command aborted the program for the Mills & Petticord steel double-cantilever bomber maintenance hangar of 1951. In September 1951, immediately after Mills & Petticord submitted its August revisions for the double-cantilever hangar, the Army Corps of Engineers contacted Kuljian Corporation in Philadelphia—requesting that the firm design a double-cantilever hangar for SAC. Circumstances for the change from Mills & Petticord to Kuljian, like the partially verified but still illusive reference to Konrad Wachsmann, are not fully conclusive. As remembered by Arthur Kuljian in 1999, Kuljian engineering had sent one of their partners, Bob Lundgren, to the Corps of Engineers office in Washington, D.C., to introduce the Philadelphia firm to the Corps and to indicate that Kuljian was interested in being considered for military work. The call on the Corps was of the courtesy type, not anticipated to lead to any immediate opportunities. On Friday of this same week, the Corps telephoned Kuljian's office in Philadelphia, and asked to meet with a Kuljian team the following Monday in Washington, D.C. Another Kuljian partner, Jim Cherry, cut his weekend short at the New Jersey shore to join Bob Lundgren in Washington. The contract was signed that same day. As the Corps explained to Kuljian, the construction agency had called off negotiations with another firm and needed an immediate response to the engineering task at hand. All of this was unusual: as Arthur Kuljian noted, there had not been a competition for the double-cantilever bomber hangar, and, as they had been contacted from what was essentially a cold marketing call, the Corps did not have a list of engineering firms for the job from which it could turn to the next candidate.[61]

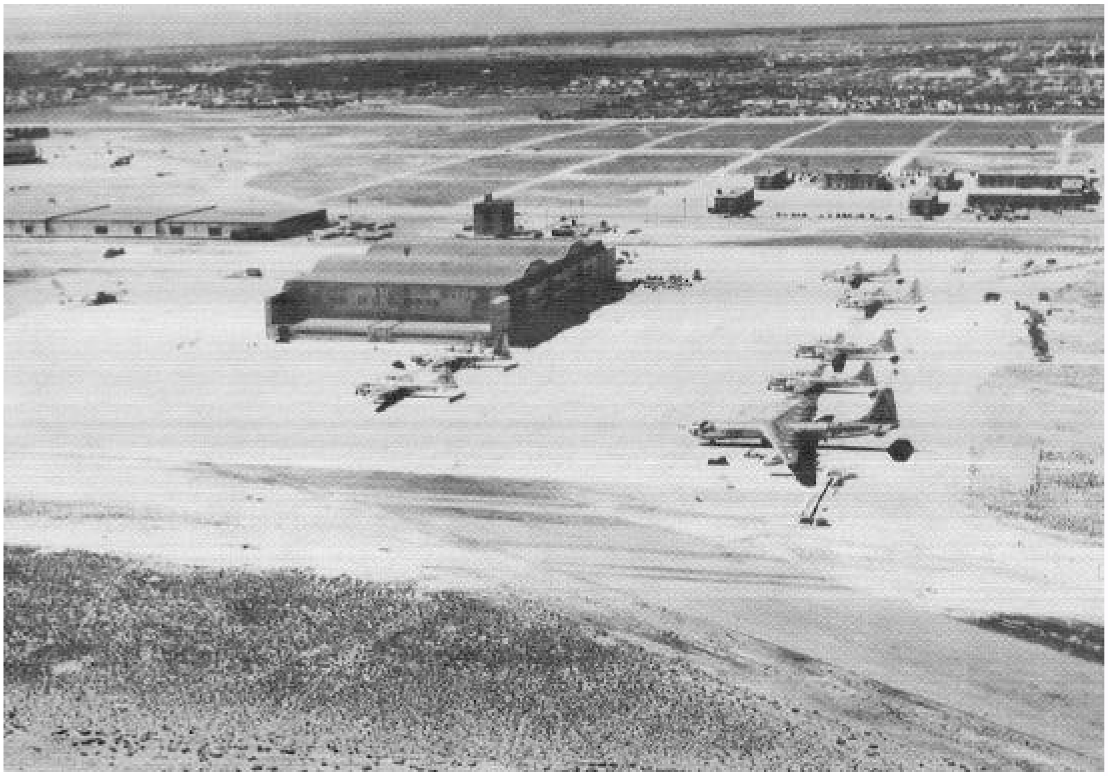

Plate 23. Mills & Petticord. Double-cantilever hangar at Kirtland Air Force Base. View of 1952. Courtesy of the Air Force Historical Research Agency.

Plate 24. Mills & Petticord. Double-cantilever hangar at Kirtland Air Force Base. View of 1998. Photograph, K.J. Weitze.

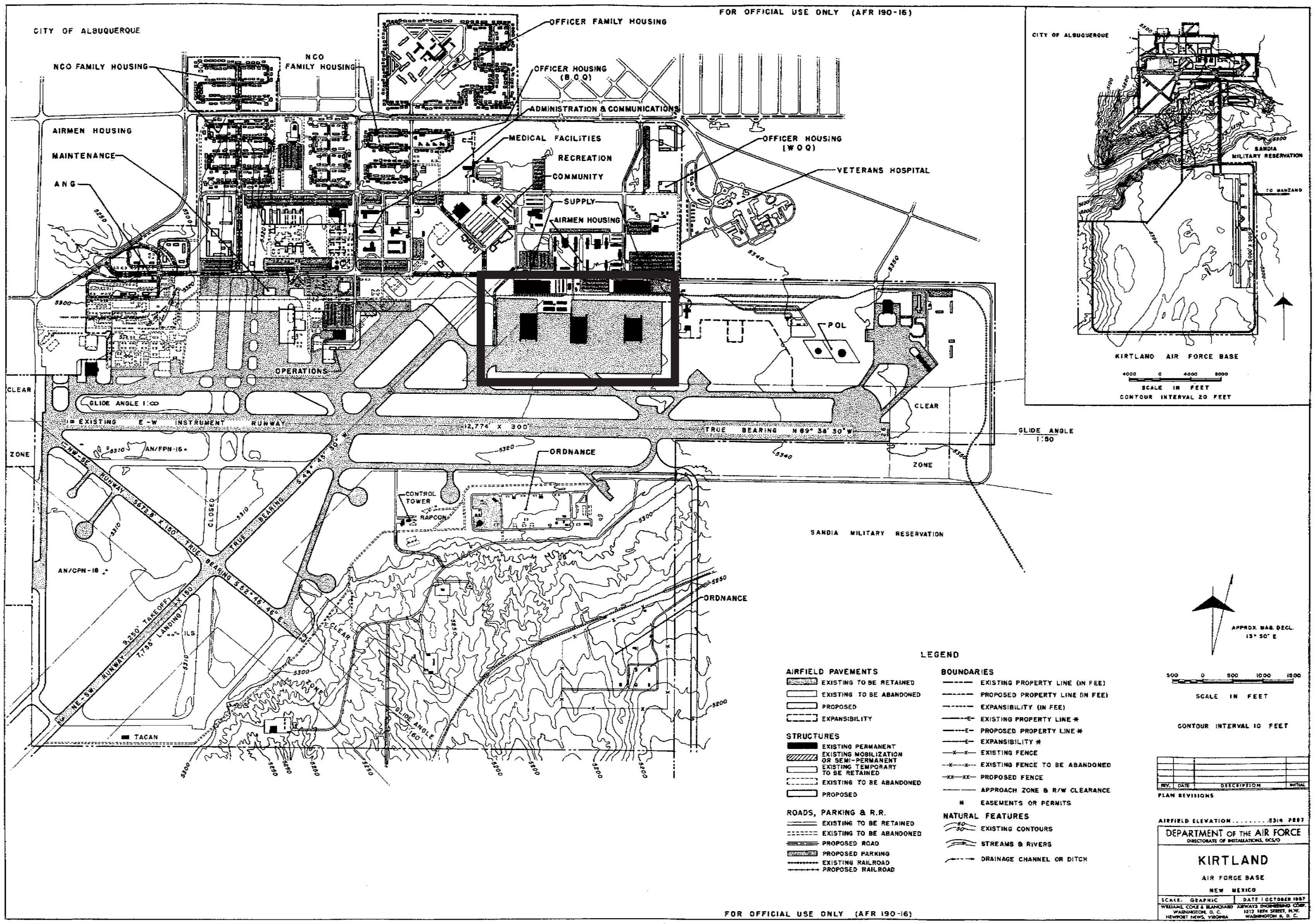

Plate 25. **Center grouping of three double-cantilever hangars. Two Kuljian hangars bracket the MIlls & Petticord hangar of early 1951. Kirtland Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

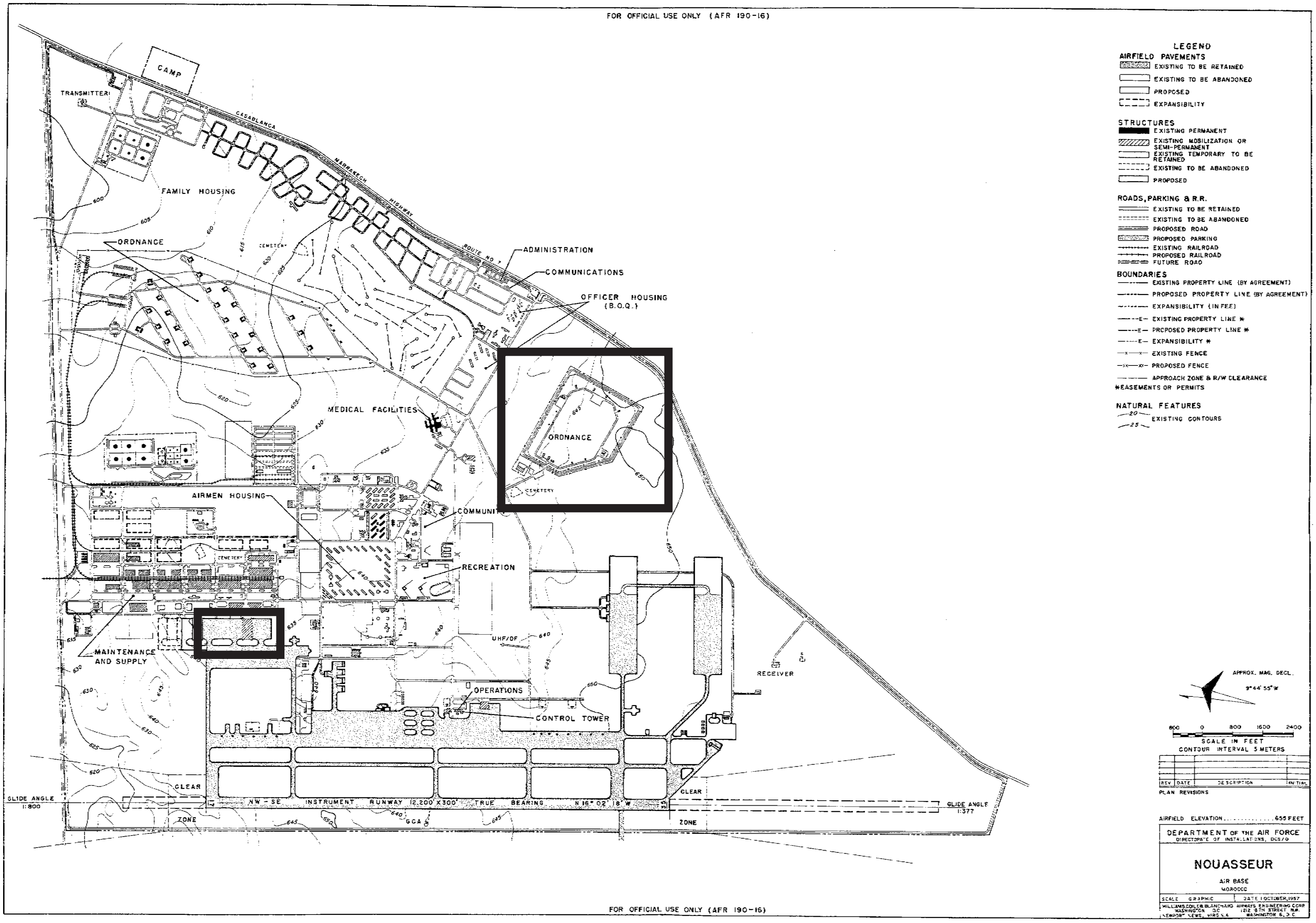

Plate 26. **Double-cantilever hangar of 1951 or 1952, left. Q Area, right.**
Nouasseur Air Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.

The Corps (in essence for SAC) requested the programmatic hangar explicitly: it was to be a steel double-cantilever hangar; it was to come in three sizes and have expansible versions. The SAC bomber hangar, in its five versions, was annotated as HB (heavy bomber for the B-36), MB (medium bomber for the B-47), X-1 (basic version, expansible), X-2 (intermediate—medium bomber—expansible), and X-3 (ultimate—heavy bomber—expansible). Kuljian was to design a hangar for different temperature zones; for earthquake conditions; with three alternate roof loading specifications (for 20, 30, and 40 pounds per square foot), and exterior sheathing in cement asbestos fluted paneling ("protected metal siding"); and accommodating heating systems for coal, oil, or gas. The Corps specified that the cantilever system was to spring from interior shop towers (also referred to as "columns" in published engineering articles). As submitted the Kuljian designs had footprint dimensions matching those of the August 1951 Mills & Petticord designs precisely, and had interior cantilevered transverse trusses. The straight-chord trusses and the arched trusses were also all of nearly an exact match—strongly suggesting that these items, too, were in the specifications provided to Kuljian by the Corps.[62] Kuljian issued its first drawings for the SAC hangar on 28 September 1951, almost exactly a month from the date of the second Mills & Petticord submittal and the cutoff of the Mills & Petticord contract. Arthur Kuljian's handwritten note in the firm's book of project schedules for drawings noted: "Drawings, designs, specs all done in record time of 15 weeks." Kuljian completed its issuance of the initial drawings series—more than 200 drawings—on 7 December 1951.[63] As the project moved forward each of the five hangars in the double-cantilever series would require 60 to 65 individual drawings[64] (Plates 27-28).

Dr. Harry A. Kuljian, Arthur Kuljian's father, had founded Kuljian Corporation in 1930 as an engineering firm primarily handling industrial and power generation projects. Dr. Kuljian had immigrated to the U.S. from Turkey as a teenager just before World War I, after working there in a textile factory since age eight. Continuing work in the U.S., and attending high school at night, Dr. Kuljian entered the Massachusetts Institute of Technology (MIT). Subsequently he worked as an engineer for two power companies and finally American Viscose, a company manufacturing rayon. When Dr. Kuljian went into business for himself, he leveraged his expertise in power plant and textile industry engineering to design captive power generation for eight rayon production sites in the U.S. and Canada. During World War II, the Navy hired Kuljian Corporation to design power plants at multiple Naval yards on the East Coast and in Subic Bay, in the Philippines. The firm undertook some work in regional transportation engineering as of 1949-1950, inclusive of engineering for the expansion of the Philadelphia airport. Handled by Kuljian's chief engineer, Walter Fasshauer, the SAC double-cantilever assignment of 1951 was the firm's first work for the Air Force. Of German descent, Fasshauer had been with Kuljian since 1934. Kuljian Corporation handled a significant amount of international work, particularly in the Middle and Far East, from its early years forward. By 1958, the firm expanded to fully 75 percent of its work overseas, with large foreign government projects in India, Pakistan, Iran, Iraq, and Korea, and inclusive of a 10,000-foot runway for the airport in Kurachi, Pakistan during 1958-1960.[65]

The Kuljians were active members of the Armenian community, and as such Dr. Kuljian knew Arsham Amirikian (1899-1990), the brilliant, highly innovative Armenian engineer who served as the chief of engineering for the Navy's Bureau of Yards and Docks. Amirikian had arrived in the U.S. just after World War I, and after a degree from Cornell worked as a structural draftsman for a series of steel fabrication shops. His career with the Navy ran from the late 1920s into the early 1970s. An interesting coincidence, perhaps, both Arsham Amirikian and Anton Tedesko matriculated with their doctorates late in their lives at the Institute of Technology in Vienna—while they continued their professions in the U.S. Dr. Amirikian also retired in the Air Force Reserves. Among his most noteworthy engineering accomplishments had been the design of the Navy's wood dirigible hangar of World War II (for which Tedesko had designed a steel prototype for the Naval Air Station in Lakehurst, New Jersey); the design of special structures; and the early analysis of engineering for nuclear blast.[66] And, immediately prior to the first designs for the double-cantilever hangar, Amirikian had engineered the Navy's 300-foot steel arch hangar at Patuxent. With the active role of the engineering division of the Navy Yards and Docks in the

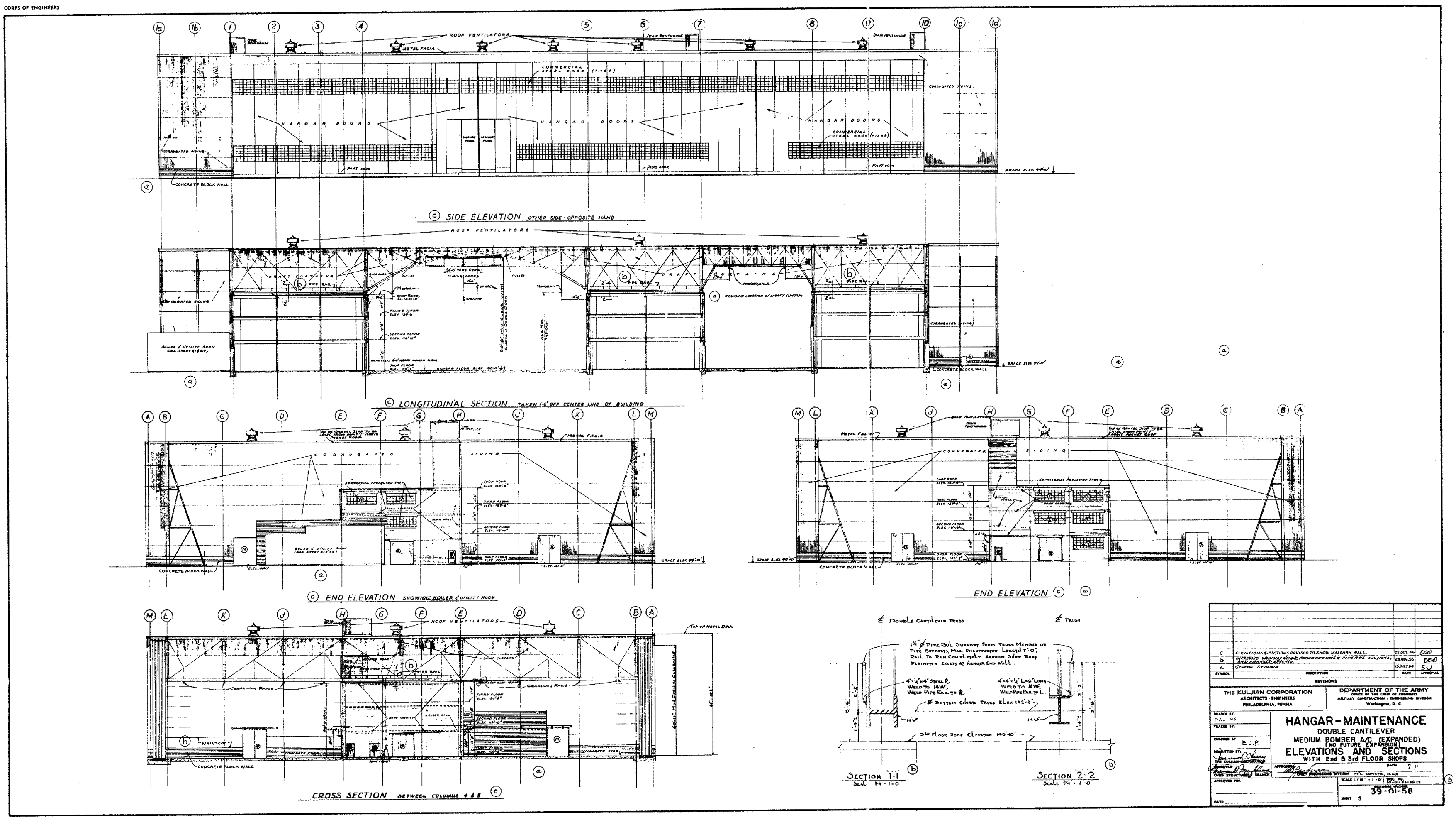

Plate 27. **Kuljian Corporation. Double-Cantilever Medium Bomber Hangar, Elevation. December 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

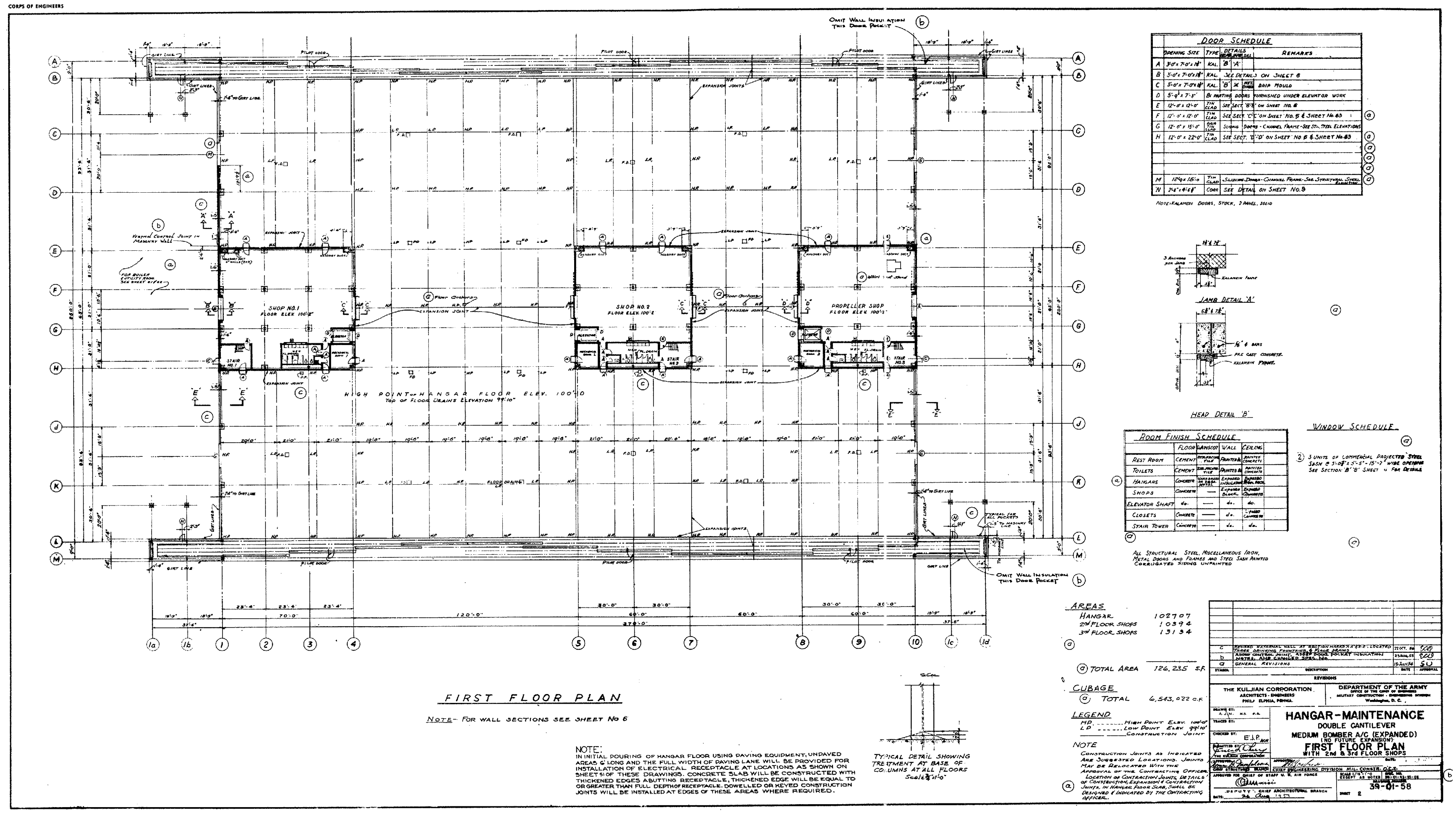

Plate 28. **Kuljian Corporation. Double-Cantilever Medium Bomber Hangar, Plan. December 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

construction efforts of the Air Force in the late 1940s and early 1950s, and with the first B-36 thin-shell hangars at Ellsworth and Loring strongly linked to Navy precedents, it is probable that Amirikian may have played a role in the Corps' call to Kuljian.

SAC built approximately 50 to 60 of its second generation bomber maintenance hangars at approximately 46 Air Force installations in the U.S. and internationally between 1952 and 1955[67] (Plates 29-38). (See Table 2, chapter 3.) The hangar effectively came in three sizes, with the intermediate and largest structures also possible in an expansible version. The smallest hangar could accommodate two B-36s, and was sometimes referred to as a single-bay, eight-panel structure. The intermediate hangar could accommodate four B-36s, and was alternately designated a two-bay, 11-panel structure. The largest hangar could accommodate six B-36s, referenced as a three-bay, 16-panel structure. "Bays" were configured based on the interior trussed archways, while "panels" referred to the number of motorized door panels running on railroad track across the front and rear facades. Although the hangar presented the appearance of a pull-through structure, it was intended to be entered from each side by three bombers, with either aircraft noses or tails left projecting through canvas-sheathed openings in the appropriate panels.

Plate 29. Kuljian Corporation. Heavy bomber (three-bay) double-cantilever hangar at the former Loring Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

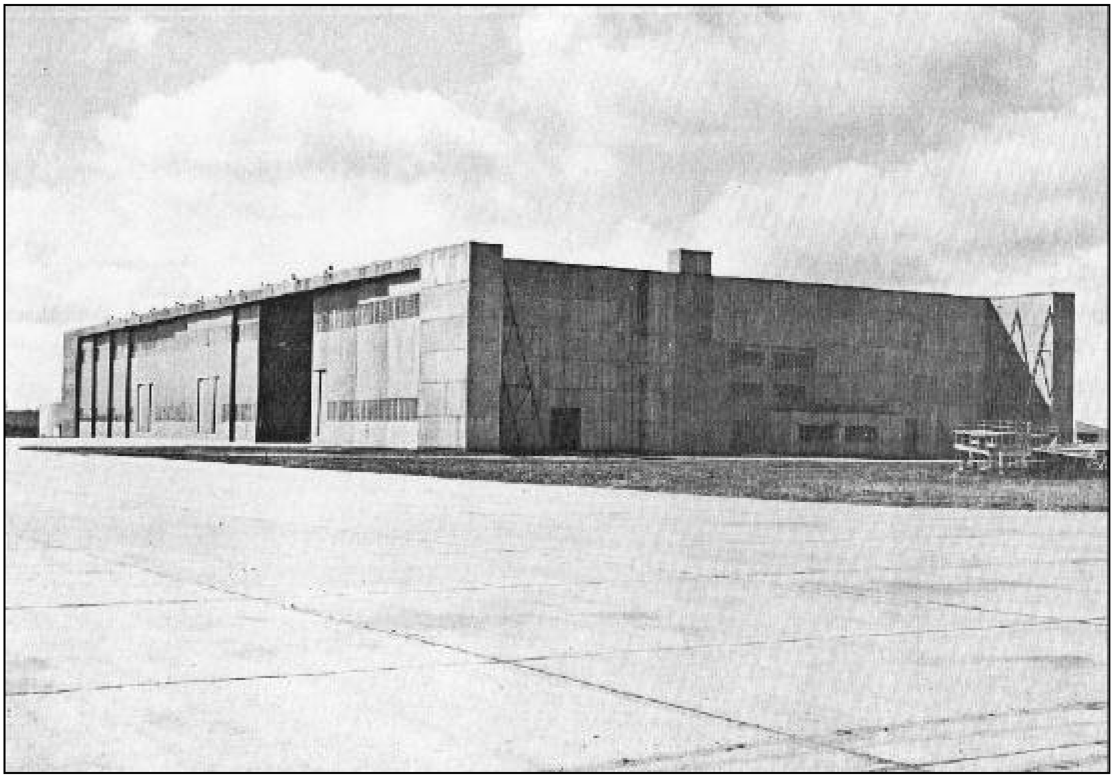

Plate 30. Kuljian Corporation. Heavy bomber (three-bay) double-cantilever hangar at Carswell Air Force Base. View of the middle 1950s. Courtesy of the Kuljian Corporation.

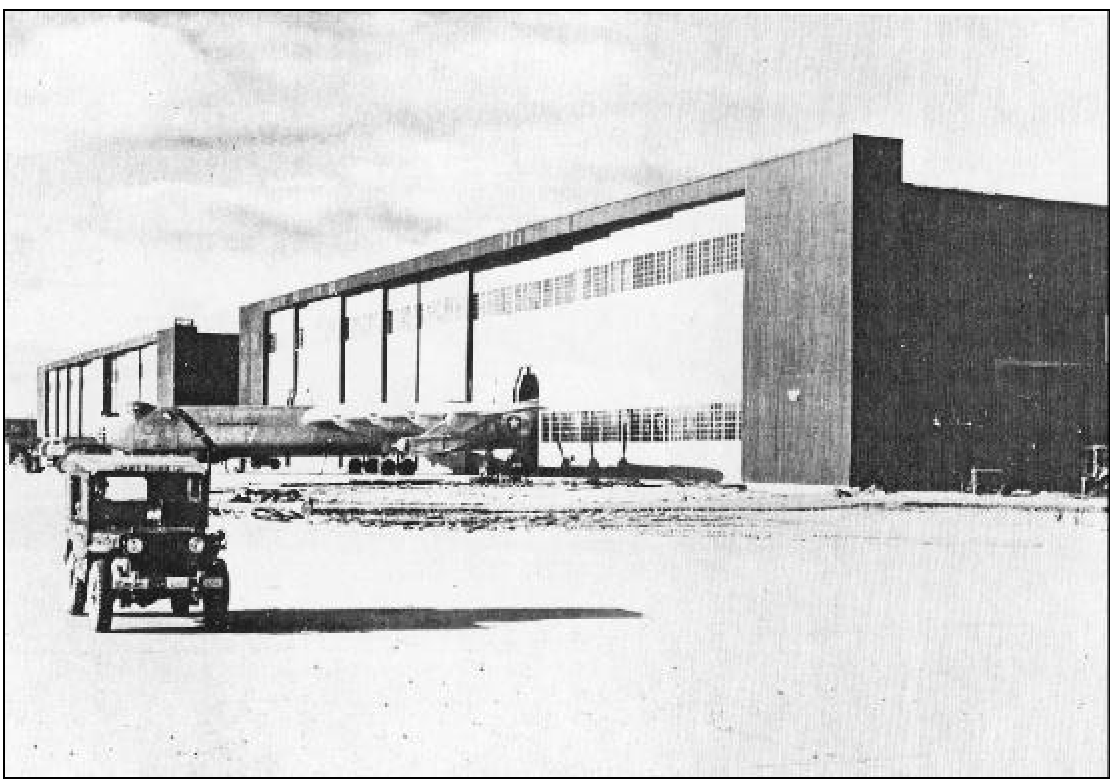

Plate 31. Kuljian Corporation. Paired, medium bomber (two-bay) double-cantilever hangars at Goose Bay Air Base. View of the middle 1950s. Courtesy of the Kuljian Corporation.

Plate 32. Kuljian Corporation. Heavy bomber (three-bay) double-cantilever hangar at the former Castle Air Force Base. View of 1998. Photograph, K.J. Weitze.

Plate 33. Kuljian Corporation. Heavy bomber (three-bay) double-cantilever hangar at the former Walker Air Force Base. View of 1998. Photograph, K.J. Weitze.

Plate 34. Kuljian Corporation. Medium bomber (two-bay) double-cantilever hangar at the former Schilling Air Force Base. View of 1999. Photograph, K.J. Weitze.

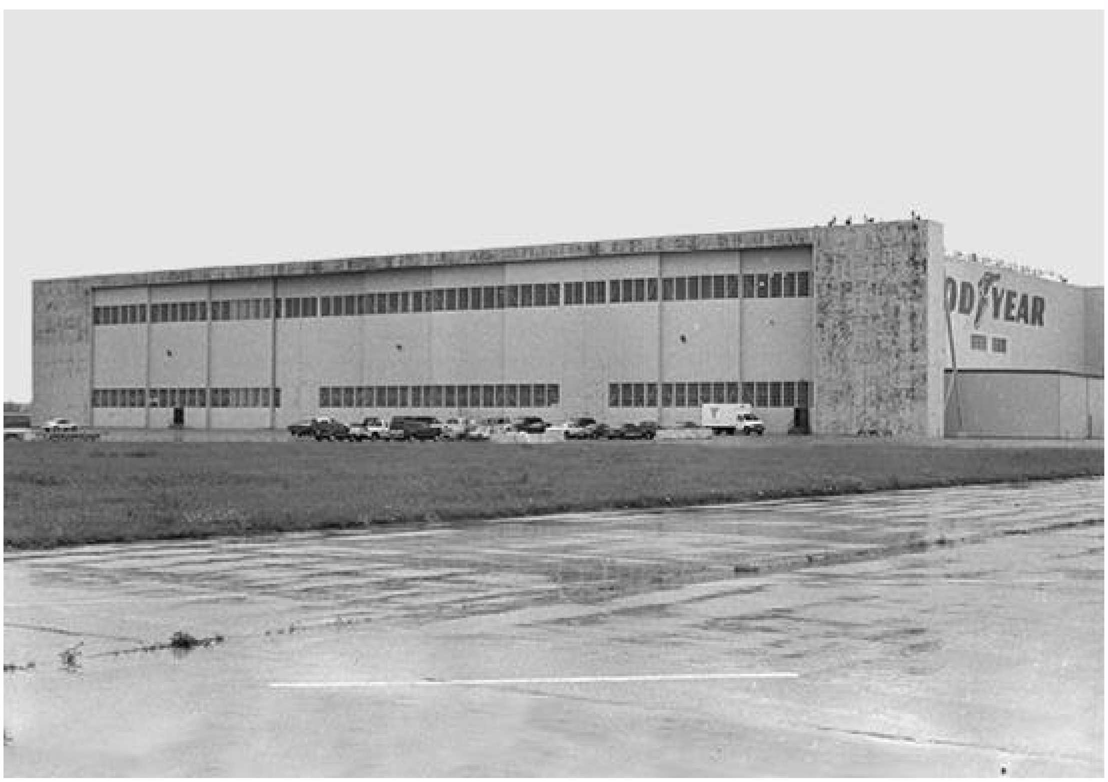

Plate 35. Kuljian Corporation. Medium bomber (two-bay) double-cantilever hangar at the former Lincoln Air Force Base. View of 1999. Photograph, K.J. Weitze.

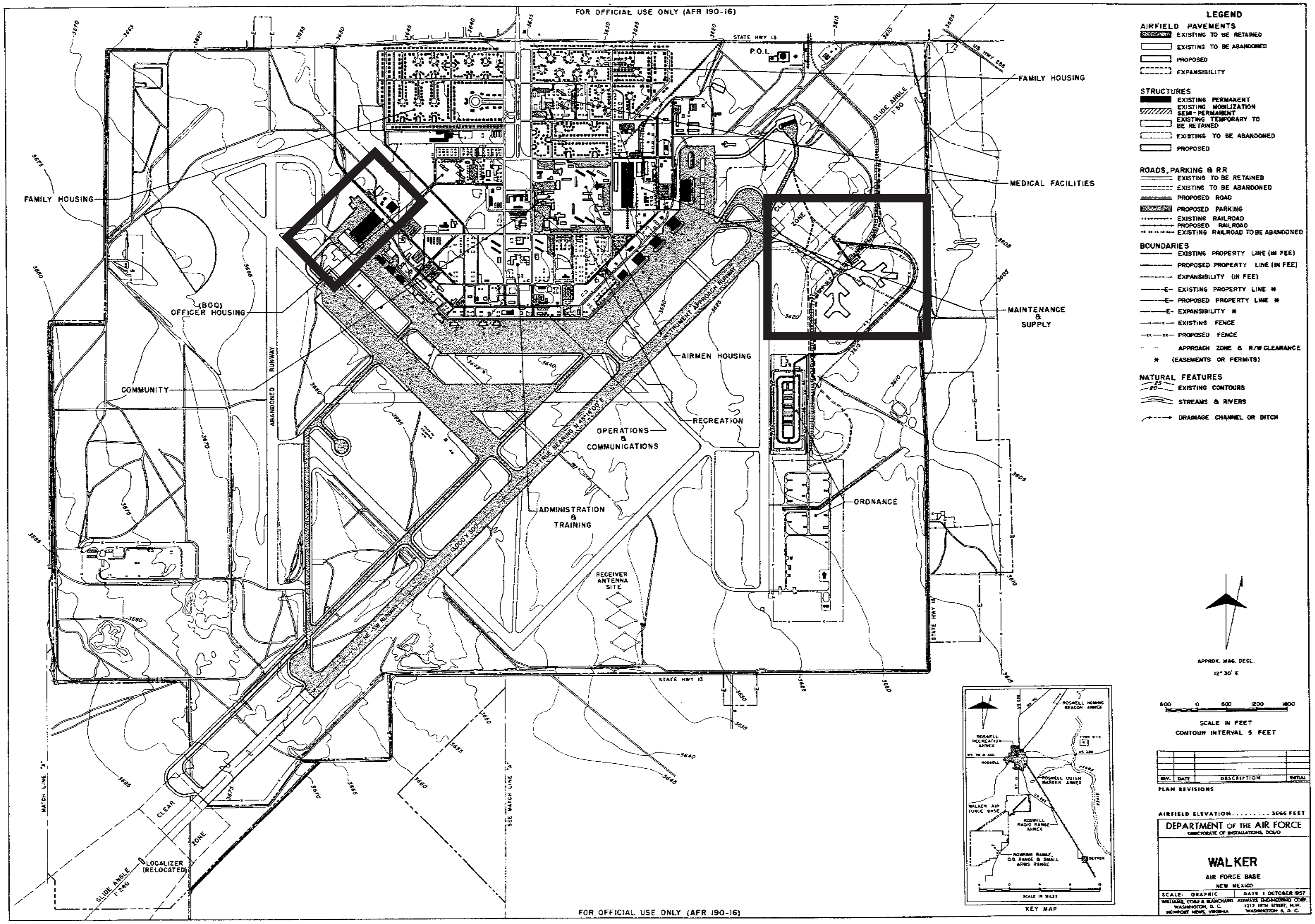

Plate 36. **Heavy bomber double-cantilever hangar, left. Planned SAC Christmas tree alert, right. Walker Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

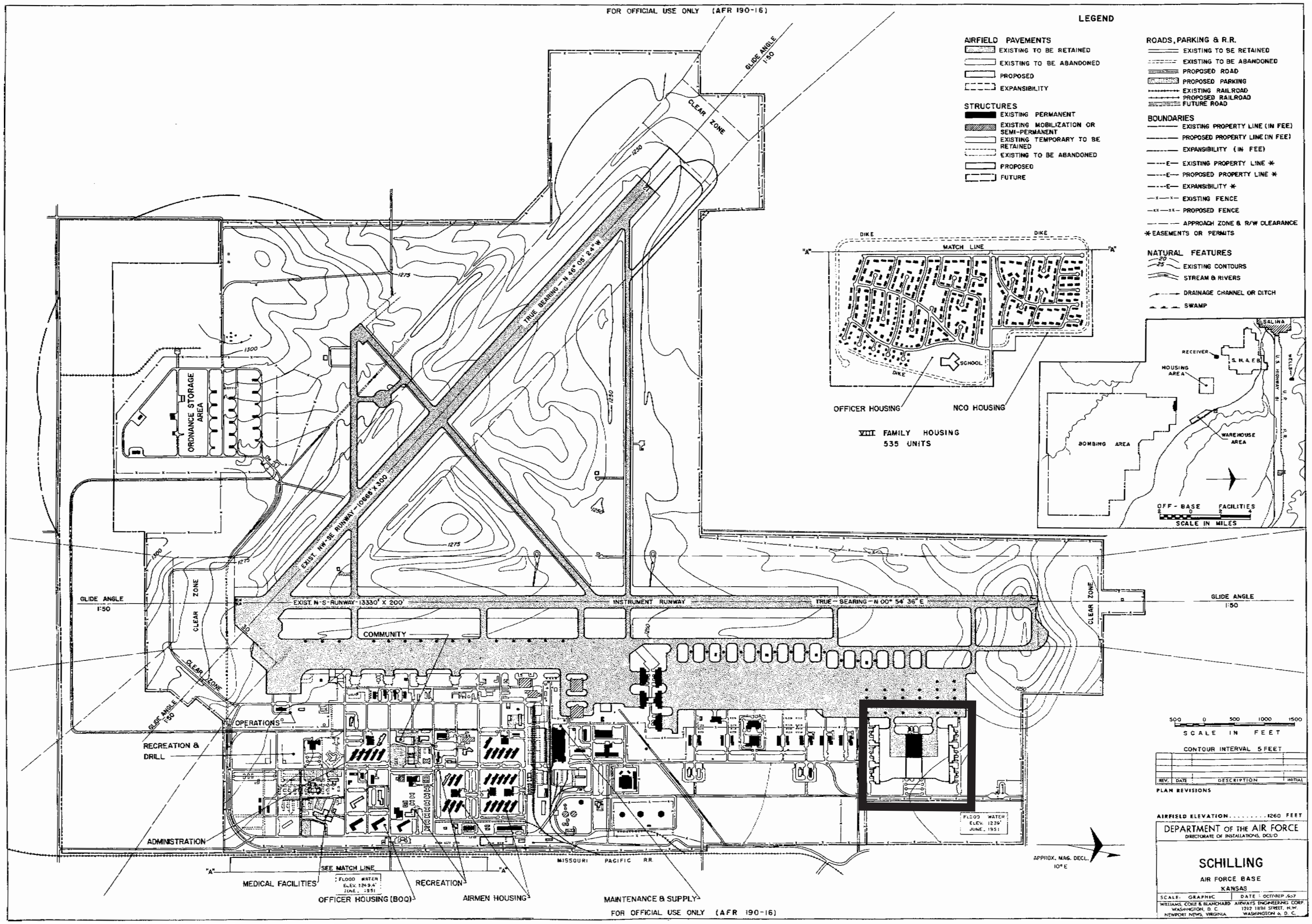

Plate 37. Medium Bomber double-cantilever hangar, expansible. Planned for doubled capacity, with six wing hangars [unbuilt]. Schilling Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.

