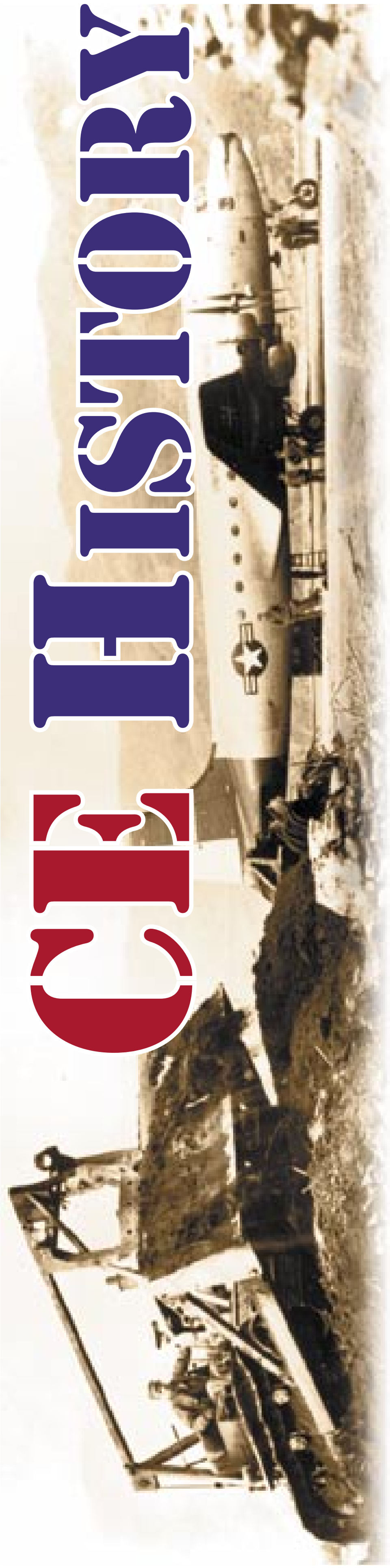

THE CIVIL ENGINEER AS PARTNER: ICBM FACILITY CONSTRUCTION

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Civil Engineers in the late 1940s and early 1950s experienced similar problems as today's engineers—weapons systems designers working without input from civil engineers on the basing implications of their designs. However, for a period of time in the 1950s and 1960s this changed. With the beginning of operational planning for the intercontinental ballistic missile (ICBM) program, it became evident that the designer of the missile ground environment had to work in an integrated fashion with the designer of the missile.

The Air Force began its missile development work following World War II with the recruitment of German scientists and the capture of a stockpile of German V-2 rockets. Lack of funds hampered the effort until the Soviet Union announced its successful test of a thermonuclear bomb in August 1953. Suddenly, President Dwight D. Eisenhower called for a massive effort toward the development of an ICBM to keep from being eclipsed by the Soviets. Air Force leaders such as Maj Gen Bernard A. Schriever headed the effort to develop the missile and its ground support.

ICBMs

Work began almost simultaneously on two ICBMs, the one-and-a-half stage Atlas and the two-stage Titan with many interchangeable subsystems, to broaden the knowledge base and stimulate competition to turn out a weapon in the shortest time. The pressure to develop and field an ICBM was intense. Work that would have taken an estimated 13 years was accomplished in less than 5. This had great implications for Air Force civil engineers because they had to begin the planning, programming, and design work for the site construction contemporaneously with the missiles' development. More important than the time constraints was the fact that the ground environment was not an afterthought in the weapon system development. "An airplane can fly with a minimum of ground support, but a ballistic missile is useless without proper launching facilities," was the view put forth by Brig Gen William E. Leonhard, Deputy Commander, Civil Engineering, Air Force Ballistic Missile Division (BMD), Air Research and Development Command, one of the leading civil engineers on the project.

SITE SELECTION

The missiles' special requirements and compressed time schedule affected all aspects of the construction effort, beginning with the site selection process. Dozens of survey teams each comprising Air Force engineers, Corps of Engineers representatives, members of architect-engineer firms, and BMD personnel, scattered throughout the country to examine over 250 possible sites for the Atlas program alone. The teams made site surveys from Nebraska to Georgia and from New Mexico to New York. The rigid standards used in judging a site's acceptability were staggering. Strict soils and geological requirements were necessary to construct missile silos that extended to a

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A missile silo construction site.

depth of 174 feet with a diameter of 52 feet, a launch control center silo 40 feet wide and deep, and a personnel tunnel and cableway connecting the two silos. In addition the distance requirements meant that a silo had to be at least 18 miles from its support base and from any town with a population of more than 25,000. Also, they had to be 7 miles from each other, 1,875 feet from an inhabited dwelling, and 1,200 feet from any public highway. Public access roads to the sites had to accommodate large missile carrier vehicles. After the technical criteria were evaluated, final site selection depended on the site's economic feasibility; i.e. the cost to dewater a silo or to construct roads. Once a site was selected and approved, work could begin.

