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# USAF's Ballistic Missiles — 1954-1964

## A Concise History

*BY DR. ERNEST G. SCHWIEBERT*

### *From the Author . . .*

MONDAY morning quarterbacking has always been a diverting and favorite pastime in this country. There is always the temptation, even for the historian, to view earlier history in the light of subsequent perspectives. Leopold von Ranke, the father of modern history, laid an exacting requirement on the Air Force historian when he stated that the historical account must reconstruct the historical climate of an event "as it actually was." In at least one respect the Air Force historian enjoys a marked advantage over his academic colleagues in that he is able to consult the written sources without regard to security classifications while files are still intact. In addition, he has the advantage of being able to consult the actual participants in an event, since documents alone cannot be accepted as prima-facie evidence.

The author is therefore deeply grateful for interviews with many persons intimately associated with the ballistic missile program. The late Dr. Theodore von Kármán both granted an interview and made available portions of his personal files. Others who granted interviews were Dr. James H. Doolittle (Lt. Gen., USAFR, Ret.); Lt. Gen. Donald L. Putt, USAF (Ret.); Gen. Thomas S. Power; Lt. Gen. Gordon P. Saville, USAF (Ret.); Maj. Gen. John W. Sessums, Jr., USAF (Ret.); T. F. Walkowicz; and Peter J. Schenk. Particularly helpful because of their close association with the ballistic missile effort were Maj. Gen. Osmond J. Ritland; Maj. Gen. Charles H. Terhune, Jr.; Brig. Gen. Otto J. Glasser; Col. R. K. Jacobson; Col. Samuel W. Bishop, USAF (Ret.); Col. Edward N. Hall, USAF (Ret.); Col. W. A. Sheppard, USAF (Ret.); Col. Beryl L. Boatman, USAF (Ret.); Col. M. A. Cristadoro; Col. W. Bruce Arnold; Maj. J. C. Stokes; and Dr. Alfred Rockefeller.

Much helpful information was obtained from Mr. George Friske of the Office of Assistant Chief of Staff, Intelligence (Hq. USAF), who made Intelligence information available; from Col. S. D. Kelsey, Foreign Technology Division, AFSC, who furnished information on the Peenemünde staff exploitations by the Soviets and the August 1952 briefing; and Mr. Darol Froman, Los Alamos Scientific Laboratory, for explanations of nuclear developments leading to a ballistic missile warhead.

Mention must also be made of the contributions of the entire staff of the Office of Information in AFSC Headquarters, which was most cooperative in supporting this effort. This account also draws heavily on contributions of individual historians at each Air Force Systems Command division or center whose periodic histories reveal the contributions of that unit in support of the massive undertaking. To all these the author extends his heartfelt thanks.

There are numberless other contributors to the success of the ballistic missile effort. They are the thousands of nameless but not unremembered civilian scientists, technicians, shop, laboratory, and office workers, each of whom contributed to the final goal. There are also numerous Air Force members whose efforts brought the program to its final high achievement. Each of them proudly wears upon the left breast pocket of his blue uniform the silver badge of a missile in flight (*see front cover*), and by this sign you may know them.

The strictures imposed by security considerations and the limitations of space permit inclusion in this account of only the most significant portions of the ballistic missile story. Therefore, the knowledgeable reader may note omissions, condensations, and perhaps, conclusions different from his own. For these the author assumes full responsibility. Any definitive account of the massive undertaking which produced the ballistic missiles would require volumes of text and the cooperative labors of a large team of historians from many organizations. However, the public is entitled to an accounting of what it has received in return for an investment of some $17 billion and ten years of effort. The brief narrative on the following pages is an attempt to provide that accounting.

**About the Author . . .**

Dr. Ernest G. Schwiebert, Command Historian of the Air Force Systems Command, did graduate work in history at Ohio State and Chicago Universities, and earned his doctorate in Modern European History at Cornell University in 1930. After serving as Professor of History for a number of years, he accepted a position with the State Department during the Occupation of Germany (1948-50) in the department of Education and Cultural Affairs. During this tour he served both as University Adviser and Visiting Professor of the University of Erlangen in Bavaria. Upon his return from Germany he became the first Command Historian of the Air Research and Development Command, later the Air Force Systems Command, where he organized and has directed the historical program for more than twelve years.

*Our thanks and appreciation go to Dr. Schwiebert, himself, as well as to all those he mentions above. Every professional writer knows that it is harder to "write it short" than to "write it long." So do not be deceived by his modesty. He has worked hard and he has worked well. The Editors of* AIR FORCE/SPACE DIGEST, *who have worked intimately with Dr. Schwiebert from the conception of this history, salute his efforts. For the appearance of the final product, including layout, selection of pictures, writing of captions, and the like, the full responsibility is ours.*—THE EDITORS

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## Chapter 1

# Dawn of the Missile Age

***World War II had ended and the cry, heeded, was "bring the boys home." Military budgets dropped to rock bottom, and the decision was to concentrate on manned strategic systems. It seemed clear to us that we had the nuclear monopoly. But there were other reasons, too, why little was done about missiles . . .***

JIMMY Doolittle has pointed out that in the period immediately following World War II, the temper of the American public practically repeated the trend of events that had followed World War I. Both the fighting men and the people at home were sick of war. The hue and cry was to "bring the boys home," and the quicker the better. Responding to the demand, the services released their members as rapidly as possible. Anyone who wanted to could

One of the leaders who early saw the dangers of too-fast demobilization was Doolittle.

"Bring the boys home!" was the cry across the land as war ended. And the boys, like these at Langley, were glad to go home. But US defenses were denuded.

*But we had the bomb, and we had it alone and felt secure and began postwar testing. Generals Curtis E. LeMay, Thomas S. Power, at Eniwetok, July 1, 1946.*

*Grim war in Korea showed Soviet hand. Here, a grief-stricken US infantryman is being consoled by his buddy after death of a friend in action. In background, a corpsman methodically fills out the required casualty tag.*

be discharged; the determining factor was length of service with little regard for rank or requirement. The policy impacted hard on an Air Force which found itself denuded almost overnight of its most experienced men, be they generals or mechanics. Doolittle expressed it dramatically when he said they were "destructively and explosively" demobilized. The result was devastating; from 243 groups only two effective groups remained. And while the Soviet Union retained sixty percent of its strength, the United States retained about ten percent. This ten percent who were left found themselves equipped with broken-down airplanes and no mechanics to rehabilitate them.