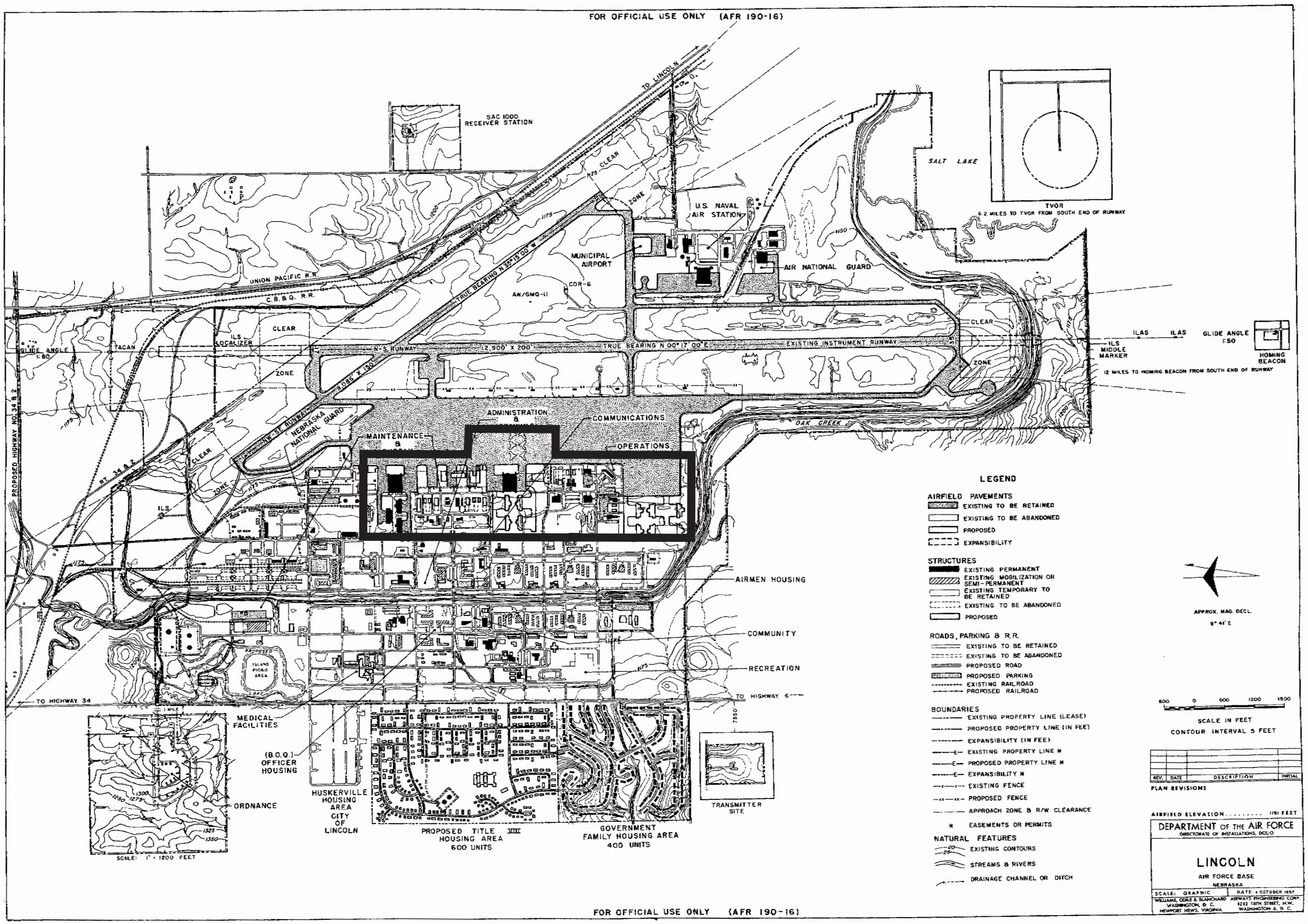

Plate 38. **Paired medium bomber double-cantilevers hangars. Multi-purpose wing hangars, left. B- wing hangars, center, planned for removal. Grouping of 10 multi-purpose wing hangars, planned, center and right [unbuilt]. Lincoln Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

The key achievement of the structure was its very wide, unobstructed clear span and its flexibility: the Air Force could adapt the very large hangar, in any of its five versions, to multiple aircraft over time; and, should the Air Force choose, it could expand the hangar with relative ease. Kuljian redesigned the towers to be a uniform 60 feet square throughout the hangar (rather than 70 feet square for the towers along the sides of the structure and 60 feet square in the center). The firm also thereby extended the trussed cantilevers from the 92 feet of Mills & Petticord's final August 1951 version, to 93.6 feet center to rear, and to 104 feet center to front. The hangar, in its steel-frame construction, recalled mobilization infrastructure through its standardized, shippable components, all of which could be handled by non-specialized labor. Steel fabrication and bridge companies could manufacture the truss segments. Corrugated insulated exterior paneling, typically left unpainted during the early Cold War decades (and sometimes still found in this state), resembled that of prefabricated metal buildings. Cost for the Kuljian hangars was approximately three-and-one-half to four-and-one-half million dollars. The hangar covered two to three-and-one-half acres of ground[68] (Plates 39-42).

Of the buildout for the second generation SAC bomber maintenance hangar, most hangars were of the single-bay type, with the triple-bay structure relatively rare. It is unknown whether SAC actually ever expanded a double-cantilever hangar once erected, but as of its master planning in late 1957, the intent was to do so at over 20 installations. Triple-bay hangars in the U.S. included ones for Biggs (Texas), Carswell (Texas), Castle (California), Loring (Maine), McGuire (New Jersey), Pease (New Hampshire), Plattsburgh (New York), and Walker (New Mexico);[69] with additional triple-bay hangars known to have been built for Lajes (Azores), Nouasseur (French Morocco), and Keflavik (Iceland). Tonnage of structural steel, for example, in the hangar at Castle totaled 3,262, fabricated by the Union Steel Company of Los Angeles. Each trussed cantilever itself weighted 35 tons, with door panels weighing 18 to 22 tons each. Door panels measure 30 to 35 feet wide, by 60 feet tall.[70] Contractors shipped the doors in 12 by 60-foot sections, then assembling the final panels at the installation. For the hangars at Keflavik and Lajes, the construction team finished one hangar, and after a brief vacation back in the U.S., flew to the next location—facing entirely different local conditions.[71] The double-cantilever hangar is the equivalent of a building six-and-one-half stories in height. Kuljian handled the definitive design for the SAC double-cantilever hangar (December 1951), as well as a major revised drawings series in 1952, and site adaptations for most of the individual installations.[72] Occasionally, as at Keflavik and Lajes, distinctive site adaptations were made. In 1954, Kuljian revised the drawings again, to eliminate the expansible feature.[73]

Early in the buildout, Kuljian also performed an "alternate design review" for four hangars—those at Biggs, Castle, Kirtland, and Walker Air Force Bases. These alternate designs pre-existed Kuljian in at least some capacity. That at Kirtland is the January-February 1951 double-cantilever hangar designed by Mills & Petticord. (See Plates 23-24.) Those at the other three installations are each triple-bay hangars, erected very early, and at least in the cases of Castle and Walker, appear to be standard Kuljian hangars from their exterior. (The trussed arches do not protrude from the roofline.) The Biggs hangar is as yet unseen for interpretation here. If these three hangars are not Kuljian designs, then they too are likely regional Corps of Engineers adaptations from one of the Mills & Petticord aborted designs. If so, the interior tower shops will have a larger footprint and the cantilevered trusses will measure 66.5 or 92 feet, instead of 93.5 and 104 feet; and, shop tower plan dimensions will measure 60 by 100 feet, or 70 feet and 60 feet square. As-built, the overall height of the hangar should have been about five stories instead of six-and-one-half. Of note, the records of the 93rd bombardment wing at Castle describe that installation's double-cantilever hangar as having 70-foot square shop towers, and of five stories height—suggesting an adaptation from the August 1951 Mills & Petticord design, with a more conservative cantilever of 92 feet.[74] Supporting the possibility that the Biggs, Castle, and Walker hangars are derived from the August 1951 Mills & Petticord version of the double-cantilever hangar are annotations on the Corps card index for the drawings: although Mills & Petticord made only two sheets of drawings for this version of the hangar, penciled is a date of 10 October 1952—strongly suggesting that SAC used these drawings for several of its earliest double-cantilever hangars, even as the Kuljian program was beginning buildout.[75] In three instances, bases chose to add unauthorized basements under the shops within the double-cantilever

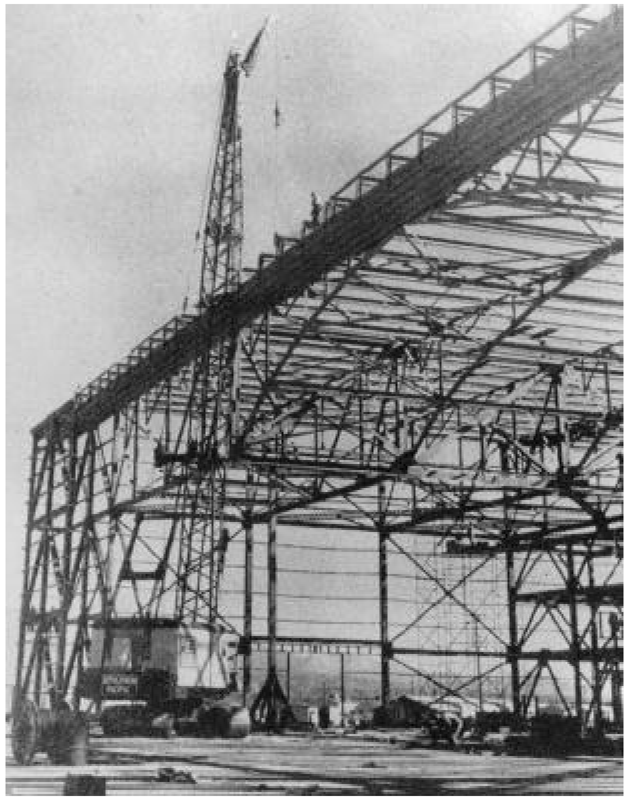

Plate 39. Double-cantilever hangar under construction at March Air Force Base. *Engineering News-Record*. 12 May 1955.

Plate 40. Construction for recessing doors. Double-cantilever hangar program. Courtesy of Kuljian Corporation.

Plate 41. Upper tracks for recessing doors. Double-cantilever hangar at the former Mather Air Force Base. View of 1998. Photograph, K.J. Weitze.

Plate 42. Kuljian Corporation. Basic double-cantilever hangar at Barksdale Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

hangar—at Biggs, Pinecastle, and Charleston. Headquarters Air Force ordered these sealed off in early 1955.[76]

Although the Air Force was beginning to address the needs of nuclear blast-resistant construction during the 1950s—particularly fringe area, non-direct hit construction, the first and second generation SAC bomber maintenance hangars could only be interpreted as coincidentally touching upon these issues. The thin-shell, reinforced concrete hangar of 1947 was an arch structure, and as such the arch and the dome best withstand the large lateral and vertical loads of airblast waves when a structure of more than 150 feet, like the SAC bomber hangar, is required.[77] Reinforced concrete also offers some shield from radiation. Wide-span steel-frame structures do not offer much, if any blast or radiation protection, without reinforced concrete shear walls. Nominally though, the rectangular shape of the unexpanded double-cantilever hangar (in any of its five versions) of 1951; its length to width ratios (as taken from either the front/rear facades or from the sides)—not in excess of the one to three ratio known to be a benchmark by the middle 1950s; its interior tower shops heavily encased in reinforced concrete (serving as partial shear walls); and, its deeply corrugated exterior metal paneling—fit the profile for simple blast effective design parameters. Personnel, too, would have been minimally protected within the tower shops from radiation.[78] The SAC bomber hangars of 1947 and 1951, nonetheless, were not explicitly designed to resist the loads quantified for nuclear blast during the early 1950s.[79]

The greatest number of double-cantilever hangars were clustered in the interior U.S., across the Midwest between Nebraska and Louisiana, with both coasts also supplying bases for the bomber. At selected installations, SAC built two separate double-cantilever hangars, achieving the capacity of the triple-bay hangar. The hangar programs for Ernest Harmon (Newfoundland) and Goose Bay (Labrador) were of this type. Preeminent among the expansions planned by SAC in 1957, were ones for the Northeast—at Pease and Plattsburgh. At these locations, SAC intended to have two triple-bay hangars at buildout. Most of the B-36 bases were sited immediate to key nuclear weapons storage and production sites; major aircraft manufactories; command headquarters and research and development sites for the Air Force; and, the industrial Northeast and the seat of government. The SAC arsenal of nuclear bombs stood at over 1,600 at the close of 1954. One of the functions of the double-cantilever hangar, beyond its technological advancement of design and engineering, was its symbolic role as a monolithic anchor for parked B-36s and B-47s poised to retaliate against the Soviet Union. In this role, the Kuljian hangar foreshadowed the architectonic statement that would be made by the apron, aircraft, and crew quarters of the late 1950s alert-configured B-52.[80]

As of 1955, Anton Tedesko officially served in the role of engineering advisor to the Air Force, and perhaps not surprisingly, the SAC program for a bomber maintenance hangar changed significantly. With the shift from the B-36 to the B-52 as SAC's heavy bomber, SAC also stopped building the Kuljian double-cantilever hangar—although the Directorate of Installations still mapped expansion of the hangar at multiple bases as late as October 1957. The clearest indication to date that the both the Mills & Petticord, and the Kuljian, double-cantilever hangars were in fact directly derived from specifications and design work undertaken by Konrad Wachsmann also occurs exactly at this time (early 1954): the Engineering Division of Directorate of Construction formally notes that Wachsmann's contract for an "unusual hangar design" was being phased out.[81] In 1955, the office of the Assistant Chief of Staff, Installations, further commented that SAC—*in support of its alert concept*—had a new requirement for "alert hangars, organizational maintenance hangars and operational shelters for the B-52 aircraft. A study of a structure that will satisfy all three (3) requirements is now in process."[82] SAC did not establish a massive buildout program for such a multi-purpose hangar. Instead the command concentrated on a program of bomber alert aprons with immediately adjacent, semi-hardened, aboveground crew quarters. SAC maintained the B-52 largely at the existing Kuljian double-cantilever hangars and at wing hangars. New bases with a SAC mission, such as Grand Forks and Minot in North Dakota, relied on B-52 wing hangars exclusively.[83]

The Air Force, however, did commission the design for such a hangar, referenced as the "S-250": the structure returned to the arch, now steel, with "a clear span and full cover for all type of aircraft up to and including the B-52." The Air Force did erect this hangar in selected instances during 1958 and 1959. The most noteworthy examples of the hangar were a flight test hangar at McClellan Air Force Base in Sacramento, California, and the SAM-CRT hangar at Andrews Air Force Base in Maryland. The Directorate of Civil Engineering explicitly noted that the hangar "will replace the old cantilever hangar designs," and would house one B-52 but could house a combination of smaller aircraft.[84] Tedesko was more than likely the source engineer. Although not verified herein, hangar span was likely 250 feet. Air Research and Development Command also continued hangar engineering and design in this direction through a test hangar for experimental aircraft erected at Edwards Air Force Base in California at this same time (1956-1957). *Engineering News-Record* described the Edwards hangar as directly derived from the 300-foot steel arch hangars at Idlewild in New York—the 1949 triple hangar grouping designed by Tedesko for Roberts & Schaefer. The Edwards structure featured a 360-foot clear span, a 400-foot length, and motorized, recessing doors 55-feet tall. In effect, the hangar replaced the Kuljian double-cantilever hangar through its dimensions[85] (Plate 43).

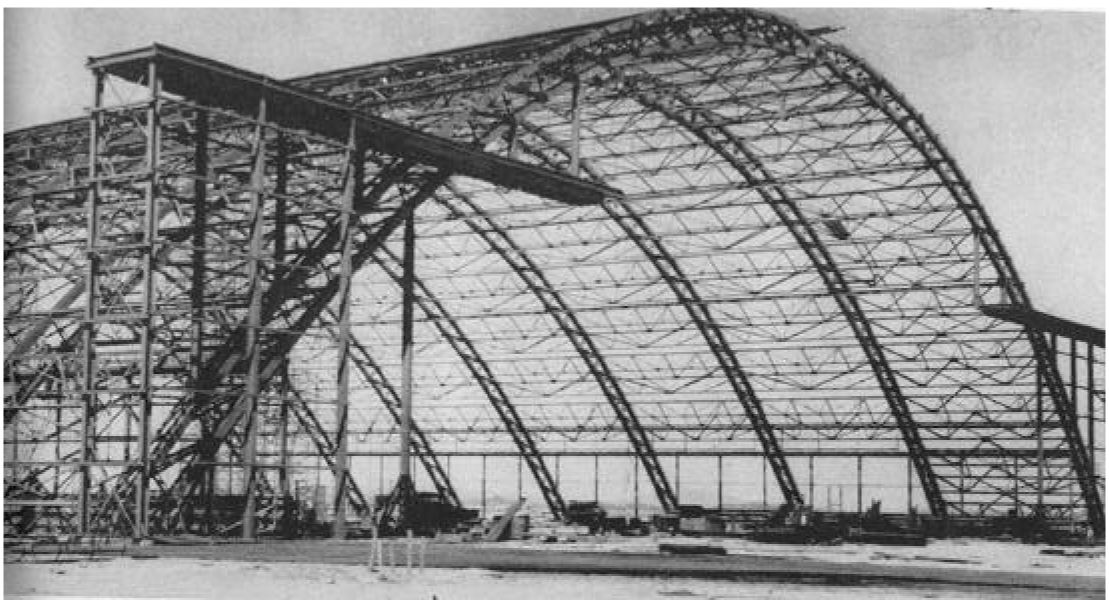

Plate 43. Construction for test hangar at Edwards Air Force Base. *Engineering News-Record.* 9 August 1956.

Throughout the 1954 to 1959 period U.S. engineers continued to design progressively longer steel cantilevered and arch spans[86] for hangars at civilian airports, complementing the achievements of SAC through its second generation maintenance hangar for the B-36, B-47, and B-52. Cantilevers, in particular, became rapidly longer. In autumn 1953, Boeing led the efforts with a 780 by 200-foot flight test hangar in Seattle. The steel hangar, like the Kuljian double-cantilever hangar, employed paired trussed bents supported by steel towers with a free cantilever of 122 feet.[87] In 1955, two hangars erected at Orly Field in Paris directly reflected the design of the SAC double-cantilever hangar. These hangars were 712 and 535 feet long, built side by side, with 125-foot cantilevers and featuring 50-foot tall motorized door panels.[88] In 1956, for Pan American World Airways at Idlewild in New York, and for a TWA hangar at the Philadelphia International Airport, engineers moved forward with cantilevers of 133 and 130 feet. Amman & Whitney, competitors of Roberts & Schaefer for the thin-shell, reinforced concrete hangar during the late 1940s, engineered both hangars. In these cases, cable suspension augmented the cantilever support, permitting the extra lengths.[89] In 1957 the race continued, with United Airlines commissioning two hangars, at the San Francisco and Newark airports, that featured girder cantilevers of 142 and 140 feet. The engineering community praised the San Francisco hangar, designed

Plate 44. Skidmore, Owings & Merrill. United Airlines hangar, San Francisco International Airport. *Engineering News-Record*. 23 April 1959.

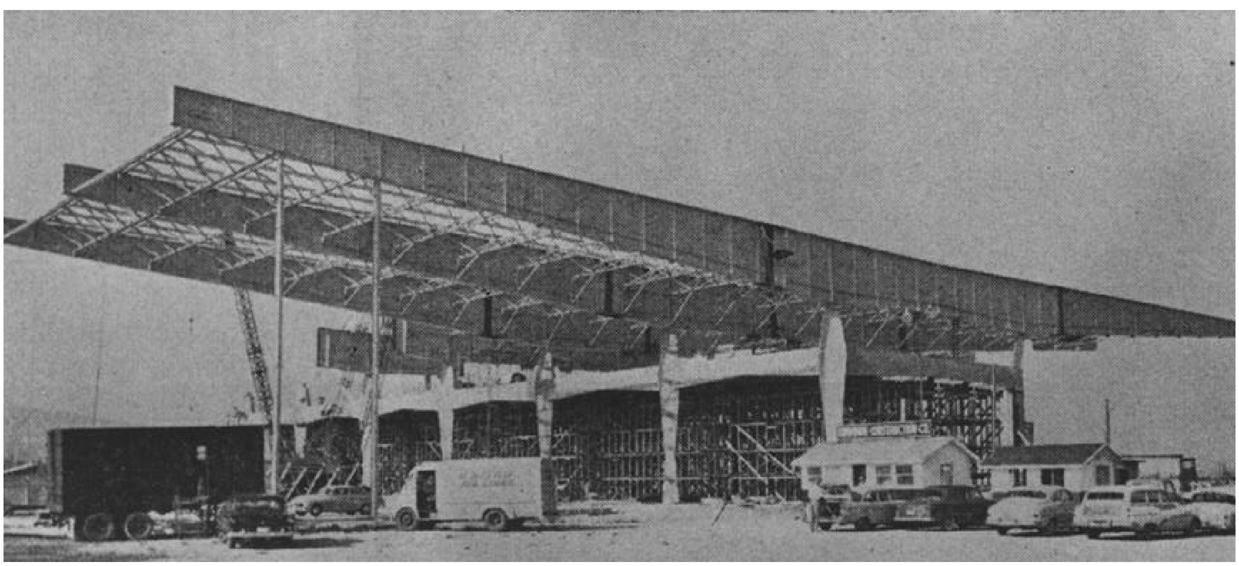

Plate 45. Skidmore, Owings & Merrill. Cantilever construction for United Airlines hangar, San Francisco International Airport. *Engineering News-Record*. 30 January 1958.

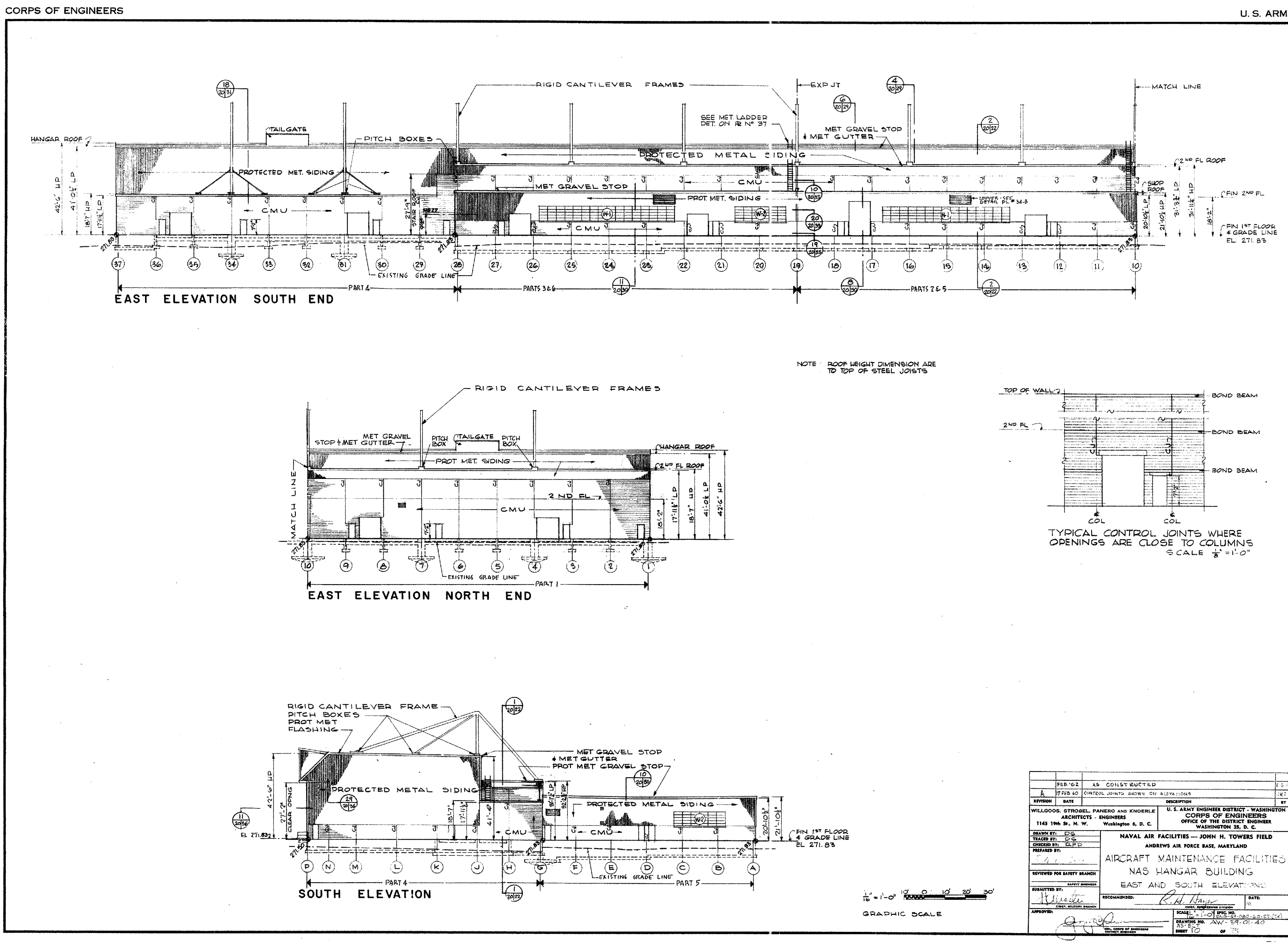

Plate 46. Willgoos, Strobel, Panero & Knoerle. Naval Air Station Hangar, Elevations. 1959. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.

by Skidmore, Owings & Merrill, in particular[90] (Plates 44-45). By 1958, cantilevers had achieved 150 feet at the Oakland International Airport; 158 feet at Idlewild (for a 400 by 600-foot hangar); and, by mid-1959, 177 feet for Delta Air Lines in Atlanta. Each of these hangars featured cable-assisted cantilevers.[91] In 1959, both the Air Force and the Navy also began to erect cable-assisted cantilever hangars—although with a more modest cantilever length, and, for the Navy, of single-cantilever type[92] (Plate 46).

Prefabricated, Mobilization Infrastructure

Nose Docks, Temporary Shelters, and Wing Hangars

During the hiatus between the erection of the Roberts & Schaefer thin-shell, reinforced concrete maintenance hangars for the B-36 at Ellsworth and Loring in 1947-1949, and, the achievement of the Kuljian standardized steel, double-cantilever hangar in 1951-1952, SAC faced a several-year gap for its critical repair infrastructure. As the hangars required a year or more to erect, and many were not in construction until 1953-1954, the period of years without closed maintenance facilities actually ran from about 1950 into 1955. The solution to this issue was open steel-frame maintenance facilities sheathed in corrugated steel panels, better known as nose docks and wing hangars. "Open" referred to the substantial protrusion of the body and tail of the bomber from the hangar. As the Cold War unfolded, these structures, like the B-52, became the infrastructural work horse of the entire period, evolving as multiple types—sometimes dismantled and shipped to other locations, but often becoming permanent after the 1950s. SAC grouped the wing hangars in linear configurations on large parking aprons and as rectangular pens perpendicular to these flightline aprons. As such, the way in which SAC clustered the wing hangars also directly foreshadowed formal alert status for parked bombers, with the later wing hangars referenced as full aircraft shelters. Locations with sustained, harsh winters received many more wing hangars than sites with mild weather. During the late 1950s—when change was perhaps the most rapid—some bases had wing hangars designed for the B-29 sitting next to ones for the B-52, occasionally mixed in an almost ad hoc manner at the flightline.

This type of infrastructure had precursors during World War II in the then-used canvas aircraft shed and mobilization hangar. Only partially sheltering the front of planes (with wings and tails exposed), the shallow-cantilever sheds were the prototype for the nose docks of the early Cold War. As described in 1945, the aircraft was to "nose into the structure and thus obtain shelter for the forward part of the plane." Maintenance personnel could drop a "front wall canvas" across the shed to temporarily enclose it. SAC was thoroughly familiar with this type of structure, as the AAF had employed it heavily for the B-29. Built in repeated sections, the sheds were erected from prefabricated parts, easily shipped to site, and required only minimal local materials and non-specialized labor.[93] The military used several types of these hangars at the close of World War II. The Navy named their structures "nose-in repair docks," noting that personnel could erect an arched, canvas-covered steel structure of 30 by 78-foot dimension in 300 man-hours. The Navy's prototypical nose dock also left the wings and tails of the aircraft exposed, sheltering the nose and engines with sufficient strength to withstand 80-mile-per-hour winds and temperatures to 40 degrees below zero. The International Derrick and Equipment Company, Columbus, Ohio, designed this particular nose-in repair hangar for the Navy[94] (Plate 47).

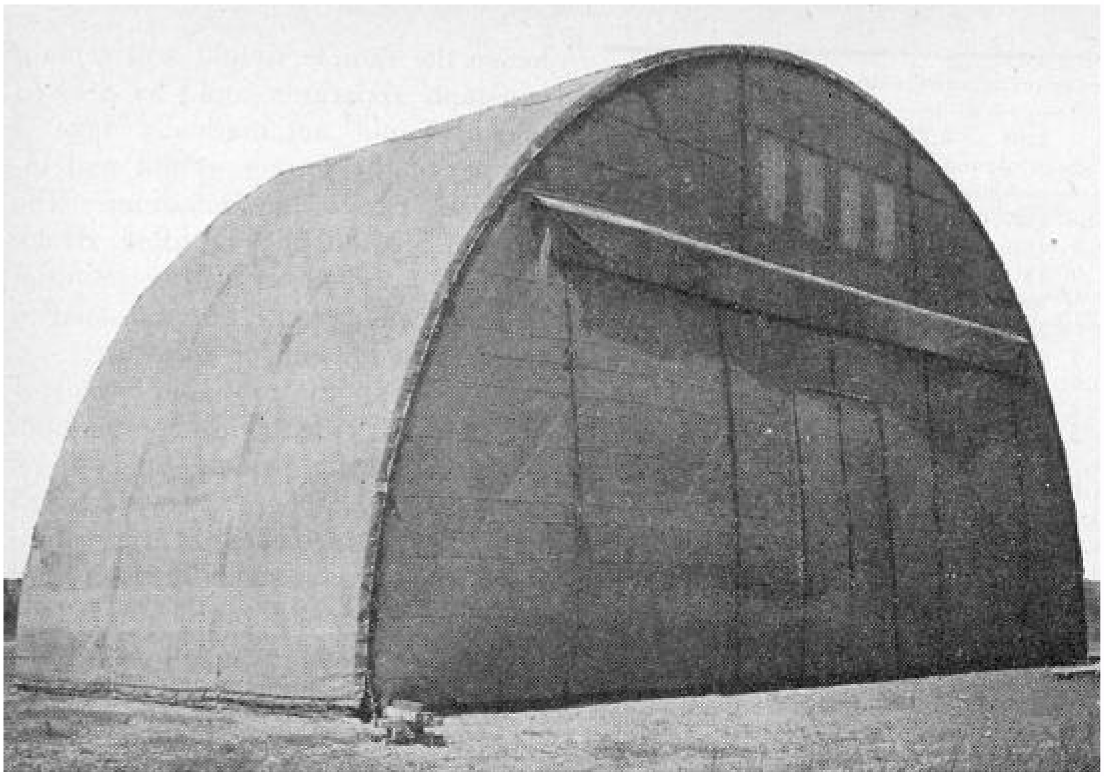

Plate 47. Navy Nose-In Dock. *Engineering News-Record*. 22 March 1945.

The Air Force apparently used a similar dock to that of the Navy, likely designed for the B-29, after 1945. This structure, larger than the Navy's nose-in dock and not yet verified via photographs, is mapped into 1957 on flightlines at 12 installations in nearly 100 units as a semi-circular/oval footprint. Notable bases of the late 1950s with this very early nose dock were heavily in the southern United States, and included Altus (Oklahoma), Barksdale (Louisiana), Dyess (Texas), Homestead (Florida), Hunter (Georgia), Lake Charles (Louisiana), Little Rock (Arkansas), MacDill (Florida), March (California), Pinecastle (Florida), Schilling (Kansas), and Shaw (South Carolina)[95] (Plate 48). This dock is of unknown dimensions, but was likely a slightly scaled-down version of AAF steel-arch hangars of this same period, with canvas roofs and two-piece door flaps. The full-size hangars typically were 130 by 160 feet, and 160 by 200 feet, in plan. Initial manufacturers included the Armco Drainage and Metal Products Company of Ohio and the Stran-Steel Division of the Great Lakes Steel Corporation. AAF engineers internally designed two standardized hangars of this type in 1944, with a pilot model erected in Melrose Park, Illinois, at the plant of the Mississippi Valley Structural Steel Company[96] (Plates 49-54). During 1951 (if not before), at the warmer-weather bases of Biggs (Texas) for the B-50; and Carswell (Texas) and Walker (New Mexico) for the B-36, and at Ellsworth adjacent to the Roberts & Schaefer thin-shell hangar, SAC was also using moveable engine and wing docks of two types—one of an arched steel-frame type with a canvas covering, with individual docks for each engine of the B-50, and, a second of a steel-frame structure open on its front and sides, with docks for each wing of the B-36. Maintenance personnel wheeled these structures in place[97] (Plates 55-57). As of early 1952, SAC continued to plan for additional bomber nose docks appropriate to the World War II aircraft. Mills & Petticord produced single drawings for nose docks for the B-29 and B-50 (essentially a modified B-29) in March. These docks do not appear to have been built.[98]

The earliest uncovered drawings for SAC very heavy bomber nose docks, soon called wing hangars, date to January 1951, and are a part of the mobilization effort for the Korean War. From extant Air Force photographs, it is additionally clear that engine docks were already in use at some installations and that

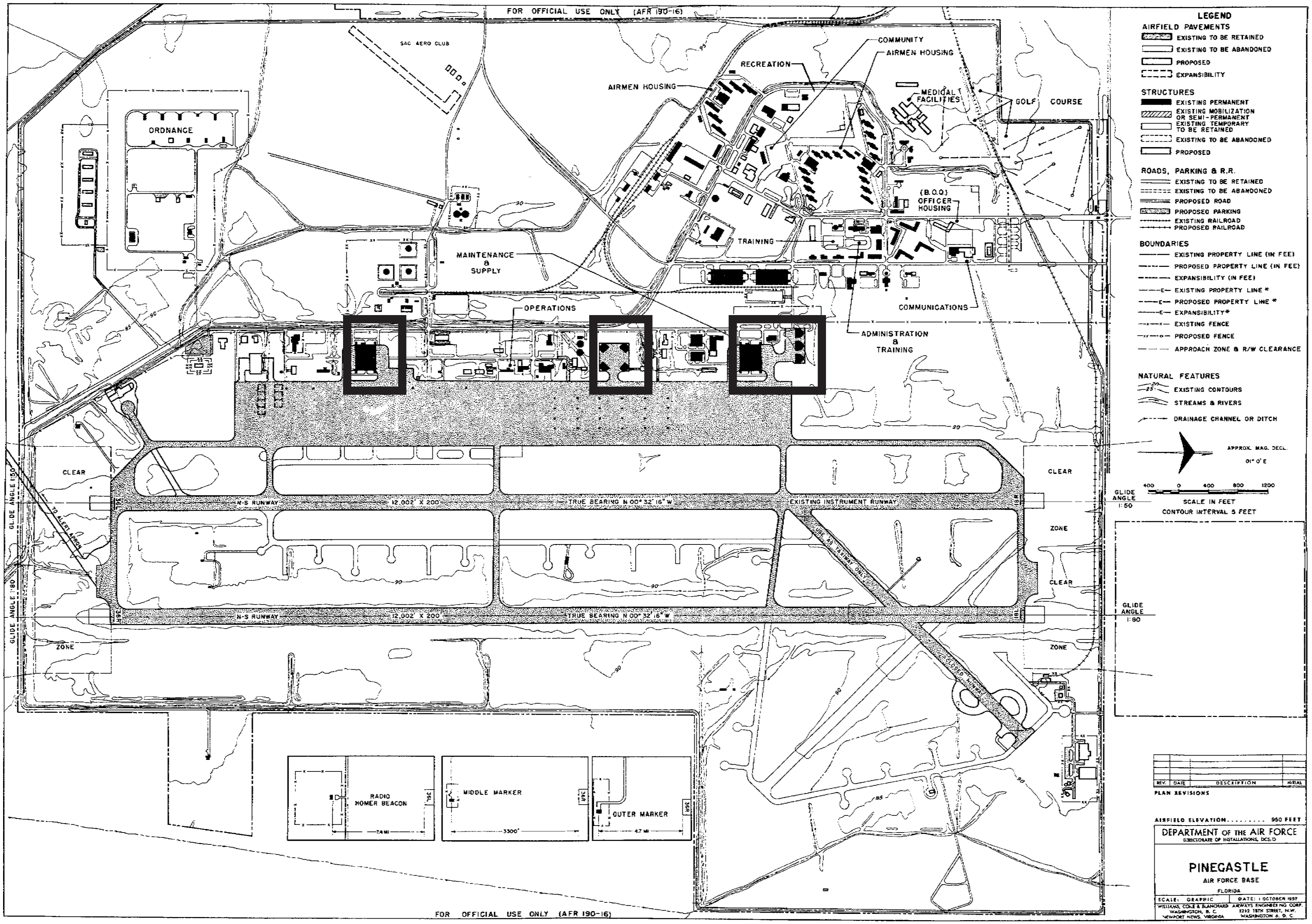

Plate 48. **Groupings of three and four B-29 nose docks at the flightline. Also, two double-cantilever hangars. Pinecastle Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

Plate 49. Butler Manufacturing. Canvas-covered hangar for the Army Air Forces. 1942. Courtesy of the Butler Manufacturing Company.

Plate 50. Butler Manufacturing. Erection of the superstructure for the canvas-covered hangar, Army Air Forces. 1942. Courtesy of the Butler Manufacturing Company.

Plate 51. Butler Manufacturing. Combat hangar, type CH, erected at Espiritu Santo, New Hebrides, Army Air Forces. 1942. Courtesy of the Butler Manufacturing Company.

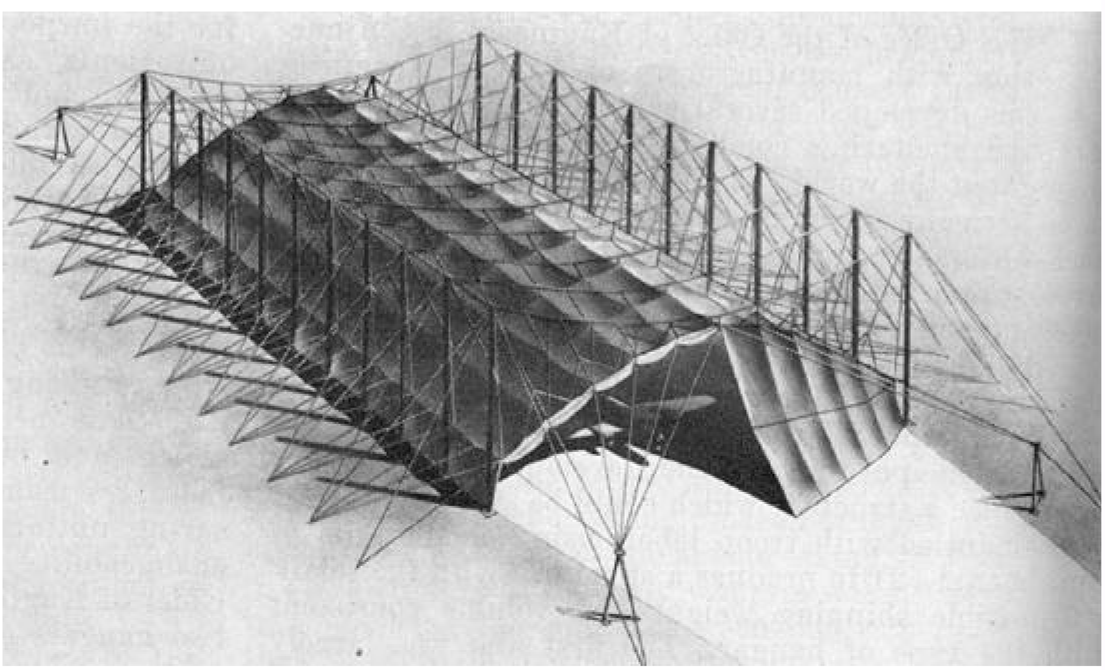

Plate 52. Luria Engineering. Canvas-covered, lightweight catenary tent hangar for the Army Air Forces. 1942-1944. *The Military Engineer*. May 1945.