One difficulty facing the engineers responsible for designing and constructing the ground facilities was that work on the missile and its support structure were proceeding simultaneously and at a rapid pace. Launch facilities had to be ready when the missiles were ready. Necessary design changes in the missiles themselves were reflected in modifications of the facilities, forcing construction work to be carried out under conditions of near-combat urgency.

Silo Construction

The variety of missile storage modes, launch modes, and degree of dispersion of the missiles impacted the engineers' work. For example, some Atlas D models were stored in an exposed vertical mode with a service tower, while others were stored horizontally and sheltered from the elements. The Atlas E was stored in a horizontal position within a semi-hardened structure. The Atlas F, Titan I and II were all stored vertically in hardened silos.

Construction of the silos was an enormous engineering task. For example, at Schilling AFB, Kansas, engineers built 12 silos to house Atlas F missiles. Work began with an open excavation 40 feet deep. This was the foundation of the control center, connecting the tunnel and upper portion of the silo. The remaining lower portion of the silo was then mined an additional 135-140 feet below the open excavation. To construct the silo itself, workmen used the slip-form process. Concrete was continuously poured as the frame was raised some 140 feet up the silo wall at a rate of about 14-16 inches per hour. Working day and night, workers placed 500 tons of steel and 5,000 cubic yards of concrete in just six days for each silo. When completed, a single Atlas silo contained the equivalent composite mass of a 15-story structural steel building weighing approximately 1,500 tons.

Electrical Power

To provide a power source for the launch complexes, engineers evaluated several alternatives, including diesel engines, nuclear, fuel cells, batteries, gas turbines, and various combinations with commercial sources. The source had to be highly reliable, uninterruptible, and self-contained within the launch complex. They also had to be capable of absorbing extremely high accelerations, caused by nuclear blast induced ground shock, or had to be mounted on shock mounts. Both the system's initial cost and operating and maintenance costs were evaluated. The old reliable diesel engine was selected to provide prime power to the sites. In designing the systems, heat produced by the equipment was used in every manner possible, including heating of water and incoming air. A typical Atlas site had four 1,000kW units in each plant supporting a cluster of missiles.

Overhead Door Design

The design of the overhead doors for the silos created an engineering dilemma. The doors covering the 300 square foot opening had to: protect the missile against extremes of weather, nuclear radiation, overpressures, and structural rebound; not affect the firing and guidance of the missile; open fully within 30 seconds after signal; and operate as a sequential item in the missile countdown procedure. They also had to be designed to permit construction of the closures and full assembly, installation, and checkout in the field. Each potential design such as the single leaf design or the roll-away design had its own particular set of drawbacks that eliminated it from consideration. Finally, a double-hinged, double-leaf, flat door design was accepted. The problem of the center crack between the two halves was resolved by the special wedge design of the door and using a step mesh with a neoprene gasket to further improve the seal.

Site Activation

To pull together all of the diverse elements involved in the construction and activation of the various missile sites was the Site Activation Task Force Commander's job. He was given operational control over all Air Force elements participating in the ballistic missile site activation program at a given base, regardless of parent command. Coming predominantly from the civil engineering and intelligence career fields, the commanders directed the construction of field support facilities and housing, provided construction surveillance, and managed the installation, checkout, and turnover of the site to Strategic Air Command. They had to be a civil, mechanical, and electrical engineer, an expert on cryogenics, thermal stress and shock mounting, a funds controller, a public information officer, and an explainer to Congressional investigators. In short, they were the individuals who made it happen for the Air Force. By 1961, they had activated sites at 11 bases with 120 Atlas missiles and sites at 5 bases with 54 Titan missiles.

Award-Winning Effort

This article has only briefly touched on the diverse engineering challenges faced by the man and women involved in this massive effort. The magnitude is still remarkable—earthmoving totaled 37.55 million cubic yards of earth, rock, and mud. This equaled an irrigation ditch 10 feet deep and 10 feet wide from Los Angeles to Pittsburgh. The steel used at the sites could build a railway track from San Francisco to Washington, DC. At the time, a national news magazine stated, "The missile base construction programs make the pyramids look like a Tinker Toy exercise." Te American Society of Civil Engineers named the ICBM Facility Construction Program as the "Outstanding Civil Engineering Achievement of the Year" for 1962. Equally important, the whole effort represented a turning point in how the Air Force viewed its civil engineers. At a time when Air Force engineers were searching for increased respect and acknowledgment of their professionalism, their work on the ICBM project paved the way.