After the mad rush to get out had subsided, more sober reflection revealed how much havoc had been done. Inner circles of government were beginning to realize that one former ally, the Soviet Union, was becoming increasingly unfriendly and even exhibiting signs of open hostility. How to rebuild a demobilized defense force in the face of public sentiment against war and everything connected with it, including military spending, was a gigantic problem. The United States possessed the atomic bomb, to be sure, but had only limited means to deliver it on any likely target.

In the light of this general environment it is not difficult to understand why the nation did not embark on an extensive ballistic missile program through the late 1940s and early 1950s. The outbreak of the Korean conflict in 1950 clearly exposed the Soviet intention, and method, of world conquest, and served to reawaken the nation to its mortal danger. The Air Force, recently separated from the Army (1947) and placed on an independent basis, shared the responsibility for the nation's security. There was not enough money to build up both the defensive and the strategic forces. The decision was, therefore, to emphasize the Strategic Air Command, which, with the threat of the atomic bomb, could keep the enemy from our shores.

But why was there no sense of urgency toward developing ballistic missiles of intercontinental range? True, there were missiles of various ranges under development, but their progress was moderate and unhurried, exploring and expanding the state of the art step by step. Lack of funds was a primary factor, but it was not the sole cause.

## Chapter 2

# Scientists, Too, Are Fallible

***Even the "farthest-out" scientific advisers to the Air Force—in the early postwar years—put most of their faith in strategic jet power. In retrospect, it is clear that they were reflecting the public's complacency. But a few voices, crying in the wilderness, were already demanding missile R&D . . .***

FROM the perspective of time, there were many reasons why we, as a nation, were not too excited about ballistic missiles in the period immediately after World War II. Had we not won the war? Where was there a nation that could match our bomber and fighter strength? Were we not the sole possessors of the atomic bomb? So what if the Soviet Union was becoming cool toward us, or perhaps even hostile? It would be many years before they could achieve atomic weapons, and, even though they had copied some B-29s which had fallen into their hands during the war, they could not hope to challenge American airpower. Missiles were only a newfangled idea that might prove useful for short ranges, but from across the Atlantic or from bases in northern Russia across Canada such a threat seemed remote. In such a climate of opinion there seemed little risk in reduced budgets for military research and development in the late 1940s.

*The post-World War II climate was unfavorable to expenditures for military advances, and the diplomatic events of the period gave little spur to R&D daring. Soviet dictator Stalin, as war ended, seemed unimpressed at Potsdam by Truman's A-bomb revelation.*

Further support for this viewpoint was gained from impressions left at Potsdam, where President Harry S. Truman informed Stalin that the United States possessed the atomic bomb. The impassive Soviet dictator showed little interest and later spoke of the atomic bomb as a horror weapon intended only to frighten people "with weak nerves." He stated that he did not believe that a war could be won by atomic weapons. Later from Communist China came similar reactions and the claim that only vast land forces could win a war. Even intelligence sources had no knowledge of the real Soviet activities beyond those of the German Peenemünde scientists in the '40s. Small wonder then that public opinion favored reduction in military spending and a return to the normal peacetime pursuit of happiness.

But there were those who sensed that the roots of the national malady were far too deep to be recognized by the general public. Chief of the Army Air Forces in 1946 was Gen. H. H. "Hap" Arnold, a man of stature and vision, who had learned his flying from the Wright brothers as part of "an Air Force which had more spirit than gasoline and more guts than horsepower." He has been called a "human bulldozer" who could demolish formidable obstacles to accomplish his

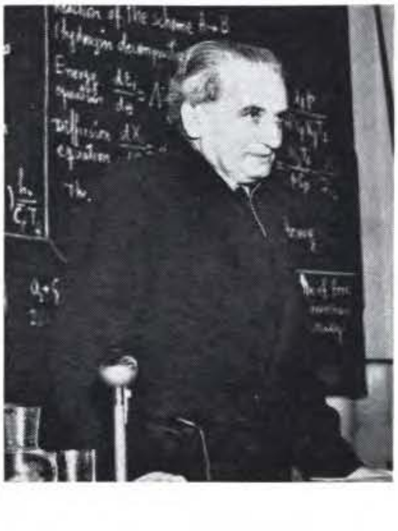
*Wartime Air Force chief, Gen. H. H. "Hap" Arnold, was deeply concerned at war's end by demobilization and saw need for scientific study of strategic future.*

*Although there was little enthusiasm for ballistic missile R&D, US military studied German V-2 effort, fired captive vehicles, tried building "Chinese copies."*

purpose. In the closing days of World War II he called in his scientific advisers and asked for a survey of achievements in science and technology accomplished by any and all nations, with special emphasis on jet propulsion and the V-1 and V-2 German missiles. The survey was conducted by the renowned Dr. Theodore von Kármán.

The findings of the von Kármán survey were published in the well-known report, "Where We Stand," released in August 1945. The recommendations based on the information gathered were published in December of that year under the title *Toward New Horizons,* the introductory volume of which was titled "Science: The Key to Air Supremacy." Generally speaking, it is interesting to note that these reports reveal many of the same kind of "blind spots" that were afflicting the ordinary citizen. Principal emphasis was placed on the "jet age" and the development of a strong capability in this field. As for missiles, after examining the German missile program in detail, von Kármán's group concluded that ballistic missiles were still far off and that considerable advancement in the state of the art was required before any particular achievements could be expected. The defense of the nation for years to come would lie in jet-propelled aircraft; the road to ballistic missiles of the final type lay by way of air-breathing, pilotless aircraft some decade or two in the future.