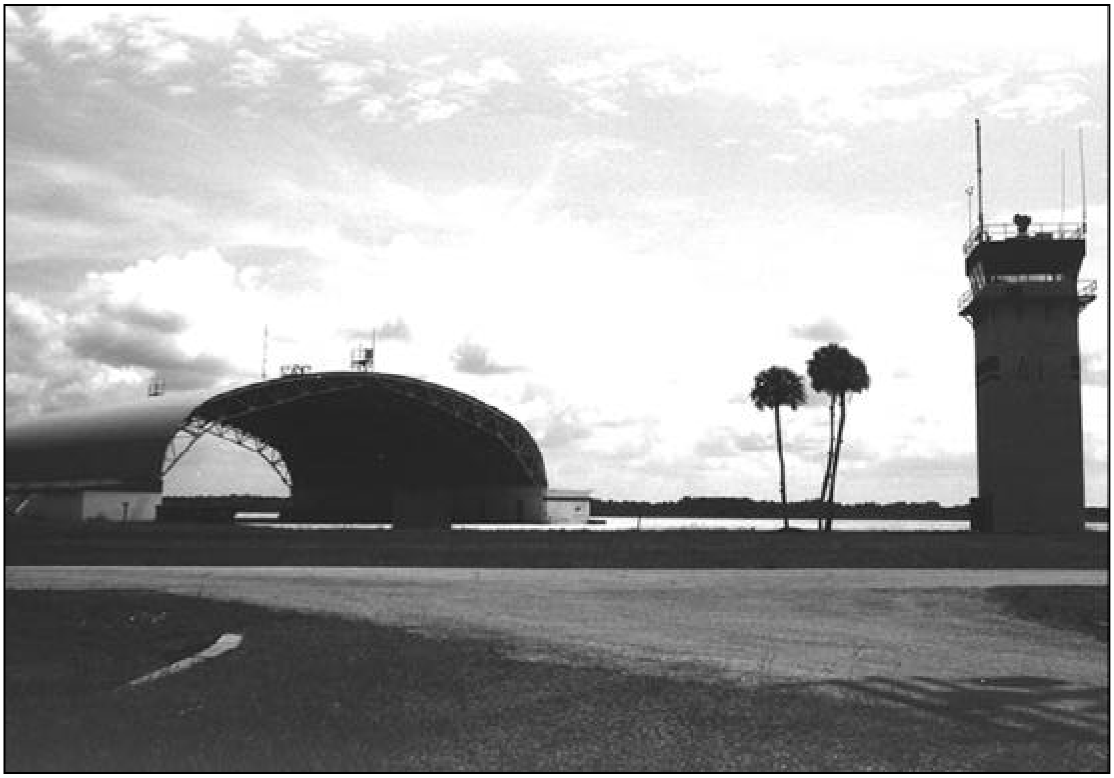

Plate 53. Army Air Forces. Steel combat hangar. Avon Park, Florida. Bombing range for MacDill Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

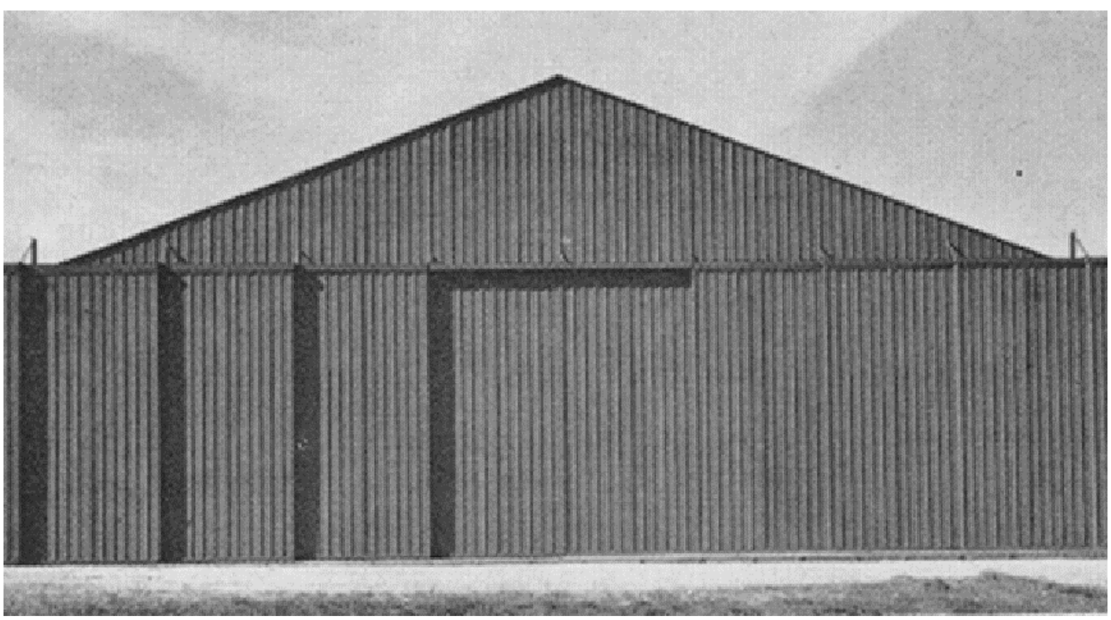

Plate 54. Butler Manufacturing. Prefabricated hangar for the Army Air Forces, with steel doors and roof. 1945. *The Military Engineer*. May 1945.

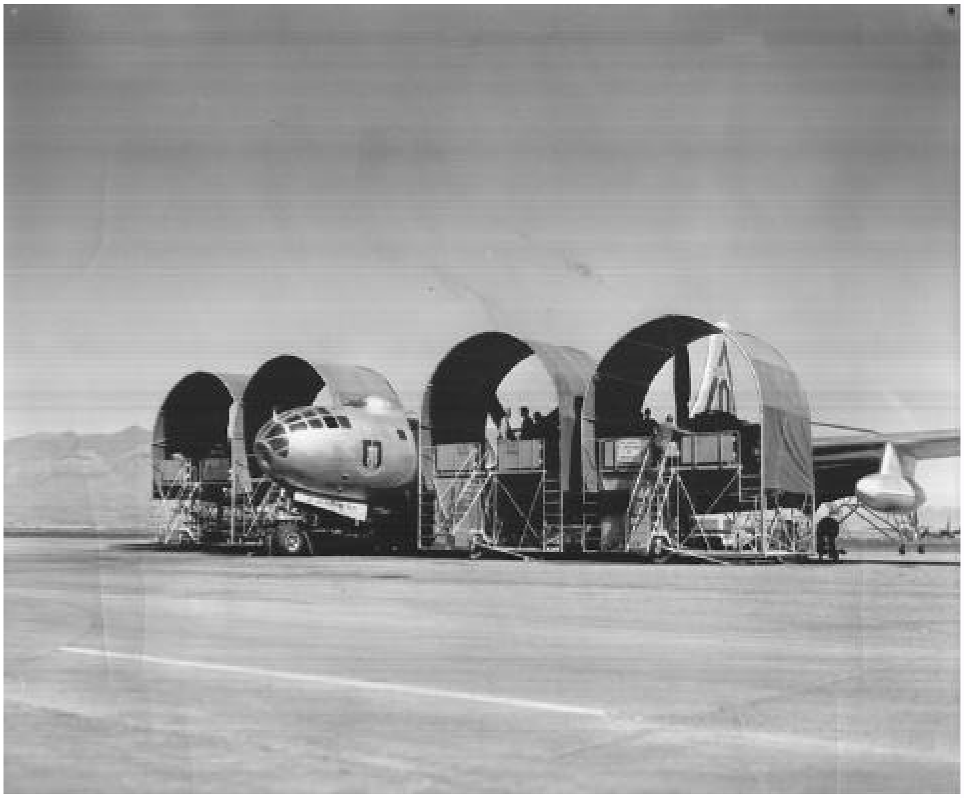

Plate 55. Moveable repair docks for the engines of the B-50. Biggs Air Force Base. 14 September 1951. Courtesy of the Air Force Historical Research Agency.

Plate 56. B-36 and moveable wing docks. Walker Air Force Base. 28 August 1952. Courtesy of the Air Force Historical Research Agency.

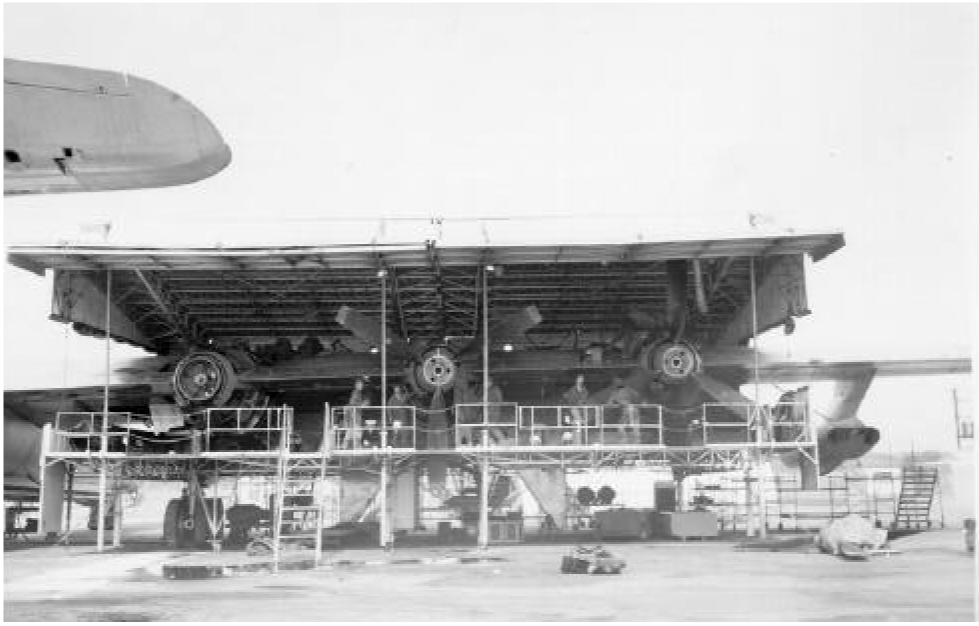

Plate 57. B-36 in wing dock, ready for repair. Carswell Air Force Base. July-December 1952. Courtesy of the Air Force Historical Research Agency.

variant designs existed, the latter in test at the Air Proving Ground, Eglin Air Force Base, 1942-1948.[99] The Corps contracted with Mills & Petticord—in a continuance of late 1940s military work with the firm—for the first Air Force contracts for the nose dock. Mills & Petticord completed several versions of a nose dock between January and August 1951. That for the medium bomber (the B-47) had initial dimensions of 58 by 94 feet—augmented to 65 by 148 feet; that for the heavy bomber (the B-36), 280 by 61 feet.[100] Although no known drawings for the Mills & Petticord B-36 dock survive, its dimensions indicate that the planned structure sheltered only the nose and propeller-engines of the bomber, leaving wings and body of the plane exposed. Drawings for the Mills & Petticord August 1951 medium bomber nose dock survive, revealing that the nose dock drew directly upon pre-existing designs for World War II aircraft sheds *and as planned* led to preliminary ideas for an enclosed large SAC maintenance hangar. Intent was to cluster nose docks together, both laterally as in the mid-1940s AAF sheds, and, back-to-back. Plans illustrating four docks grouped together in this manner created a structure 130 feet deep and 382 feet wide. Four interior shops, 101 feet deep by 31 feet wide at the sides, with a combined 72-foot width for the center pair, provided the supports for cantilevered trusses, front and rear, of 29 feet[101] (Plate 58). Cantilevers of such shallow depth were a long way from those suggested by Wachsmann in 1944-1945, but from this conservative direction too a double-cantilever hangar was evolving.

As had been true in its negotiations with Mills & Petticord for its version of the double-cantilever hangar, the Corps contracted for alternate bomber nose docks almost immediately after submission of the Mills & Petticord designs at the turn of 1951. Luria Engineering of New York, manufacturers of prefabricated, mobilization buildings for the Army during World War II, in consultation with engineer Peter A. Strobel, submitted drawings for a "B-36 Maintenance Dock" in April. Measuring 291feet, nine inches wide by 111 feet, 7.5 inches deep, the wing hangar was nearly elegant in its simplicity and closely followed the lines of the B-36's long nose and wide wings. Space for the nose alone measured 31.5 feet wide by 50 feet deep. An inflatable, bladder-like intertube closing wrapped around the body of the B-36 in the center panels of the wing hangar's recessing steel panel doors, measuring 12.5 feet in diameter, with the "torus tube" itself 2.5 feet across. SAC maintenance personnel also had a Luria-designed collapsible steel meshed-panel floor available for set up under the engines of the bomber.[102] SAC immediately began to use the Luria wing hangars, with erection of eight under construction before the close of 1951 adjacent

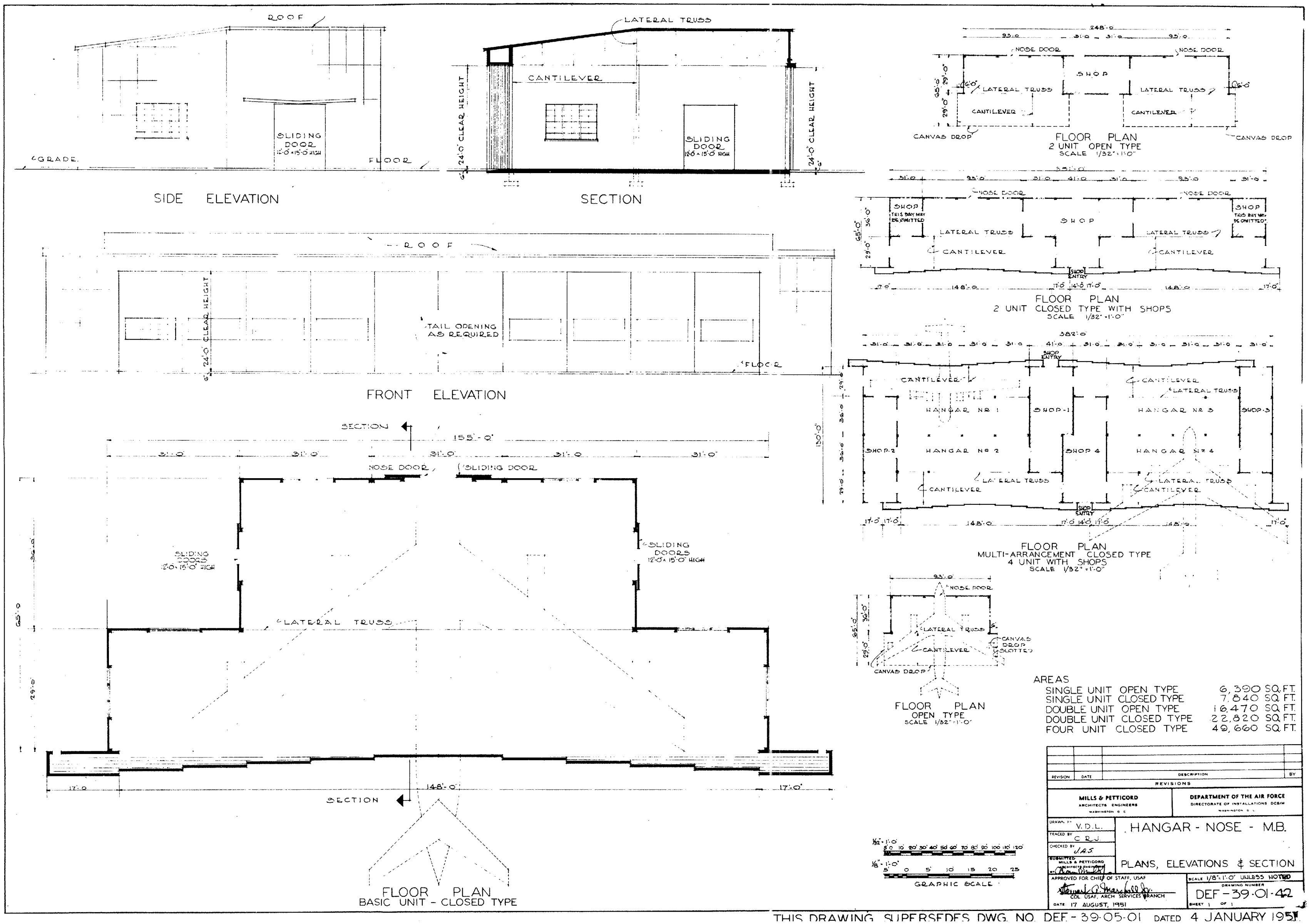

Plate 58. **Mills & Petticord. Medium Bomber Nose Dock, Elevations, Plans and Section. August 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.**

to its Roberts & Schaefer thin-shell concrete hangars at Loring and Ellsworth Air Force Bases[103] (Plates 59-60). These 1951 B-36 wing hangars represented a transitional solution, and as interpreted through infrastructural footprints on the Air Force-wide installation master plans of 1957, appear to be correlated directly with the placement of alert Q Areas—special weapons storage depots for atomic bomb components—at installations with severe winter weather. In September 1952, SAC added three "explosion-proof telephones" at each dock, suggesting that the command was aware of the need for some level of blast-resistant construction and that the hangars were interpreted as minimally likely to survive interior aircraft explosion.[104] SAC appears to have employed these structures at Ellsworth (South Dakota), Fairchild (Washington), Loring (Maine), and Westover (New York), with their total originally numbering about 32.[105] At Ellsworth, SAC ran tests on their heating in early 1953, to obtain information for revised criteria applicable for future wing hangars.[106] These structures today are rare. Those at Ellsworth, Fairchild, and Loring were extant as of 1995; those at Westover are of unknown status.[107]

Luria (possibly again with engineer Strobel) likely also designed and manufactured a wing hangar for the B-47 at this same time. The B-47 first entered SAC inventory in October 1951. Although drawings have not been found for this dock, its footprint is also distinctive, and, like the Luria-Strobel wing hangar for the B-36, very closely mimics the shape of the bomber's nose and wings. Photographs of a cluster of eight B-47 docks do survive for McConnell Air Force Base in Kansas, showing just how remarkably the structure followed the swept-back form of the B-47.[108] This hangar was in use at early B-47 installations, as well as at ones where the numbers of the aircraft were high and SAC training programs were active, inclusive of McConnell in Kansas; Lincoln in Nebraska; and Castle in California[109] (Plates 61-65). Construction of the structure likely dates to 1952-1953, paralleling the arrival of the B-47 at SAC bases. By 1957 the Air Force still planned to ship it to selected bases using the B-47, inclusive of Anderson in Guam.[110] Numbers of B-47 wing hangars were similar to those for the B-36. The Air Force mapped this dock at only five installations in 1957: Altus (Oklahoma); Anderson (Guam); Castle (California); Lincoln (Nebraska); and March (California). The Castle and Lincoln configurations are classic for the dock's state-of-the-art B-47 use. By this date, however, SAC was already dismantling these docks and shipping them to installations accepting a variety of surplus docks, or, to installations receiving the B-47 late in its life. For example, McConnell had eight of the B-47 docks configured in a proto-alert configuration in the middle 1950s, but completely gone by late 1957. At this same time, SAC planned for Anderson (Guam), with six B-47 docks, to receive 12 more. Survival of the B-47 dock in the continental United States appears very infrequent and in the one known instance at Seymour-Johnson Air Force Base in North Carolina is likely an example of surplus availability and alternate use, as the base never received the B-47.[111]

By mid-August 1951, Luria had begun design efforts for a more versatile SAC wing hangar than either of the two intended explicitly for the B-36 or the B-47. Luria's multi-purpose wing hangar accommodated configurations of the B-29 / B-50 (two), the B-36 (one), the B-47 (two), and the as yet only planned B-52 (one), measuring approximately 124 feet deep by 296.5 feet wide.[112] The Luria multi-purpose wing hangars continued to minimize enclosed space—closely following the dimensions of the bombers intended for service in a stepped configuration widest for the aircraft wings and only about 40 feet deep by 36 feet wide for the aircraft nose. The nose space met the requirements of the B-52, and was only partially deep enough for the B-36.[113] The Luria multi-purpose wing hangars continued to be mobilization structures, intended for efficient erection and with the potential for takedown and shipment to a new installation. The Luria multi-purpose dock went through rapid minor revisions during 1952, altering the width and depth in increments of less than two feet.[114] By early 1953, the Luria multi-purpose wing hangar was under construction at selected installations, continuing to be erected from the 1952 drawings well into 1955. Luria wing hangars were planned as multiples, but in placement side by side, not back to back as suggested at the outset of 1951 by Mills & Petticord (Plates 66-74).

By early 1953, the Air Force authorized SAC headquarters at Offutt Air Force Base in Omaha to develop the definitive criteria for warm-climate, multi-purpose docks.[115] Andrus Martin Associates of Omaha submitted drawings for the definitive SAC multi-purpose wing hangar in August 1953—most likely

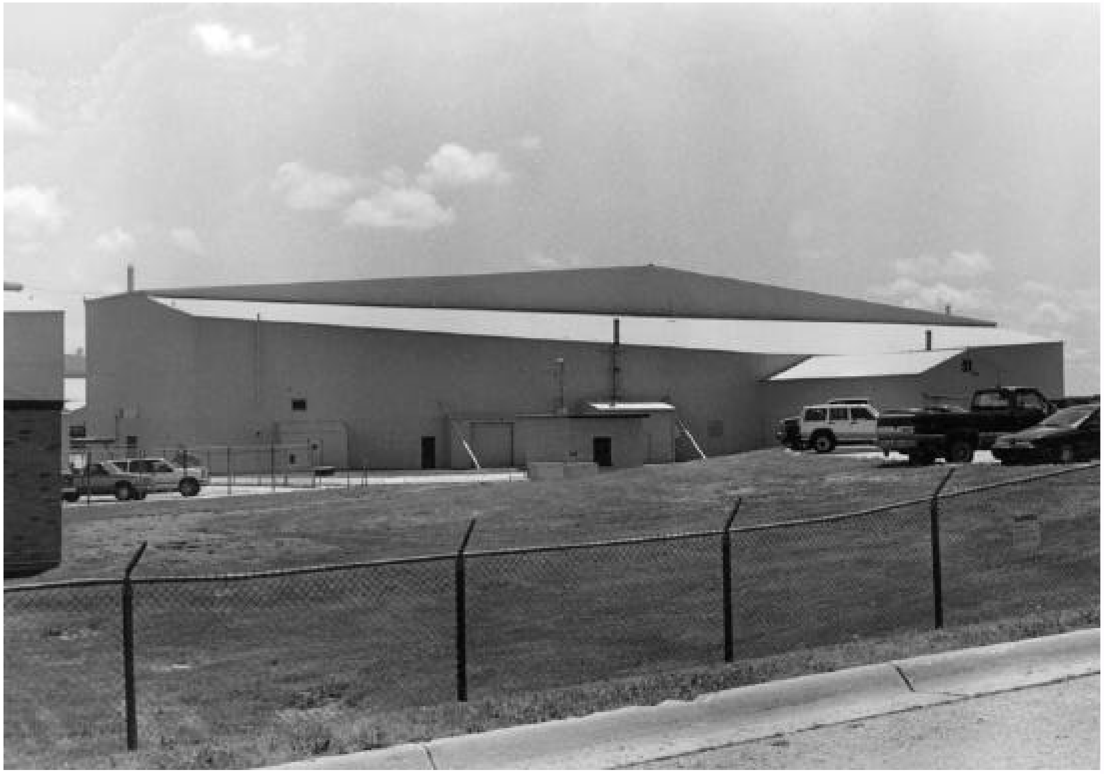

Plate 59. B-36 wing hangar (rear). Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Table 1

Strategic Air Command
Nose Docks and Wing Hangars

	Northern Tier	East Coast	West Coast	Mid/ South	Overseas	Total
B-29	0	34	8	46	4	92
B-36	31	0	0	0	0	31
B-47	0	0	18	12	6	36
Multi-purpose Luria	92	14	4	15	4	129
Late 1950s Generic (B-52)	27	17	11	7	17	79
Other	1	16	8	13	0	38
Total	151	81	49	93	31	405

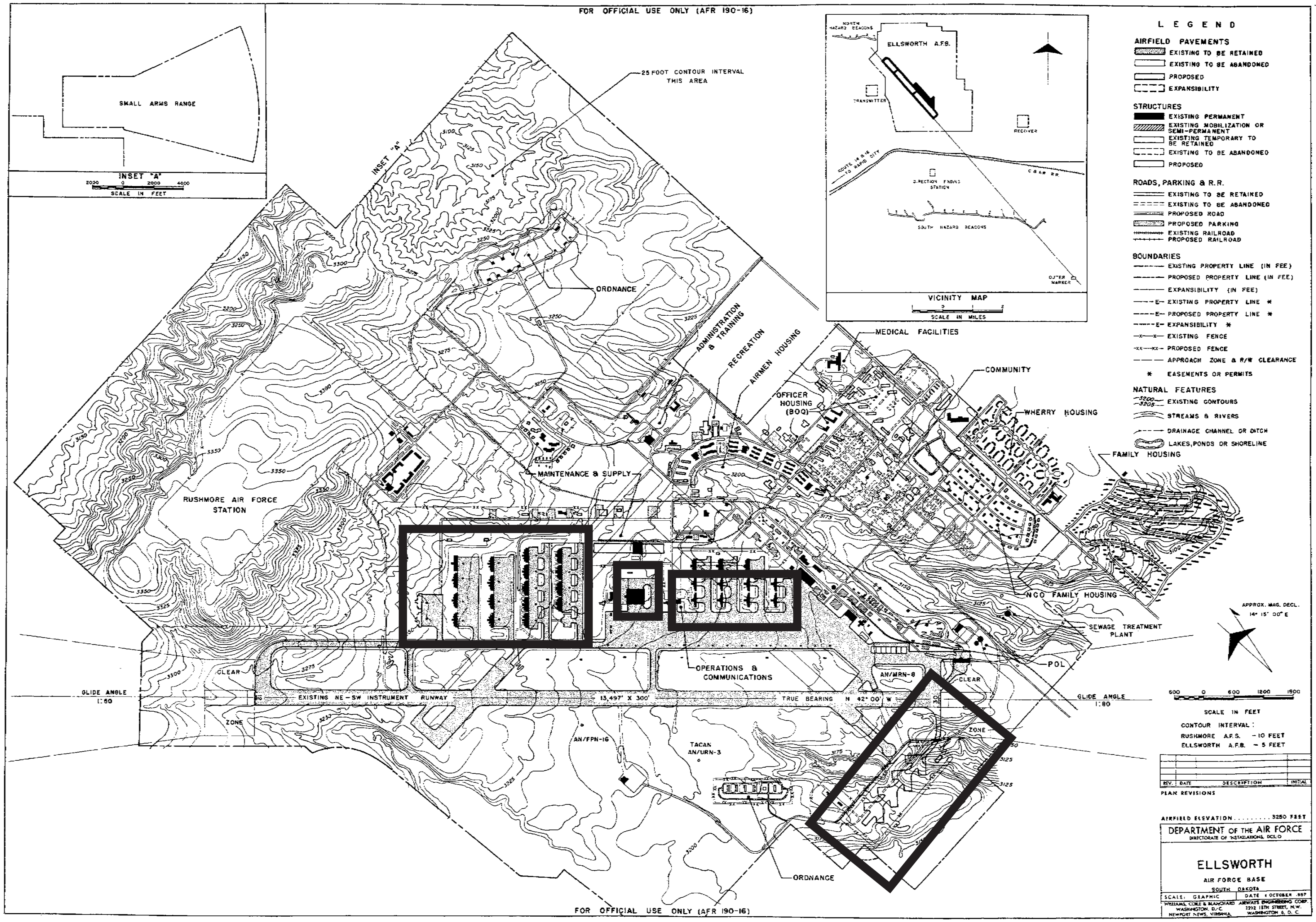

Plate 60. **Grouping of eight B-36 wing hangars, midground right. Grouping of 17 multi-purpose and B-52 wing hangars, midground left. Thin-shell concrete B-36 hangar, center. Planned SAC alert, right. Ellsworth Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

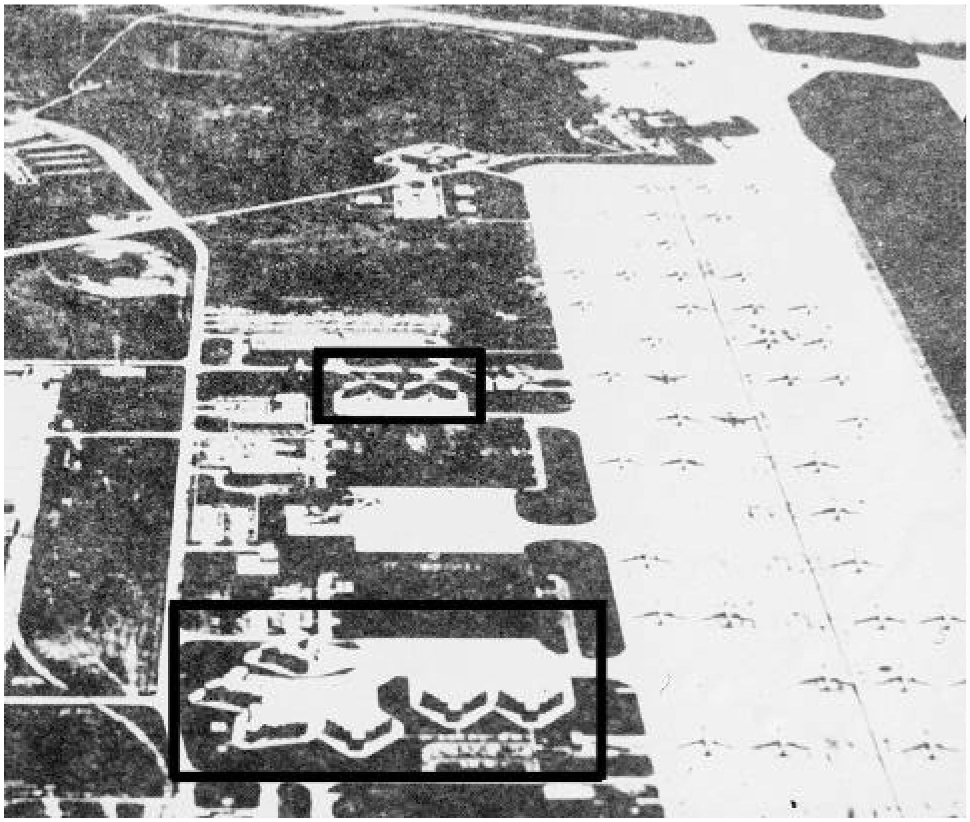

Plate 61. Groupings of six (foreground) and two (midground) B-47 wing hangars. McConnell Air Force Base. 1952. Courtesy of the History Office, McConnell Air Force Base.

Plate 62. B-47 in flight. View of 1956. Courtesy of the Air Force Historical Research Agency.

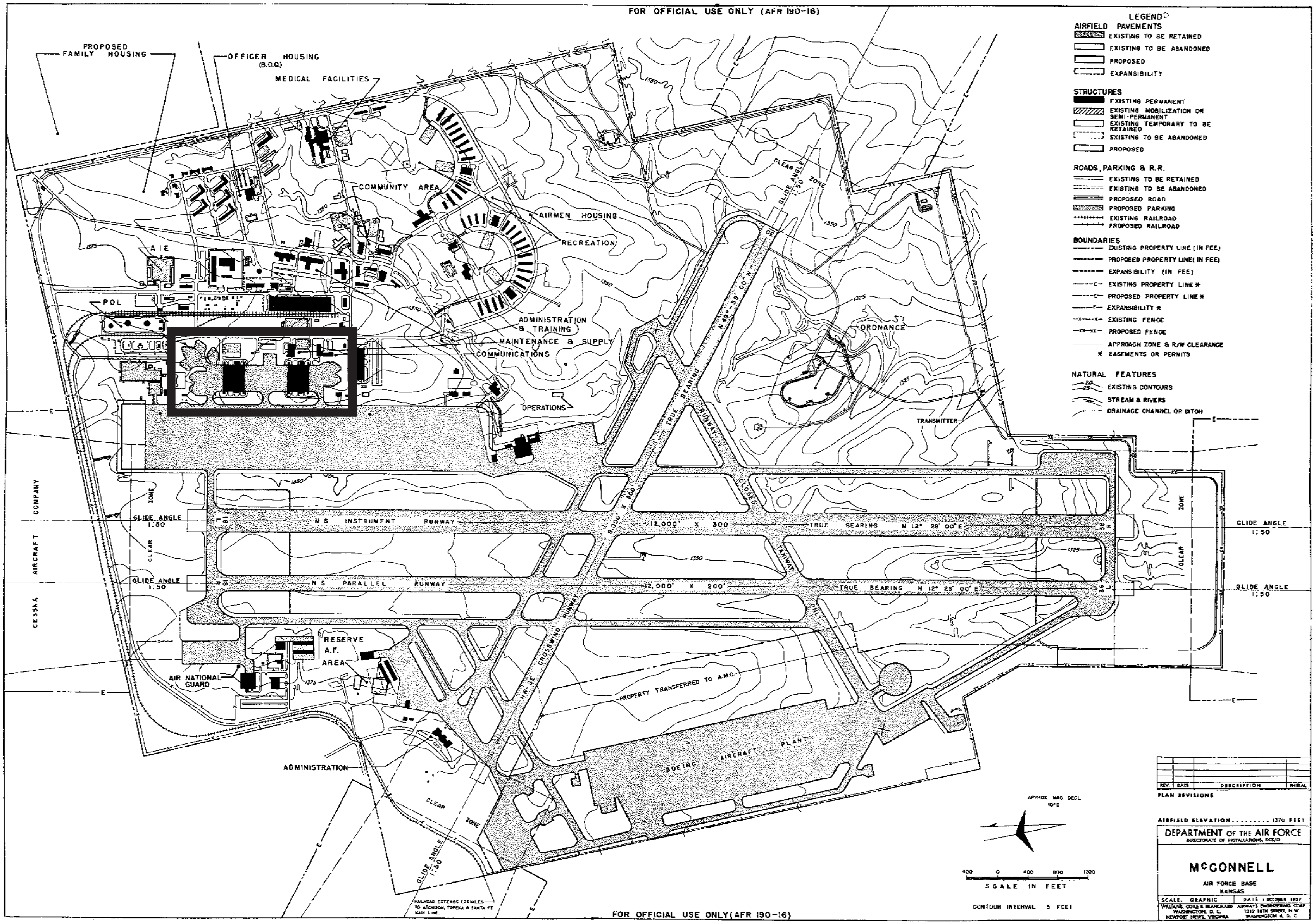

Plate 63. McConnell Air Force Base. Showing parking aprons for the B-47 wing hangars, midground left. A pair of medium bomber double-cantilever hangars present by about 1954. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.

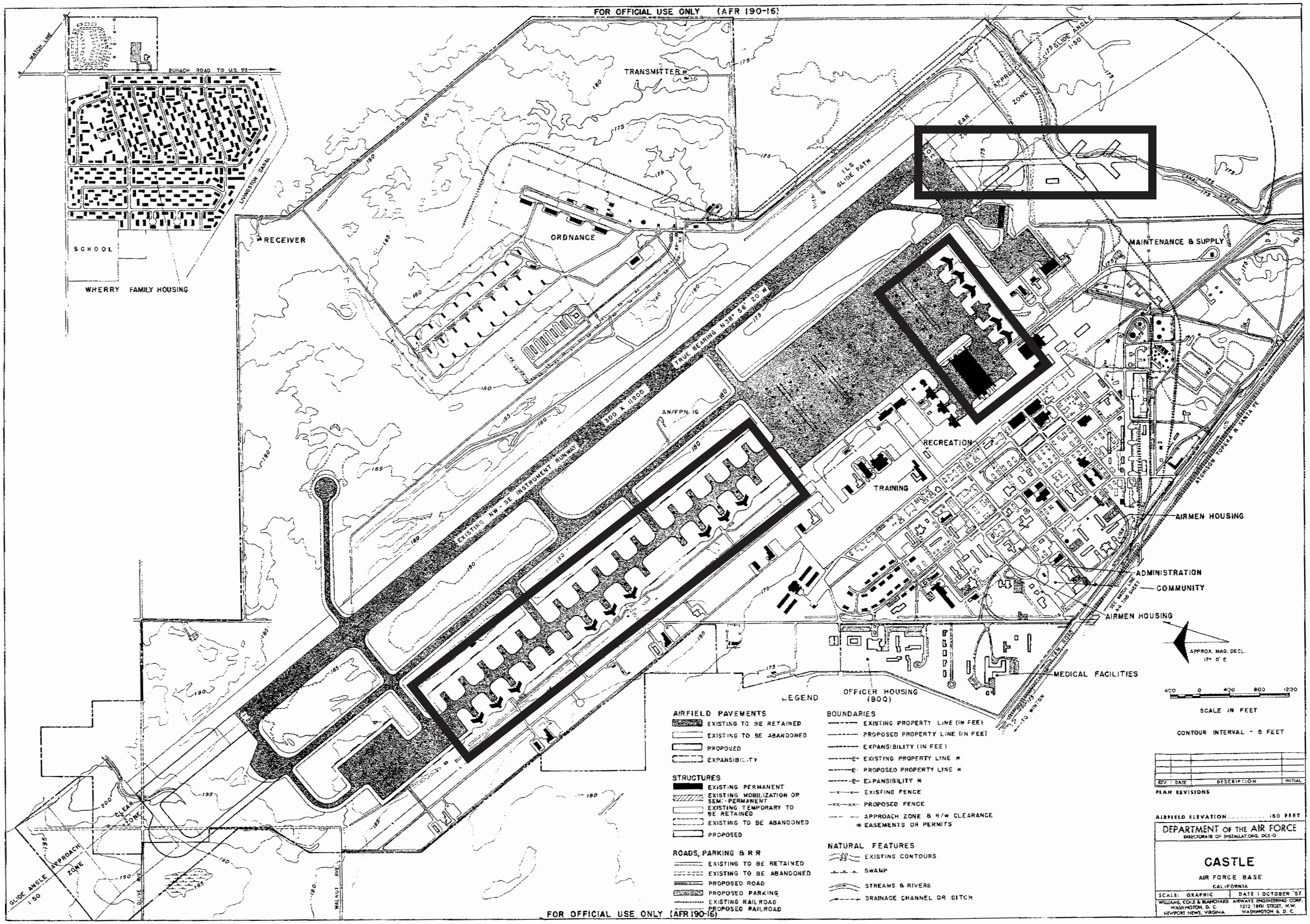

Plate 64. Castle Air Force Base. Groupings of nine and five B-47 wing hangars, parallel and perpendicular to the flightline. Heavy bomber double-cantilever hangar, with smaller grouping and planned SAC alert, right. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.

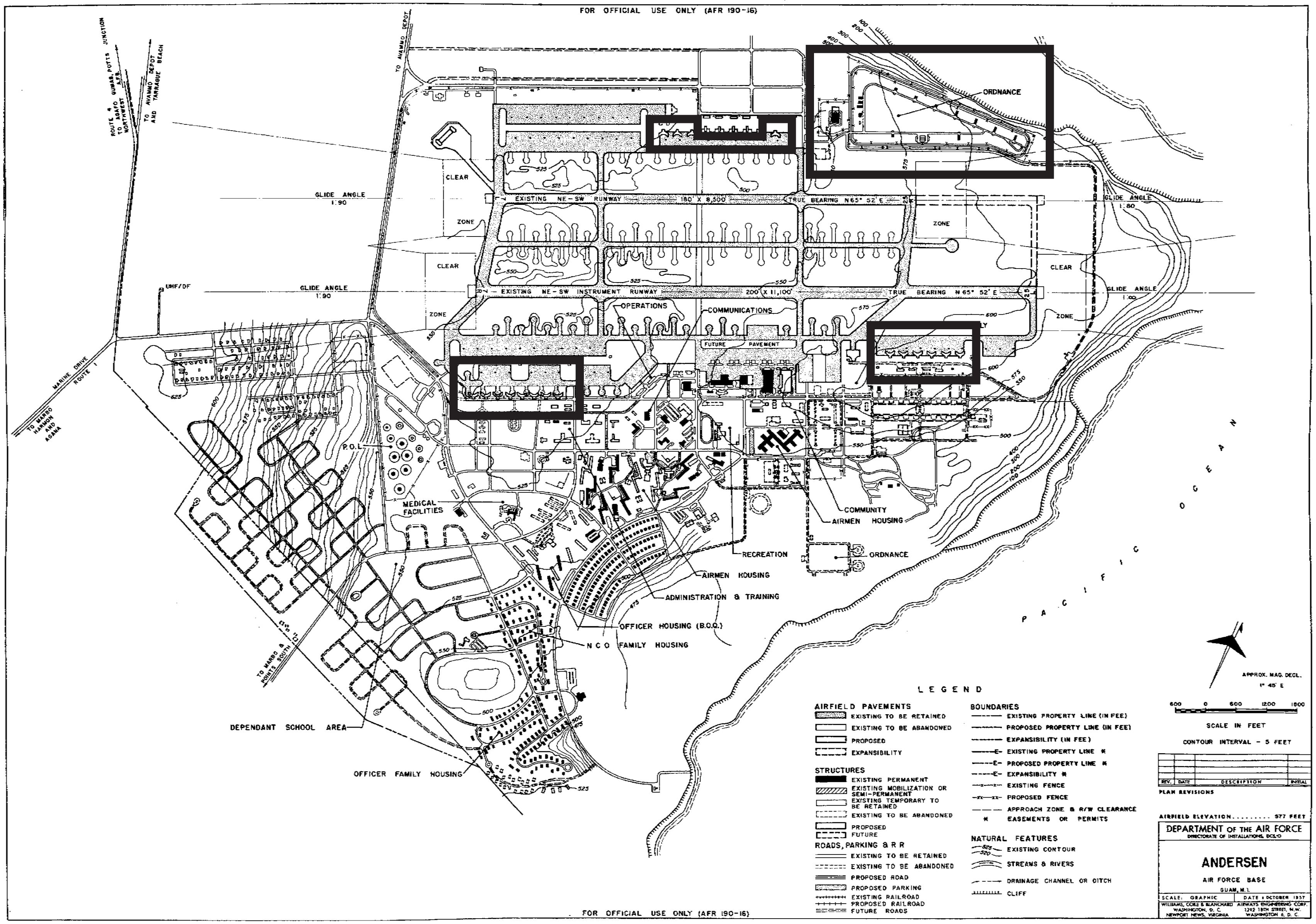

Plate 65. Andersen Air Force Base. Groupings of eight (midground left), six (midground right), and four (background center) B-47 wing hangars, planned for erection. Q Area, upper right. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.

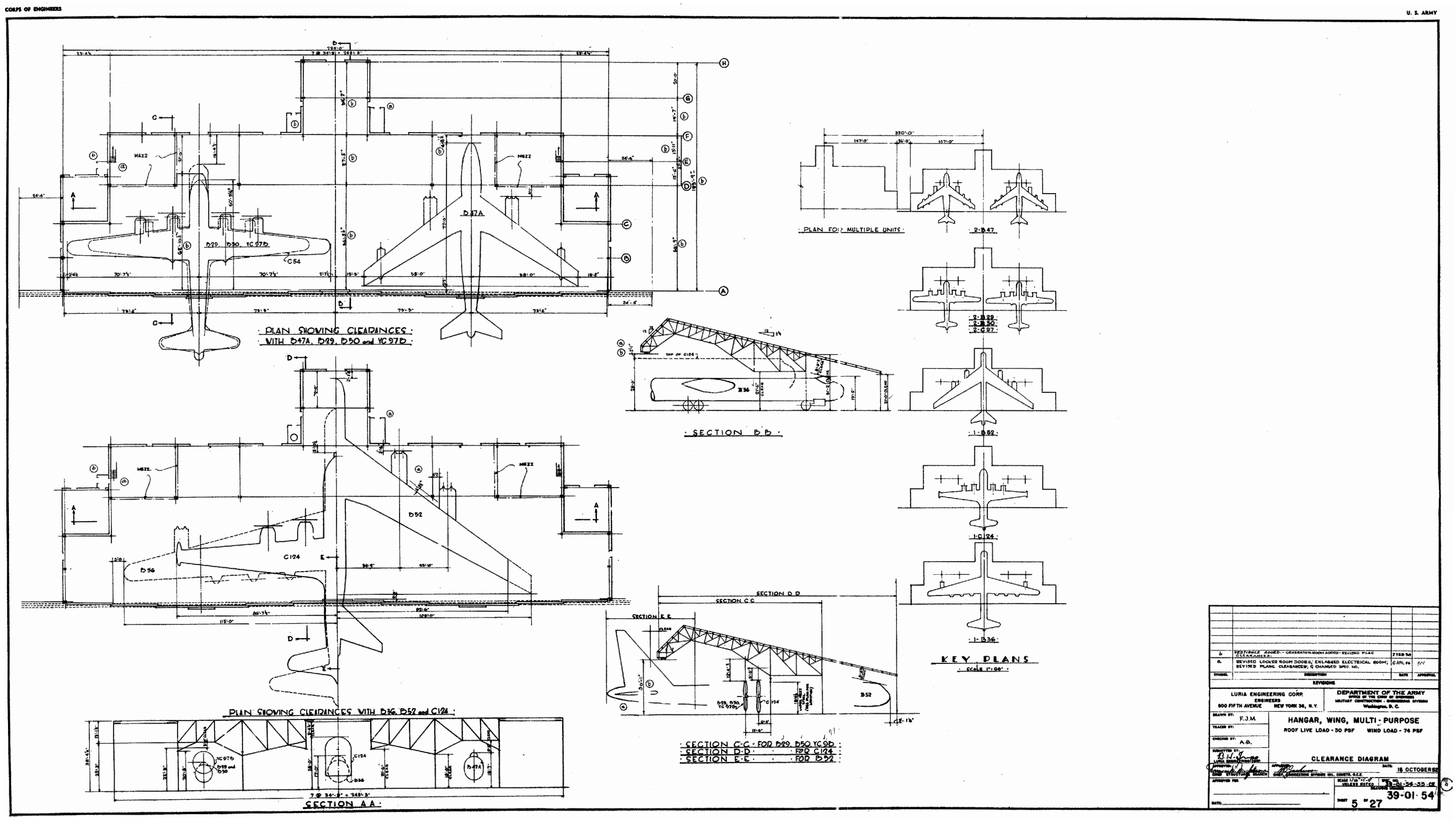

Plate 66. Luria Engineering. Multi-purpose wing hangar. August 1951. Courtesy of the History Office, Army Corps of Engineers, Fort Belvoir, Virginia.

Plate 67. Luria Engineering. Multi-purpose wing hangars. Ellsworth Air Force Base. Front oblique view, July 1999. Photograph, K.J. Weitze.

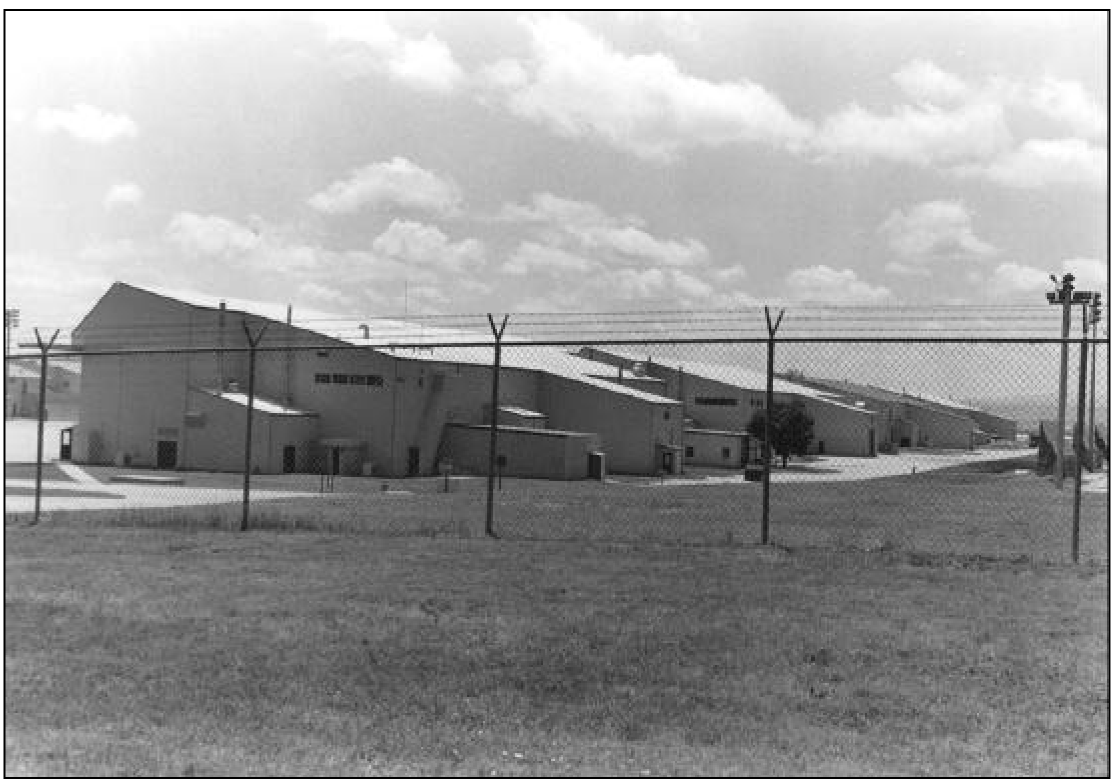

Plate 68. Luria Engineering. Multi-purpose wing hangars. Ellsworth Air Force Base. Rear oblique view, July 1999. Photograph, K.J. Weitze.

Plate 69. Luria Engineering. Multi-purpose wing hangars. Ellsworth Air Force Base. Front full view, July 1999. Photograph, K.J. Weitze.

Plate 70. Luria Engineering. Multi-purpose wing hangar at the former Loring Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 71. Luria Engineering. Multi-purpose wing hangar at the former Lincoln Air Force Base. Front view, July 1999. Photograph, K.J. Weitze.

Plate 72. Luria Engineering. Multi-purpose wing hangar at the former Lincoln Air Force Base. Rear view, July 1999. Photograph, K.J. Weitze.

Plate 73. Luria Engineering. Multi-purpose wing hangar. Whiteman Air Force Base. Rear view, July 1999. Photograph, K.J. Weitze.

Plate 74. Luria Engineering. Multi-purpose wing hangars at the former Forbes Air Force Base. Front oblique view, July 1999. Photograph, K.J. Weitze.

working from Luria baseline designs. SAC distributed the specifications for this wing hangar to Corps district offices out of Seattle, Charleston, Savannah, the Eastern Atlantic, and the Middle East.[116] Actual construction from these definitives is unknown. Engineer Peter A. Strobel re-entered the design picture for the docks in early 1953, with a formal Strobel & Salzman revision of the Luria multi-purpose wing dock of 1952. The number of sheets associated with the dock increased from 27 to 39 with this effort.[117] Strobel had gone into partnership with Salzman after his work with Luria on the B-36 dock in early 1951, designing one of the first ADC alert hangars shortly thereafter. Progress on the docks continued to be evolutionary in type, with historic lineage confusing and ties to the basic Luria 1952 design sometimes obscured. In 1955, Kuljian—the engineers of the double-cantilever hangar—also executed a formal revision of the dock for SAC.[118] The total multi-purpose dock grouping, in all of its variations, numbered about 130 units at 23 bases by late 1957.[119]

During the next several years—with the Kuljian double-cantilever hangar largely in place and the Kuljian formal revision of the Luria multi-purpose wing hangar the latest in the evolutionary pattern, SAC use of wing hangars continued. SAC primarily split dock construction for its B-36s and B-47s between the Luria wing hangars of 1951 and 1952, and the ad hoc solutions wheeled into place. During the middle and late 1950s, too, SAC modified the Luria 1951 wing hangars for the B-36 to accommodate the B-52 as it replaced the B-36. Leo A. Daly, SAC's lead firm out of Omaha, handled the modifications for the dock, adding a rectangular section across the front of the dock 36 feet deep and increasing the height above the original 38 feet.[120] (See Plates 59-60.) At Loring, the 42nd Heavy Bombardment Wing modified their eight B-36 docks with SAC assistance for receipt of the KC-135—the tanker accompanying the B-52—in the autumn of 1957, after first attempting to work with Luria directly.[121] The noses of the B-52 and KC-135 filled only a minor part of the B-36 nose spatial cavity, but the extension allowed just at 100 feet for the body of the aircraft. The wing hangar, as modified, became more nearly a full shelter for the B-52, with only tail exposed through the door. At Loring, the modifications caused a structural deterioration of the Luria wing hangars, which were considered unsafe by the late 1950s.[122] At Ellsworth, the docks remain in use and appear in excellent condition today. Not until after the Air Force discontinued the double-cantilever hangar program in 1955, and the modified Luria B-36 and multi-purpose docks proved less than fully satisfactory for the B-52, did SAC push a next generation program of maintenance docks. In July 1956, Luria provided the Air Force with the design for a standard aircraft shelter intended primarily for the B-52. This structure measured 246.5 feet wide and 177 feet deep, completely accommodating the B-52.[123] Formal revisions soon followed, with submitted drawings for the dock in early 1957.[124] By late in the same year about 80 of these docks were in place at 16 bases[125] (Plate 75).

With the suspension of the double-cantilever hangar program—and even with the intent of replacing it with the S-250 steel-arch hangar of 1957—SAC continued to depend heavily on the wing maintenance hangar for the buildout of the B-52 program during the late 1950s and early 1960s. The Military Construction Program of 1957-1958 (fiscal year 1958) called for 77 additional Air Force maintenance docks, with 70 such docks (primarily for the B-52) centrally procured after mid-1957.[126] Procurement of B-52 docks was steady and in large numbers during the late 1950s. Luria provided new baseline designs in 1957-1958, with the dock simplified to a more generic box shape about 130 feet deep and 225 feet wide.[127] By 1959, the Directorate of Civil Engineering also formally noted that SAC was dismantling older and excess docks, shipping them to the installations with the greatest need.[128] As of 1960, the Air Force directed "maximum economic use of available facilities," conducting a "nation-wide dock analysis" in November "to determine where surplus aircraft maintenance docks were available for relocating to bases deficient in covered maintenance space." SAC's needs for new B-52 docks, as of this date, were still interpreted to be 22 for fiscal year 1962, but relocation was to suffice. Congress did nonetheless appropriate over seven and one-half million dollars for 17 B-52 docks, planning for 34 new docks in fiscal year 1961. As of early 1961, too, SAC commissioned its final major aircraft dock of the early Cold War, a fuel systems dock. Ten were in planning for fiscal year 1961. The pilot SAC fuel systems dock went under contract in March 1961 at Robins Air Force Base in Georgia for Air Materiel Command (AMC), and the first of this late 1950s SAC dock went in at the northern tier bases across Montana, North

Plate 75. Luria Engineering. B-52 wing hangar. Offutt Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Dakota, and Michigan.[129] During 1961 and 1962, SAC erected 20 new B-52 docks and eight additional fuel systems docks, continuing to achieve some of their dock goals through relocation across installations.[130]

The B-52 maintenance docks of the late 1950s and early 1960s—the final evolution of the Luria wing hangar of 1951—defined the next stage of the SAC landscape after that established through the double-cantilever hangar program. At full buildout, the two chief types of B-52 dock appear to have numbered about 200. B-52 docks were typically clustered in groups of four to six, and bracketed one or more double-cantilever hangars where they were present. At bases where no double-cantilever hangar existed, such as those in construction after 1955, the B-52 docks alone defined the landscape. Examples of this phenomenon include Grand Forks and Minot Air Force Bases in North Dakota.

Prefabricated Airmen Dormitories

In about 1951, SAC also undertook an experiment in prefabricated, steel airmen dormitories, partially reflective of steel panel housing tried Air Force-wide at about this time and of the Air Force's formal study of "prefabricated structures and methods of construction."[131] The SAC turn to steel airmen dormitories, however, went well beyond a mobilization solution in response to Korea. SAC picked up where the Army had left off in its experimental barracks project at Camp Grant, Illinois, of 1941. There, Holabird & Root—a Chicago firm also heavily participating in early Cold War design for ADC—designed eight prototype dorms, four of which were completely steel construction (and four of which were hollow tile and concrete block)[132] (Plate 76). SAC commissioned a limited number of three-story dormitories, in clusters of two, three, and four, beginning at its headquarters installation Offutt Air Force Base in Omaha. These dorms went up very quickly; used highly standardized components; were engineered for wind and vibration resistance; were especially economical; and provided a two-man room with connecting baths, with lounges on each floor—considered a well-deserved luxury for the SAC bomber pilots and crew members who were on call to fly 24 hours a day.[133] The dorms were both

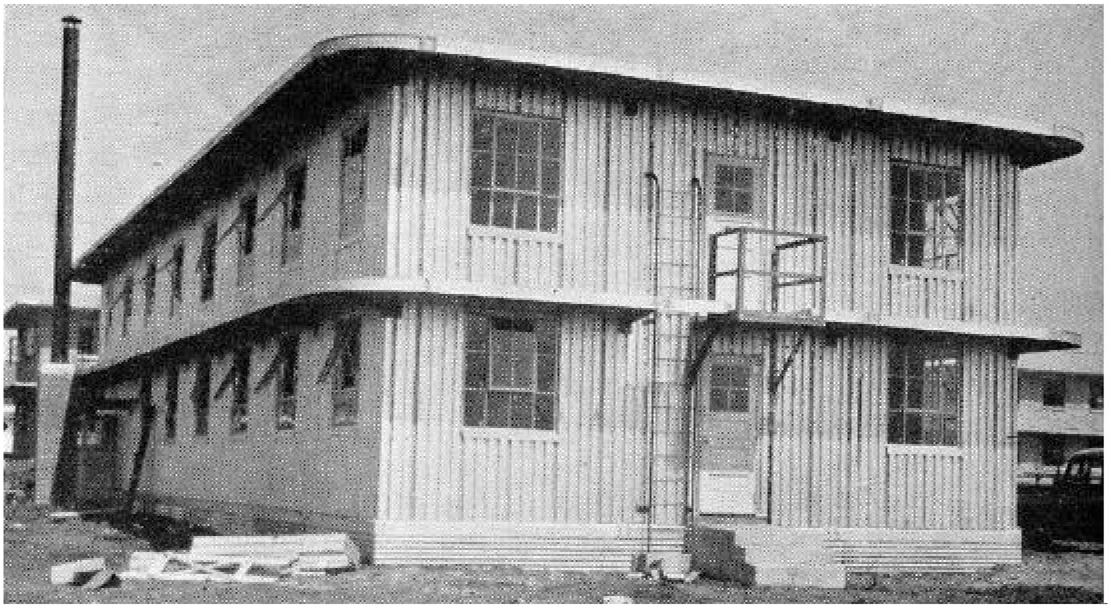

Plate 76. Holabird & Root. Experimental steel dormitory (two of this design built). Camp Grant, Illinois. *Engineering News-Record*. 22 May 1941.

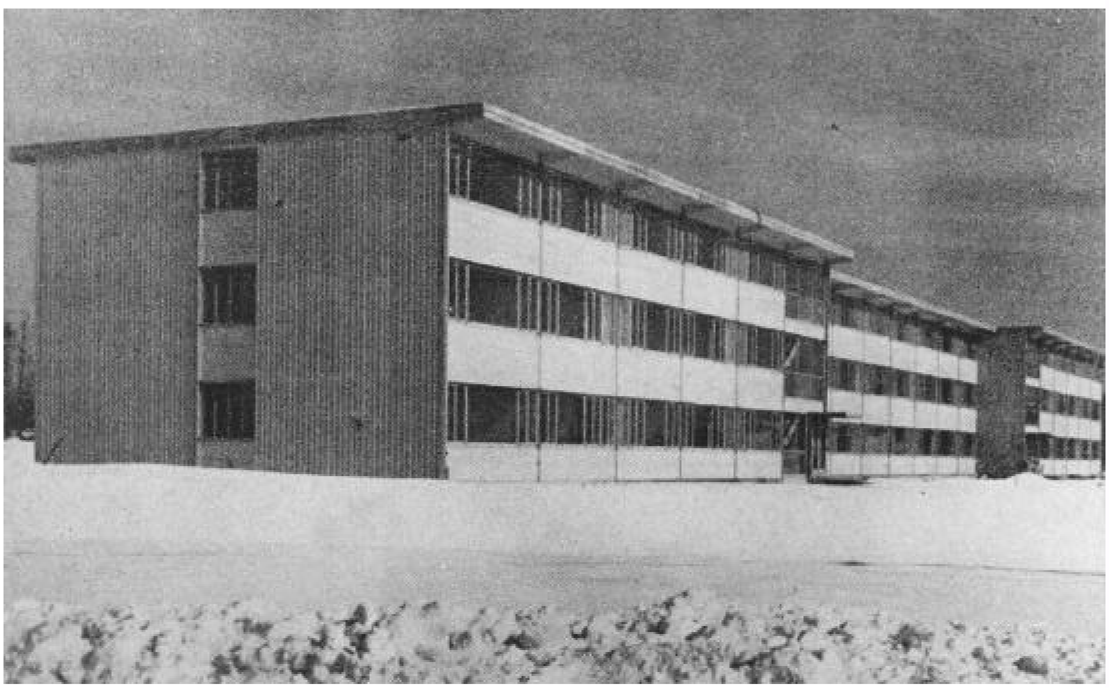

Plate 77. Detroit Steel Products Company. SAC airmen dormitory. Pease Air Force Base. *Engineering News-Record*. 28 February 1957.

Plate 78. Concrete-block airmen dormitory, with three-man rooms. Bergstrom Air Force Base. 1952-1953. Courtesy of the Air Force Historical Research Agency.

Plate 79. Detroit Steel Products Company. Paired SAC airmen dormitories (renovated). Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

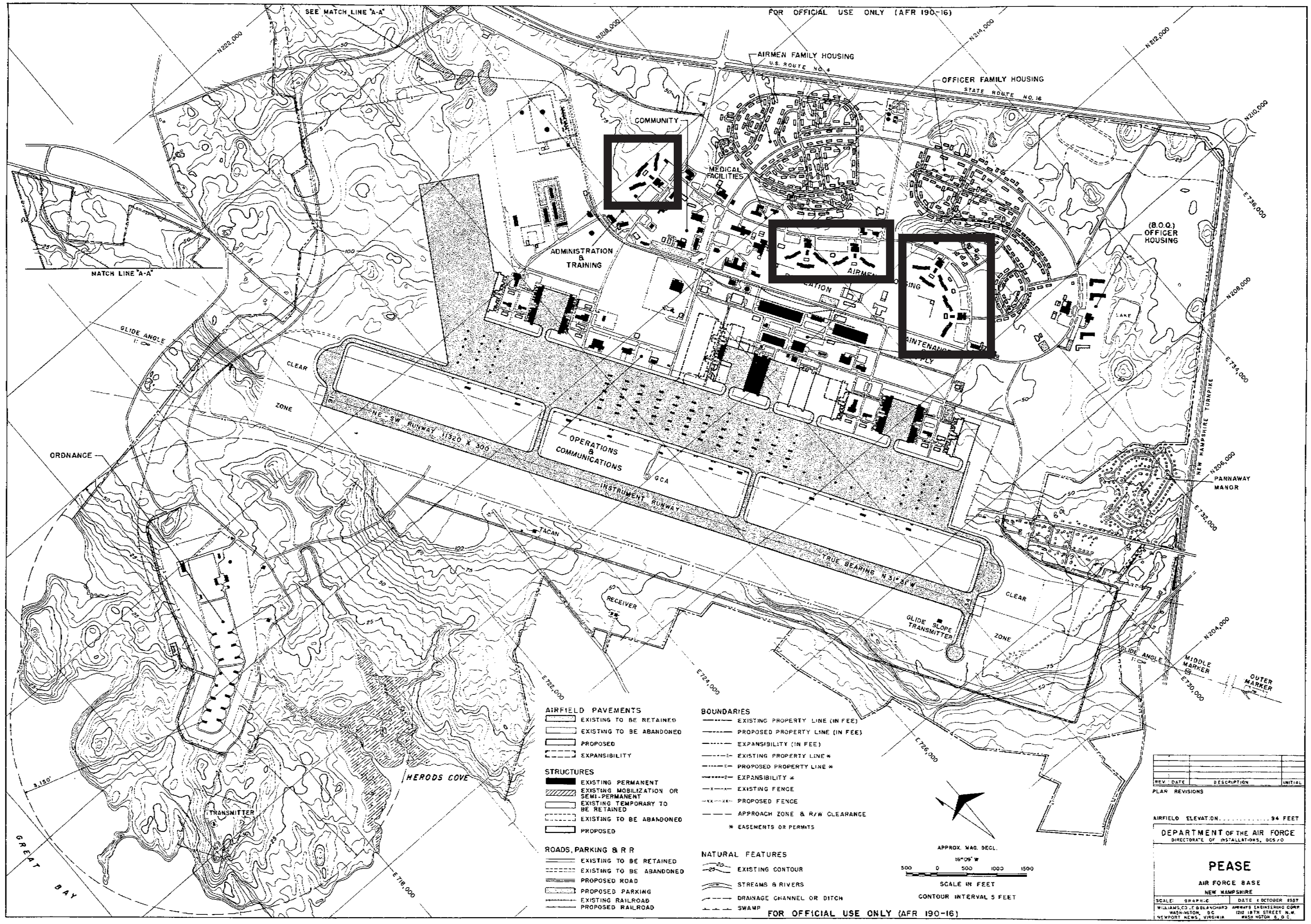

Plate 80. **Five groupings of SAC airmen dormitories in clusters of two and three at Pease Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

July-August 1952 THE MILITARY ENGINEER 33

Only $1.11 Per Cubic Foot for this 37 x 282-ft., 3-story Offutt Air Force Base barracks housing 216 men. Total cost about 321 thousand dollars—approximately 30% less than conventionally built barracks . . . and the whole building is firesafe! Contractor: Korshoj Construction Company, Blair, Nebraska. Designed by AAF Engineers.

Only $1.11 per Cubic Foot for Beautiful Offutt Barracks
Fenestra* Metal Building Panel Construction
Saves Time, Labor, Materials, Money

As compared to the cost of conventional barracks construction, estimated at $2,300 per man, the cost of the nonconventional barracks illustrated above is only an estimated $1,485 per man (just $1.11 per cubic foot)!

And this barracks at Offutt Air Force Base, Omaha, Nebraska, is something special. Flyers of the Strategic Air Command fly "around the clock". As some sleep, others are "taking off". So army engineers are giving them 2-man rooms for peaceful quiet and privacy, better and more convenient bath facilities, a pleasanter place in every way—all at $1.11 per cubic foot . . . a saving of one-third. How?

First, they erect a steel frame. Then into the frame go Fenestra "C" Panels to form curtain walls. These strong, lightweight steel sandwiches packed with glass fiber insulation are 16 inches by 14 feet and can be placed by two men. They form a finished, prime-painted, noncombustible outside and inside wall at the same time. After three courses of "C" Panels, in goes a 14-foot window assembly including Fenestra Steel Windows. Then more panels and up leaps the building!

No mason, no carpenter, no lather, no plasterer. Just a steel worker and a painter, period!

Floors, ceilings and roof are Fenestra "AD" Panels, cellular, with a smooth, flat surface top and bottom. This "AD" Panel floor is topped with two inches of concrete and finished in asphalt tile. And the bottom of the panels forms a finished, prime-painted, noncombustible ceiling for the rooms below.

Think of the advantages in using structural material that also forms finished walls and ceilings. No wonder building costs were cut one-third!

Make Those Same Savings Yourself. Call the Fenestra Representative today (he's listed under "Fenestra Building Products Company" in your Yellow Phone Book). Or write Detroit Steel Products Company, Dept. ME-7, 2284 East Grand Blvd., Detroit 11, Mich.

Fenestra METAL BUILDING PANELS
. . . engineered to cut the waste out of building

"D" Panels for floors, roofs, ceilings. Standard width 16". Depth 1½" to 7½".

Acoustical "AD" Panels for ceiling-silencer-roof. Width 16". Depth up to 7½".

"C" Insulated Wall Panels. Standard width 16". The depth is 3".

Holorib Roof Deck. 18" wide—lengths up to 24'. Surface can be plain or acoustical.

Plate 81. Detroit Steel Products Company. Advertisement, Fenestra System, illustrating SAC dormitory at Offutt Air Force Base. *The Military Engineer*. **July-August 1952.**

Plate 82. Detroit Steel Products Company. Advertisement, Fenestra System. *The Military Engineer*. **May-June 1952.**

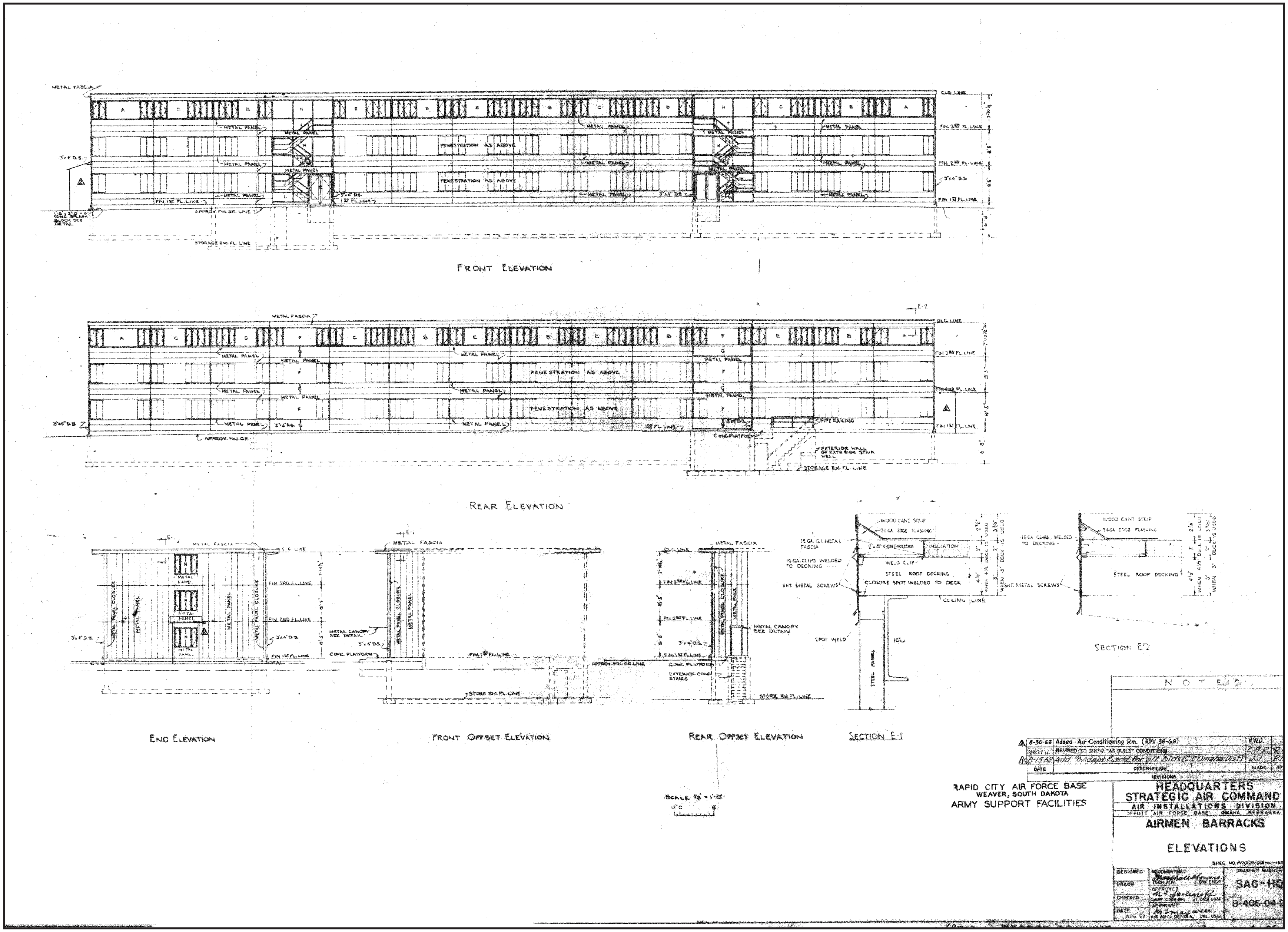

Plate 83. **Detroit Steel Products Company with the Army Corps of Engineers, Omaha District. SAC airmen dormitory. Drawings for Ellsworth Air Force Base dated August 1952.**

futuristic and evocative of mobilization infrastructure of World War II. With regards to the former, the buildings clearly conveyed an imagery intended by SAC's commander Curtis LeMay, and exactly paralleled the SAC character shown to the nation in the film *Strategic Air Command* of 1954. The steel paneling was crisp, with a large amount of window glass and slightly overhanging, flat steel roofs. At this same time, the Air Force erected a limited number of concrete-block "new type barracks" at selected installations of the Eighth Air Force. Both varieties of SAC dorms were highly modern in exterior design and interior plan (Plates 77-79).

The pair of steel flightline dormitories at Offutt had sister facilities at Ellsworth and Loring, erected during 1952-1953.[134] For Ellsworth, SAC erected two distinct pairs at individual sites bracketing the Roberts & Schaefer thin-shell concrete hangar; for Loring, the situation is unclear. A concrete-block dining hall accompanied the dormitories in each case. At Offutt SAC added a cluster of four additional steel airmen dormitories, somewhat removed from the flightline. At least one other grouping of these premier SAC airmen dorms went in—at Pease Air Force Base in New Hampshire in 1955. For Pease, the group of distinctive dormitories was quite large, numbering 13 in clusters of two and three, each cluster with a mess hall[135] (Plates 77 and 80). Designed by SAC engineers at Offutt, the dorms were steel-frame structures sheathed in steel insulated panels manufactured by the Detroit Steel Products Company. The Fenestra panels, in particular, were engineered for earthquake, bomb, and fire resistance.[136] The Detroit Steel Products Company advertised these airmen barracks, each 37 by 282 feet in plan, as costing only $1.11 per cubic foot of construction. The dormitories came in two sizes, one housing 144 men and the other housing 216 men. The larger dorm at Offutt, in the four-unit cluster removed from the flightline, cost $320,000, a figure about 30 percent less than that for conventional barracks.[137]

The dorms were considered permanent construction, and the penultimate in modernity. Fiberglass insulated the Fenestra panels were 14 feet long by 16 inches wide, and three to seven and one-half inches thick. The panels formed a curtain wall on the steel frame, complemented by Fenestra steel windows (Plates 81-83). The Detroit Steel Products Company described the construction process for *The Military Engineer* in 1952[138]:

> First they erect a steel frame. Then into the frame go Fenestra "C" Panels to form curtain walls. These strong, lightweight steel sandwiches packed with glass fiber insulation…can be placed by two men. They form a finished, prime-painted, noncombustible outside and inside wall at the same time. After three courses of "C" panels, in goes a 14-foot window assembly including Fenestra Steel Windows. Then more panels and up leaps the building!
>
> No mason, no carpenter, no lather, no plasterer. Just a steel worker and a painter, period!
>
> Floors, ceilings and roof are Fenestra "AD" Panels, cellular, with a smooth, flat surface top and bottom. This "AD" Panel floor is topped with two inches of concrete and finished in asphalt tile. And the bottom of the panels forms a finished, prime-painted, noncombustible ceiling for the rooms below.

SAC built these dormitories for airmen of the B-36, an aircraft requiring a crew of 16 men. From installation footprints, it is difficult to discern whether or not SAC intended a distinction in use for the paired and isolated smaller dormitories at Offutt and Ellsworth—possibly as proto-alert crew quarters. Each of these dormitories accommodated the crews for nine B-36s. The larger dormitories were typically clustered in larger groups, at Offutt and Pease—with a set also at Ellsworth. (See Plate 80.) These dormitories do not suggest a heightened readiness, but do acknowledge SAC's premier position in the Air Force of the early 1950s. Of note, these structures were among a very few designed internally by SAC

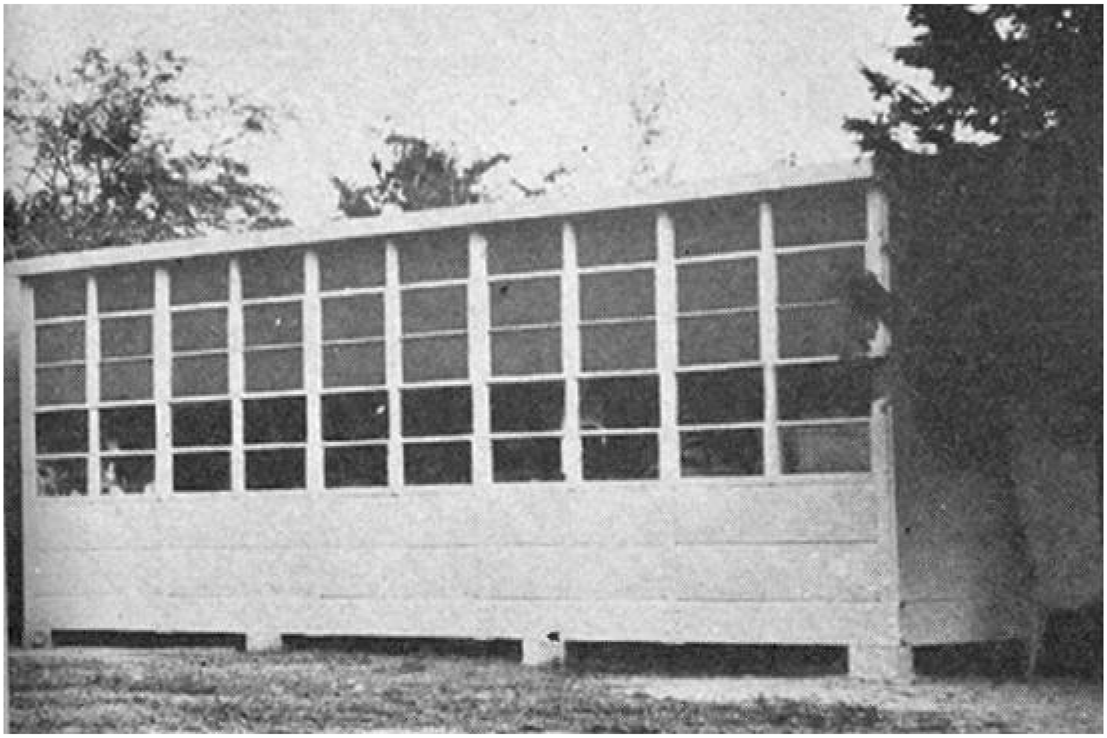

Plate 84. Detroit Steel Products Company. Portable classroom for South Carolina. *Engineering News-Record*. 6 June 1955.

engineers.[139] By 1955, the Detroit Steel Products Company was designing and manufacturing steel-paneled, portable classrooms for school districts in South Carolina[140] (Plate 84).

A final challenge is estimating the total number and time-period of construction for these B-36 SAC crewmen dormitories, and whether or not the Air Force adopted these structures as housing elsewhere in a more generic manner. The shippable, prefabricated nature of the buildings, as well as the ability of the Air Force to erect them without specialized, skilled labor, does suggest that these buildings would have been employed by SAC more generically, or by the Air Force generally, during 1951-1954. The highly recognizable footprint of the structure, with its central section set out, is present for non-commissioned officer family housing at Ernest Harmon Air Force Base in Newfoundland (16 small "dorms"); Lowry Air Force Base in Colorado (48 large and small "dorms"); and Travis Air Force Base in California (30 large "dorms"). These three bases may have the steel structure, but have not been field-checked, and may also represent a coincidence in footprinting.[141] The Air Force Directorate of Engineering did discuss a dormitory type in consideration for bachelor officers, between mid-1954 and mid-1955, that is distinctively reminiscent of the SAC steel airmen housing: the design featured a two-room suite (as in the SAC airmen dormitories), which would allow the officers to sleep in one room and permit them to use the other as a living room.[142] A larger buildout for the steel dormitories was still in consideration as late as mid-1956, when the Department of Defense authorized the Air Force to conduct a cost exercise for its "three standard designs for airmen's dormitories at three geographic areas." The cost exercise specifically referenced the use of different materials, "including steel panels."[143]

Pavement Experimentation for the Very Heavy Bomber

As SAC transitioned from the B-29 and the B-50 to the B-36, all airfields required runway extensions to 11,000 feet and longer, with extensive subsurface construction to support the very heavy bomber coming into the inventory. The problem of properly engineered runways dated back to 1941, when the U.S. Army Corps first began to address experimentation and standards for airfield pavement. Headquarters, Army Air Corps, Washington, D.C., advocated the adoption of soil-cement as standard paving at this time—a material that had been used for highways in California and for foundation stabilization at the Presidio batteries at San Francisco from the late 1930s forward[144] Douglas Aircraft and the Los Angeles Corps discovered the first demonstrated pavement problems with the experimental B-19, in 1941, when the bomber broke through the asphalt airfield pavement to a depth of 12 inches before its planned maiden takeoff in Southern California. Climatic conditions were ideal, dry weather, low water table, and a lightly loaded aircraft—and still the problems were daunting. The technology barrier demanded concrete runways with Portland cement, capable of withstanding much heavier loads than ever before, high landing speeds, damaging vibrations, and engine blasts (first propeller, then jet). "Runways would have to be longer and wider, pavements stronger, and grades gentler than before. Drainage would be more complex and dust control more needful." By 1944, the Corps faced the serious challenge of "longer, stronger landing strips" for the B-29.[145]

Airfield and runway experimentation took highway engineering advances and standards as its starting point, with the Army conducting major soils and hydraulics research and tests at the Corps' Waterways Experiment Station in Vicksburg, Mississippi, and through the Ohio River Division's work with flood control. The Army conducted large-scale pavement tests at Wright and Langley Fields. Successively loading sections of pavement until they achieved failure, engineers tested centers, edges, and corners of concrete pavement slabs; measured deflections; compared concrete laid on differing subgrade construction. The National Advisory Committee for Aeronautics, the Public Roads Administration, and the Portland Cement Association provided additional technical advice. While the Army concentrated on concrete pavement, testing also went forward on asphaltic runways. Engineers in the California Division of Highways, too, made significant contributions through the introduced California Bearing Ratio (CBR) test that measured shear resistance of base and subbase materials. The Corps adopted the CBR for airports during the early 1940s, with tests conducted on commercial airfields in California, Montana, North Dakota, Texas, and Alabama. Additional pavement tests, both concrete and asphaltic, went forward at military fields nationwide. Some test pavement sections were elaborate, as were oval test tracks at Barksdale (Louisiana), Eglin (Florida), and Lockbourne (Ohio) Air Fields of 1943.[146]

As it came into the AAF inventory in mid-1944, the B-29 weighed 140,000 pounds loaded, with an effective range of 3,250 miles. Pavements failed, and at their best, behaved erratically. No airfield pavement had been designed for more than 120,000 pounds gross weight. The Corps began experiments anew with pavement overlays at Hamilton Field north of San Francisco. At this same time, Corps engineers understood that an entirely new plateau of achievement needed reaching: the B-36, already in planning, anticipated that airfield pavements would need to be capable of supporting gross loads of 300,000 pounds—more than twice the load of the B-29. Post-war plans for the first American superairport were for Idlewild in New York, where engineers envisioned 10,000-foot runways (about double the runway length of World War II) able to handle loads up to 250,000 pounds. General Arnold of the AAF inquired as to where the B-36 might land in the U.S. once it was in the military inventory. Engineers told him that the very heavy bomber would break through any airfield pavement in the country. Estimated costs for upgrading a single airfield for the B-36 were about seven million dollars. Experimental pavements were tested for the B-36 in California, Florida, and Alabama. The AAF also immediately understood the importance of cold weather locations for future strategy, and testing for pavements appropriate to these kinds of regions received prioritization beginning at Dow Field in Maine.[147]

The B-36 necessitated runways 11,000 feet long by 300 feet wide; new fighter jets, soon required 10,000-foot runways, 200 feet wide. Very high landing speeds demanded longer clear zones (overruns). High contact pressures (which were partially offset by the development of multiple-tire landing gear) necessitated thicker pavements *and* higher quality materials.[148] Some World War II airfields could be expanded to meet the new conditions; some could not. The problems were many.[149] At the outset of the Cold War, engineers planned SAC runways for the known takeoff and landing distances of the command's bomber inventory, beginning with calculations figured for the aircraft at sea level and 59 degrees Fahrenheit. The engineers then adjusted for elevation and average maximum temperatures, adjusting further for safety. In 1950, SAC runways for the B-47 required ten "battalion" months to build; for the B-36, 18 battalion months—an increase of 50 percent in time over that needed to accommodate the B-29. Generally, two battalions provided the workforce for construction, with SAC runway construction time varying from five to nine months under optimal conditions.[150]

The Air Force built two types of runways during this period: asphaltic and concrete. Concrete pavement was considerably more expensive, although the Air Force strongly preferred it and scheduled the material at permanent (25-year) bases. High temperatures, jet blasts, and spillage of jet fuel damaged asphaltic runways more seriously than these factors affected concrete, and in either case, jet blasts eroded runway shoulders while jet engines sucked in debris. Hence, runway shoulders required stabilization as the Cold War unfolded.[151] The Air Force Directorate of Installations recorded accelerated tests for "tar-rubber" runway and airfield pavement at Hunter Air Force Base in early 1952, in hopes of developing a pavement less costly than concrete.[152] Even where concrete was planned, the material was confined to hangar access; maintenance, fueling, and parking aprons; calibration platforms; warm-up pads; and the final 1000 feet of runways.[153] By mid-1953, the Air Force initiated a formal study of its runways considered "economically infeasible to extend or to be replaced with new runways." Already at this early date, six installations fell into this category.[154] The next year, 1954, Air Force concern over the asphalt versus concrete dilemma reached its height, and the Secretary of Defense requested that the National Academy of Sciences make a separate evaluation. The Highway Research Board of the Academy appointed a committee of consultants to review effects at 12 Air Force Bases and at 12 Naval Air Stations.[155] Additional consultants observed pavement construction in the U.S. for monitoring airfield pavement construction at airfields in Great Britain.[156]

During the late 1940s and the first half of the 1950s, SAC sponsored major runway work at its premier installations. Knowledge of cold weather runway construction benefited from engineering at Loring Air Force Base in particular.[157] During 1954, the Air Force completed two of the world's longest runways—at Kirtland Air Force Base in Albuquerque and Edwards Air Force Base in Mojave Desert of Southern California. The Kirtland runway, accented by three SAC double-cantilever maintenance hangars, featured a subgrade compacted earth 17 to 20 inches thick; a base grade of compacted gravel and stone eight to 13 inches thick; and a top four-inch layer of asphalt. The 1000-foot ends of the runway were concrete, 15 to 19 inches thick.[158] The Air Force constructed the Edwards runway entirely of concrete. At 15,000 feet in length, and with a concrete depth of 17 to 19 inches, the runway was engineered for aircraft weighing up to 500,000 pounds. Taxiways, parking aprons, warm-up pads, and the final 1000 feet at each end of the runway; and, the center 500 feet of the runway; featured the maximum depth of 19 inches, while the remainder of the runway featured the 17-inch concrete paving. The Air Force built the Edwards runway as a prototype for all its future runways, and as a flight test facility.[159] In an opposite direction, SAC tried the tar-rubber paving in a major way at Homestead Air Force Base in Florida when that installation was refurbished for bomber dispersal in 1955. The Corps had previously only laid test sections of the tar-rubber pavement—at Dow Air Force Base in Maine in 1952. At Homestead, SAC based B-47s with a single apron of 1,150 by 8,000 feet, taxiways, warm-up pads, and the 1000-foot overruns were all tar-rubber, in addition to the primary 11,400 by 200-foot runway. The U.S. Rubber Company manufactured SAC's tar-rubber pavement, calling it Sulfa-Aero-Sealz 3080 and shipping it in by tanker trucks from New Jersey[160] (Plates 85-88).