While exhibiting little alarm over the prospect of ballistic missiles, von Kármán did make an interesting observation with reference to German success in their V-2 program. Aside from the fact that they began their program as early as 1935, von Kármán attributed the success of the Peenemünde operations to a novel single managership. "It is important for us to note," he said, "that one element in their success was the fact that they had under a single leadership in one organization experts in aerodynamics, structural design, electronics, servomechanisms, gyros and control devices, propulsion, in fact, every group required for the development of a complete missile." Von Kármán pointed out that leadership in the development of the new weapons of the future could be assured only by assembling a similar band of experts and by "providing them with facilities for laboratory



*Late great Dr. Theodore von Kármán was unimpressed by ICBM idea, stressed manned strategic jets.*

*First meeting of USAF Scientific Advisory Board, June 17, 1946, in the Pentagon. Seated, from left: Dr. George E. Valley, Jr., Dr. Frank L. Wattendorf, Dr. George A. Morton, Dr. Nathan M. Newmark, Dr. Walter S. Hunter, Dr. Lee A. Dubridge, Dr. Detlev Bronk, Dr. Theodore von Kármán, Dr. Charles W. Bray, Dr. C. Richard Soderberg, Dr. Courtland D. Perkins, Dr. Charles S. Draper, Dr. Harold T. Friis, Dr. William R. Sears. Standing, from left: Dr. Pol E. Duwez, Dr. Hsue-shen Tsien, Dr. William H. Pickering, Dr. Ivan A. Getting, Dr. W. J. Sweeney, Dr. W. Randolph Lovelace, II, Dr. Julius A. Stratton, Dr. Duncan P. MacDougall, Dr. Edward M. Purcell, Dr. Vladimir K. Zworykin, Dr. Fritz Zwicky, Dr. Robert H. Kent, Col. William S. Stone, and Col. R. C. Wilson. Missing were E. Fermi, G. Gamow, H. L. Dryden, W. A. MacNair, Col. B. C. Holzman.*

and model shop production in their specialties and with facilities for field tests." Such an undertaking, he said, must be given adequate financial resources and fully supported by the highest-ranking military and civilian leaders.

Since the von Kármán reports did not "sound the alarm" nor convey any immediate sense of urgency, it was several years before his advice was heeded. The fact that his title spoke of "air supremacy" was an indication of the line of thinking prevailing among the members of his group, forerunner of the present Scientific Advisory Board, and the impressive list of contributing scientists lent considerable weight to their recommendations. A review of the two reports leads to the conclusion that the Air Force followed exactly the route which the von Kármán group recommended when it decided to develop the Snark and the Navaho air-breathing, pilotless aircraft—an evolutionary rather than revolutionary approach. Those who advocated more advanced missile programs were but "voices crying in the wilderness."

One of these voices belonged to Maj. Gen. John W. Sessums, Jr., USAF (Ret.), who related how he, as late as 1950, appeared before the appropriate panel of the Scientific Advisory Board, stressed the urgency of a stronger ballistic missile program, and was "laughed out of the room." Their reaction was, in effect, "What are you trying to sell—a meteorite?" All agreed that a nose cone made of currently available materials could not withstand the reentry heat encountered when the ballistic missile reached the terminal-dive phase of its trajectory. The old charge that the "fly boys" just would not listen to the scientists does not stand the test of historical investigation.

Stringent curtailment of funds forced the Air Force to reevaluate its missile programs. After an extensive review by the Requirements people in the Pentagon, assisted by the best scientific brains available, a document was issued in June 1947 establishing priorities for all types of missiles. Titled "Operational Requirements for Guided Missiles," the directive placed long-range, surface-to-surface missiles at the fourth level of effort. The three top priorities went to those missiles to be used in defense and to increase bomber and fighter striking power. With the limited funds available for research and development, the wiser course of action appeared to be toward advancing the state of the art in propulsion, guidance, materials, and a satisfactory atomic payload, meanwhile keeping the country safe by superiority in jet-propelled bombers, fighters, and in due course, pilotless aircraft. These factors accounted for the cancellation in 1947 of what later became the ballistic

*Dr. Vannevar Bush, right, being congratulated in 1947 by Secretary of Defense James Forrestal on assumption of R&D advisory post, was among leading scientists who pooh-poohed short-term feasibility of developing ICBMs. He, and the others, were wrong.*

missile program, its revival in 1951, and its snail's pace progress until 1953.

The same "Hap" Arnold who put the von Kármán group to work was the moving spirit behind the establishment of the RAND Corporation, a nonprofit organization staffed with the best available men in many scientific and related disciplines. As early as 1946 the Air Staff's Maj. Gen. C. E. LeMay called upon RAND to investigate the possibilities of satellite vehicles. Had the RAND report on a "World-Circling Space Ship" been accorded sufficient attention, this nation might have "beat" the Soviet Sputnik I by about six years and acquired the international reputation earned by that Soviet scientific feat. But the nation as a whole was not aware of a need, nor was it in a mood to spend the money to develop such a project.

As late as 1949 another weighty voice in scientific and governmental circles, that of Dr. Vannevar Bush, cast considerable doubt on the future of missiles in his *Modern Arms and Free Men.* Bush was dubious of German predictions of missiles that would span the oceans as a practical means of delivering atomic payloads. He ridiculed the German V-2 as a weapon of war, and was certainly far from foreseeing the dawn of the missile and space age, even though he was standing on its threshold.

Meanwhile, though completely unknown in this country, the Soviets had begun to leapfrog the various intermediate, evolutionary steps proposed by American scientists. Russian scientists had been investigating the field of rocketry and spaceflight since the close of the nineteenth century, and by the 1930s they had made remarkable progress. The work of captive German scientists and technicians served as a yardstick against which Soviet accomplishments could be measured, and the Soviets were capable of extracting those developments useful to their program and of discarding others which they had already surpassed. The Soviets had early decided to build large boosters and were working on both atomic and hydrogen warheads. Their principal advantages lay in their early decisions, a relatively simple program, and maximum support in facilities and funds.

On the other hand, in this country we had all but ignored one of the earliest rocket experts—Dr. Robert H. Goddard, whose work was widely read, admired, and emulated abroad, and who was truly a prophet without honor in his own country. As a result, this nation had little capability even to evaluate the captured German V-2 rockets, and had to begin practically from scratch in its search for propulsive methods for the missile age.