In 1956, the Air Force finalized the asphalt-concrete controversy by adopting concrete for runway pavement exclusively at any primary use facility. The Asphalt Institute protested this policy decision, and as one final test the Air Force constructed a test track of flexible and rigid pavement panels at Kelly Air Force Base in San Antonio. The flexible panels failed, substantiating the Air Force choice of concrete.[161] More sophisticated tests of concrete pavement did continue, however. Later this same year, the Air Force tested prestressed concrete and nominally reinforced concrete in sections constructed at Columbus Air Force Base (Mississippi), additionally studying problems of drainage design problems.[162] By the end of the decade, SAC had lengthened its runways to a typical 13,000 to 13,500 feet at most installations. In

Plate 85. Original aphaltic concrete paving at Loring Air Force Base. 1948. Reproduced from *Army Engineers in New England* (1978).

Plate 86. Reinforced concrete overruns (1000 feet) and warm-up pads, 21 inches thick. Added, Loring Air Force Base, 1956. *Engineering News-Record*. 28 February 1957.

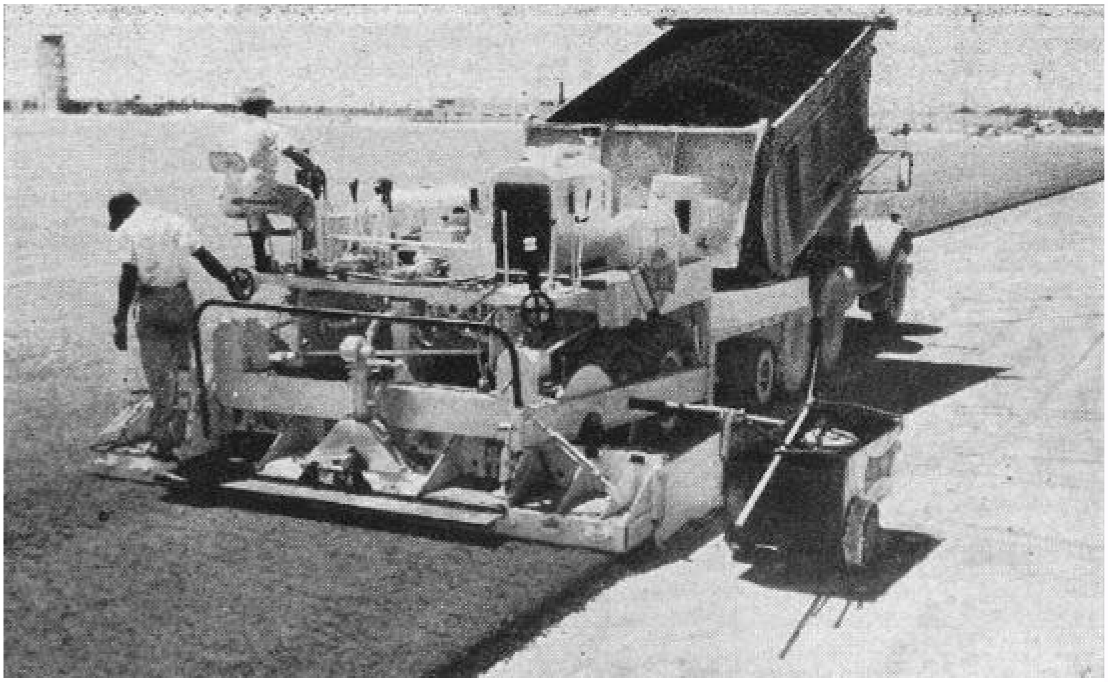

Plate 87. Paver laying tar-rubber surface resistant to jet fuel and bl ast damage. Homestead Air Force Base. *Engineering News-Record*. 16 June 1955.

Homestead Pavement Design

BINDER COURSE

For 200-psi Tire Pressure — Limerock, Limerock Screenings & 85-100 Penetration Asphalt

Sieve size	Specified limits	Job mix approved	Limerock 12%	Limerock 22%	Limerock 18%	Limerock C. scr. 40%	Limerock F. scr. 8%
1½ in.							
1 in.	100	100	100				
¾ in.	89–99	94	50	10ᴐ			
½ in.	74–84	79	6	55			
⅜ in.	—	—	4	11	100	100	
No. 4	43–53	48	0	2	8	95	
No. 10	30–38	34		0	4	63	
No. 20	—	—			0	44	100
No. 40	16–24	20				31	99
No. 80	8–16	12				10	95
No. 200	3.5–6.5	5.0				2	53
% bitumen	5.2–5.8	5.5					
Grade bitumen	AP-3	AP-3					
Stability-lb (Marshall)	1,000 or greater	3,650					
Flow 0.01 in.	16 or less	8					
% voids total mix	3.5–5.5	4.4					
% voids filled	70–80	73.2					
Density-lb/cu ft		138.5					
Theoretical density		144.8					
Stripping %		Negligible					
Swell %		0.02					

SURFACE COURSE

For 200-psi Tire Pressure—Crushed Limerock, Limerock Course of Fine Screenings and Surfa Aero Sealze 3080A Tar-Rub. Blend

Sieve size	Specfied limits	Job mix approved	Crushed limerock C.A. 17%	Crushed limerock Intermed. 13%	Limerock coarse screenings 59%	Limerock fine screening 11%
1½ in.						
1 in.						
¾ in.	100	100	100			
½ in.	88–96	92	55			
⅜ in.	81–89	85	11	100	100	
No. 4	64–72	68	2	8	95	100
No. 10	46–52	49	0	4	63	99
No. 20	34–40	37		0	44	96
No. 40	25–31	28			31	92
No. 80	10–16	13			10	64
No. 200	3–6	4.5			2	30
% bitumen	8.4–9.0	8.7				
Grade bitumen	Tar-Rubber	Tar-Rubber				
Stability-lb (Marshall)	1,000 or greater	3,400				
Flow 0.01 in.	16 or less	9				
% voids in total mix	1.5–3.5	2.9				
% voids filled	80–90	84.2				
Density-lb/cu ft		140				
Theoretical density		144.1				
Stripping %		Negligible				
Swell %		Negligible				

Plate 88. Technical specifications for the tar-rubber pavement surface at Homestead Air Force Base. *Engineering News-Record*. 16 June 1955.

Plate 89. Q Area personnel passes. Board at Fairfield Air Force Station, Travis Air Force Base. July-December 1959. Courtesy of the Air Force Historical Research Agency.

the civilian sector, the Federal Aviation Agency (FAA) had developed policy to limit runways to 10,500 feet, in an attempt to force aircraft manufacturers to focus on equipment design issues rather than working with the assumption that runways could be lengthened indefinitely.[163]

Q Areas

In order to carry out its primary Cold War mission to maintain the capability of launching a sustained attack in a nuclear environment, SAC needed a stockpile of protected special weapons, with storage and assembly sites. SAC had 20 such facilities internationally by the close of the 1950s. The Armed Forces Special Weapons Project (AFSWP) oversaw these sites, commonly known as Q Areas, at their outset in 1946-1951. The civilian AFSWP, historically followed by the Defense Atomic Support Agency (DASA) and today the Defense Nuclear Agency (DNA), maintained the reins for selected Air Force, Army, and Navy nuclear facilities during the first years of the Cold War, paralleling jurisdiction of the 1946 Atomic Energy Commission (AEC). The assembly, test, and storage sites came to be known as Q Areas due to the AEC security clearance restrictions. The Q clearance mandated a full Federal Bureau of Investigation check for all personnel—AEC, AFSWP, or contractor—with access to restricted data or excluded areas (Plate 89). Q Areas were geographically dispersed, always associated with an abutting military reservation, and focused upon stockpiling atomic, then thermonuclear, bomb components. Stockpiled special weapons of the 1950s required the storage and testing of detonators (pits); the assembly and disassembly of training bombs for SAC (not live weapons); training alerts inclusive of convoying a training weapon to a SAC bomber on the flightline; laboratory capabilities; a command post; ready crew quarters; radioactive dump sites; and, ancillary units such as power and fire stations. Q Areas were guarded sites, distinct from their surroundings. The U.S. military housed a sizeable stationing of military men immediate to each Q Area, with these individuals too segregated from the larger adjacent installation. Two types of Q Areas existed historically: operational storage sites and main stockpiles. Although both types were mirror images of one another in their infrastructural components, the operational storage sites were alert facilities assigned the task of achieving a maximum war effort in a number of hours.[164]

The Sandia Corporation of Albuquerque, New Mexico, completely controlled initial management of the Q Areas. Its predecessor, the Z Division of Sandia Laboratory—named for Jerrold R. Zacharias, a physicist who had been brought to the project from the Massachusetts Institute of Technology's Radiation Laboratory by J. Robert Oppenheimer in mid-1945—was organized as numbered groups, such as Z-7 (assembly) and Z-9 (stockpiling).[165] The Z Division next became known as Sandia Base, assuming responsibility for the engineering details, production sites, and military-assisted assembly, testing, and maintenance of ready-state atomic weapons in 1947. Sandia evolved from work at Los Alamos during World War II into a separate installation, near Kirtland Air Force Base in Albuquerque. Stockpiling of the atomic bomb began slowly, with only 13 in the entire arsenal in 1947; 56 in 1948; 298 in mid-1950. The leap came during the Korean war, between 1950 and the close of 1952, when stockpiles reached a total of 832 bombs. In 1955, the United States sustained an inventory of 2,280 nuclear (atomic and thermonuclear) bombs. The first four sites were of the main stockpile type, and were built before 1950. All sites were alpha-coded, with a break in the alpha sequencing for overseas locations.[166]

Sites A, B, C, and D included Mansano Base adjacent to Kirtland Air Force Base and Sandia Base itself; Clarksville Base, adjacent to Campbell Air Force Base and Fort Campbell (Tennessee and Kentucky); Medina Base, adjacent to Kelly and Lackland Air Force Bases (Texas); and Killeen Base, adjacent to Gray Air Force Base and Fort Hood (Texas). Site B achieved completion first in 1948, with Sites A and C operational in 1949. Sandia Base initiated construction of the operational storage sites, the physically smaller alert facilities of key strategic importance, in 1950. The first five of these installations were set up by Sandia immediately neighboring selected SAC bases. These Q Areas were Caribou Air Force Station (AFS) [Site E] at Loring Air Force Base (Maine); Rushmore Air Force Station [Site F] at Ellsworth Air Force Base (South Dakota); Deep Creek Air Force Station [Site G] at Fairchild Air Force Base (Washington); Fairfield Air Force Station [Site H] at Travis Air Force Base (California) (Plate 90); and, Stonybrook Air Force Station [Site I] at Westover Air Force Base (Massachusetts). Two additional main stockpile sites were in construction during the early 1950s, inclusive of Bossier Base, adjacent to Barksdale Air Force Base (Louisiana).[167] Sandia transferred operation of the five alert sites bordering the SAC bases to Air Materiel Command after a shakedown period during which Sandia personnel worked at the sites with the Air Force and AEC. Air Materiel Command designated the sites depots, with associated Air Force personnel referenced as Aviation Depot Groups, and subsequently, Aviation Depot Squadrons. Ordered as they had been built, chronologically, the five squadrons were the 3080th through the 3084th, and reported to the 3079th Aviation Depot Wing at Air Materiel Command headquarters at Wright-Patterson Air Force Base in Dayton, Ohio. The 3079th maintained a liaison office at Kirtland Air Force Base near Sandia. Total U.S. continental Q Area sites, inclusive of main stockpile installations and operational storage (alert) sites, was 13. In 1962 the Air Force achieved full control of the Q Areas neighboring its installations through SAC.

The AFSWP did not confine Q Areas to the United States. By August 1950, seven operational storage sites were under contract on foreign soil. Of these, the key group clustered in French Morocco and Spain, with those in Morocco—at Nouasseur, Sidi Slimane, and Ben Guerir—in planning out of SAC headquarters at Offutt in January 1951 and under construction in May. (See Plate 26.) Master plans for Air Force installations of late 1957 indicate that additional Q Areas were located at Goose Bay Air Base in Canada; Anderson Air Force Base in Guam; and, Moron and Torrejon Air Bases in Spain. (See Plate 65.) French Morocco siting developed out of Allied presence there at the close of World War II. Nousasseur, Sidi Slimane, and Ben Guerir were critically important for SAC during its first reflex exercises with B-36 and B-47 bombers, and KC-97 tankers. Noussasser hosted the B-36; Side Slimane and Ben Guerir, the B-47 and KC-97, with asphalted-concrete runways of 12,000, 11,000, and 14,000 feet, respectively. During the early and middle 1950s, the air bases supported the command's emergency

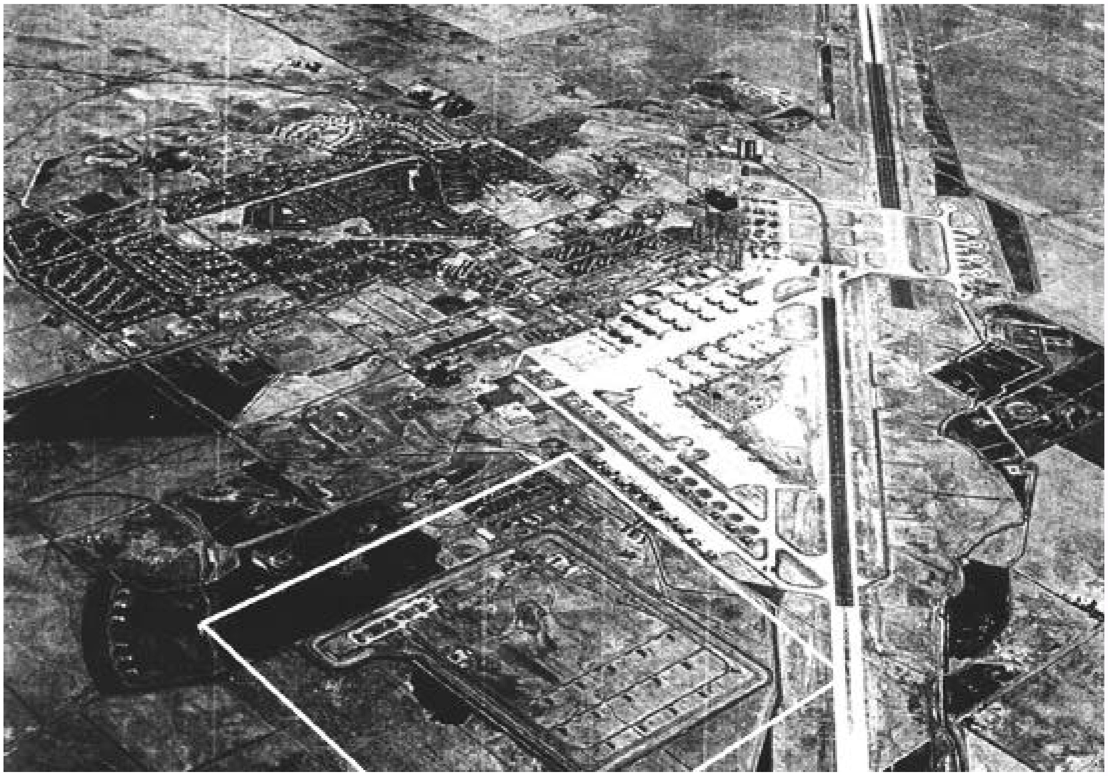

Plate 90. Aerial view of the Q Area at Fairfield Air Force Station, Travis Air Force Base. View of 1962 or 1963. Courtesy of Geo-Marine, Inc.

war plan as staging areas for bombers pointed at the Soviet Union.[168] (See Map 1.) However, with the destabilization of French government in Morocco, and Moroccan independence in 1956, the government of Mohammed V wanted the U.S. Air Force to pull out of the SAC bases in Morocco, insisting on such action after American intervention in Lebanon in 1958. The United States agreed to leave as of December 1959, and was fully out of Morocco in 1963. SAC felt the Moroccan bases were much less critical with the long range of the B-52, and with the completion of the Spanish bases in 1959. After the coup by Muammar Qadhafi in 1969 in Libya, that leader evicted SAC from Wheeler Air Base as well. Libya's SAC base was renamed Uqba bin Nafi Airfield, and went into Soviet use, an irony of the Cold War.[169]

Q Areas typically included about 40 to 50 buildings, inclusive of an igloo nuclear weapons storage area comprising a large percentage of the grouping and distinctly sited within the larger segregated environment. Circumscribed by high, chain-link fences topped with strands of barbed wire, as well as by patrol and maintenance roads, the compounds evolved in three stages. In the initial phase, Q Areas focused on a minimal administrative group of buildings at the main entrance gate, with an underground command post; a weapons spares area with emergency power plant and buried radioactive dump sites; a semihardened, multi-part assembly plant interconnected by an underground vestibule (two plants, I and II—also referenced as A and B—at storage sites augmented for the thermonuclear [TN] weapon); an isolated, detonators (also known as pits or initiators) storage building, the A structure; a checkout building for the stored bomb components, the C structure; and, the igloo storage area. Sandia built alert crew quarters immediate to the assembly plant at the operational storage sites. During 1954-1957, Q Areas augmented their administrative components, focused on greater hardening of the command and control buildings, and the articulation of their multiple communications links; and adding a special weapons crew building, replacing the alert quarters at the assembly plant. Key additions were the nuclear booster storage buildings, the A-2s, substantially bermed or completely underground; and, the S structure, a separate "surveillance" building used to conduct another level of quality assurance activities for weapon disassembly and maintenance. In 1959-1960, Q Areas expanded their assembly plants to accommodate new nuclear weapons technologies, also adding laboratory facilities for heavy metals studies at some locations.

Key buildings within the Q Area were the A and A-2 structures; the C structure; the assembly plants I and II (A and B); the command and control building; and the S structure.[170]

A Structures

The A and A-2 structures both stored nuclear weapons components, also known as "bird cages." The A structure housed atomic bomb detonator pits, while the A-2 structure housed booster capsules for the thermonuclear, or hydrogen, bomb (Plates 91-95). The A-2 structure did not become part of the Q Area until the shift toward the TN bomb in 1954. Generally, both structures are referenced as "A" structures. The roles of the A and A-2 structures were parallel. Both were considered hardened structures, with that of the A-2 additionally shielded by bermed earth or built completely below ground. Identical in design, the A and A-2 structures were built of reinforced concrete, with 10-foot thick walls. For the windowless, aboveground A structure, measuring 41.5 feet by 53 feet (21.5 feet by 33 feet, interior, of nine-foot height), a second story actually provided more protection through its 17 feet of solid reinforced concrete. For the A-2 structure, the storage space for the capsules is entirely bermed or below ground, with a false single story aboveground (again, actually solid reinforced concrete) in the cases where berming was selected. The interior space is divided into four, single-entry rooms with a narrow bisecting corridor between pairs. Each room contained four, six-cubicle; and two, three-cubicle; structural steel Holt racks welded to special weapons storage standards. One A structure stored 120 detonators, 30 per room. Both the A and bermed A-2 structures furthermore gave the appearance of office buildings, when viewed from any distance, through the addition of bands of paired false fenestration and a projecting entrance offset. The bermed A-2 structure was less convincing in this regard from a near perspective, due to the mounded earth and the resultant tunnel-like extension of the offset on one facade. Of curious note, the Q Area A structure is closely related in its generic appearance to the building housing the first command headquarters for SAC at Offutt Air Force Base. That structure, designed in 1941 by architect Albert Kahn for the Martin Bomber Plant adjacent, contained Curtis LeMay's office from 1948 into 1957. When viewed from the side, the first SAC headquarters also offered a simple rectangular box shape, with banded fenestration and a corner entrance offset. LeMay's early headquarters was known as the A Building—a continuance from its designation during the Martin bomber days[171] (Plates 96-97).

Plate 91. Black & Veatch. A Structure in the Q Area at Barksdale Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

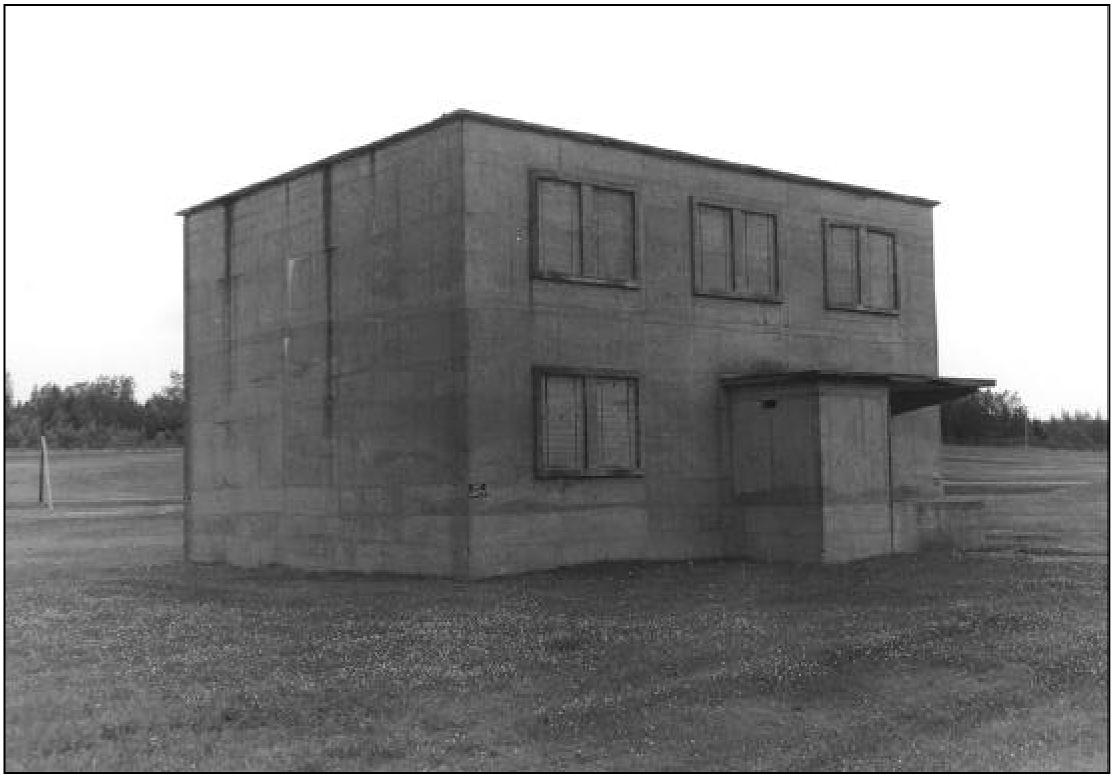

Plate 92. Black & Veatch. A Structure in the Q Area at the former Loring Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

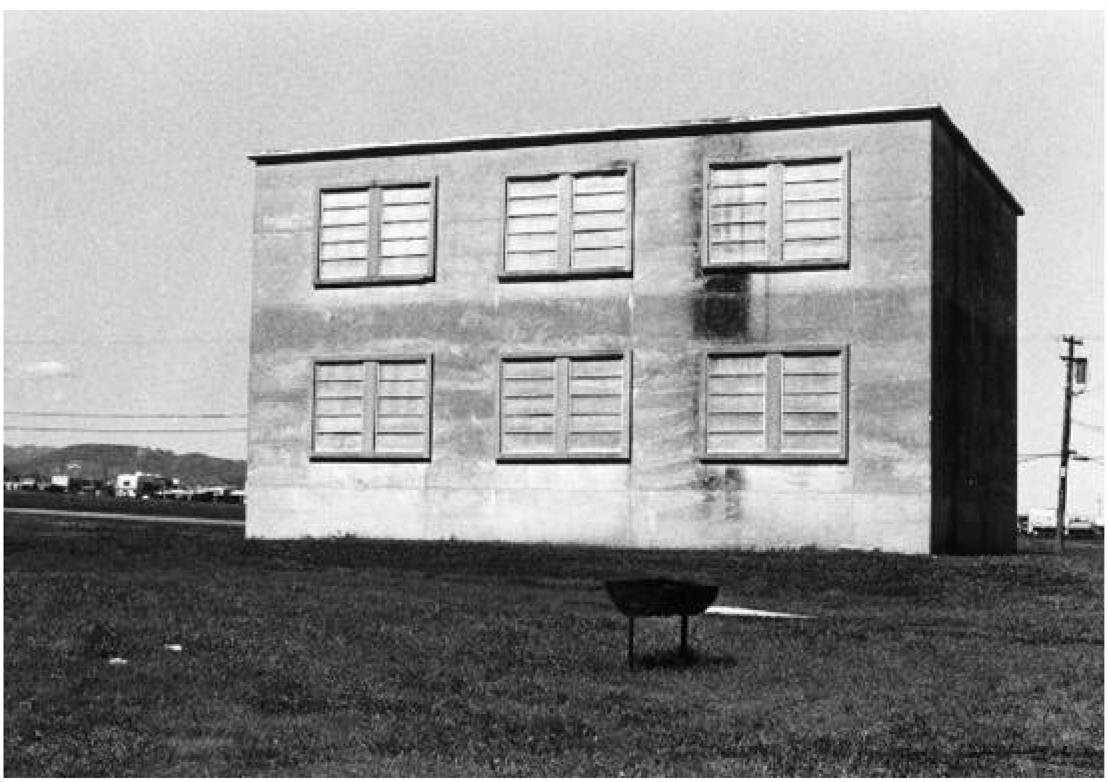

Plate 93. Black & Veatch. A Structure in the Q Area at Travis Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

Plate 94. Black & Veatch. A-1 Structure in the Q Area at the former Loring Air Force Base. Entrance view, 1995. Courtesy of Mariah Associates, Inc.

Plate 95. Black & Veatch. A-1 Structure in the Q Area at the former Loring Air Force Base. Rear corner view, 1995. Courtesy of Mariah Associates, Inc.

Plate 96. Albert Kahn. A Building of the Martin Bomber Plant (1941). SAC Command Headquarters, 1948-1957. View of July 1999. Photograph, K.J. Weitze.

Plate 97. Oblique view of the A Building (first SAC Command Headquarters). View of July 1999. Photograph, K.J. Weitze.

C Structure

Q Area personnel used the architecturally undistinguished C structure to maintain the pits and capsules stored in the A and A-2 structures. The early atomic bomb required polonium/beryllium detonator pits (or initiators) to generate the neutrons of the explosive sequence. Polonium-210 has a half-life of about 138 days, a fact that mandated the replacement of the pits periodically. In order to access the pits, personnel opened threaded couplings machined from fissile uranium—a process that produced radioactive waste items buried within the Q Area. With the phasing out of the atomic bomb, and the phasing in of the TN weapon, a sealed neutron initiator replaced the polonium/beryllium pit. These second generation capsules, brought into the inventory as of late 1954, still required periodic disassembly to verify the integrity of the fissile materials. As of 1962, capsules were completely phased out and AEC maintenance activities with nuclear materials ceased in the C structure.

Plants I and II (A and B)

Plant I (A) served as a maintenance and assembly building for the non-nuclear components of the atomic bomb. Plant II (B) had the same function for the first generation TN weapon of 1955-1957, and was built at selected Q Areas after 1954 (Plates 98-99). The plants were always multi-unit reinforced concrete facilities, earthen embanked, and tunnel interconnected. Concrete arch construction varied in thickness from two feet at the base to 12 inches through the spring, with a crown of 1.5 feet thickness. Plant I was a six-bay structure; Plant II a two-bay structure. Activities in the plants consisted of weapons sub-assemblies during maintenance; inspection and testing of non-nuclear mechanical and electrical systems; and maintenance of TN booster cylinders. For the latter activity in Plant II, a special room vented tritium gas through a vacuum intake device through the top of the building.

Plate 98. Black & Veatch. Plant I (A) in the Q Area at Ellsworth Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 99. Black & Veatch. Plant II (B) in the Q Area at Ellsworth Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 100. Black & Veatch. Command/Control Bldg. Q Area, Caribou AFS, former Loring Air Force Base. View of 1957. Courtesy, Air Force Historical Research Agency.

Command and Control Building

Q Areas added a command and control building in about 1955-1956, coincident with augmentation for the special weapons facilities generally, and with the addition of TN bomb capacity at some locations. The building featured a below ground command post with heightened communications in place, with a single aboveground story. Bands of windows accented the upper story on all of its facades, while the flat roof cantilevered out from the structure (Plate 100).

S Structure

The S structure was a large additional maintenance building constructed after 1954 to augment quality control by separating routine maintenance and assembly functions performed in Plants I and II from other distinct quality assurance activities. Also known as a surveillance structure, the S structure contained electrical and mechanical bays, a calibration room, and a photographic laboratory. Sandia staffed the Quality Assurance and Inspection Agency responsible for work in the S structure.

A single engineering firm, Black & Veatch of Kansas City, designed the primary structures of all Q Areas.[172] The firm began its specialized work for the U.S. government with these facilities, dating to 1946, when the company "accomplished all the architect-engineer services in connection with original planning for Los Alamos."[173] Partners Ernest Bateman Black and Nathan Thomas Veatch, Jr., had founded the firm in 1915, first undertaking city water, sewage disposal, and power systems across Kansas. During World War I, Black & Veatch was among the firms selected to provide the engineering design for U.S. military camps. Beginning in the late 1920s, the firm also involved itself in major highway projects in Jackson County. During that period, Thomas Veatch became close friends with then county judge Harry S. Truman. Black & Veatch maintained its connections to Truman while he served as Senator in Washington, D.C., and later during his Presidency. It was during the Truman term in office, 1948 to 1952, that the firm established itself as the leader in design of special weapons storage facilities—both for SAC and ADC. Design Group 115, of Black & Veatch, handled the Q Areas project, with engineer Harry Callahan involved from the beginning. The firm's Design Group 470 initiated work at the Army Ordnance Plant, Burlington, Iowa, at this same time, to convert the facility to a nuclear components plant. Black & Veatch would go on to design missile checkout and assembly structures and heightened military security systems. Today, Black & Veatch continues as a leader in the design and engineering of advanced technology facilities; hardened structures; and security design. Their expertise extends to radioactive and electromagnetic environments, clean rooms, weapons research facilities, laboratories, nuclear-chemical waste treatment, blast resistant design, blast containment design, and storage magazines.[174]

The Air Force Directorate of Installations (later, the Directorate of Civil Engineering) made explicit references to the development of design and engineering standards for the SAC specialized weapons depots between 1952 and 1956. The project ranked among the top construction concerns—given on a short list that focused on air defense infrastructure, not SAC. The list included the ADC fighter-interceptor alert facilities, the ADC first generation command and control centers, and the ADC early warning radar web.[175] Nonetheless, discussion for the Q Areas was lengthy, noting that SAC proposed Aviation Depot Squadrons at home and overseas. Funding for fiscal year 1953 was roughly five million dollars for three planned Q Areas, with three other special weapons depots actively in the design and construction process. The Directorate anticipated that four of the first Q Areas would be fully completed by the close of 1953. This year was a highpoint for the SAC specialized weapon storage program, and was the period during which Black & Veatch prepared the definitive drawings and facilities criteria that "would identify to the major commands, the construction requirements to support the Air Force Atomic Energy program throughout the world. … These definitive drawings and other pertinent information will be incorporated into a brochure for distribution to major commands."[176] In mid-1954, the Directorate referenced planned construction for a Q Area at one of the Spanish bases, which would complement the three already in place in French Morocco.[177] From this point forward the Q Area program was approaching buildout, and SAC sought approval for its specialized weapons storage as “standard.” The upcoming shift marked the transition from engineering and construction, to full scale special weapons receipt and day-to-day operations at the storage sites.

In late summer of 1954 Air Force headquarters prepared to submit a written plan of the comprehensive SAC special weapons storage facilities—siting and operations—to the Joint Chiefs of Staff, followed by Secretary of Defense and Presidential review. The Air Force then met with Black & Veatch in Kansas City in August. The next month, the Directorate of Construction within the office of the Assistant Chief of Staff, Installations, produced the formal schedule for a second-tier SAC program of special weapons storage design and construction, estimated dates of completion, and beneficial occupancy dates. In October formal guidance was ready for distribution to the appropriate SAC bases. During the remaining months of 1954, the Air Force held meetings with Black & Veatch, amended original guidance, and received Presidential approval.[178] In early 1955, the Armed Services and Appropriations Committees gave this SAC special weapons storage program the necessary clearances, with the Secretary of Defense, the Joint Chiefs of Staff, and the AFSWP staff produced and received memoranda discussing the “responsibilities for the provision of Zone of Interior atomic weapon storage facilities.” The AFSWP had the role of approving “site and building plans for each location in the program.” Agencies in charge were to approve SAC base locations as accepted for the special storage sites at four per month.[179] As of the close of 1956, 15 of the Q Areas were considered fully complete and approved, with the remaining five Q Areas anticipated to achieve the same status by June 1957.[180]

SAC’s planned use of the atomic bomb, and later TN weapon, hinged on its bomber force and their access to the Q Areas. While the Cold War was gearing up during the 1948-1953 years, SAC had B-36s (as of late 1948) and B-47s (as of late 1951) in its inventory. The B-36 could carry the atomic bomb and the very large, first generation TN weapon; the B-47 could not. After the middle 1950s, large yield TN devices compatible with the B-47 were developed. Before 1954, SAC B-36s were required to fly to one of the main storage Q Areas from their home base to receive their bombs, then proceeding on either a hypothetical strike mission or deploying to a forward base—such as those in French Morocco—from which they were posed to launch a strike mission. This first method of coordinating the bombers with the bombs was cumbersome and slow, and meant that SAC could not penetrate the Soviet early warning radar net in a mass strike in under 36 hours. Not until 1954 did several bases with operational special weapons storage sites (alert Q Areas) began receiving atomic bombs. And not until 1956 were atomic bombs in place at all five of the alert Q Areas neighboring Ellsworth, Fairchild, Loring, Travis, and Westover Air Force Bases.[181] It was no coincidence that these five bases also each had large percentages of the total B-36 SAC inventory and the only clusters of the first generation Luria B-36 wing hangar. In select instances, bomber infrastructure supported a specialized mission directly related to an adjacent Q Area, rather than to a wing of B-36s. At Kirtland Air Force Base, neighboring Sandia and the main storage site of Mansano Base, SAC conducted atomic bomb and TN weapon handling courses for crews of the B-36, and subsequently B-47 from 1953 to late 1955.[182] Kirtland supported three double-cantilever hangars—one prototypical medium bomber hangar (and likely the first built in the nation), and two standard medium bomber hangars. By 1957, SAC had the infrastructure, weapons, and organization to “use both atomic and thermonuclear weapons on a mass scale,” honed through “major atomic exercises.”[183] The SAC mission was a fully integrated one.

Alert Apron Configurations and Crew Quarters

By the early 1950s, SAC was planning for an all-jet, intercontinental bomber, the B-52, and an accompanying all-jet refueling tanker, the KC-135. SAC took delivery of its first B-52 in June 1955. Castle Air Force Base was SAC’s first B-52 base, with the installation receiving aircraft in 1956. Loring and Westover also began to receive B-52s before the close of the year. As 1957 opened 88 B-52s were located at SAC bases, while 17 more were in test programs or being modernized at the Wichita Boeing plant. The KC-135 production ran slightly behind that of the B-52, with its initial flight in August

1956.[184] Inventories arriving at SAC installations for both aircraft were steady by 1959. The B-52 and the KC-135 (essentially a modified Boeing 707), like the B-36, were heavy aircraft, requiring the longer, wider runways and upgraded pavement construction. Unlike the large crew needs of the B-36, the B-52 only required a crew of six. The B-52 Stratofortress had eight jet engines, reached speeds of 650 miles per hour, and had a combat range of 6,000 miles without refueling. With refueling by the KC-135, the B-52 "could deliver an hydrogen bomb anywhere in the world and return to the United States without landing enroute."[185] Simultaneous with the changeover toward the B-52 and KC-135, reflex assignments, satellite dispersal, and alert programs went into effect for SAC. Although SAC was still in its infancy, generally, the Air Force programmed 29 bases for the command as of February 1955, planning for another 34 as of April that same year. These programmed SAC installations were in addition to the 38 U.S., and 13 foreign, bases already operational for the command by mid-decade. Of some note, SAC requested a total of 329 bases by July 1959, a fantastic idea. SAC installations, inclusive of those overseas and of tenant bases, peaked at 85 in 1962.[186] As SAC began to put its bombers on sustained alert status at selected bases from 1956 forwards, with dispersal planned for 55 bases at the end of the next year,[187] the command also addressed the needs of a specialized alert apron and immediately adjacent crew quarters.

SAC placed its B-36s, B-47s, and early B-52s on alert first through several distinct configurations, near one end or the other of a runway typically lengthened (or built) for the heavy bomber, and with an awareness of the need for alert billeting. The issue was one of location: could planes be placed in a position for immediate takeoff? Could crews reach their aircraft quickly? SAC's initial time-frame for alert was one hour from notice to takeoff for one-third of its assigned fleet at each of its bases, a change from the six-hour minimum existing before the ready-alert concept. It would become 15 minutes. Both bombers and their counterpart tankers went on alert. The first step was adjusting to existing conditions. In some cases, crew quarters already were in place reasonably close to the flightline: these became alert quarters. In other cases, temporary quarters were established near the planes on alert. In all instances, this first alert posture used apron parking that was in place. The second step was the design and construction of permanent alert crew quarters, with a definitive alert apron. The goal was to achieve take-off within the 15 minute window assumed to be required by 1961: by that date SAC anticipated that the Soviet Union would have an operational ICBM, with a "detection to detonation time" of a quarter-hour.[188]

SAC had established a formal need for new infrastructure supporting an alert concept very early, in July 1954. At that time, the command sought "alert hangars, organizational maintenance hangars and operational shelters for B-52 aircraft"[189]—the latter still a year away from actual receipt. This plan for alert strongly suggests that SAC was following ADC in its conceptualization of what was required for alert aircraft at the flightline: in fact, SAC would not use hangars or shelters in its final buildout for alert, and would continue to use the double-cantilever hangar for maintenance. By late 1955, the command had a study in progress for a "structure that will satisfy all three (3) requirements" [alert hangar, maintenance hangar, and operational shelters].[190] This structure is of unknown specifics, but was also not used. SAC approached the first step toward alert beginning in late 1956 and running through 1958. Some bases, such as Schilling in Kansas, had airmen dormitories near the main bomber parking apron, toward the end of the runway. The time needed to get from these quarters to the aircraft was only three minutes. In this case, as in others, the selected quarters were renovated for SAC alert during 1957. SAC conducted surveys, installation by installation, of its existing buildings to ascertain those that could serve as ready crew facilities. This interim solution focused on barracks able to accommodate one-third of the flight and maintenance crews for an assigned wing, with a few miscellaneous personnel. For the B-47, for example, the sought-after quarters needed to house about 110 men. The building also needed enough space for operations activities, and "should be as close to the flight line as possible."[191] SAC headquarters at Offutt instructed its bases to set aside a specified area of the main ramp as "an alert aircraft parking area" with security for fully-loaded planes. SAC did not advise extensive modifications during this interim period of 1957 to 1958/1960. "Normally a SAC definitive dormitory [including the steel dormitories] or modern type barracks will be used for the interim alert facility."[192] Both the interim alert crew quarters and the interim alert parking area on the main ramp were perimeter fenced, with secure access gates.[193] The command further ordered that installations develop a "colored base layout indicating distances" between parked alert aircraft, alert crew quarters, the messhall, and the parked bombers, with the routes clearly marked in red.[194] SAC then tested this arrangement in operation Try Out, followed by Watch Tower and Fresh Approach.[195]

After establishing an interim policy for alert, SAC undertook the planning needed for a formal alert apron and new permanent alert crew quarters adjacent. Apron assessment, with new construction specifically for alert, moved quickly. SAC had two generic apron configurations in place by late 1957: a main, rectangular apron for mass aircraft parking, and, "stub parking" for individual planes. Within the Eighth Air Force, these configurations were split about equally.[196] The two categories of configuration, however, are an oversimplification of what actually existed across SAC by 1957. The large, single parking apron did of course still exist, as did patterns of single or multiple taxiways lined with short aircraft stubs—the latter represented by Biggs (Texas), Castle (California), and Loring (Maine). (See Plate 64.) Both of these primary apron configurations often had wing hangars in varying numbers at the edge of the single apron or at the individual stubs. But by this date, bomber apron design had begun to seriously change. At Ellsworth, for example, SAC arranged lines of the B-36 and multi-purpose wing hangars perpendicular to the main apron, rather than along its edge. This created short lengths of right-angle stubs, very different from the long stubbed taxiways. By late 1957, Ellsworth had eight such perpendicular stubbed parking areas. (See Plate 60.) Several other bases took this idea further by placing perpendicular parking pens as well as stubs at the end of the runway, facilitating fast takeoff. Griffiss Air Force Base in New York is an excellent example on a large scale (Plate 101); Forbes in Kansas, on a small scale. At McConnell, SAC had eight B-47s, with wing hangars, arranged bracketing the installation's two double-cantilever hangars: six of the B-47s were patterned in a proto-herringbone pattern. (See Plate 63.) One more situation existed in 1957: hot cargo loading pads lining the taxiway parallel to the main runway at its end. Travis and Campbell Air Force Bases are good illustrations. Both of these installations may have engineered the pads to accommodate the special munitions in their adjacent Q Areas[197] (Plate 102).

SAC selected a tentative alert apron before the close of 1956, aware not only of the configurations across its installations, but also of the alert solution developed by ADC in 1951-1952. SAC revisited the alert apron issue several times during 1957 and 1958. First choice was a parking stub configuration, similar to those at Griffiss and Forbes, with individual stubs at 90-degree angles to a 45-degree alert taxiway and with "earth barricades" between the parked alert aircraft at each stub.[198] During the first half of 1957 SAC built 10 alert aprons of this type (Plates 103-104). In the latter half of 1957, SAC changed plans for the alert apron to a herringbone configuration—one where not only was the alert taxiway at 45 degrees, but also the individual aircraft stubs. SAC credited its shift to an analysis of ADC alert aprons, also taking the name from ADC: "Christmas trees."[199] ADC alert aprons were in fact less well defined that what the SAC alert aprons would shortly become. Yet, parking alert aircraft at 45 degree angles was the essence of both alerts. The name Christmas tree stuck for the final SAC configuration, although herringbone was often used in the early written descriptions. By the close of 1957 SAC formally decided to use the Christmas tree alert apron, leaving the 90-degree stub pattern only at installations where construction was too far along to merit stopping and redesign. In October 1957, just four of the new Christmas tree alert aprons were completed: at Mountain Home (Idaho), Robins (Georgia), Wright-Patterson (Ohio), and Wurtsmith (Michigan)[200] (Plate 105). (See also Plate 103.)

By October 1957, the Air Force mapped 43 of the SAC alert aprons on its service-wide master plans, inclusive of the 14 built. The figure represented two-thirds of the total program at buildout. SAC designed only a small number of its alert aprons with individual stubs intended to accommodate the B-36; the remainder were planned for the B-52. SAC channeled funds in fiscal year 1957 to alert aprons at seven B-52 bases, and to alert aprons at five "heavy" [B-36] bases in fiscal year 1958. Immediately after the Soviet launching of Sputnik, SAC alert received $24.6 million in supplemental funding in fiscal year 1958—boosting completion of the program.[201] As such, the apron at Wurtsmith was the first in the program built in the mature Christmas tree pattern explicitly proportioned for the B-52. Wurtsmith, a

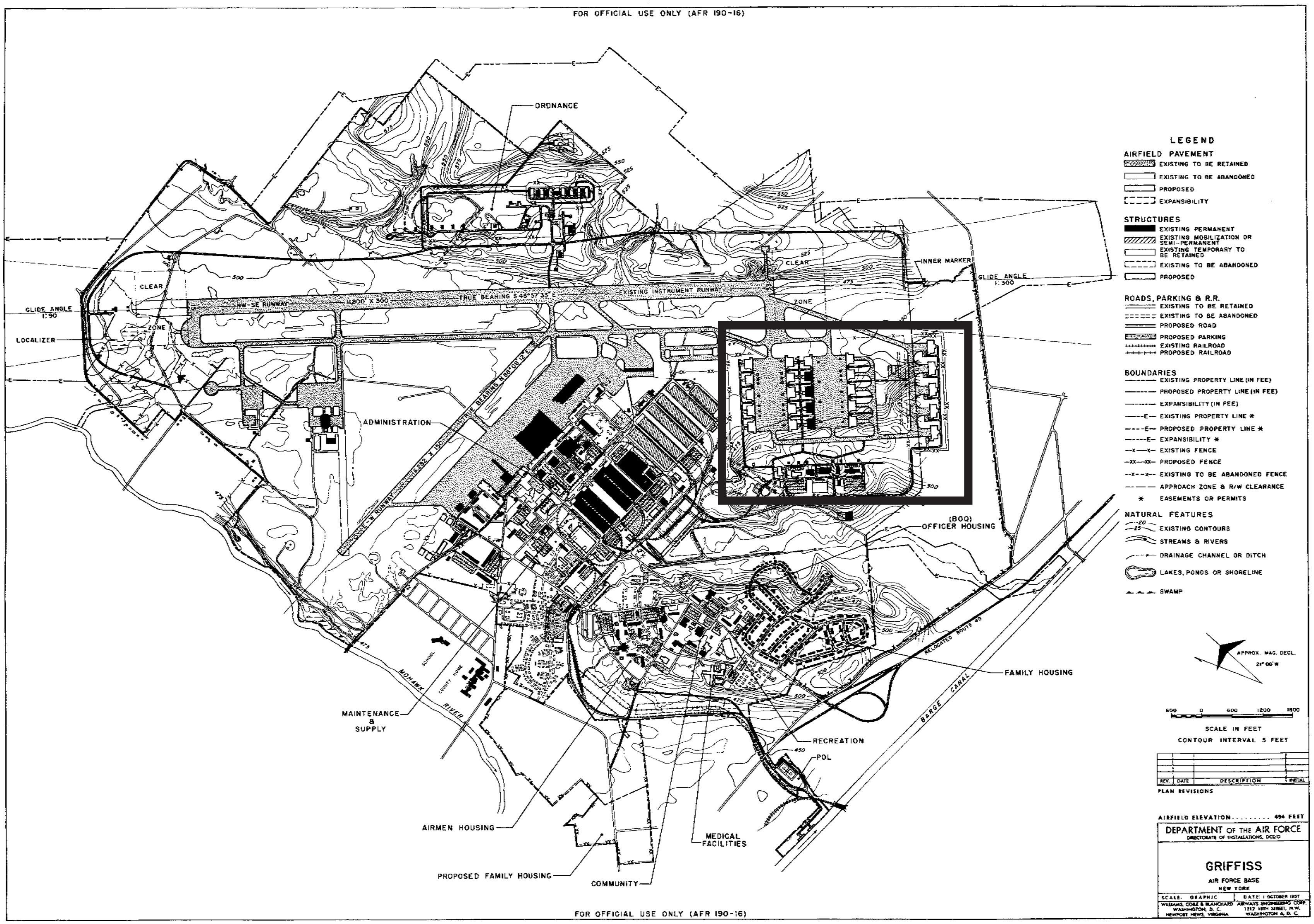

Plate 101. **SAC rectangular stubbed parking aprons and angled alert taxiway, with wing hangars built and planned (midground right). Griffiss Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

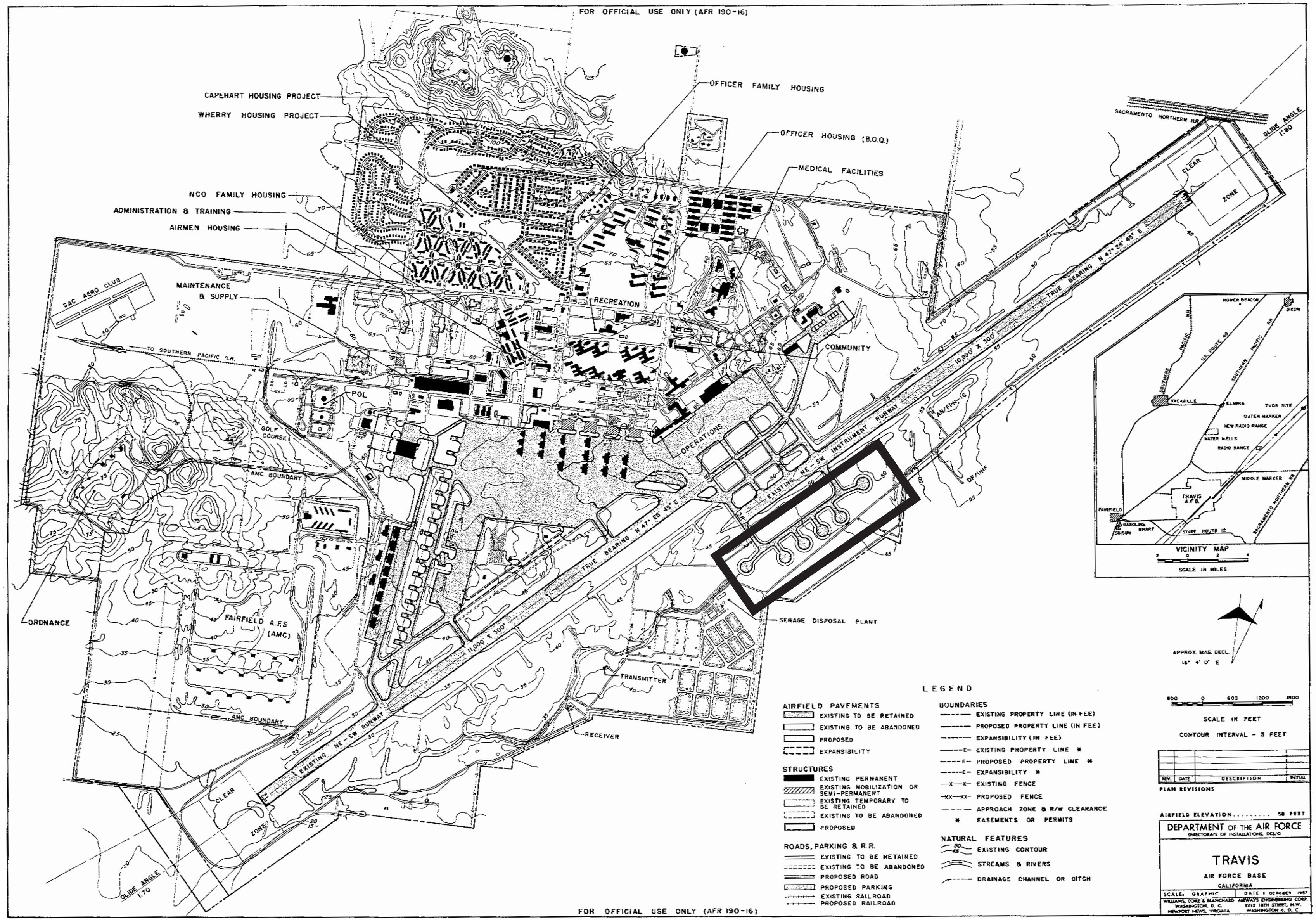

Plate 102. **SAC hot cargo loading apron (midground center). Travis Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

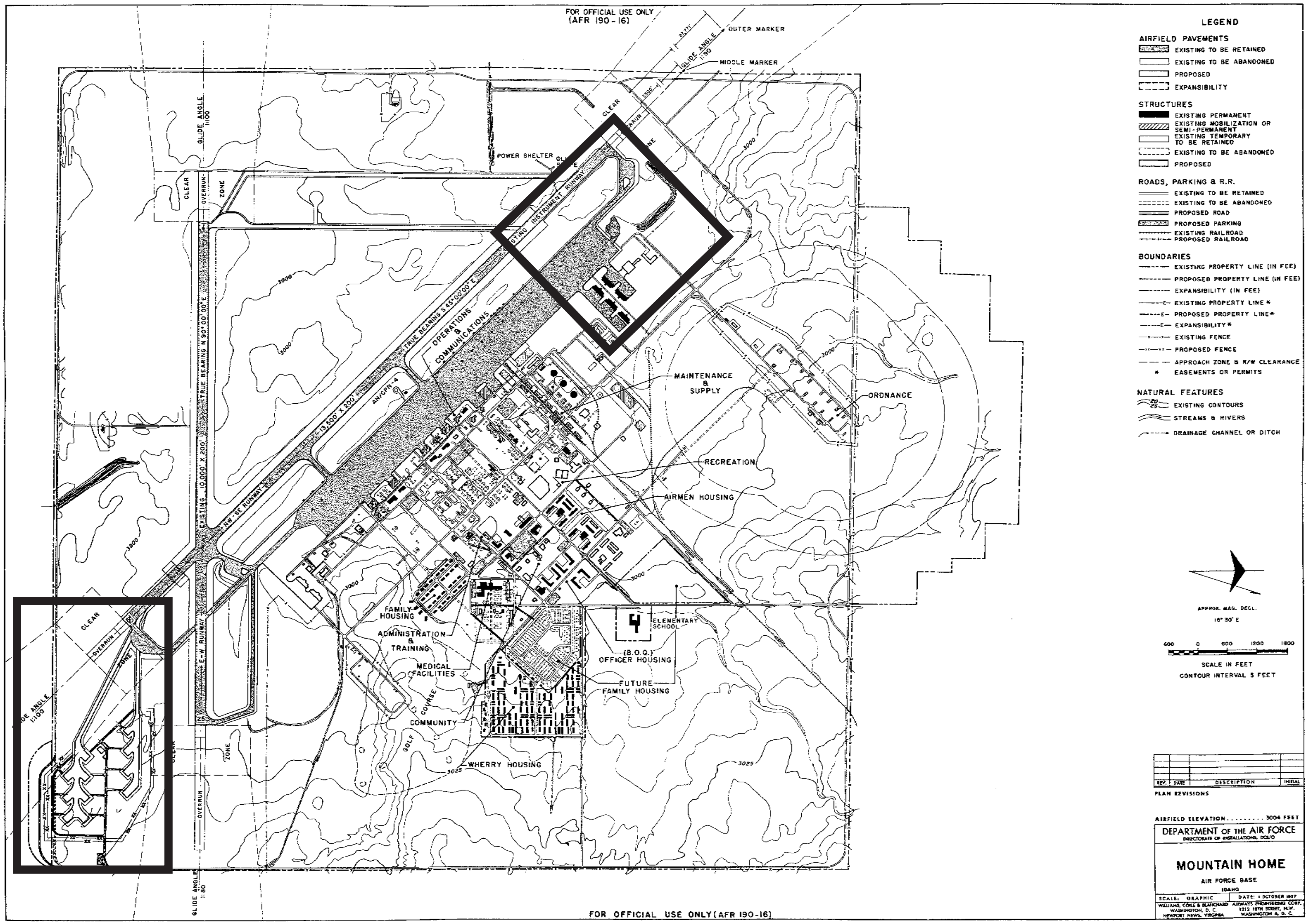

Plate 103. **SAC stubbed parking apron (background right) and planned 1½ Christmas tree alert aprons (foreground left). Mountain Home Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

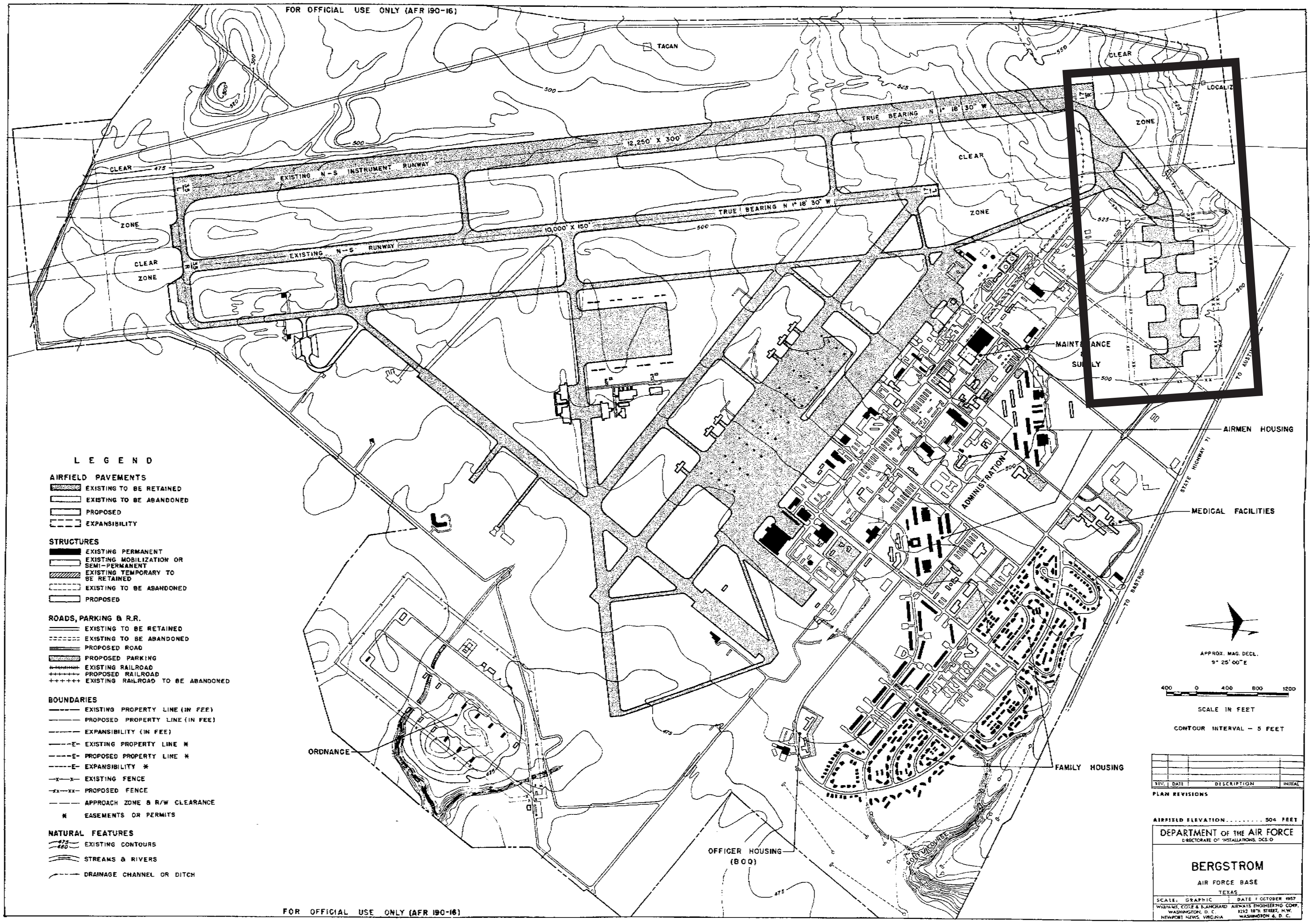

Plate 104. **SAC stubbed alert apron (background right). Bergstrom Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

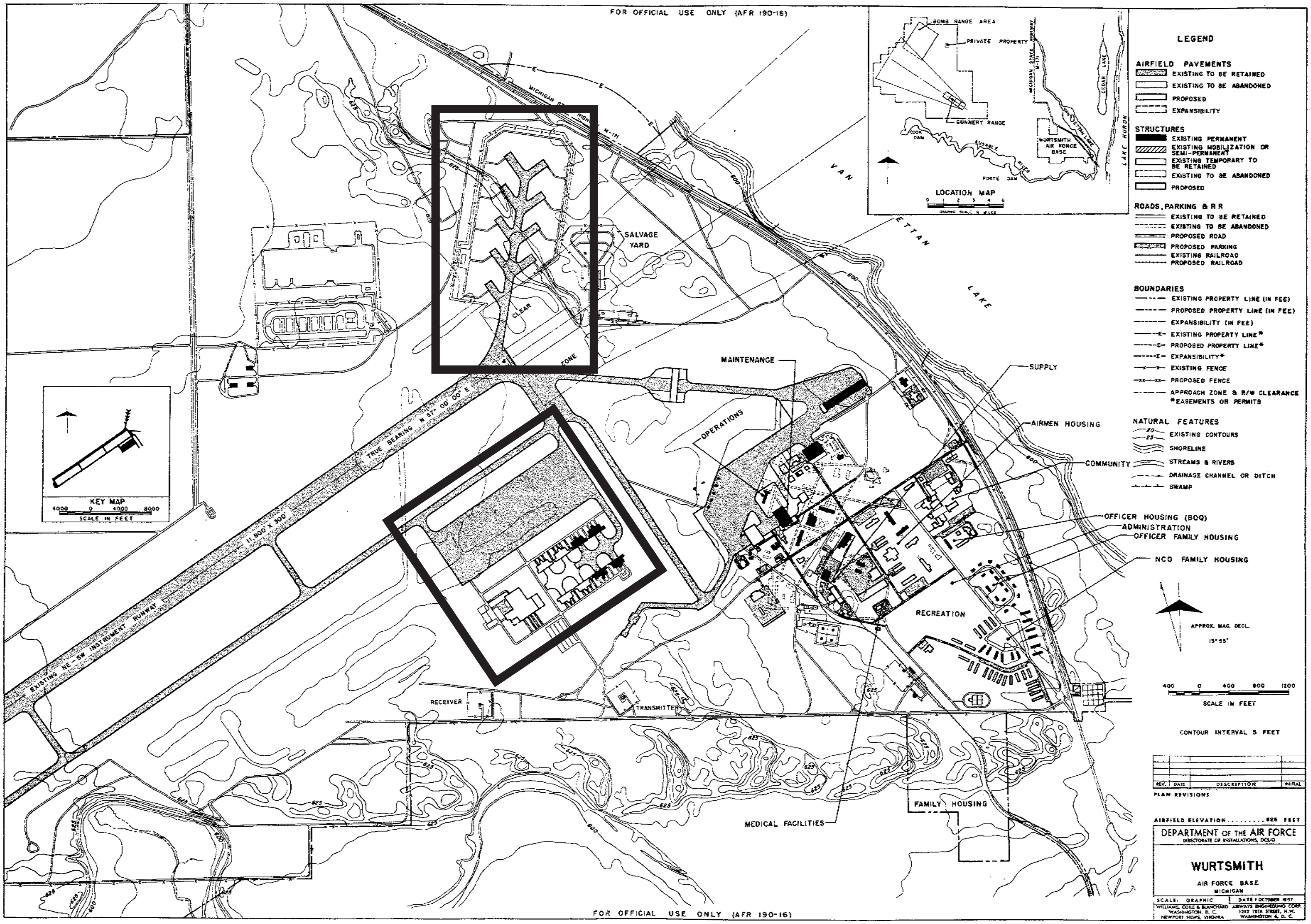

Plate 105. **SAC Christmas tree alert apron, background center. Proto-alert stubbed apron and tanker pen, center. Wurtsmith Air Force Base. Directorate of Installations. Master Plan of October 1957. Collection of K.J. Weitze.**

northern tier base of the middle-to-late 1950s, rejuvenated an AAF/Air Force installation at Oscoda—one that had served as an air proving ground and aircraft artillery training range from about 1939 through 1952.[202] SAC reassigned some of the aprons originally built for the B-36 in the right-angled configuration to a tanker alert status, choosing others for complete reconstruction as Christmas trees. Where SAC required a priority bombing mission and a right-angled apron was in place, reconstruction or redesign occurred expeditiously. Two such instances were those at Loring (reconstructed) and at K.I. Sawyer, Michigan. The right-angled aprons were uniformly mapped in only a five-stub or a nine-stub size. The Christmas tree aprons varied from a minimum size of four stubs, to a graduated size of seven, eight, and ten stubs. By October 1957, Christmas tree alert included three design schemes: a single large-capacity apron; two nearly equal size aprons angled toward a single taxiway; and, two unequal size aprons (six- and four-stub), again angled toward a single taxiway. In the latter case, several variant patterns existed. (See Plates 36, 60, 64, 103, and 105.) Simultaneously with the shift from the right-angled to the 45-degree alert apron, SAC changed its strategy to that of dispersal employing both bombers and tankers, and dramatically reoriented its basing emphasis from the interior of the United States to the northern tier of the country.

When the SAC alert apron program was finished, most aprons were Christmas trees; a limited number were the first generation, right-angled type; and, a few were anomalies. When terrain at the ends of runways did not allow the construction of a Christmas tree without extensive fill, or when purchase of needed additional land was difficult, SAC chose to place its planes on a pre-existing rectangular apron near the end of the runway, or to expand an existing parallel taxiway into a small rectangular pen for alert aircraft (Plates 106-107). In the case of Travis, SAC reused the hot cargo pads already there. And finally, in a unique solution at Lincoln, SAC placed its 45-degree stubs directly off the end of the airfield's NW-SE runway, converting it in effect to the alert taxiway for the primary 12,900-foot N-S runway. Whiteman would return to this idea in the late 1960s, planning for a Christmas tree directly at the end of its primary runway (unbuilt)—to replace an ad hoc rectangular pen of the late 1950s.

Plate 106. SAC alert, aerial view, McChord Air Force Base. Molehole adjacent to rectangular parking apron (background left). View of ca.1969. Courtesy of Geo-Marine, Inc.

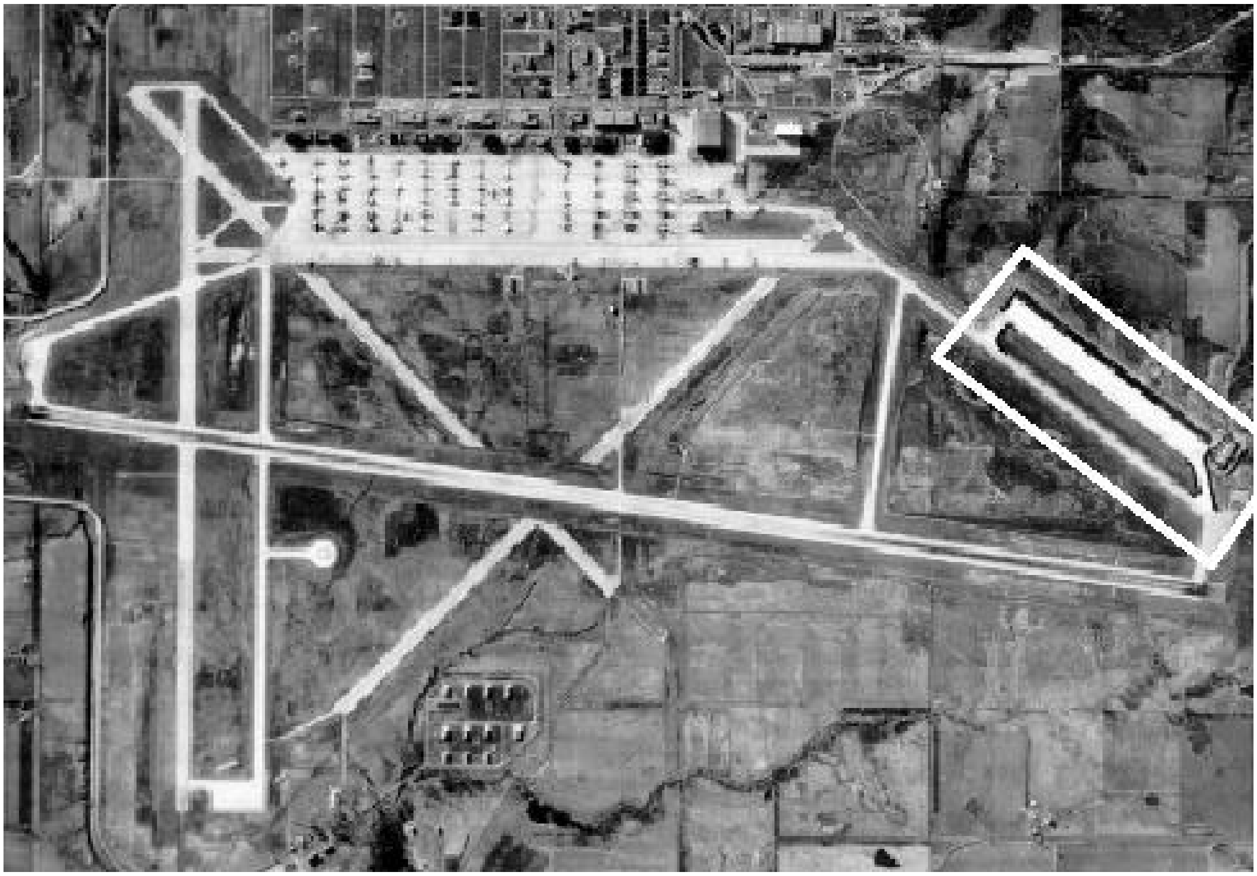

Plate 107. SAC alert, aerial view, Whiteman Air Force Base. Molehole adjacent to long rectangular apron (center right). 1959. Courtesy of Whiteman Air Force Base.

In late 1957 none of the existing alert aprons in any configuration included permanent crew quarters. Individual installations followed the orders from SAC headquarters and adapted barracks and dormitories near the flightline where possible, but this was soon found to be expensive. The Second Air Force influenced the form that a second interim solution would take, with its commander asserting that commercial house trailers were the answer to a ready-made, moveable, interim alert housing. In December 1957, the Second Air Force's commander, General J.P. McConnell, requested and received permission to purchase four commercial house trailers for testing by the 301st Bomb Wing. McConnell maintained that the trailers "could be moved to either end of the runway in case wind changes required a change in the takeoff direction, and if the dispersal plan was expanded, … could be readily moved to other bases."[203] SAC tested these units during the first months of 1958 at Barksdale Air Force Base in Louisiana. SAC commissioned formal trailer production by the Travelite Trailer Company of Fort Worth, Texas, in the latter half of 1958, with 56, 50-foot trailers manufactured and delivered to the Air Force at a cost of $336,000. SAC shipped these facilities in multiples to Carswell (Texas) [five]; Chennault (Louisiana) [two]; Hunter (Georgia) [five]; Lincoln (Nebraska) [five]; MacDill (Florida) [seven]; Westover (Massachusetts) [six]; and Whiteman (Missouri) [three]. SAC shipped the remaining 23 trailers to overseas bases. All trailers left the Fort Worth plant before the end of December 1958.[204] During 1959, SAC bought a fleet of alert vehicles, both station wagons (539) and panel trucks (93), to transport airmen to and from alert duty (Plate 108).

Plate 108. SAC practice alert in progress. Three-man B-47 crew. Unidentified Air Force location, ca.1960. Courtesy of Geo-Marine, Inc.

While the existing renovated flightline barracks and interim alert crew trailers were in use, SAC decided that a single, permanent readiness crew facility sited at the head of the alert apron was the preferred solution to alert housing. Even before trailer service testing, the Air Force mapped plans for consolidated crew quarters, to become known as moleholes, at 15 installations. Following the Soviet launching of its Sputnik satellite in late October 1957, SAC announced activation of formal operational alert crews. Initially, SAC placed 11 percent of its 1,528 bombers and 766 tankers on alert, thus readying approximately 170 bombers and 84 tankers (Plate 109). SAC reached a 20 percent readiness in 1959, attaining the 33 percent goal in 1960. Just a few months earlier, SAC hired Leo A. Daly, near its headquarters in Omaha, to design three sizes of standardized crew quarters: 18,000 square feet (70 men); 22,500 square feet (100 men); and, 31,000 square feet (150 men) (Plates 110-112). An architectural-engineering firm founded in 1915 and with substantial World War II military experience, Leo A. Daly had designed for SAC since at least 1955. Daly handed its first underground command post and chapel at Offutt, as well as the standardized expansion of the Luria B-36 wing hangar. The SAC alert crew quarters, like the SAC command post, were partially below ground structures, the design of which gave Leo A. Daly growing specialized expertise during the 1950s and 1960s.[205] The Daly firm prepared drawings for the SAC alert crew quarters in April 1958. The three sizes of molehole perhaps reflected

Plate 109. KC-135 refueling a B-52 in flight. July-December 1956. Courtesy of the Air Force Historical Research Agency.

Plate 110. SAC alert. Leo A. Daly. 150-man molehole at Whiteman Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 111. SAC alert. Leo A. Daly. 70-man molehole at the former Schilling Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 112. SAC alert. Leo A. Daly. 70-man molehole at the former Castle Air Force Base. View of December 1998. Photograph, K.J. Weitze.

the shifting from the large crew of the B-36 to the much smaller crew of the B-52, then in progress, as well as planning for more bombers on alert at some installations than at others. Of reinforced concrete and concrete-block construction, moleholes were of two-story height, with one story below ground. These windowless alert quarters were identical everywhere, with tunnel-like egress covered in corrugated steel (Plate 113). In selected cases, due to ground water table conditions, the moleholes were built fully aboveground, with the lower story earthen bermed for semi-hardening (Plates 114-115).

As of April 1959 SAC had 64 moleholes under construction, or definitely slated for construction by 1961. Two additional moleholes were in design (Ramey and R.I. Bong), with a 67th cancelled for SAC headquarters at Offutt.[206] Eleven of the group were 150-man facilities: Bunker Hill (Indiana); Forbes (Kansas); Hunter (Georgia); Lincoln (Nebraska); Lockbourne (Ohio); Malmstrom (Montana); Mountain Home (Idaho); Pease (New Hampshire); Plattsburgh (New York); R.I. Bong (Wisconsin); and Whiteman (Missouri). Ten more were 100-man quarters: Chennault (Louisiana); Clinton County (Ohio); Davis-Monthan (Arizona); Dyess (Texas); Homestead (Florida); Little Rock (Arkansas); MacDill (Florida); March (California); McCoy (Florida); and Selfridge (Michigan). The remaining 45 were all the smallest version of molehole, housing 70 men: Altus (Oklahoma); Amarillo (Texas); Barksdale (Louisiana); Beale (California); Bergstrom (Texas); Biggs (Texas); Blytheville (Arkansas); Carswell (Texas); Castle (California); Clinton-Sherman (Oklahoma); Columbus (Mississippi); Dow (Maine); Dover (Delaware);

Plate 113. Tunnel egress for the molehole at the former Castle Air Force Base. View of December 1998. Photograph, K.J. Weitze.

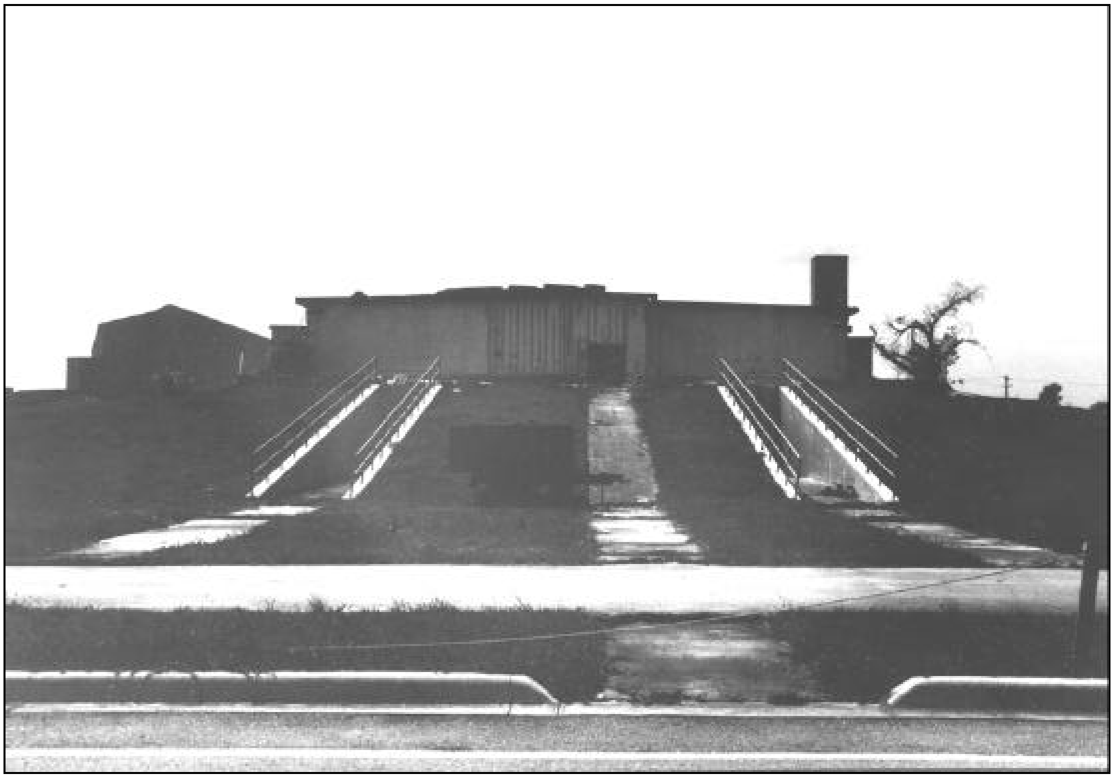

Plate 114. SAC alert. Leo A. Daly. 100-man molehole at the former Homestead Air Force Base. Built aboveground: bermed. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 115. SAC alert. Oblique view of berming for the molehole at the former Homestead Air Force Base, 1995. Courtesy of Mariah Associates, Inc.

Eglin (Florida); Ellsworth (South Dakota); Fairchild (Washington); Glasgow (Montana); Grand Forks (North Dakota); Griffiss (New York); Kinross (Michigan); K.I. Sawyer (Michigan); Larson (Washington); Loring (Maine); Mather (California); McChord (Washington); McGuire (New Jersey); Minot (North Dakota); Otis (Massachusetts); Ramey (Puerto Rico); Robins (Georgia); Schilling (Kansas); Seymour-Johnson (South Carolina); Sheppard (Texas); Travis (California); Turner (Georgia); Walker (New Mexico); Westover (Massachusetts); Wright-Patterson (Ohio); Wurtsmith (Michigan); Goose Bay (Labrador); Ernest Harmon (Newfoundland); Cold Lake Royal Canadian Air Force Station (RCAF) (Canada); Churchill (RCAF, Canada); Namao (RCAF, Canada); and Frobisher Airport (RCAF, Canada).[207] The SAC moleholes represented the Second, Eighth, and Fifteenth Air Forces, and their tenant bases.[208] The Canadian installations of Cold Lake, Churchill, Namao, and Frobisher were all SAC northern refueling (tanker) bases under construction as of mid-1958.[209]

SAC had initially programmed for 63 moleholes in May 1958, subsequently augmenting the program. The next month construction began at Grand Forks, Griffiss, Malmstrom, Minot, Mountain Home, Pease, Plattsburgh, and Westover, with Goose Bay, Ernest Harmon and Frobisher immediately following. These were the priority SAC installations across the northern tier of the United States and further north in Labrador and Newfoundland for timely response to a Soviet missile attack. Within this group, one could also see SAC planning for sustained importance: the alert configurations at Malmstrom, Mountain Home, Pease, and Plattsburgh were of the 150-man type, while the others were the small version for 70 men. Minot and Grand Forks effectively worked together through their relative proximity to one other. The other alert sites, although important to the northern tier, were not destined for a major sustained role. SAC started construction for another 21 moleholes at the close of the year at Clinton-Sherman, Columbus, Dow, Dyess, Eglin, Fairchild, Forbes, Homestead, Hunter, Lockbourne, Loring, MacDill, McChord, McCoy, Otis, Robins, Seymour-Johnson, Turner, Cold Lake, Churchill, and Namao. This second group was much more mixed. The final group of moleholes all began construction during the first six months of 1959, and included 32 sites. Construction for most molesholes finished in late 1959 or early 1960. Final buildout was 64 or 65 moleholes, dependent on SAC construction at Ramey. The Air Force cancelled all construction for R.I. Bong. (See Table 3, chapter 3.)

In the 1957-1964 years, military analysts predicted that an attack would be missile-started, followed by a second wave bomber contingent. In a sense, SAC moleholes and alert aprons were most critically important during this transition from a bomber threat to ICBMs, and were significantly less important *as a comprehensive response web* after placement of Atlas D, E, and F, and Titan I, ICBMs during 1958-1962. Some of the most critical SAC bomber bases of the early Cold War—such as Forbes and Schilling in Kansas, Lincoln in Nebraska, and Walker in New Mexico—became much less important as bomber readiness shifted to the northern tier and ICBMs went in place adjacent to their installations. In addition, SAC decisions for placement of the B-52 influenced the futures of bomber missions at bases previously key for B-36 and B-47 wings. The situation was similar for highly significant early Cold War ADC bases, with the first generation command and control, and even the mature Semi-Automatic Ground Environment (SAGE), having very short lives in some locations. ICBM maturity in 1965, with the placement of the Titan IIs and Minuteman Is, effectively meant that the first Atlas and Titan configurations, themselves, were obsolete—and again affected which bomber alerts SAC sustained.[210] At about this same time, the Air Force began excessing some of its early Cold War bases—a number with moleholes important for the transition during the late 1950s and early 1960s, but of reduced need by mid-decade.

At an unknown number of SAC installations, the command maintained both bombers at its molehole apron and tankers at an adjacent secured rectangular apron. This situation, different from that of either bombers *or* tankers on secured alert at the molehole, appears to date to about 1964, as SAC put in place its Titan II and Minuteman I missile squadrons and was again seriously changing strategy. In that year and several following, the 416th Bombardment Wing of B-52s and its supporting KC-135s were on alert at Griffiss Air Force Base in New York. Six to eight bombers, and eight to 12 tankers, were on "called" alert during 1964-1966. These alerts were exercises of Bravo and Coco type—the former involving engine starts only, the latter requiring movement of the aircraft to takeoff position.[211] To accommodate this dual bomber and tanker alert configuration at single installations, SAC again returned to the use of alert trailers at Griffiss, placing 15 four-bedroom trailers in two rows at the end of a rectangular pen in April 1964, with the Christmas tree and molehole across the runway (Plate 116). Alert tanker crews had to meet split launch and non-optimum launch conditions at the base. In the time period while the trailers were set up for alert, the Air Force housed the men in a dormitory nearly two miles from the flightline.[212] The dual bomber-tanker alerts accelerated in the early and middle 1970s, with introduction of the short range attack missile (SRAM). For this program, SAC built fairly elaborate tanker aprons (such as at K.I. Sawyer and Minot Air Force Bases), or heavily modified the existing alert apron at the molehole into a rectangular pen. For many of these pens SAC built undistinguished ready crew housing nearby, either as centralized quarters or as individual units at each parked aircraft (surrounding the pen, or at the former molehole stubs). Orchestration of alerts for the KC-135s is not as clear as that for the bombers. The B-52 could easily make its target fully loaded, even under adverse fuel consumption conditions. The unknown was a matter of reliable return or need to stay in the air. For any strategic scenario, the KC-135 had a variable transfer radius. The tanker could fly about 1,150 miles to deliver its standard 120,000 pounds of fuel. SAC deployed nearly 800 KC-135s between 1957 and 1966.

New weapons systems of the middle 1970s and middle 1980s caused many of those alert aprons still useable for bombers to undergo major alterations. For example, SAC enlarged the five-stub Christmas tree at Barksdale (Louisiana) to seven stubs, and subsequently to nine stubs, to accommodate the SRAM (1972-1974) and air-launched cruise (ALCM) deployments during the final phase of the Cold War under President Reagan. Both of these weapons systems have nuclear warheads, with the radical ALCM a ground-hugging, self-guided missile. Each system required that SAC construct additional ancillary buildings at the perimeter of the alert apron, inclusive of power station, surveillance tower, a reserve fire team and security structure, and family visitation quarters. In some instances, SAC built four to six readiness crew quarters at intervals along the perimeter of the apron, and often the molehole itself was enlarged by 50 percent.

Plate 116. SAC tanker alert trailers (center), with molehole (background right). Griffiss Air Force Base. View of 1964. Courtesy of the Air Force Historical Research Agency.

Headquarters Command Post and the SAC Chapel

Command Post

The dynamic character of SAC commander Curtis LeMay raises questions of a SAC imagery created for public consumption, as well as for practical Cold War strategy. The large web of Christmas tree alert aprons and their companion moleholes of 1957-1960 were perhaps the mature manifestation of such imagery during the early Cold War. While the *Strategic Air Command* of 1954 had showcased the B-36, the B-47, and James Stewart, the film had not emphasized any physical infrastructure. In 1962, *A Gathering of Eagles*, starring Rock Hudson, depicted SAC alerts, using the molehole at Beale Air Force Base to portray alert for the B-52 bomber. The imagery had mystique, the evolution of which dated back to the middle 1950s at SAC headquarters, Offutt Air Force Base. In 1955 Leo A. Daly designed two buildings for SAC on base: the headquarters command post, with above and below ground components, and, the chapel. Both structures, like the moleholes, were more than functional, and both offered a portrait of the Cold War easily enhanced through imagination. In 1959, the follow-on commander of SAC, General Thomas S. Power, authorized a museum for SAC bombers at Offutt. Although not undertaken until the early 1970s, the museum was also a Leo A. Daly design, as was the second generation SAC Museum completed in 1998 at an off-base site between Omaha and Lincoln (and jointly designed with Butler Manufacturing). And, of course, the epitome of SAC imagery—albeit skewed—came with Hollywood director Stanley Kubrick's classic *Dr. Strangelove* of 1964, with a storyline of SAC-gone-awry based on the British novel *Red Alert* (1958). *Red Alert*, not surprisingly, also indirectly referenced the heightened nature of SAC alert during this transitional period of moleholes, missiles, and mayhem.