From our present perspective, the factors contributing to the nation's lethargy can be discerned: the climate of public opinion, weary of war, fearful of inflationary budgets, complacent in its military strength and possession of the atomic bomb; ignorance and neglect of primary research efforts of individual scientists; lack of vision and disregard of revolutionary concepts; all were symptomatic of the nation's malady from which it was finally shocked into action by reports of Soviet progress, after many precious years had been lost. It was not until 1953 that Trevor Gardner provided the spark which set in motion the "Teapot Committee," led by Dr. John von Neumann, which reevaluated the strategic missile program and got it back on the track.

*Prophet virtually ignored in his own land was US rocket pioneer Dr. Robert H. Goddard, here with his 1926 booster. He did not live to see vindication.*

## Chapter 3

# Early Efforts Toward Missiles

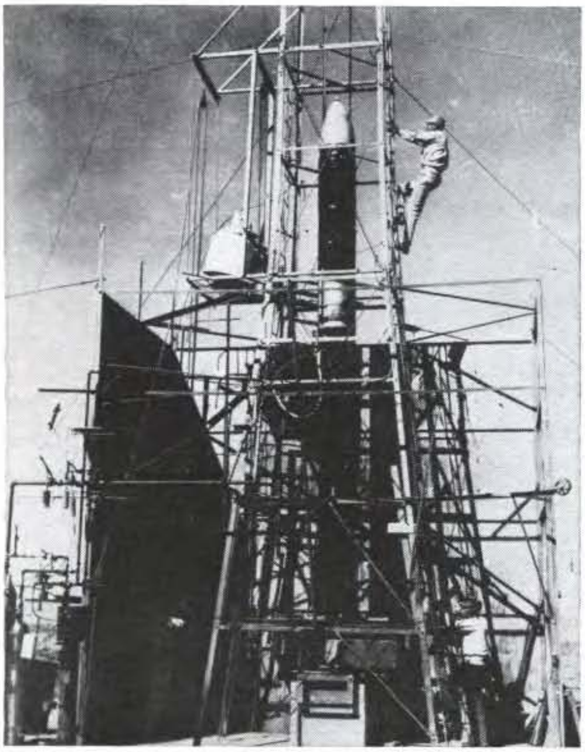
***It is a vast irony that the work of the American "loner," rocket genius Robert H. Goddard, went scarcely recognized even during World War II. And after his death in 1945, there was no vocal advocate of the* ballistic *missile. Some missile programs did get started, but the emphasis was on the pilotless aircraft . . .***

SEMINAL thinkers often live far in advance of their times. Leonardo da Vinci envisioned his flying machine centuries before science could build an engine which would have enabled his aircraft to leave the earth. Albert Einstein evolved the formula leading to the exploitation of atomic energy some three decades before an atomic bomb exploded over Hiroshima. Rocketry, also, had its pioneers, the most famous of whom in this country was Professor Robert H. Goddard. As so many others who carried on their investigations unknown and unnoticed, he was much misunderstood and little appreciated.

In spite of claim and counterclaim, we shall perhaps never know what country was most advanced in rocketry at a given time. Some of Goddard's earlier exploits are known; others are only now coming to light. Willy Ley, the German-born rocket expert, claimed that Goddard was more famous in Germany than in the United States. Goddard's first crude attempt at a rocket engine was about 1908, which places him in the time period of Esnault-Pelterie of France, the Germans, Ley and Oberth, and the Soviet missile experts of the '30s, Glushko and Korolev. In the limited financial support Goddard received was a small Guggenheim grant which made possible his early tests in New Mexico (after his Massachusetts neighbors had protested). In December 1930 he fired a rocket that rose to 2,000 feet and by 1934 had developed rockets with movable vanes, thus anticipating the German V-2 type.

*America's first rocket expert was Robert H. Goddard, whose experiments in 1930s, like this one in New Mexico, made him more famous abroad than at home.*

Yet, it must be sadly admitted that the country had no interest in Goddard's genius in the prewar days. Even during World War II his talents found no better work than exploring the possibilities of rocket boosters to assist the takeoff of heavily loaded or carrier aircraft. And when Goddard died in 1945 just as the war ended, he had founded no school and left no disciples to interpret and carry on his work, or to direct our attempts to exploit and extrapolate the German V-1 and V-2 programs. (Col. Bruce Arnold, "Hap" Arnold's son, tells of trips as a teen-ager with his father on many pioneering expeditions along country roads in remote and isolated areas in search of "some crazy crackpot" who was reportedly experimenting with rockets or missiles of one kind or another.) Of this country's position in the rocket



*Aided by a Guggenheim grant, Goddard continued his rocket developments until the eve of World War II but received no encouragement from the government.*

and missile fields, one of von Kármán's experts had this to say:

"There is practically a universal belief among laymen, scientists, and military leaders that the development of guided missiles is in its infancy. The state of the art is often compared with that of aircraft design in the first World War, and it is fully expected that great advances will be made before another war."

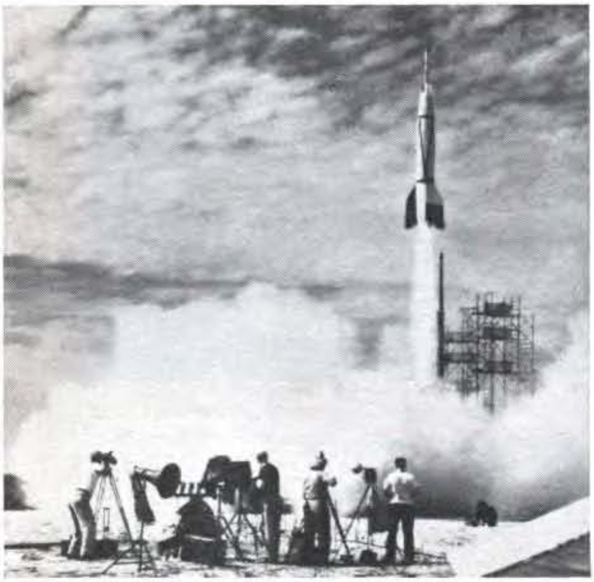
## Exploiting the V-1 and V-2

The story of our efforts to duplicate the V-1 and V-2 programs is also a dramatic one. Colonel Arnold, who was active in the V-1 program which had been assigned to the Air Force (the V-2 went to the Army), tells how we had optimistically entered into the program in the hope of turning the weapon against the Nazis. But when we tried to reproduce the weapons, we encountered all manner of difficulties, chief of which was that the missiles would not fly! A "Chinese copy" of a German V-1 became the United States' JB-2. Testing was performed at Eglin Air Force Base, Fla., but inferior components, lack of autopilot reliability, great launching difficulties, and the low priority accorded the program all contributed to failure to get the JB-2s off the ground. According to Colonel Arnold we did learn something, if only what not to do. But the V-1s were never used against their inventors, nor against the Japanese as had been hoped. The program was, however, the precursor of the Snark, a pilotless, air-breathing missile.