Leo A. Daly designed the SAC command post at Offutt at the outset of February 1955. The post replaced the simple three-story office building, the A Building, that SAC had adapted from the Martin Bomber Plant. The new command post featured a four-story, reinforced concrete and masonry office building aboveground, more than 16 times larger than the modest administrative A Building. Sometimes called the Western Pentagon, the aboveground SAC headquarters building was of classic 1950s office design[213] (Plate 117). Although the administrative structure had a basement, it was a segregated, adjacent three-story structure below ground that served SAC as its command post throughout most of the Cold War period. Of hardened reinforced concrete, the below ground command post was itself more than five times the size of the original A Building. The underground command post had 24-inch thick walls and base floor, with 10-inch thick intermediate floors, and 24-to-42-inch thick roof; blast- and gas-proof doors; and, ramped tunnels with non-skid surfacing and decontamination areas connecting to an extended tunnel leading up to the aboveground office building.[214] The final ramped tunnel was eight-foot in diameter, with two-foot thick reinforced concrete walls.[215] Historically, and today, the below ground command post is known at Offutt as the "molehole" due to its ramped tunnels and self-contained condition.[216] The SAC headquarters underground command post was in construction during 1955-1957—simultaneous in its later stages with planning for the SAC bomber and tanker alert aprons and semi-subterranean crew quarters, the latter also known as moleholes.

The structure also featured lavish and modern connections to the world outside. Its "big board," a series of maps and postings showing military conditions worldwide, ran along the 264-foot side of the post.[217] In the beginning, SAC updated the board manually, using personnel in cherry-pickers, and making the setting more theatrical through its frontal suspended lighting and drawn curtain (Plates 118-119). Key military personnel looked down on the big board from glassed-in offices.[218] Communications links were state-of-the-art, with the first SAC command post computer the IBM 704, installed in 1957. The IBM 704 was the more popular name for the AN/FSQ-7, the mainframe computer developed for ADC's SAGE early warning program. The IBM 704 was one of the earliest production computers to incorporate random access memory (RAM). It also incorporated a dual arithmetic element that processed the X and Y positions of data simultaneously, allowing greatly enhanced speed. The IBM 704, available in 1954-

Plate 117. SAC Command Headquarters, aboveground structure. Offutt Air Force Base. View of early 1957. Courtesy of the Air Force Historical Research Agency.

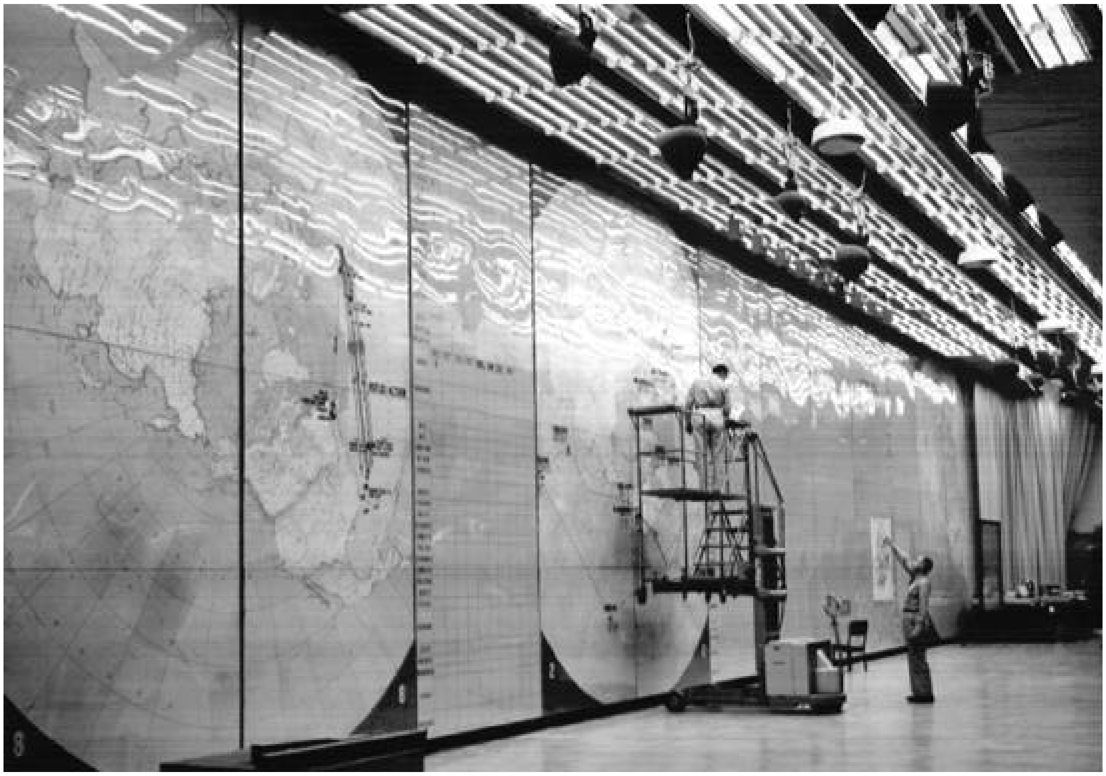

Plate 118. SAC Command Headquarters, underground structure. The "big board." View of early 1957. Courtesy of the Air Force Historical Research Agency.

Plate 119. Detail of Reflex Actions mapped on the "big board." View of early 1957. Courtesy of the Air Force Historical Research Agency.

1955, was primarily used in the military and in scientific laboratories, as late as 1959.[219] Six 16-foot data display screens updated SAC personnel in the war room.[220] A "red phone" system, with dedicated connections to 200 operating locations internationally, further supported communications in the SAC underground command post. Approximately 1000 people worked underground at the height of the command post's use, with the capacity to sustain up to 800 people underground for two weeks.[221]

SAC Chapel

SAC imagery of heightened intrigue and world destabilization continued in its Offutt chapel, designed again by Leo A. Daly in November 1955.[222] Architecturally a reflection of straight-forward 1950s design (Plate 120), the chapel featured an alarm system for key squadrons and two rear pews designated for alert airmen. Distinction for the chapel came with General Power's initiation of a program of memorial stained glass windows, begun in 1958 and dedicated in mid-1960. In addition to the elaborate stained glass project, SAC established an annual SAC memorial Sunday—to take place each year on the Sunday preceding the anniversary of the founding of the command. Offerings from base chapels across SAC funded the hiring of a stained glass studio. SAC chose the studio, Wallis-Wiley of Pasadena, California, after a formal competition between eight pre-selected studios who had submitted drawings for SAC review. John Harrison Wallis of Wallis-Wiley became the artist for five large stained glass windows: one each for the Second, Eighth, Fifteenth, and Sixteenth Air Forces, and the main SAC Memorial window next to the altar.

Plate 120. Leo A. Daly. SAC chapel at Offutt Air Force Base. View of July 1999. Photograph, K.J. Weitze.

The very large stained glass windows are each remarkable for their imagery capturing the Cold War. The memorial window is the most toned down, a tribute to SAC airmen, their families, and peace through military deterrence. The other four windows, lining the sides of the chapel, vary from that of the Second Air Force in which a map of Korea and a B-47 are the highlights, to that of the Eighth Air Force in which Korea is again illustrated, but is overshadowed by the portrayal of the mushroom cloud from the atomic bomb test drop at Eniwetok in 1948. The window of the Fifteenth Air Force also depicts Korea, the valued B-47, and even President Truman's sending of the B-29s of the 301st Bomb Wing from Kansas to Germany during July 1948—in response to the Soviet blockade of Berlin. The final window, that of the Sixteenth Air Force, is the most powerful of the group: it again illustrates the B-47, but concentrates on SAC's operations in French Morocco, Spain, and Iceland, even including a visual interpretation of the 480-mile oil pipeline—needed for SAC fuel—in Spain. And, most notable in a panel of this window, is SAC's headquarters red phone, symbolizing its use in the underground command post just recently completed.[223] Interesting here is the very early Cold War focus of the entire group of windows. Depicted events are directly linked back to subordinate milestones in World War II in several cases, and in each window the focus is primarily on the achievements of 1948 to 1952. The B-36 is missing—and was out of the inventory by the date of the windows, as is the B-52—which was relatively new to SAC installations in 1958. The pipeline in Spain was a very recent achievement.[224] And the red phone was just operable, symbolizing almost a Hollywood casting to it all (Plate 121). Artist Wallis (born 1907) completed his art education in Boston, teaching painting at the Wilbur Herbert Burnham Studios and at the Scott Carbee School of Art from 1927 through 1945. He founded John Wallis & Associates in Pasadena in 1946. Prominent stained glass commissions in addition to the SAC chapel included ones for churches in California, Florida, and Hawaii, with that for the Pearl Harbor Memorial Church following the work for SAC.[225]

Plate 121. Wallis-Wiley Studio. Stained glass window depicting SAC's Sixteenth Air Force. Red phone, center right. Designed 1958. Courtesy, Nebraska State Historical Society.

Late Cold War SAC Infrastructure

During the terms of Presidents Carter and Reagan, from about 1976 through the end of the Cold War in 1991, SAC sponsored a second major phase of new infrastructure. Although construction in support of the B-52 bomber mission really required no new major designs for SAC after the late 1950s, the command did require new infrastructure for the continuing sophistication in command posts and for the B-1. (During the 1962-1976 period, overall, construction for SAC focused on its missile missions.) The idea of an established airborne command for SAC, with a parallel airborne post for the President, the Secretary of Defense, and the Joint Chiefs of Staff, dated to 1960, with the initial testing of a Post-Attack Command and Control System (PACCS) and the National Emergency Airborne Command Post (NEACP). Also known as Looking Glass, PACCS used five KC-135s, configured for airborne command at Offutt Air Force Base. NEACP, set up at Andrews Air Force Base, is assumed to have also used a modified KC-135. For NEACP, it is assumed that the alert-ready aircraft parked inside the steel-arch SAM-CRT hangar built there during 1959-1960—the hangar likely designed by Anton Tedesko to replace the Kuljian double-cantilever hangar of 1951, and itself essentially a design of 1949-1951.[226] For PACCS, the backward look for infrastructure was similar. Like the crews of the B-52 bombers and KC-135 tankers on alert at their aprons and moleholes after 1958-1960, the crews of the KC-135s modified for PACCS—known as EC-135s—were trained to achieve airborne status within 15 minutes of notice. PACCS was the airborne counterpart to the SAC headquarters below ground command post, mirroring its function directly. The aircraft, however, were part of an existing inventory, and as such did not require design of new wing hangars. The structures serving as infrastructure for PACCS at Offutt were standard Luria docks designed in 1958, and part of the escalation in wing hangar construction for SAC to accommodate the deployment of the B-52 and KC-135, generally. They were already in place in a typical pattern for the B-52 / KC-135 by 1959 at Offutt, and, had SAC built a molehole and alert apron at the base, they would have been adjacent. This kind of adaptation of existing, or off-the-shelf infrastructure, during the 1960s and well into the 1970s was characteristic of the period.

By the 1976-1977 years, however, the situation had begun to change—for both SAC and ADC. NEACP moved from Andrews Air Force Base, near Washington, D.C., to Offutt in 1975 and came under the jurisdiction of SAC as another command post at the installation. Construction for the Offutt NEACP, unlike that for PACCS, did entail new infrastructure. And while the alert crew quarters were functional, but otherwise undistinguished, the hangar for the modified Boeing 747 (E-4B) represented a major new design. Burns & McDonnell of Kansas City designed the NEACP hangar for SAC in April 1977[227] (Plate 122). The hangar is sited near the end of Offutt's 10,000-foot runway, and as such reflects SAC planning similar to that undertaken for its moleholes and alert aprons of the late 1950s. Spanning 216 feet, and of 359-foot length, the hangar is supported by shops along its length. Its trussed gable roof system; recessing panel doors; and east / west façade fuselage apertures continue the evolution for the two-aircraft maintenance hangar present sent the first designs for the Roberts & Schaefer B-36 hangar, but its deeply cut-in (approximately 60 degrees) angled north and south facades are entirely new for Air Force infrastructure and make viewing the east and west facades particularly dramatic. Facing for the roof trusses on the east and west facades are also cut with unusual emphasis on non-rectilinear angles, adding to the overall sculptural dynamics. Burns & McDonnell, founded in 1898 by engineers Clinton Burns and Robert McDonnell, had expanded as a company centered on hydroelectric and water-systems plants through the 1930s. In the early 1940s, the firm undertook the master plan engineering for Smoky Hill Air Force Base (renamed Schilling Air Force Base) in Kansas—a base that served as a key early Cold War SAC installation during the late 1940s into the middle 1950s. During the 1950s, Burns & McDonnell continued airfield and associated structures work for TWA and at Dulles Airport in Washington, D.C. At Dulles, in particular, Burns & McDonnell became responsible for designing one of the first hydrant refueling systems for a civilian airport in 1959. The firm handled more airport master planning and hydrant refueling systems assignments through the 1960s and 1970s, including a refueling project for the Chiang Kai-shek Airport in Taiwan just before undertaking the SAC NEACP hangar at Offutt.[228]

Plate 122. Burns & McDonnell. NEACP hangar. Offutt Air Force Base. View of July 1999. Photograph, K.J. Weitze.

SAC undertook new infrastructure associated with its bomber and command-post missions a second time during the late Cold War during the Reagan years of 1984-1989. This phase of introduced design was of two types: design for a large maintenance hangar, a fuel system maintenance dock, a wing hangar (aircraft shelter); and, a second generation underground command post. For the first effort, SAC appears to have relied entirely upon the Army Corps of Engineers, Omaha District, for its baseline designs, with local architectural-engineering firms hired to carry out the final efforts for the large maintenance hangar across the pertinent SAC installations. All drawings associated with the B-1 and B-2 infrastructure carry the same series number,[229] suggesting that the new infrastructure was really one large project, intended to be employed generically where appropriate. A large maintenance hangar, designed in 1984 in all of its basic parameters by the Omaha Corps, is sheathed differently at Offutt and Dyess Air Force Bases, and was under construction at these installations during 1985-1986 as a maintenance hangar for the PACCS and NEACP missions at Offutt, and as the B-1 maintenance hangar at Dyess[230] (Plates 123-124). Simultaneously, SAC also modified existing infrastructure, where possible, to accommodate the B-1. At Ellsworth Air Force Base, SAC reused the existing Roberts & Schaefer thin-shell hangar of 1947 for the B-1, with little exterior modification. The command also heavily renovated existing Luria multi-purpose hangars of 1952 through the addition of substantial new sections of 60-foot depth and approximately 210-foot width at the front of the hangars—strongly changing the shape and dimensions of the underlying early Cold War structure[231] (Plate 125). At Whiteman Air Force Base, in Missouri, SAC significantly remodeled the Kuljian double-cantilever maintenance hangar of the middle 1950s for the B-2 in 1989, simultaneously constructing multiple new wing hangars for the bomber (Plate 126). Again, the Corps of Engineers, Omaha District, directly carried out the design and engineering for the project.[232]

The second major instance of new design for SAC infrastructure was for a new headquarters underground command post. Leo A. Daly handled this assignment, between 1986 and 1989, as it had the first below ground command post in 1955-1957. The SAC command post of the late Cold War was a 16,000 square-foot, two-story reinforced concrete structure, joined to the earlier command center. In addition to reasonable hardening, the new underground command post included protection against electromagnetic pulse. As had been the case in the middle 1950s, the post featured state-of-the-art communications links and information displays.[233] Imagery for SAC was still paramount, with that for this particular subterranean command post even commented upon by the popular author of late Cold War thrillers, Tom Clancy. He wrote in *The Sum of All Fears* in 1991 that local rumor at Offutt had it that the second generation command post "had been built because Hollywood's rendition of such rooms was better than the one SAC had originally built for itself, and the Air Force had decided to alter its reality to fit a fictional image."[234] Fiction or fact, the Clancy observation was not far from true in its understanding of just how much Hollywood film had nurtured the popular understanding of SAC and the Cold War. By 1961, even engineers were using the term "Hollywood hard" in distinguishing between truly hardened infrastructure and visually "hard" infrastructure—the latter always fortress-like for the public, but often vulnerable.[235] As early as 1954, the Air Force Installations Board commented: "Beyond 1960, the increase in weapons yield will be such that…above-ground hardening will not be economically or operationally feasible."[236] For both generations of SAC command posts at Offutt, appeal to the popular imagination played a real role.

Plate 123. U.S. Army Corps of Engineers, Omaha District. PACCS and NEACP maintenance hangar. Offutt Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 124. U.S. Army Corps of Engineers, Omaha District. B-1 maintenance hangar. Dyess Air Force Base. View of 1995. Courtesy of Mariah Associates, Inc.

Plate 125. Luria multi-purpose wing hangars, remodeled for the B-1 during the late 1980s. Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 126. U.S. Army Corps of Engineers, Omaha District. B-2 shelters. Whiteman Air Force Base. View of July 1999. Photograph, K.J. Weitze.

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[2] Karen J. Weitze, *Inventories 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); Karen J. Weitze, "On Alert: Assessing Military Airfield Infrastructure of the Early Cold War, 1946 to 1962," paper presented to a meeting of the Transportation Research Board, San Diego, July 1998; Necah Stewart Furman, *Sandia National Laboratories: The Postwar Decade* (Albuquerque: University of New Mexico Press, 1990), 662-663.
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[5] Roberts & Schaefer, "V.V.H.B. Hangar, Monolithic Concrete Construction," drawing series no.35-04-01, 10 May 1947. Drawings signed by Anton Tedesko. The only known complete set of 40 drawings, ink-on-linens, survives in the civil engineering vault at Ellsworth Air Force Base.
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[9] Billington and Hines, "Anton Tedesko, Model Research."
[10] Anton Tedesko, *Verzeichnis der von Herrn Tedesko nach Amerika mit genommen Zeichmingen Im Akt. "Roberts and Schäfer" Kuppelbau U.S.A. ablegen* [Tedesko's Register of (Dyckerhoff & Widmann) Drawings Taken to the U.S. and filed with the documents of Roberts & Schaefer], handprinted partial account book of Tedesko's, in the Anton Tedesko papers, Department of Civil Engineering, Princeton University.
[11] Roberts & Schaefer Company Engineers & Constructors, website at www.r-s.com, 5 February 1999.
[12] Several typed biographical paragraphs on John E. Kalinka, originally in the files of Roberts & Schaefer, now in the Anton Tedesko papers, Department of Civil Engineering, Princeton University.
[13] David P. Billington, interview with Karen J. Weitze at the Department of Civil Engineering, Princeton University, 20 May 1999. Billington began his career as an engineer at Roberts & Schaefer in Chicago in 1952-1960, working with Tedesko prior to his professorship at Princeton. The Billingtons became close friends with the Tedeskos from the 1950s through Anton Tedesko's death in 1994, with the Tedeskos living in the Northeast after 1956, following Anton Tedesko's move from Chicago to Washington, D.C., to head a branch office of Roberts & Schaefer there.

[14] "Publications on Shell Structures in the English Language," a comprehensive typed list of articles appearing in British, American, and Canadian engineering, concrete industry, and architectural journals from 1929 through August 1944, 5pp. In the Anton Tedesko papers, Department of Civil Engineering, Princeton University.

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[16] Carl W. Condit, *American Building Art The Twentieth Century* (New York: Oxford University Press, 1961), 179-182.

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[24] Franz Dischinger and Ulrich Finsterwalder, *Neuere Entwicklungsformen der Schalen-Bauweise: System Zeiss-Dywidag* (Berlin: Verlag Ernst & Sohn, 1932). In the Anton Tedesko papers, Department of Civil Engineering, Princeton University.

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[94] "Portable 'Nose-In' Hangar of Steel and Canvas," *Engineering News-Record* 134, no.12 (22 March 1945): 106-108.
[95] USAF, Directorate of Installations, *Master Plans*, October 1957.
[96] Hiner, "Combat Airplane Hangars," 186-188.
[97] Photograph of B-50 in repair at Biggs Air Force Base, 14 September 1951, and, photograph of B-36 in repair at Ellsworth Air Force Base, undated: in Strategic Air Command, *Eighth Air Force History 1 January – 30 June 1953*; photographs of B-36s and engine repair docks, Carswell Air Force Base (undated) and Walker Air Force Base (28 August 1952): in Strategic Air Command, *Eighth Air Force History 1 July – 31 December 1952*.
[98] "Nose Dock for B-29 & B-50," drawing series no.39-05-04, 10 March 1952, annotated card index for superceded definitive drawings, History Office, U.S. Army Corps of Engineers, Humphreys Engineering Center, Fort Belvoir, Virginia.
[99] "Final Report on Test of Airplane Maintenance Shelter (Bushman-Moore Co.)," 21 December 1942, in Folder "3-42-78," Box 195, Entry 191, Record Group 341; "Final Report on Test of Shelter, Maintenance, for B-29 Airplane," in Folder "(M-4) 484," Box 256, Entry 191, Record Group 341; and , "Final Report on Comparative Test (Climatic Hangar Cold) of Docks, Maintenance, Types I and II," in Folder "3-47-91," Box 342, Entry 191, Record Group 341. All at the National Archives II, Maryland.
[100] "Hangar—Nose—M.B." (January and August 1951 versions) and "Hangar—Nose, HB" (February 1951), drawings no. 39-05-01 and 39-01-42; and, 39-05-02, annotated index cards for superceded definitive drawings, History Office, U.S. Army Corps of Engineers, Humphreys Engineering Center, Fort Belvoir, Virginia.
[101] Mills & Petticord, "Hangar—Nose—M.B., Plans, Elevations & Section," drawing series no.39-01-42, 105mm microfiche copy, History Office, U.S. Army Corps of Engineers, Humphreys Engineering Center, Fort Belvoir, Virginia.
[102] Luria Engineering Corporation, with Peter A. Strobel, consulting engineer, New York, "Department of the Air Force, B-36 Maintenance Dock, contract no. AF 33(038)–18824; Foundation, Floor Plan & Notes; Plans, Elevations, Sections; Torus Closure Tube; and Jet Service Platform," 23 April 1951.

[103] SSgt William E. Stevens and AIC Paul G. Tyson, *The Loring Episode* (Loring Air Force Base: 42nd Bombardment Wing History Office, 9 April 1980), 27; Karen Lewis, R. Blake Roxlau, and Katherine J. Roxlau, *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* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, August 1997); "Foundation for Maintenance Docks: Site Plan & Index, and, Layout & Grading Plan, Rapid City [Ellsworth] Air Force Base," 20 June 1951.
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[106] *History of the Directorate of Installations 1 January 1953—30 June 1953*, "Architectural and Engineering Division."
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[108] 384th Air Refueling Wing, History Office, *McConnell AFB A Historical Perspective* (Wichita: McConnell AFB, 1986), aerial photograph of 1952.
[109] Headquarters, Strategic Air Command, *The SAC Bombardment Training Program 1946-1959*, Historical Study No.80, 8-11.
[110] Comprehensive master plans for the USAF, Directorate of Installations, 1 October 1957.
[111] James A. Lowe, John A. Evaskovich, and Katherine J. Roxlau, *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* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, July 1997). A B-47 wing hangar is clearly visible in an aerial photograph of Seymour-Johnson, 29 October 1965. This structure, Building No. 4828, is photographed only from the front in the Mariah inventory, and as such does not offer the reader a clear view of the sharply angled facade (although the swept back facade is apparent). Sequential aerial photographs exist in the Mariah project files.
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[114] Luria Engineering Corporation, "Hangar, Wing, Multi-Purpose," drawing series evolved from no.39-01-50, including at least no.39-01-53 (November 1952) and no.39-01-54 (October 1952). Each numbered set of drawings included 27 sheets. That of no.39-01-53 is verified as-built at Ellsworth and Whiteman, and may be the standardized "version" of the Luria 1951-1952 design effort selected for buildout.
[115] *History of the Directorate of Installations 1 January 1953 – 30 June 1953*.
[116] Andrus Martin Associates, "Multipurpose Wing Hangar (Warm Climate)," drawing series no.39-05-08, 5 August 1953, annotated card index, History Office, U.S. Army Corps of Engineers, Humphreys Engineering Center, Fort Belvoir, Virginia.
[117] "Revisions. Strobel and Salzman. Hangar, Wing, Multi-Purpose. Foundation Details and Schedule 30 psf," drawing series no.39-01-53, 28 January 1953. Held in the civil engineering vault, Whiteman Air Force Base.
[118] "Revisions. Kuljian Corporation. Hangar, Wing, Multi-Purpose," drawing series no.39-01-53, before March 1956. Held in the civil engineering vault, Whiteman Air Force Base.
[119] The figure of 130 is approximate, and is calculated from footprints on the 1957 installation master plans across the Air Force.
[120] Leo A. Daly Company, "Modification of Wing Hangars: Elevations, and, Cross Sections and Details," drawing series no.39-05-03, 22 August 1955.

[121] 42[nd] Bombardment Wing, Strategic Air Command, *42[nd] Bombardment Wing, Heavy 1-31 July 1957*, 8.
[122] Stevens and Tyson, *The Loring Episode*, 87.
[123] Luria Engineering Company, "AMC Standard Aircraft Weather Shelter, Contract No. AF 33 (602) – 7888," drawing no. E-AF 2200-FI, 26 July 1956.
[124] Reynolds-Smith-Hills, "USAF Dock, Maintenance, Large Aircraft," drawing series no.39-05-10, 18 January 1957; and, "Dock, Maintenance, Medium Aircraft," drawing series no.39-05-09, annotated card index, History Office, U.S. Army Corps of Engineers, Humphreys Engineering Center, Fort Belvoir, Virginia.
[125] The figure of 80 is approximate, and is calculated from footprints on the 1957 installation master plans across the Air Force.
[126] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 January 1957 to 30 June 1957*, 33.
[127] Luria Engineering Company, "Aircraft Servicing Dock, Contract No. AF33 (600)-36934, December 1957 – May 1958.
[128] Headquarters, USAF. Air Force, *History Directorate of Civil Engineering 1 July 1959 – 31 December* 1959, 45.
[129] Headquarters, USAF, *History of the Directorate of Civil Engineering 1 July 1960 to 31 December 1960*, 24, 51-52.
[130] Headquarters, USAF: *History of the Directorate of Civil Engineering 1 January 1961 to 30 June 1961*, 41; *History of the Directorate of Civil Engineering 1 July 1961 to 31 December 1961*, 10-11; *History of the Directorate of Civil Engineering 1 January 1962 – 30 June 1962*, 20; *History of the Directorate of Civil Engineering 1 July 1962 – 31 December 1962*, 6-7.
[131] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970,* Holloman Air Force Base Cultural Resources Publication No.5. (El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997), 177; Headquarters, U.S. Air Force, "Plans Division," *History of the Directorate of Installations 1 January 1952 – 30 June 1952,* 11.
[132] "Experimental Barracks at Camp Grant," *Engineering News-Record* 126, no.21 (22 May 1941): 50-52.
[133] Lori E. Rhodes, Patience Elizabeth Patterson, and Katherine J. Roxlau, *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* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, October 1997), 23, 48.
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[136] Detroit Steel Products Company, "Fenestra Metal Building Panels," *The Military Engineer* 44, no.299 (May-June 1952): 6.
[137] Detroit Steel Products Company, "Fenestra Metal Building Panels," *The Military Engineer* 44, no.300 (July-August 1952): 33.
[138] *Ibid.*
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[143] Headquarters, USAF, *History of the Assistant Chief of Staff, Installations, 1 July 1956 to 31 December 1956*, 62.
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[151] Lee B. Washbourne, "Effect of Jet Conversion Program on Air Installations," *The Military Engineer* 45, no.306 (July-August 1953): 257-258.
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[153] Headquarters, USAF, "Architectural and Engineering Division," *History of the Directorate of Installations 1 July 1952 – 31 December 1952*, unpaginated.
[154]Headquarters, USAF,, "Planning and Programming," *History of the Directorate of Installations 1 January 1953 – 30 June 1953*, 11.
[155]Headquarters, USAF,, "Directorate of Construction," *History of the Assistant Chief of Staff, Installations 1 July 1954 to 31 December 1954*, 21-23.
[156]Headquarters, USAF,, "Directorate of Construction," *History of the Assistant Chief of Staff, Installations 1 January 1955 to 30 June 1955*, 31.
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[158] "Longest Runway," *Engineering News-Record* 154, no.15 (14 April 1955): 26.
[159] "Concreting the world's longest runway," *Engineering News-Record* 152, no.12 (25 March 1954): 44-46.
[160] "Homestead Airbase: Vast Apron, Fast Paver, Tar-Rubber Mix," *Engineering News-Record* 154, no.24 (16 June 1955): 54-58.
[161]Headquarters, USAF, "Use of Portland Cement Concrete," *History of the Assistant Chief of Staff, Installations 1 January 1956 to 30 June 1956*, 59.
[162] Headquarters, USAF, "Engineering," *History of the Assistant Chief of Staff, Installations 1 July 1956 to 31 December 1956*, 58.
[163] "FAA Will Halt Runaway Runways," *Engineering News-Record* 162, no.22 (28 May 1959): 22.
[164] Baseline Q Area discussions are taken from "The USAF-AFSWP Relationship: Q Areas for Atomic Weaponry" and the "AFSWP Q Area," in Weitze: *Inventory of Cold War Properties: Travis Air Force Base, Fairfield, California* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, October 1996); Furman, *Sandia National Laboratories,* 320-322.
[165] Furman, *Sandia National Laboratories*, 125-134.
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[167] *Ibid*, 323-324.
[168] Fifth Air Division, *History of the Fifth Air Division 1 January – 30 June 1957*, volume 1, 6-10, 27-30, 61, 66, 82, 84, 87, 90, 94.
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[176] *History of the Directorate of Installations, 1 January 1953 – 30 June 1953*, 29-31.
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[178] *Ibid*.
[179] *History of the Assistant Chief of Staff, Installations, 1 January 1955 to 30 June 1955*, 18-19.
[180] *History of the Assistant Chief of Staff, Installations, 1 July 1956 to 31 December 1956*, 51.
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[183] *Ibid*, 52.
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[195] Strategic Air Command, Headquarters, *The SAC Alert Program 1956-1959*, Historical Study No.79, table of contents.
[196] *Eighth Air Force Historical Data July-December 1957*, volume 1, 248.
[197] Analysis of the 1957 USAF *Master Plans*.
[198] *The SAC Alert Program 1956-1959*, 28.
[199] *Eighth Air Force Historical Data July-December 1957*, volume 1, 248.

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[225] Resume for John Wallis, The Studio of John Wallis & Associates, Makers of Stained Glass Windows and Teachers of Stained Glass, 2175 East Foothill Boulevard, Pasadena, California. Information courtesy of the Nebraska State Historical Society.

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[228] Burns & McDonnell internet website at www.burnsmcd.com.
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[230] U.S. Army Corps of Engineers, Omaha District, "Aircraft Maintenance Facility," 1984. As reviewed through the Dana Larson Roubal and Associates, Omaha, drawings: "Aircraft Maintenance Facility—Phase II; North and South Elevations, and Building Cross Sections," drawing series no.211-12-01, January 1985, held in the civil engineering vault at Offutt Air Force Base. Also, James A. Lowe, Patience Elizabeth Patterson, and Katherine J. Roxlau, *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* (Albuquerque: Mariah Associates, Inc., for Air Combat Command, June 1997).
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Chapter 3: Character-Defining Features and National Register Integrity

Each of the key property types for SAC bomber infrastructure, inclusive of subcategories for those property types, can be further refined with respect to character-defining features and issues of historic integrity. 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 here 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 eight property type categories set forth for the SAC bomber 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 SAC during the first 15 years of the Cold War; to interpret the evolution of early jet aircraft; and to address a more popular mythic symbolism of the newly atomic world. And perhaps, most important of all, the bomber infrastructure of SAC—inclusive of its many airfields—offers a way of seeing the military strategy and technological innovation 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 Maintenance Hangar: the Thin-Shell, Concrete Structure

Character-defining features of the thin-shell, reinforced concrete maintenance hangar for the B-36 are focused on the structure's engineering innovations. As such, the thin-shell B-36 hangar represents a plateau of international architectural-engineering achievement covering the period of the 1920s through the middle 1950s. The hangar is an excellent example of the work of Viennese engineer Anton Tedesko; the contributions of the American architectural-engineering firm Roberts & Schaefer; the German-American experimentation with ZD construction; and the engineering continuity for major hangar design of the late World War II and early Cold War years. The thin-shell B-36 hangar is also strongly evocative of initial SAC planning as a command. Only two of these SAC hangars were ever built, at Ellsworth, and the former Loring, Air Force Bases. They are, however, part of a small group of similar hangars and public stadia of the 1947-1955 period, including civilian hangars both inside and outside the United States; Navy hangars; and, exposition halls designed as large-span, open-interior spaces.

Key character-defining features include:

- the thin-shell, reinforced concrete construction;
- the strengthening arched ribs;
- recessing, panel doors spanning both facades of the hangar;
- and the immediate setting at the flightline.

With regards to the construction, both the thinness of the concrete shell, as well as its stabilizing ribs, were historically visible—prominently so. In addition, the particular construction technology created a hangar with elegant, catenary-like lines. At the time of its erection, and for much of its history, the thin-shell B-36 hangar dominated its flightline, and could be seen from many vantage points. This kind of setting enhanced the structure's design qualities, and showcased its technological innovation. From a military perspective, the addition of the earliest B-36 and multi-purpose wing hangars (Luria) also keenly contribute to interpretation of the hangar.

It is to be anticipated that interior changes to the thin-shell B-36 hangar will be many. However, maintaining a clear view of the thin-shell concrete work from some vantage points within the interior is recommended, due to the historic importance of the engineering and to the absolute rarity of this hangar within the Air Force.

Plate 127. New construction adjacent to the B-36 hangar. Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Issues of integrity are centered on maintaining and safeguarding the visibility, and possible interpretation, of the character-defining features for the hangar. Encasing or sheathing the thin-shell concrete, and especially the strengthening arch ribs, is not advised. Renovating the recessing door panels (inclusive of the fenestration pattern and aircraft tail openings), except in so far as replacement mechanisms are needed, is also discouraged. Extensive new construction immediate to the hangar should be planned carefully, as should all base construction affecting the longer-range visibility of the hangar. In this regard, care should be exercised to leave open lateral views of the hangar—allowing at least partial views of the hangar's catenary lines and arched ribs (Plate 127).

Second Generation Maintenance Hangar: the Steel, Double-Cantilever Series

Character-defining features of the steel, double-cantilever maintenance hangar for the B-36, B-47, and B-52 are focused on the structure's engineering innovations and its large buildout in multiples of three basic sizes. The SAC double-cantilever hangar represents the beginnings of engineering technological achievement for the structural type, rather than the final plateau seen in the thin-shell, concrete hangar that immediately preceded it. Through the use of longer and longer cantilevers to create unobstructed, open space for aircraft maintenance, the steel cantilever hangar came to dominate expansion at civilian airfields of the 1950s. The idea of an "expansible" cantilever hangar is further tied to the futuristic and innovative genius of German architect Konrad Wachsmann, and to the specific double-cantilever hangar patented by Wachsmann and Paul Weidlinger in 1945. SAC built about 50 to 60 of the double-cantilever hangars, with selected erection for air bases outside the United States (Table 2). Estimates for the numbers of basic (small); medium; and large hangars are difficult to verify, due to the generic similarity in footprint between the basic and medium hangars when rendered on Air Force master plans—although these hangars are easily verified through their engineering drawings. The large double-cantilever hangar was rare, the basic hangar the most common.

Key character-defining features include:

- the three sizes of hangar, with slightly different dimensions for those structures intended as expansible;
- the interior steel shop towers, sheathed in reinforced concrete;
- the interior trussed cantilevers and arches;
- the exterior, corrugated steel sheathing;
- recessing panel doors, spanning both facades of the hangar;
- flat, parapeted roof line (or, visible, arched roofline combination in the case of Kirtland Air Force Base);
- lack of attached exterior shop wings;
- and the immediate setting at the flightline, inclusive of bracketing wing hangars in many cases.

Historically, SAC often left the double-cantilever hangar unpainted. Although it is rare to come across the double-cantilever hangar in this condition today, it is the condition most evocative of the structure's original, mobilization character. As such, low-key, neutral paint schemes are those closest to the unpainted sheathing of the as-built hangar, while brightly colored schemes accented with stripes or lettering are non-historic. Resheathing of the double-cantilever hangar can also be anticipated in certain situations of extreme damage or deterioration, or when the Air Force is renovating the hangar for a new aircraft program such as the B-1 or B-2. In this case it is advised against creating new gable roof lines for the two facades; adding lateral attached shop wings; or, changing the original fenestration pattern and aircraft tail openings for the recessing doors (Plates 128 and 129). Carrying forward renovations in this manner will most often lead to a loss of National Register integrity, and while not all double-cantilever

Table 2

Strategic Air Command Double-Cantilever Hangar Program
October 1957

	Total Locations	**Northern Tier**	**East Coast**	**West Coast**	**Mid/South**	**Overseas**	**Sited With SAC Alert**
Confirmed on Kuljian Job List	30	3	8	2	11	5	17
Mapped USAF	*46	7	12	5	18	4	30
Expansion Planned for Existing Hangars	7	2	1	1	3	0	6
New Hangar Locations Planned	9	1	0	0	4	4	0
Basic/Medium	36	4	12	4	14	2 (Canada/ North)	22
Heavy	10	3	0	1	4	2	8
Paired Hangars, Single Installations	6	1	1	0	3	1	3
Air Force Property August 1999	21	0	10	3	7	1	11

* 46 locations (53 hangars). Cross-referencing verifies 55 hangars, total, as-built.

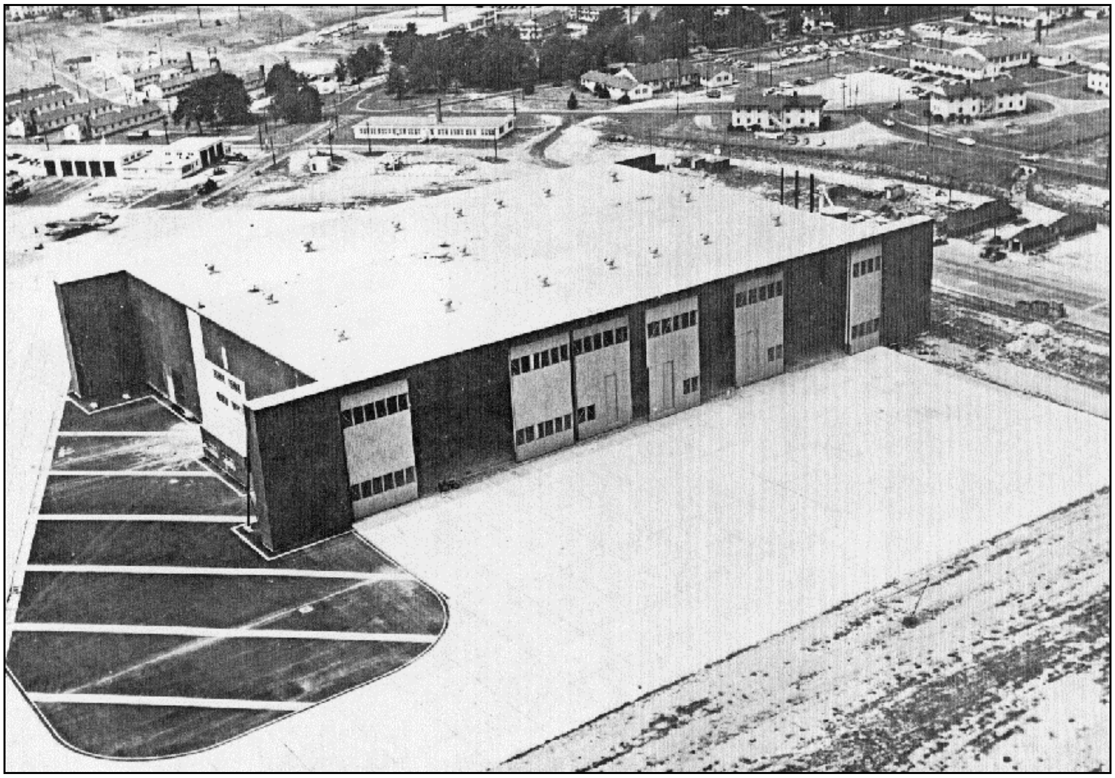


Plate 128. Kuljian Corporation. Double-cantilever hangar. Shaw Air Force Base. View of the middle 1950s. Courtesy of the Kuljian Corporation.

Plate 129. Renovated double-cantilever hangar. Whiteman Air Force Base. (Identical changes at McConnell and Shaw Air Force Bases.) July 1999. Photograph, K.J. Weitze.

hangars can be assumed eligible to the Register, a number will be so assessed for their engineering and for their association with specific installation-level missions within SAC.

Typically, SAC erected the double-cantilever hangar with entrances parallel to the flightline, usually bracketing the hangar with wing hangars. Multiple types and periods of wing hangar are to be expected, from those of 1951 through the early 1960s. In selected cases, SAC also built more than one double-cantilever at a single flightline, siting these either end to end, or side to side. The presence of wing hangars, in numerous patterns, adds substantially to the historic feeling and association for the double-cantilever hangar.

Extensive interior changes are again to be anticipated, but maintaining views of the trussed cantilevers and arches is critical to the hangar's National Register integrity.

Prefabricated, Mobilization Infrastructure

Wing Hangars

Character-defining features of the SAC steel wing hangars for the B-36, the B-47, and the B-52 bombers (as well as the KC-96 and KC-135 tankers) are focused on the structures' abilities to convey the urgency of Cold War mobilization during the 1950s. SAC commissioned a series of wing hangars, suited to its progressive bombers. Luria Engineering of New York is assumed to have designed most, and possibly all, of the SAC wing hangars, beginning with one for the B-36 in 1951. That wing hangar, and a later wing hangar for the B-47, closely mirrored the lines of the bomber it was intended to service. As the decade unfolded, Luria designed a wing hangar that could accommodate multiple types of bombers in varied configurations of one or more aircraft. Design toward a generic wing hangar was even more pronounced toward the end of the decade, and typifies the large program for the B-52. Wing hangars could be moved, dismantled, and shipped to other locations. Actual movement of wing hangars appears to be concentrated only on those remaining from World War II (for the B-29 and B-50) and on the B-47 (heavily shipped overseas after use in the United States). The Air Force appears to have treated the original B-36 wing hangar; the multi-purpose wing hangar; and the series of B-52 wing hangars as more permanent infrastructure, with some movement of the multi-purpose hangar on single flightlines. Although these structures are large, they essentially sheltered the nose and wings of serviced aircraft, leaving tails protruding. The earliest wing hangars were built in the fewest numbers; the latest in a very large buildout. (See Table 1, Chapter 2.)