*First guided missile to be widely used in wartime was the German V-1 pulsejet buzz bomb, shown here in a postwar US display. Before the end of World War II, AAF tried to copy it for use against Germany and Japan but failed to build a flyable model in time.*

Army efforts with the V-2 were more fruitful. In its Hermes program the Army, with the assistance of General Electric, assembled and tested some twenty-five complete missiles from about 100 partially completed missiles acquired and shipped to the United States. The Hermes program, and the Bumper which followed it, tested the feasibility of such concepts as airborne telemetry, flight control, and two-stage rockets, while

*Captured V-2s were turned over to US Army which achieved more success in launching them than the Air Force did with V-1s. Experience gained in these launches led to Army's Jupiter and Redstone projects.*



*First missile to be fired from USAF's new missile test center at what is now Cape Kennedy, Fla., was this modified V-2 with a WAC "Bumper" second stage, launched in July 1950. In contrast to today's coverage, only a few newsmen were on hand.*

providing valuable data on design, fabrication, handling, and launching. The Navy was an interested observer, as were representatives of several aircraft manufacturers. The V-2 program was the forerunner of the Army's missile program at Redstone Arsenal which produced the Jupiter and the Navy program which culminated in the Polaris. It was also the ancestor of the Air Force Navaho program conducted by North American Aviation, Inc., whose engineers had gained valuable data from V-2 tests.

The missile business was picking up. As early as 1946 the Air Force alone had initiated twenty-six guided-missile programs, including many different types for different missions. Each type had its ardent and vocal proponents. There were air-to-air missiles to be used by interceptors against attacking bombers, surface-to-air for ground defenses, air-to-surface to be used against ground installations in the flight path of friendly bombers, and surface-to-surface of varying ranges to destroy enemy ground targets. Without a Goddard to advocate the feasibility and usefulness of rocket boosters, the long-range ballistic missile was put so low on the development list that stringent budget restrictions dictated the missile's cancellation in 1947.

Three major Air Force programs finally evolved, aimed at satisfying the requirements for a long-range surface-to-surface missile capable of destroying most enemy installations wherever located from launching areas in the continental United States. These were the above-mentioned Snark and Navaho, both the pilotless-aircraft type. The Snark was being developed by Northrop Aircraft, Inc., the Navaho by North American Aviation, Inc. The third program was the Atlas, the only truly ballistic missile program, under development by Consolidated Vultee Aircraft Corporation (later Convair).

As originally proposed the Snark program has been termed "overly ambitious" and impractical in many ways. Specifications called for a long-range surface-launched, remotely controlled, pilotless aircraft of the flying-wing type, propelled by six turbojet engines, and, in its operational stage, directed by "automatic celestial guidance." A nuclear reactor was proposed as a heat source for the turbojets in order to reach an optimum range of 5,000 miles. Both the atomic powerplant and the sophisticated guidance specified were beyond the existing state of the art. Being an air-breathing vehicle, its flight path and speed were both limited by nature. How would such a slow, lumbering pilotless aircraft penetrate the forty-five miles of concentric rings of Soviet surface-to-air missiles guarding the approaches to Moscow?

First proposed in January 1946, the Snark sur-

*Northrop Snark, shown here in 1958 test flight from Cape Canaveral, was first US guided missile with intercontinental range. It never achieved design specifications, but broadened the base of the technology.*

*North American Navaho, riding piggyback on its rocket booster in this test flight, was to be a supersonic air-breathing missile of intercontinental range. Though it never reached production, its rocket booster is forerunner of many current USAF missiles.*

vived many near cancellations until finally overtaken by the ballistic missile program. Only thirty operational missiles were built, but the program did provide the opportunity for a large body of technical people to study problems related to missiles. Also, had the need arisen, the Snark might have been used as a backup for bombers and might have been reasonably effective in mass attack.

In July 1946 North American was given a definitive AF contract which, through many alterations, finally became the Navaho. This program aimed for a surface-to-surface missile designed to travel 5,500 miles at supersonic speed carrying a massive payload to be delivered on a target at rather low circular probable error (CEP). Accuracy was to be achieved by gyro controls to correct navigational drift. Propulsion was to be by a combination of rocket-booster launch and ramjet-engine cruise power.

Caught in the 1957 budget cutback, the Navaho program was canceled in July of that year without ever having reached its third phase, the 5,500-mile supersonic missile. All the effort expended was not a total loss, however. Who can say whether or not its existence restrained the enemy and prevented a nuclear war? But aside from any intangible benefits, the program produced considerable "fallout" which aided subsequent programs. Development of the rocket booster proved to be one of the principal contributions. Its usefulness is attested by the fact that the Navaho booster, with relatively slight changes to accommodate itself to a different envelope, was adapted to a majority of the ballistic missiles being developed by the Air Force. Two of these engines were used in the Atlas along with a third smaller engine. Had the ballistic program depended upon new rocket-engine development, it would have encountered considerable delay, for it was not until much later that funds were made available for large rockets.

Guidance systems developed for the Navaho also proved of value to other programs. Its X-1 system was the first inertial-guidance system to fly in this country, and adaptations of it found their way into nuclear-powered submarines, the Navy's A-3J, and Hound Dog and Minuteman missiles, among other uses.

From our hindsight vantage point we should not judge too harshly the lack of foresight of military planners in the mid-1940s, nor criticize too severely their choice of the Snark and Navaho over the Atlas. There was no money to explore many of the promising approaches under consideration. The best scientific minds believed this was the route to follow, and the military took more naturally to missiles which resembled their familiar aircraft, flew at comparable speeds, and could be controlled by guidance they understood. So the Atlas, first proposed in 1946 but canceled in the 1947 cutback because it did not "promise any tangible results in the next eight to ten years," was consigned to limbo to await a partial resurrection in 1951.

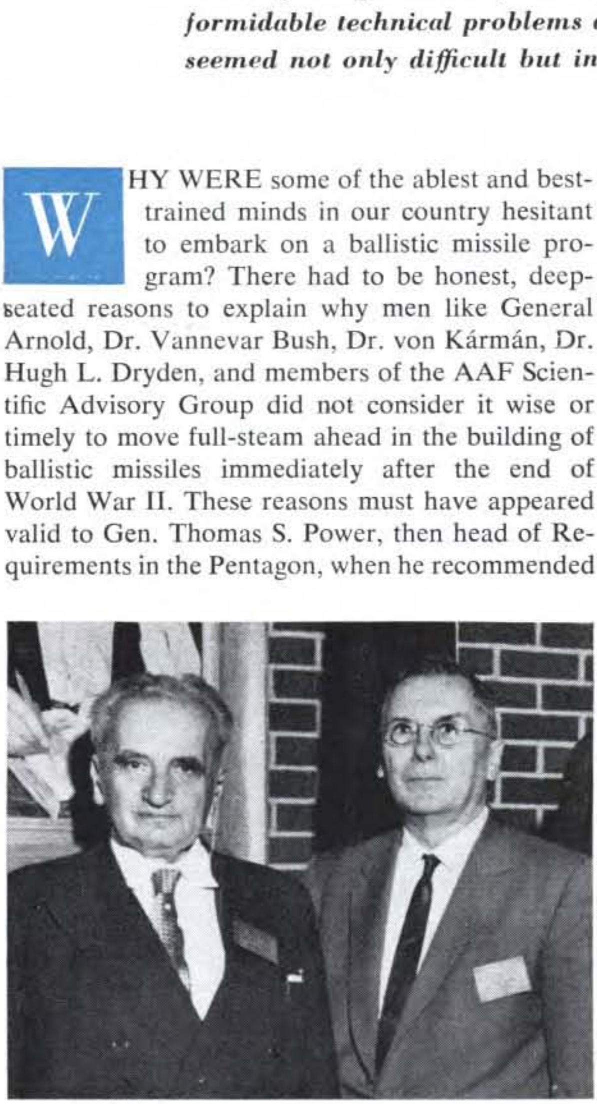
*Today's Atlas evolved from the Convair MX-774, shown here in a 1948 launch. Though the project had already been canceled by that time, three MX-774s were built, affording experience in gimbaling of engines, guidance techniques, and lightweight missile airframe structures.*

## Chapter 4

# Scientific Barriers to Missiles

***In the beginning there was a real "mental barrier" in the late 1940s that prevented the best scientific and military minds from understanding the potential of the ballistic missile. But there were also formidable technical problems associated with ballistic missiles that seemed not only difficult but insuperable at the time . . .***

WHY WERE some of the ablest and best-trained minds in our country hesitant to embark on a ballistic missile program? There had to be honest, deep-seated reasons to explain why men like General Arnold, Dr. Vannevar Bush, Dr. von Kármán, Dr. Hugh L. Dryden, and members of the AAF Scientific Advisory Group did not consider it wise or timely to move full-steam ahead in the building of ballistic missiles immediately after the end of World War II. These reasons must have appeared valid to Gen. Thomas S. Power, then head of Requirements in the Pentagon, when he recommended placing ballistic missiles fourth in order of priority, and to Gen. Benjamin W. Chidlaw of Air Materiel Command when he followed through on the directed cancellation of the Convair ballistic missile program in 1947, continuing only limited research on components. What were the reasons?



*Drs. Theodore von Kármán and Hugh L. Dryden were among many distinguished scientists and top military leaders who, recognizing the enormous technical problems, did not think it wise or timely to move swiftly into building missiles in the period immediately after the close of World War II.*

The climate surrounding the thinking of that day has been succinctly described as follows:

"Until the war the potential performance of long-range missiles was largely misunderstood. The hurdle which had to be annihilated in correcting this misunderstanding was not a sound barrier, or a thermal barrier, but rather a mental barrier, which is really the only type that man is ever confronted with anyway."

This thesis may be true to a degree, but in the

*Gen. Thomas S. Power, now SAC Commander, rated ICBM fourth in priority when he headed AAF Requirements office in the late '40s.*

*Gen. B. W. Chidlaw was Commander of AMC when decision was made to cancel Convair missile but to continue research plans.*

*Veterans of German V-2 project are shown soon after their arrival in US to help guide our early missile efforts. In 1952 other Peenemünde veterans who had been conscripted by USSR and subsequently repatriated met with a US, British, and Canadian scientific panel seeking to compare Soviet and US missile development. Panel concluded they were about parallel, but not all of them shared that optimistic view.*

late '40s the technical problems to be overcome were more real than imaginary. What was known of Soviet efforts toward solving these problems was scrutinized in a very special briefing, held at Dayton, Ohio, in August 1952, attended by five general officers and including representatives from Air Force headquarters, five major air commands, the Army, the Navy, the Central Intelligence Agency, Atomic Energy Commission, Royal Canadian Air Force, and sixteen scientific and industrial organizations. The briefing was sponsored by the Air Technical Intelligence Center whose operatives, in cooperation with the British Air Ministry, had interviewed more than 200 German scientists and engineering experts who had recently been repatriated to their homeland after varying lengths of service in Soviet captivity. These men had been previously connected with the German ballistic missile program carried on at Peenemünde and supporting locations throughout Germany. Substance of the briefing was a digest of the information obtained from the repatriates and a comparison of Soviet technology with that of the United States.