Key character-defining features include:

- a steel structure, bolted to the concrete service pad;
- early configuration for the lines of the serviced bomber;
- middle configuration for multiple servicing of the B-29, B-50, B-36, B-47, and B-52;
- late standardized simplicity as an aircraft shelter;
- limited mobility (dismantling, shipping, and re-erection);
- corrugated steel exterior sheathing;
- recessing, panel doors with openings for the tail of serviced aircraft;
- standardized extensions across the fronts of the earliest wing hangars;
- and, patterned clustering at the flightline, often in rows, but sometimes in small groups of four, or bracketing a large double-cantilever maintenance hangar.

As had been the case for the double-cantilever hangar, SAC typically left wing hangars unpainted. Over time most of these wing hangars sustained a neutral, low-key paint scheme. The addition of bright paint, and high-profile graphics, is non-historic. The Air Force has heavily altered many of its wing hangars

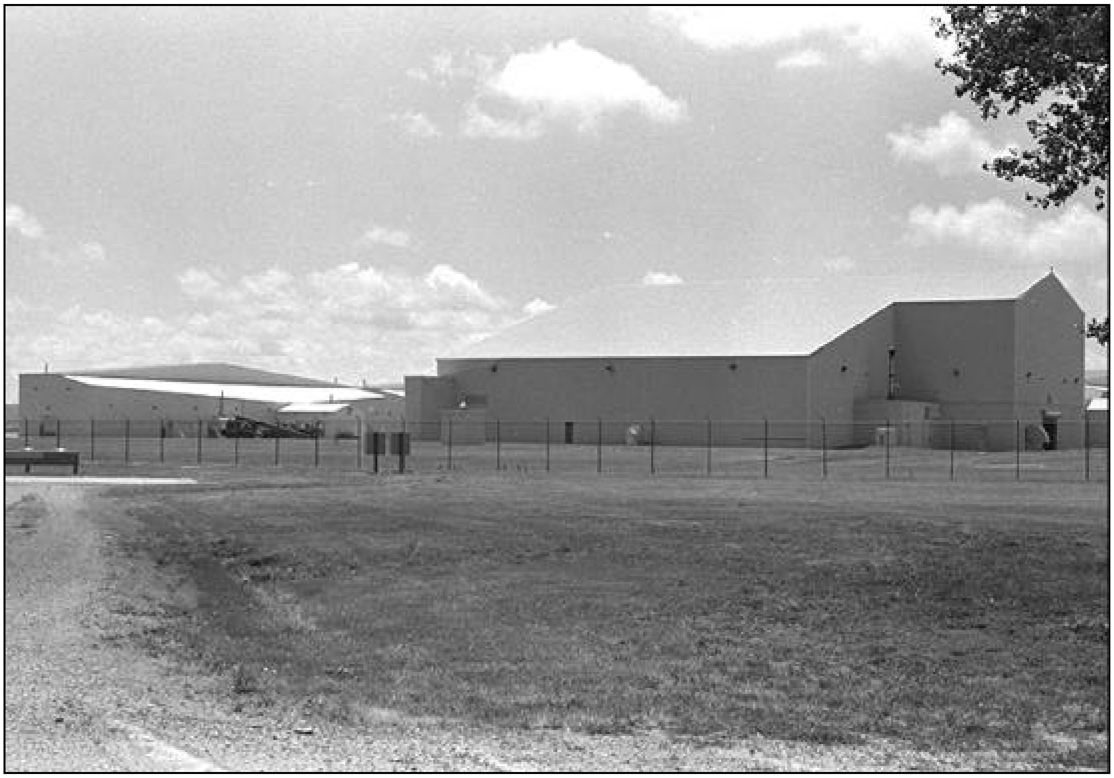


Plate 130. Intrusive addition to B-52 wing hangar (right). Period addition to B-36 wing hangar left). Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

Plate 131. Remodeling of B-52 wing hangars for the B-1 (right). Original multi-purpose wing hangars (left). Ellsworth Air Force Base. July 1999. Photograph, K.J. Weitze.

across the nation through later expansion. For the earliest B-36 and B-47 wing hangars, rarity is a major issue. The presence of a B-36 or B-47 wing hangar, in an unaltered state, should be considered exceptionally significant. Also of note, any surviving clusters of B-36 hangars with the Leo A. Daly extensions of the middle 1950s are also very rare. In most of these cases—unless further additions accrued after 1955-1957—the additions should be interpreted as integral to integrity, not detracting from it. By the buildout for the multi-purpose and B-52 wing hangars, the number of structures is much larger as is intrinsic design flexibility. In these cases, extensions and additions to the wing hangars detract from integrity substantially (Plates 130 and 131). Particularly important for interpretation of the SAC Cold War hangar is its setting and association with other wing hangars. Clusters of wing hangars can be anticipated to be of like kind; or, layered over time at an installation; or, mixed (where moved, shipped for a second-life use, or where pulled together from ad hoc sources during times of wing hangar scarcity).

The SAC wing hangar program was an exceptionally large one, and today is characterized by numbers of altered structures. Many wing hangars will not possess either individual integrity or their historic clustering, both supportive of any National Register consideration. However, in situations where large numbers of unaltered, or minimally altered, wing hangars are extant, it is important to carefully address the potential for a National Register district or for cohesive rows / clusters.

Extensive interior changes are to be expected. Yet, due to the utilitarian nature of the wing hangar, it is equally likely that hangars will remain minimally altered, and may even possess their original steel false-floors—the latter placed at the front of the aircraft to allow bomber mechanics to work on aircraft engines.

SAC Airmen Dormitories

Character-defining features of the SAC airmen dormitories of the early 1950s are again focused on the structures' abilities to convey the urgency of Cold War mobilization, but are enhanced through their additional association with strong design tenants of the period. These structures offered quintessential steel-and-glass facades, and are linked to European modern architecture as it grew out of the Bauhaus and as it was showcased at the Museum of Modern Art in New York during the late 1930s. This level of modernism is relatively rare outside the skylines of major cities; university campuses; houses designed for individual upscale clients; and, occasionally, schools. Here, the direct association between cutting-edge design, efficiency, mobilization, and a certain elite status for SAC airmen is intended, and can be interpreted as deliberate on the part of SAC commander Curtis LeMay. The numbers of these steel dormitories, as-built, is unverified as yet, but appears to be a concentrated SAC phenomenon with a few other Air Force applications. Survival of these dormitories, unaltered on their exteriors, is presumed to be very rare, while renovation of interiors is a given. Their design in 1951 by SAC engineers themselves, using prefabricated steel paneling manufactured by the Detroit Steel Products Company, is also unusual for Air Force design, and speaks to the very earliest years of the Cold War (Plate 132).

Key character-defining features include:

- completely steel structure;
- insulated, steel Fenestra paneling;
- steel detailing, such as stairwells, window frames, and doors;
- expansive use of glass fenestration;
- crisp design lines, including flat roof and minimal overhang;
- and, construction in small groups of two and three units.

Plate 132. Remodeled SAC airmen dormitory. Original fenestration and entry (center). Ellsworth Air Force Base. View of July 1999. Photograph, K.J. Weitze.

SAC airmen dormitories are rare remnants of the bomber landscape. Known as constructed at Offutt (Nebraska), Ellsworth (South Dakota), and Pease Air Force Bases (New Hampshire), these structures were likely proto-alert facilities when erected as a pair at the flightline, or isolated as a pair near it. At this time, only the SAC dormitories remaining at Ellsworth are within Air Force real property jurisdiction, although it is possible that dormitories of this type may exist at Lowry (Colorado) and Travis (California)—historically in more generalized use.

It is to be anticipated that both substantial exterior and interior remodeling will have occurred for these structures. Partial original exterior paneling and fenestration is present for three of the four dormitories at Ellsworth, and suggests that, in at least one case, the original structure may be present in sections beneath the remodeling.

Experimental Pavement

Experimental runway and apron pavements suitable for the very heavy bombers—particularly the B-36 and the B-52—were a direct continuation of engineering undertaken during World War II. The debate focused on the appropriateness of concrete versus asphaltic pavements. Comparable costs, speed of construction, availability of materials, and permanence over time (while under heavy and abusive use by SAC bombers) were the key issues. Additionally, engineering for airfield pavements was tied to necessary runway lengthenings and widenings; eroding shoulders; effects of engine blast and spilled jet fuel; high contact pressures before the availability of multiple-tire landing gear; very high landing speeds; and micro-climatic conditions. Some SAC installations sponsored pavement test tracks and sections.

Key character-defining features include:

- specific composition of the concrete or asphalt;
- use of soil-cement;
- extensive subsurface construction;
- base grade construction;
- top surfacing construction;
- width, length, and grading of runways;
- differences between construction for the primary runway(s) and that for the associated taxiways, parking aprons, warm-up pads, and final 1000 feet of overrun (with a mixed configuration typical of the early Cold War featuring asphaltic runways and concrete taxiways, parking aprons, warm-up pads, and overruns);
- and, the presence of pavement test sections (flags) and/or tracks.

Two situations addressing historic pavement for the heavy bomber can be anticipated: bases where the Air Force adopted a particular solution for experimentation and test (soil-cement, all-asphaltic, a combination of asphaltic and soil-cement/concrete; or all-concrete) during the 1948-1956 period; and, bases where the Air Force laid pavement test sections, often placed in flags (rectangular, scored areas), or test tracks.

Again, it is anticipated that many early runway pavements will be replaced today—although, in certain cases pilots and airmen at an installation may be present who remember landing and taking off from the original test pavement and can even comment on the replacement project. One such airfield is that of the former Lincoln Air Force Base in Nebraska, now the municipal airport with an associated Air National Guard installation. Runway replacement at Lincoln was in the relatively recent past. It is also likely that installations that supported high-profile pavement testing will have full sections intact. In order to address potential National Register eligibility for infrastructure like airfield pavement, it is suggested that all of the pertinent character-defining features would need to be unaltered, and would further need to be supported by historic airfield layout and standing structures.

Q Areas

Character-defining features of the SAC nuclear munitions storage depots—the Q Areas—are focused on their specialized engineering for the weapons system most often associated with the Cold War. Originally classified, these depots still require substantial research and discussion of their historic engineering. Experimental construction, testing, and safety parameters all need further specific detailing in the open literature in order to tie physical attributes of design, engineering, and construction to the remaining standing structures. Although Q Areas were not rare, they did number only 20 internationally during the early Cold War. Today munitions use at former Q Areas is split: some maintain active and secured munitions missions, others are in a state of abandonment or complete munitions disuse.

Key character-defining features include:

- extensive used of bermed storage igloos;
- thick-walled, reinforced concrete, underground storage structures, with faux, solid reinforced concrete aboveground buildings;
- bermed maintenance and assembly buildings;
- aboveground maintenance structures for munitions components;
- a command and control building, with below ground facilities;
- security fencing and guard gate;
- and, an immediately adjacent cantonment—typically segregated from an adjacent military base.

Q Areas do have individually significant structures within their boundaries. It is suggested that the A structures (A-1 and A-2) are likely candidates for National Register eligibility, as are the Plants I and II (A and B), and the command post. For these structures, it will be important to ascertain the engineering parameters for the thick-walled construction; any special concrete mix, use of reinforcing steel, or shielding; interior storage, maintenance, and assembly room layout; any physical features incorporated for munitions and personnel safety; and siting within the overall compound, both accommodating storage requirements and alert. In addition, Register integrity would support the standard requirement that later remodelings of these buildings within a Q Area not include such items as replacement of an early 1950s flat roof with a later one of gabled type, nor the removal of faux-fenestration or porches from the A structures.

Alert Aprons and Moleholes

Character-defining features of the SAC alert apron configurations and crew quarters—moleholes—are a rare instance where the features of the historic property include ones associated with both a standing structure and an adjacent aircraft apron. Designed and engineered by Leo A. Daly, an Omaha firm also responsible for SAC's first and second generation underground command posts at Offutt Air Force Base, SAC alert facilities spread across the United States and into Canada. Design efforts began in the middle 1950s, with buildout achieved during 1957-1960. The program followed hard upon a transitional alert initiated by SAC in 1956, an alert using existing flightline dormitories and operations buildings, and one which acknowledged several different secured parking aprons. Not surprisingly, SAC undertook construction for its alert aprons first—and, again not surprisingly, design changed literally while aprons were in buildout. Resultant from this situation, two key alert apron patterns exist, supplemented by particular instances where a pre-existing rectangular apron was called into service; a new rectangular apron and taxiway were built due to land limitations and topography; or, a former hot cargo area was reconfigured for alert service. SAC also built alert aprons in different sizes—similar to its treatment of the double-cantilever hangar. Accompanying the alert aprons, and erected during 1958-1960, the moleholes also came in small, medium, and large sizes—and, like the alert aprons, occasionally were built in a non-standard manner. Nonetheless, all SAC alert facilities had an alert apron and an alert crew quarters, the latter always basically designed as a molehole.

Key character-defining features include:

- an alert apron configured for between four and 10 bombers (B-47s, B-58s, and B-52s);
- a taxiway angled at 45 degrees from the end of the primary (longest) runway;
- and, a molehole of 18,000, 22,500, or 31,000 square feet.

In addition, the molehole had its own character-defining features, including:

- two-story height, with the lower story either fully below ground, or bermed aboveground;
- egress tunnels from the underground story sheathed in corrugated metal with single-pane, wood-frame windows per tunnel and blast-framed doors;
- and, simple 1950s design detailing, including a nearly flat gable roof and windowless walls.

SAC alert facilities were secured areas, and so typically also had perimeter lighting and fencing at the molehole, with a manned checkpoint. Notably, SAC alert facilities did not have an associated cluster of ancillary structures, but were instead entirely self-contained. (ADC alert sustained an opposite character at the flightline.) Buildout for the SAC alert program was 64 or 65 facilities, dependent on actual construction at Ramey Air Force Base in Puerto Rico (Table 3). Most SAC alert facilities had very short actual lives, superceded by the emplacement of ICBMs; and by changing base priorities and assigned

Table 3

Strategic Air Command Flightline Alert

	Northern Tier	**East Coast**	**West Coast**	**Mid / South**	**Canada / North**	**Puerto Rico**	**Total**
Buildout	22	10	6	20	6	1	65
Christmas Tree Apron, Planned or In Place, October 1957	11	7	1	6	0	0	25
90-degree Stub Apron Planned or In Place, October 1957	8	0	2	6	0	1	17
18,000 sf (70-man)	15	7	5	11	6	1	45
22,500 sf (100-man)	2	3	1	4	0	0	10
31,000 sf (150-man)	5	1	0	4	0	0	10
Began Construction 1958	13	9	1	3	6	0	32
Began Construction 1959	9	2	5	16	0	0	*32
Construction Complete by August 1959	5	4	0	0	0	0	9
Construction Complete by Late 1959	13	5	6	11	1	0	36
Construction Complete by 1960	4	2	0	8	5	0	19
Air Force Property August 1999	7	7	4	5	0	1 (?)	24

* Ramey not under construction as of December 1959.

Plate 133. Heavily renovated molehole, with additions doubling square footage. Grand Forks Air Force Base. View of 1995. Courtesy of Geo-Marine, Inc.

aircraft. SAC placed both bombers and refueling tankers on alert, with a renewed alert period in the middle 1960s. At that time, single installations sometimes supported both bombers and tankers on alert, with a generic, secured tanker apron often added at the flightline. The tanker alert of this period did not have specially designed crew quarters, but rather used trailers or generic housing.

The SAC alert program was so large and widespread that remnants of its landscape can frequently be found well beyond current Air Force installations—at former bases that now function as municipal and county airfields in particular. Often it is at these locations that the least change has occurred, with moleholes many times in use for local aero clubs. (Although in some cases, former moleholes are in an abandoned state, with security fencing still in place.) At active SAC bases, layered missions, new weapons systems, and the introduction of the B-1 all caused substantial loss of National Register integrity for these 1950s alert facilities. In some cases, SAC renovated moleholes into barely recognizable "improved" quarters, typically increasing square footage by 100 percent (Plate 133). During the middle 1970s and again with the B-1 in the middle 1980s, SAC also added perimeter structures at an active former molehole—family visitation quarters and other amenities far removed from the urgency of austere high alert. And, in some instances, SAC expanded the alert apron, following the original design configuration, but giving a false impression of the Cold War programmatic function of the facility.

Register integrity should adhere closely to the full complement of character-defining features for the SAC alert facilities, and where a right-angled or herringbone (Christmas tree) alert apron is present, should include the apron as well. Removal of the corrugated egress tunnels, for example, is a substantial loss of integrity for this kind of simple, single-purpose structure. In addition, it is recommended that installation-specific history for SAC alert be addressed, before assuming eligibility. Even when integrity is present, alert mission may have been ephemeral. SAC alert facilities are significant primarily for their mission, not for their design or engineered structure.

SAC Command Post and Chapel

Command Post

The SAC command post, aboveground and below, at Offutt Air Force Base is a unique structure, and as such is strongly tied to a mythic imagery for the command and its leader during the late 1940s and 1950s, Curtis LeMay. Command post character-defining features are focused on mission, design, and engineering. The aboveground structure is evocative of 1950s office design, generally, while the underground structure is tied to the evolution of command posts in SAC's sister command, ADC. Issues centered on hardening; programmatic design for sustained alert; and command communications display and linkage are similar to the same concerns within ADC for its air defense web of aboveground command and control centers designed in 1949 (and built during 1951-1957) and its second and third generation Semi-Automatic Ground Environment (SAGE) and Backup Interceptor Control (BUIC) programs.

Key character-defining features include:

- 1950s aboveground office design;
- below ground hardened construction;
- tunnel egress from below ground compound to the aboveground office structure;
- security and contamination safeguards for the underground compound;
- and, programmatic design of the below ground situation displays and war room.

Integrity for the 1950s below ground command post is negligible today, with a second generation SAC underground command post built in the 1980s. Analysis of Register integrity for the later below ground command post, however, will address the same character-defining features, although can be anticipated to be much more sophisticated in its engineering for hardening, contamination, and security.

Chapel

The SAC chapel is a second case where imagery for the command is uppermost. The 1950s exterior design by Leo A. Daly is typical for its period, and its associated issues of Register integrity relate directly to unaltered survival over time. Character definition for the chapel, however, is focused in its four large stained glass windows, presenting the Second, Eighth, Fifteenth, and Sixteenth Air Forces within SAC during the early Cold War, and, in its memorial window symbolizing the entire command.

Key character-defining features are not analyzed here, but should address the techniques used by the artist in creating the windows and the relationship of those techniques to stained glass craftsmanship of the late 1950s and early 1960s.

Late Cold War Infrastructure

SAC infrastructure of the late Cold War is focused in the middle 1970s and again in the middle 1980s. With the exception of the second generation command post at Offutt Air Force Base, the buildings and structures of this period pertinent to the B-1 and B-2 bomber mission are too recent, generally, to assess against criteria for the National Register. One hangar, that for the National Emergency Airborne Command Post (NEACP), is visually very striking, and is likely deserving of further research and analysis. Other work may follow.

Chapter 4: Real Property Management of Historic SAC Infrastructure

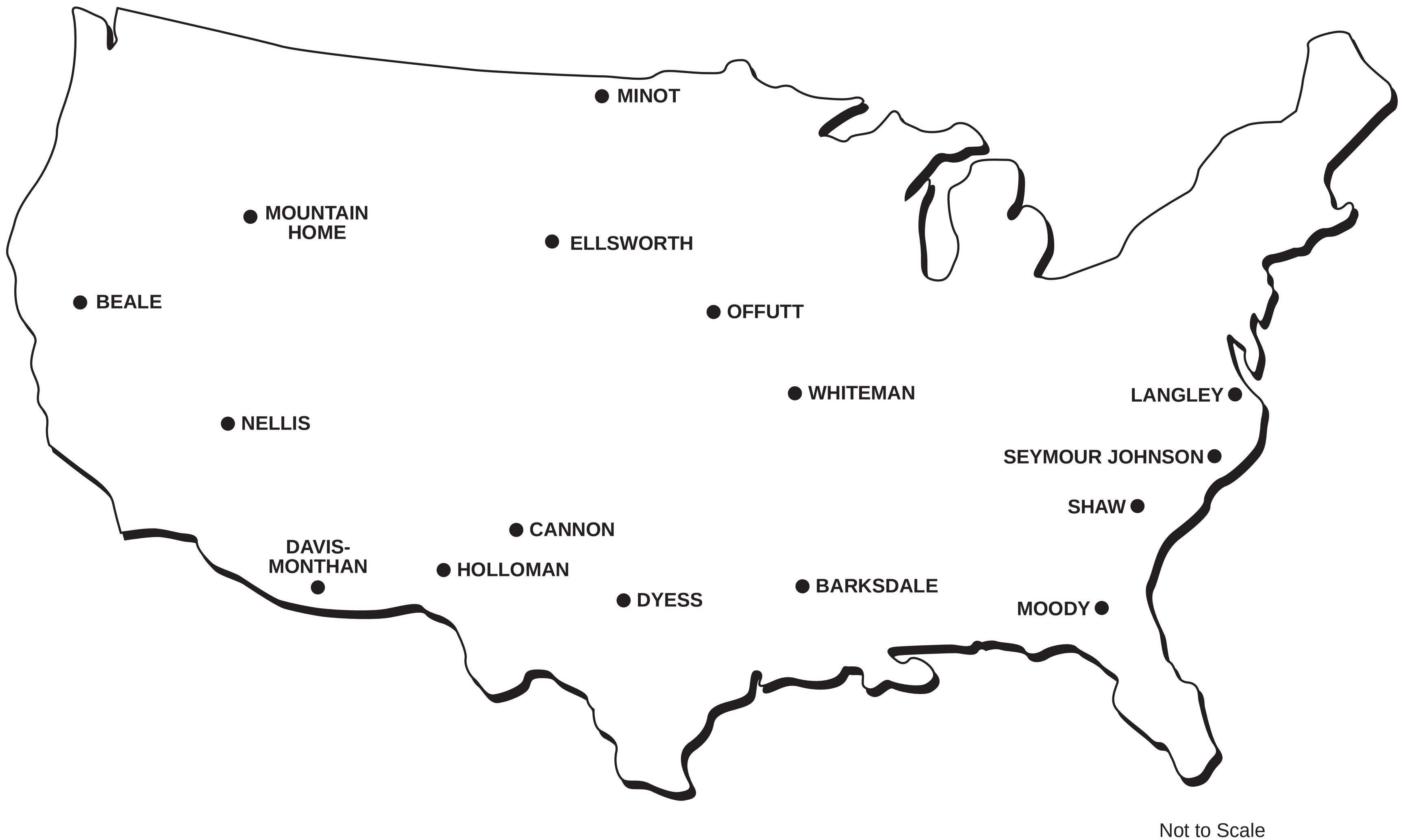
Following are one-page summaries, installation by installation, for adaptation to current Air Combat Command (ACC) real property management. The summaries are brief, and are intended to correlate information present in the baseline inventories of 1995-1997 prepared by Mariah Associates, Inc., with the context for SAC bomber 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 SAC. (Are the assigned bombers 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 SAC bomber mission of the Cold War, as discussed in chapters 2 and 3. Many of the current ACC installations also host parallel historic ADC and TAC air defense infrastructure associated with fighter, and, command and control missions. 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 Air Defense: The Fighter and Command Missions.*



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 Bomber and Tanker Aircraft:	B-26 (close of World War II into the early Cold War) B-45 (1949; phased out after 1954) B-47 (1954; phased out after 1958) KC-97 (accompanied the B-47) B-52 (received 1958) KC-135 (received 1958) KC-10 (received 1981)
Missions:	Headquarters Second Air Force, SAC AFSWP Q Area – Main Stockpile SAC Bomber and Tanker Alert SAC Airborne Alert Exercises – Chrome Dome Post-Attack Command Control System (PACCS) [Looking Glass: Auxiliary Command Post] U-2 Reconnaissance
Infrastructure:	Bossier Base [Q Area] Molehole and Christmas Tree Alert Apron (small) Tanker Alert (late added crew quarters and apron) PACCS Shelters U-2 Hangars Medium Aircraft (B-52) Wing Hangars
Integrity:	Bossier Base: high Molehole and Christmas Tree Alert Apron: lost PACCS Shelters: unassessed U-2 Hangars / Shelters: unassessed Medium Aircraft Wing Hangars: unassessed
Potential NRHP Eligibility:	Bossier Base: A-1 / A-2; command post; Plants I and II Molehole / Christmas Tree: none (heavily modified) Tanker Alert: none (generic late infrastructure) PACCS: potential use of B-52 wing hangars, unassessed U-2 Hangars / Shelters: unassessed Medium Aircraft Wing Hangars: unassessed
Other:	Barksdale supported SAC alert crew trailers in 1958. None of these trailers are known to exist today. If discovered on base, they should be assessed.

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 Bomber and Tanker Aircraft:	KC-135 (received 1959) B-52 (received 1960)
Missions:	SAC Bomber and Tanker Alert SR-71 Reconnaissance U-2 Reconnaissance TR-1 Reconnaissance
Infrastructure:	Molehole and Right-Angle Stub Alert Apron (small) SR-71 Butler Hangars U-2 Hangars TR-1 Hangars Medium Aircraft (B-52) Wing Hangars
Integrity:	Molehole and Alert Apron: lost SR-71 Hangars: intact U-2 Hangars / Shelters: unassessed TR-1 Hangars: intact Medium Aircraft Wing Hangars: unassessed
Potential NRHP Eligibility:	Molehole and Alert Apron: none SR-71 Hangars: possible U-2 Hangars / Shelters: unassessed TR-1 Hangars: late prefabricated structures, unlikely Medium Aircraft Wing Hangars: here without double-cantilever hangar, unlikely
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 Bomber and Tanker Aircraft:	B-17 (1946-1947) B-24 (1946-1947) B-29 (1946-1947)
Missions:	Training aircrews for the B-17, B-24, and B-29
Infrastructure:	None extant
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

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 Bomber and Tanker Aircraft:	B-29 (1946-1953) B-50 (1948-1953) KB-29 (1948-1953) B-47 (1953-1964) KC-97 (received 1953-1954)
Missions:	Extended Aircraft Storage SAC Bomber Alert U-2 Reconnaissance
Infrastructure:	Molehole and Christmas Tree Alert Apron (medium) U-2 Hangars / Shelters [medium aircraft wing hangars]
Integrity:	Molehole and Alert Apron: lost U-2 Hangars / Shelters: intact
Potential NRHP Eligibility:	Molehole and Alert Apron: none U-2 Hangars / Shelters: unassessed
Other:	No issues.

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 Bomber and Tanker Aircraft:	B-47 (1955-1963) KC-97 (received 1955) B-52 (1963/1965-1985) KC-135 (received 1963-1965) B-1 (received 1985)
Missions:	SAC Bomber Alert B-1
Infrastructure:	Double-Cantilever Maintenance Hangars (2) (basic and medium) Miscellaneous Wing Hangars Medium Aircraft (B-52) Wing Hangars Molehole and (ad hoc) Rectangular Alert Apron B-1 Maintenance Dock and Fuel Cell Dock
Integrity:	Double-Cantilever Hangars: intact / minor modification Miscellaneous Wing Hangars: unassessed Medium Aircraft Wing Hangars: intact and unassessed Molehole and Alert Apron: lost B-1 Maintenance and Fuel Cell Docks: intact
Potential NRHP Eligibility:	Double-Cantilever Hangars: unlikely Miscellaneous Wing Hangars: unlikely Medium Aircraft Wing Hangars: unlikely Molehole and Alert Apron: none B-1 Maintenance and Fuel Cell Docks: possible
Other:	Dyess supports a varied group of wing hangars, including two with footprints of B-29 type. It is assumed that most of the group are altered, but no real inventory assessment exists.

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 Bomber and Tanker Aircraft:	B-29 (received 1947) B-36 (1949-1957) B-52 (received 1957) KC-135 (received 1959) EC-135 (received 1965) B-1 (received 1986)
Missions:	B-36 Reconnaissance AFSWP Q Area - Alert Aviation Depot Squadron SAC Bomber Alert PACCS [Looking Glass: Auxiliary Command Post] B-1B
Infrastructure:	Thin-Shell, Concrete Maintenance Hangar B-36 Wing Hangars SAC Steel Airmen Dormitories (4) Rushmore Air Force Station (AFS) [Q Area] Multi-Purpose and B-52 Wing Hangars Molehole and Christmas Tree Alert Apron (small)
Integrity:	Thin-Shell, Concrete Maintenance Hangar: intact B-36 Wing Hangars: early minor addition, intact SAC Dormitories: lost Rushmore AFS: mixed Multi-Purpose and B-52 Wing Hangars: mixed Molehole / Alert Apron: unassessed / lost
Potential NRHP Eligibility:	Thin-Shell, Concrete Maintenance Hangar: strong B-36 Wing Hangars: strong SAC Dormitories: none Rushmore AFS (Q Area): possible structures Multi-Purpose and B-52 Wing Hangars: unlikely Molehole and Alert Apron: unlikely
Other:	Drawings in the civil engineering vault for the thin-shell, concrete maintenance hangar; the SAC airmen dormitories; and the B-36 wing hangars are quite rare.

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 Bomber and Tanker Aircraft:	None
Missions:	No Cold War bomber missions
Infrastructure:	No SAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

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 Bomber and Tanker Aircraft:	B-26 (received 1950) B-45 (received 1951) KB-50 (received 1958)
Missions:	TAC Fighter-Bomber Training and Support
Infrastructure:	Double-Cantilever Hangar (basic) Fuel Systems Maintenance Docks (5)
Integrity:	Double-Cantilever Hangar: intact Fuel Systems Maintenance Docks: unassessed
Potential NRHP Eligibility:	Double-Cantilever Hangar: possible Fuel Systems Maintenance Docks: unlikely
Other:	Relatively rare instance of a double-cantilever hangar built at a TAC installation: for use by fighter and small bomber aircraft.

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 Bomber and Tanker Aircraft:	KC-135 (received 1959) B-52H (received 1961)
Missions:	SAC Tanker and Bomber Alert
Infrastructure:	Molehole and Christmas Tree Alert Apron (small) Medium Aircraft (B-52) Wing Hangars (4) Miscellaneous Wing Hangars (2) Tanker Pen with Crew Quarters (late addition) Late Cold War Large Aircraft Maintenance Dock
Integrity:	Molehole and Original Alert Apron: lost Tanker Pen with Crew Quarters: intact Wing Hangars: unassessed Large Aircraft Maintenance Dock: intact
Potential NRHP Eligibility:	Molehole / Alert Apron: none Tanker Pen with Crew Quarters: none (generic) Wing Hangars: unlikely Large Aircraft Maintenance Dock: unlikely
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 Bomber and Tanker Aircraft:	None
Missions:	No Cold War bomber missions
Infrastructure:	No SAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

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 Bomber and Tanker Aircraft:	B-29 (received 1953) KB-29 (received 1953) B-47 (1954-1966) KC-97 (1954-1966) B-52G (1992-1994) KC-135 (received 1992) B-1 (received 1994)
Missions:	SAC Bomber Alert
Infrastructure:	Multi-Purpose Wing Hangars (5) Molehole (large) and Christmas Tree Alert Aprons (1 ½)
Integrity:	Multi-Purpose Wing Hangars: mixed Molehole and Alert Apron: intact
Potential NRHP Eligibility:	Multi-Purpose Wing Hangars: unlikely Molehole and Alert Apron: strong
Other:	No issues.

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 (1941) 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 Bomber and Tanker Aircraft:	None
Missions:	No Cold War bomber missions
Infrastructure:	No SAC infrastructure
Integrity:	N/A
Potential NRHP Eligibility:	N/A
Other:	No issues.

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 Bomber and Tanker Aircraft:	EC-135 (received 1959) E-4B (received 1974)
Missions:	SAC Headquarters PACCS (Looking Glass: Command Post) National Emergency Airborne Command Post (NEACP)
Infrastructure:	1st SAC Headquarters under LeMay (A Building) SAC Airmen Dormitories 2nd SAC Headquarters (Western Pentagon) 1st SAC Underground Command Post SAC Chapel PACCS NEACP 2nd SAC Underground Command Post
Integrity:	1st SAC Headquarters: intact (exterior) SAC Airmen Dormitories: lost 2nd SAC Headquarters: intact (exterior) 1st SAC Underground Command Post: unassessed SAC Chapel: intact PACCS: intact NEACP: intact 2nd SAC Underground Command Post: intact
Potential NRHP Eligibility:	1st SAC Headquarters: strong SAC Airmen Dormitories: none 2nd SAC Headquarters: strong 1st SAC Underground Command Post: unassessed SAC Chapel: strong PACCS: strong NEACP: strong 2nd SAC Underground Command Post: strong
Other:	Selected drawings held in the civil engineering vault are rare.

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 Bomber and Tanker Aircraft:	B-52 (1959-1982) KC-135 (1959-1985) KC-10 (1985-1994)
Missions:	SAC Bomber Alert
Infrastructure:	Double-Cantilever Hangar (basic) B-47 Wing Hangar Multi-Purpose Wing Hangar Medium Aircraft (B-52) Wing Hangar Molehole / Christmas Tree Alert Apron (small)
Integrity:	Double-Cantilever Hangar: intact B-47 Wing Hangar: unassessed Multi-Purpose Wing Hangar: intact Medium Aircraft Wing Hangar: intact Molehole [bermed] / Alert Apron: intact
Potential NRHP Eligibility:	Double-Cantilever Hangar: possible Wing Hangars: possible Molehole / Alert Apron: strong
Other:	Seymour Johnson hosts an unusual collection of three different wing hangars. The Air Force likely assigned these hangars in this manner due to a general shortage of infrastructure during the middle 1950s. Noteworthy here is the presence of a B-47 wing hangar, Building No. 4828, now very, very rare. In addition, Seymour Johnson's molehole is built aboveground, bermed for the protection typically achieved by building the first story as a basement. Only a small number of moleholes were erected in this manner.

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 Bomber and Tanker Aircraft:	RB-26 (1951-1954) RB-57A (1954-1956) RB-66 (1956 into the 1970s)
Missions:	TAC Fighter-Bomber Reconnaissance Air Force Advanced School for Tactical Reconnaissance
Infrastructure:	Double-Cantilever Maintenance Hangar (medium)
Integrity:	Double-Cantilever Maintenance Hangar: lost
Potential NRHP Eligibility:	Double-Cantilever Maintenance Hangar: none
Other:	Atypical use of a double-cantilever hangar for TAC fighter-bomber missions.

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 Bomber and Tanker Aircraft:	B-47 (1954-1963) KC-97 (1954-1963) B-58 (1969) KC-135A (1969-1970) B-2 (1988)
Missions:	SAC Bomber Alert B-2
Infrastructure:	Molehole (large) and ad hoc Rectangular Alert Apron Multi-Purpose Wing Hangar B-2 Shelters
Integrity:	Molehole / Apron: intact Multi-Purpose Wing Hangar: intact B-2 Shelters: intact
Potential NRHP Eligibility:	Molehole / Apron: strong Multi-Purpose Wing Hangar: unlikely B-2 Shelters: unlikely (generic infrastructure)
Other:	The molehole at Whiteman is one of a small number of 150-man crew quarters built by SAC, and sustains a high degree of exterior integrity. It is further unusual with its ad hoc rectangular apron.

Chapter 5: Recommendations

Recommendations for the management of real property that historically supported the SAC bomber mission of the Cold War (1946-1991) 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 SAC bomber mission indicate that the Air Force today owns approximately 35 to 40 percent of the total such property it owned historically, and that this percentage is actively declining as bases close. As the remaining, or redefined, missions merge, and as the Air Force takes major steps forward with the B-1 and the B-2, renovation will aggravate this situation intensely. (See Tables 1-3.) 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 some cases, also, early Cold War ties between the Air Force and other arms of the Department of Defense, particularly the Navy, leave a historic landscape where related Air Force, ANG, and Navy hangars and command/control structures—with their supporting ancillaries—are sited together at a public airport. Finally, the distribution of historic SAC bomber infrastructure of the Cold War is on the cusp of substantial, new major change, as local and regional airfields of long standing (which were once key SAC 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 former Air Force bases like Walker in New Mexico and Schilling in Kansas, colleges have leased or purchased major portions of the property for campuses. At the former Air Force bases of Larson in eastern Washington and George in Southern California, major international airlines have rented SAC bomber infrastructure for maintenance use, servicing their aircraft away from the more congested airports of Seattle-Tacoma and Los Angeles International. Of perhaps even higher interest, 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. At the Grant County Airport, Japan Airlines (JAL) has long used the 13,500-foot runway to train crews for the Boeing 747 and the site is currently under consideration as one of 17 possible launch-and-landing locations for a commercial space shuttle. In short, the period for the dormant survival of relatively unaltered historic SAC 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 SAC bomber mission 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 SAC real property types (discussed in chapter 2) across the Air Force; and (4) Air Force-wide challenges in the future management of historic SAC engineering and real property documents—especially drawings and master plans currently housed in installation civil engineering vaults.

Current ACC Installations: Issues of Inventory

Nose Docks and Wing Hangars

Generally, inventories of historic Cold War infrastructure have omitted any organized analysis of these structures. The docks were the workhorses of the flightline for the SAC bomber mission throughout 1951-1991. The Air Force developed elaborate patterns of usage for these structures, sometimes moving them from installation to installation, and often making systematic alterations. Certain types and levels of alteration are uniform and carried out across SAC. These changes are well within a key period of SAC importance. Other changes are more haphazard, or are very recent (late in the Cold War), and generally would be interpreted as negative alterations to the historic fabric in terms of the National Register. Sorting out the situation at the installation level is likely to be difficult, but as these structures disappear all opportunity to understand and interpret them will vanish as well.

Nose docks and wing hangars exist at Barksdale, Beale, Dyess, Ellsworth, Minot, Mountain Home, Offutt, Seymour Johnson, and Whiteman Air Force Bases. Early clusters of this infrastructure are notable at Ellsworth, Mountain Home, and Seymour Johnson, and are mapped as present at Dyess. In each case, the docks (from that for the B-29 through the multi-purpose structure of 1951) present a different assessment situation. (See brief listing and discussion in chapter 4.) B-1 fuel cell docks at Dyess, from the end of the Cold War, may also warrant inventory and analysis.

Experimental Airfield Pavement

ACC has no inventory of experimental pavement within its command. Very little work exists on this topic, beyond that undertaken by the U.S. Army Corps of Engineers. Several installations are likely to be very important in this regard. Early SAC bases in extreme climates, both cold- and hot-weather, were candidates for such testing. Barksdale is known to have had both test pavement and a test track.

Alert Crew Trailers

SAC placed crew trailers at the flightline in support of its transitional alert in 1958, before completion of its permanent program of 65 moleholes. No trailers are known to exist today, but this should be checked for Barksdale Air Force Base.

Current ACC Real Property: Issues of Documents and Drawings

ACC may choose to make copies of representative drawings for SAC Cold War structures interpreted as significantly portraying the bomber mission of 1947-1991. 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, or rare, drawings are discussed below.

Q Areas (1946-1957)

ACC may be able to compile selected representative drawings for the A and A-1 Structures; the C Structure; and Plants I (A) and II (B) from its civil engineering vaults at Barksdale and Ellsworth Air Force Bases. Due to the classified nature of this project, finding a full set of drawings at any one installation is unlikely. Another potential resource is the archives of the responsible engineering firm, Black & Veatch.

Thin-Shell Concrete Hangar (1947)

The only known set of drawings for the Roberts & Schaefer B-36 maintenance hangar of May 1947 exists at Ellsworth Air Force Base. This set of drawings is extremely important and should be copied, with the originals archived.

Nose Docks and Wing Hangars (1951-1956)

Sequencing for the series of drawings representing nose docks and wing hangars is especially complex, 1951-1956. The earliest Cold War docks are those of Luria for the B-36, followed by the firm's execution for the multi-purpose wing hangar (both in 1951). Missing to date is the drawing series for the B-47 dock. During the middle 1950s, several important engineering firms, including Strobel & Salzman and Kuljian, also executed revisions for the Luria multi-purpose wing hangar—each with a set of drawings. Both full and partial sets of wing hangar drawings, from 1951 through 1956, should be reviewed in the installation civil engineering vaults where they still exist, with copies made to compile a complete representative set across bases holding respective individual drawings.

Installations likely to have full or partial sets of such drawings include Dyess, Ellsworth, Mountain Home, Seymour Johnson, and Whiteman. Such drawings are confirmed at Ellsworth and Whiteman. Notable also: Seymour Johnson has a standing B-47 dock, and may have a set of its drawings.

Double-Cantilever Hangar (1951)

Although excellent representation exists for the Kuljian double-cantilever hangar in its full configuration as basic, medium, and heavy, including expansible, it would be prudent to make full-sized copies for each version of the hangar through available sets of drawings held at the installation level. One set of originals should be archived.

Installations likely to have full or partial sets of double-cantilever drawings include Barksdale, Dyess, Langley, Seymour Johnson, and Shaw. The Air Force has modified the hangar at Whiteman, with the original drawings no longer extant.

SAC Airmen Dormitories (1951)

Drawings for the Detroit Steel Products Company SAC airmen dormitories are rare. ACC is advised to compile a partial or full set of these drawings from available originals at Ellsworth Air Force Base. Drawings for the dormitories at Offutt Air Force Base no longer exist.

Moleholes (1958-1960)

A complete set of the standardized drawings for the Leo A. Daly SAC alert crew quarters, the moleholes, should also be compiled across three or more bases having a 70-man, 100-man, and 150-man structure. Additionally, where SAC built a molehole aboveground, using berming to shield the lower story, site-adaptation drawings should be reproduced to augment the representative 70-, 100-, and 150-man set.

ACC installations likely to have the appropriate drawings are Barksdale, Beale, Ellsworth, and Minot [70-man molehole]; Davis-Monthan [100-man molehole]; Mountain Home and Whiteman [150-man molehole]; and, Seymour Johnson [bermed 70-man molehole].

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 SAC real property types associated with the command's Cold War bomber mission. In many cases, the best solution may be to look at a property type—such as the double-cantilever hangar or the molehole—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 there 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.

In this regard, the key structures for the SAC bomber mission are:

the double-cantilever hangar;
the B-36, B-47, and multi-purpose wing hangars;
the SAC airmen steel-panel dormitory;
selected experimental pavement and test sections / tracks;
Q Areas; and, moleholes and accompanying alert aprons.
For these six property types, 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.

Another 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 SAC infrastructure. Such a tool would aid in understanding a complete property type, such as the molehole, across both time and geography.

Also suggested is making a concerted effort to contact the historic engineering firms responsible for the key SAC infrastructure of the 1947-1960 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 nuclear weapons storage, such a contribution would be invaluable. Historic photographs and other documents may also remain in the appropriate engineering offices.

More generally, 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 early motorized, recessing panel doors of the double-cantilever hangar) may also be pertinent. A number of the former men are retired, but could likely be reached systematically through the Air Force Historical Research Agency. The latter group are likely 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. Addressing 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 by SAC 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 SAC Cold War structure is found on the Corps index cards. To aid researchers, the drawing number is provided, when known.

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