The gathering was addressed by experts in the various fields of missilry, such as guidance, propulsion, propellants, and the like, with each speaker assessing Soviet efforts in his area. Based upon the information drawn from the German sources, the gathering reached the general conclusion that the Soviet program was comparable to that of the United States and was proceeding along lines marked by the Snark, Navaho, and Atlas programs. It was known that the Germans had left behind the specifications for a 120-metric-ton engine, and it was thought "possible, but not probable" that the Soviets could develop various missiles powered by two, or even four, of these engines. The twin-engine glide version was estimated to have a maximum range of 4,400 nautical miles, hardly a threat to the mainland of the United States from Soviet bases, and the building of such a sophisticated missile was unlikely. However, it was believed that by 1956 the Soviets might be capable of launching a two-stage missile carrying a 2,000-pound warhead which could reach the northwestern section of the United States; and that by 1958 they might be capable of reaching any part of the United States with an 8,000-pound warhead if top priority were placed on such a system. The representative of Consolidated Vultee Aircraft Corporation (progenitor of the Atlas) thought these estimates highly optimistic.

Completely unknown to either the Germans or their interrogators was the fact that the Soviets did, in truth, have a massive "hidden" missile program which they pursued independently of the German experts. Near the factory at Khimki, where the Germans and Soviets worked side by side, a second factory had been built which the Germans were not permitted to enter. Here the Soviets were building their own ballistic missiles and large boosters, continuing a missile technology which had begun in the 1930s, and merely checking their development against that of the Germans, discarding entirely the German specifications for the large booster.

Based upon the information disseminated at the August 1952 meeting, there seemed little cause for undue alarm over the prospect of a war employing ballistic missiles. The "missile age" appeared to be rather remote to the conferees, who displayed no particular sense of immediacy.

No new weapon, however spectacular, it has been argued, could really be justified unless it promised to perform military tasks at a lower gross cost than any preceding or other alternate weapon system. Thus, even a long-range missile had to be weighed operationally against the operating cost of the manned bomber. Obviously, the use of a TNT warhead on a ballistic missile of more than a thousand miles' range would be extremely costly unless equipped with a very precise guidance system. Even Gen. Bernard A. Schriever, then Chief of the Scientific Liaison Section in the Pentagon, was not particularly impressed by the potential of missiles. Though not against missiles per se, he just did not consider them a practical means of hurling 2,000 pounds of TNT at an enemy more than 5,000 miles away. Comparatively speaking, the job could be done much better by manned bombers, for they could carry the heavier atomic bomb.


*Gen. Bernard A. Schriever's missile experience dates from 1946 when he became chief of scientific liaison in the Pentagon. He was Assistant for Development Planning when he was promoted to brigadier general in June 1953, a year before taking command of WDD.*

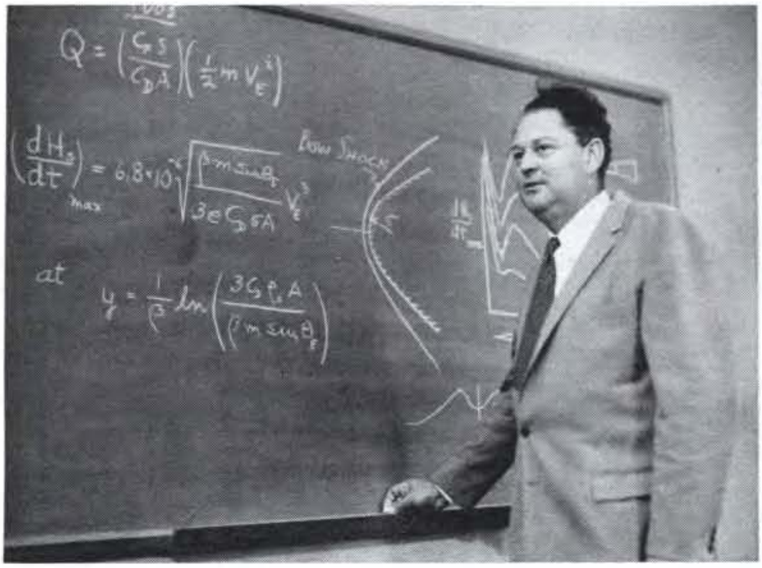
Although definite progress had been made in refining the atomic bomb since Hiroshima and Nagasaki, bomb weight was still a major problem. Dr. Darol Froman of the Los Alamos Scientific Laboratory has reminisced about those early days from a perspective of some fifteen years. He said the question most frequently asked in the early 1950s was, "When could the Atomic Energy Commission come up with a warhead light enough to make missiles practical?" For this there was no immediate answer, for it was not until laboratory tests had proved the hydrogen bomb feasible that any valid predictions could be made.

By May 1951 Los Alamos had the answer, and the Eniwetok "Mike" shot of November 1952 proved beyond question that the warhead barrier could be eliminated by the time a missile could be ready. The "Shrimp" shot of March 1954 completely revolutionized the program. Its results outmoded the Convair Atlas missile configuration and made possible basic alterations in missile requirements. Soviet accomplishments were not far behind. With the aid of nuclear know-how stolen from the West and the support of German nuclear physicists held in captivity, the Soviets had already detonated their first atomic device in 1949, had readied an improved type by 1951, and, to the world's amazement, by August 1953 had detonated their first hydrogen bomb. Certainly these feats permitted no ground for this country to slacken its efforts.

Another problem which plagued missile scientists was that of reentry of a ballistic missile warhead into the earth's atmosphere. The fate of meteorites was well known, and in 1946 no available material could withstand the terrific heat generated by a nose cone reentering the earth's atmosphere at the end of a 5,000-mile trajectory. The problem had many facets: What shape could best survive the ten to twelve seconds of shock waves created by high Mach penetration speed? Could airplane methods be simulated, parachutes perhaps? Was Convair's design of a "spearlike" nose cone the most desirable or would a blunt type be superior? If liquid cooling were introduced, how would the added weight affect speed and range? What about laminar flow and the resulting heat generated? Science could get these answers only through tests.

Many agencies were attacking these problems. Wind-tunnel tests conducted in the laboratories of the National Advisory Committee for Aeronautics (NACA) did not support the "spearlike" type

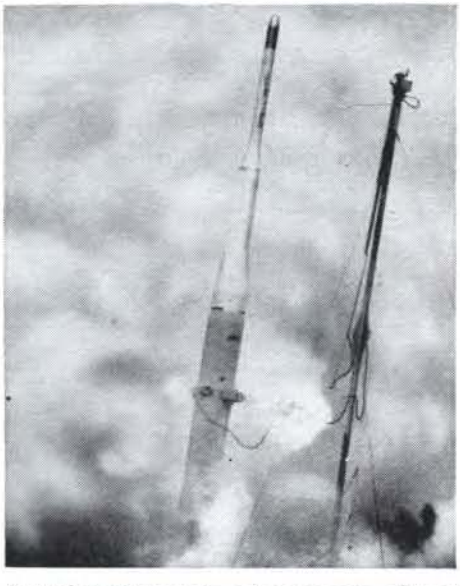
*Development of nose cone to withstand terrific heat of reentry was a major problem. Wind-tunnel tests at Mach 20 conditions proved this configuration superior to spear shape.*



*Blunt-shaped nose cone was largely brainchild of H. Julian Allen of NACA's Ames Laboratory, for which he was awarded Distinguished Service Medal.*

nose cone and found that liquid cooling by a transpiration process created more problems than it solved. (Design of the blunt-type nose cone was largely the brainchild of H. Julian Allen of the Ames Laboratory of the National Advisory Committee for Aeronautics, who began work in this area as early as 1952. In 1957 he was granted the Distinguished Service Medal for his achievement.)

Both the RAND Corporation and Ramo-Wooldridge concluded that the "blunt type" was superior as it slowed down reentry speeds. By incorporating a blunt, copper heat-sink with the reentry vehicle it appeared the problem might be solved. However, only actual tests in the Lockheed X-17 test vehicle program proved the validity of the theory. Now researchers could be sure that a blunt nose cone of known and available materials could survive the shock of reentry, but many concomitant problems remained. They included reentry stability, size of nose cone in relationship to the total missile, and, hence, optimum relationships between the total missile configuration and size of payload. But the main hurdle had been crossed; refinement would come.



*Actual reentry tests of nose-cone shapes fired into space atop Lockheed X-17 rocket booster proved validity of Allen's blunt-nose design and led to solution of nuclear warhead delivery system.*

Accuracy was another problem hampering the missilemen. The German V-2 had missed its target by ten miles at a 200-mile range. How close could a 5,500-mile missile come to a target in the Soviet Union? Accuracy depended upon guidance. Guided missiles followed trajectories that could be altered by signals from some guidance device well after the moment of launch. Ballistic missiles, on the other hand, could be guided only during the period from launch to power cutoff, an extremely short time. Their accuracy was determined by two factors: the control system, to maintain a stable attitude, and the guidance system, to establish a satisfactory trajectory. The slightest error programmed into its first upward climb and curve over into its rainbow trajectory could mean an unacceptable figure of error at impact. This problem was reduced with the hydrogen warhead with its greater destruction capability, yet extremely great accuracy was still required in programming, autopilot controls, computations of speeds attained, and the exact split-second nose-cone release. Nor was there any means of controlling the terminal dive of the nose cone, such as had been devised in the "pilotless aircraft" homing target accuracy control.

As has been noted, development of a satisfactory propulsion system was a major obstacle to the ballistic missile program. Fortunately, North American had furthered this effort by developing a rocket booster for the ramjet engines planned for its Navaho missile, but the adaptation of this engine to the ballistic missile program presented additional difficulties. A determining factor in engine design was also the type of propellant available. Other problems were: How would you build a missile if the original boosters had to be jettisoned? In addition to the large boosters, a small powerplant would be needed in the second stage to obtain greater accuracy in the required velocity. How would the large boosters and the second-stage sustainer engine be related to the fuel tank or tanks, depending on the type adopted? The final adjustment of the velocity to keep the nose cone on a trajectory to reach the desired target would be accomplished with additional rocket engines of comparatively low thrust, called vernier engines. How would the combination of several complete rocket powerplants to obtain the required total thrust affect other factors such as reliability, missile control, costs, and reduction of aerodynamic drag?

From the foregoing it is obvious that a ballistic missile system is composed of an enormous number of components and detailed parts that must be designed, developed, and assembled into a complete and operable weapon system. The over-all configuration of the missile had to be designed with all of these interlocking components in mind. The early missile design (1947-1951) was, therefore, a huge "beast," resembling an enormous inflated balloon to accommodate its multiple rocket engines and the enormous quantities of liquid oxygen required as fuel. At issue was also the question of whether the missile should be winged or plain, the glide type or the ballistic. Any and all of these considerations would influence the external configuration. The breakthrough on warhead size and yield radically changed the whole picture. In the autumn of 1952 the Air Force chose the pure ballistic type.

As problems were attacked and solutions proposed, the many experts in the various fields had to maintain close liaison and interaction. Understandably, specifications for the Atlas underwent frequent alterations during the early 1950s. Everyone realized that the optimum of the new developments needed would not be reached simultaneously, or even at the same rate. For example, several companies were working on the problem of guidance. They knew that, ideally, "all-inertial" guidance with a dead-reckoning system built into the missile itself was preferable, but requirements of such a system demanded great refinement to obtain the desired accuracy in programming, computer calculations, autopilot, and gyro controls. Therefore, it would be better to begin with the simpler, more familiar radio-inertial system having most of its equipment on the ground, thus removing the necessity for adding it to the missile itself.


*Technicians mount 1/30th scale model of Atlas in von Kármán gas dynamics facility at AEDC in preparing for test of missile configuration and propulsion.*

These then were some of the many problems facing the scientists and engineers as they sought to breach the barriers of space. Progress was being made on many fronts, but at a slow and measured pace. Even as late as 1951-52, when the Peenemünde scientists were already returning from Russia, there were still two schools of thought in the Air Force as to the best approach to the ultimate missile. One group advised waiting with a final decision on the Atlas missile configuration until all components had been fully developed and tested. The other group urged that the development of a missile system proceed according to the principle of concurrency, that is, that the missile configuration, propulsion system, components, test facilities, and eventual field installations all move forward at the most rapid pace possible on a concurrent, well-planned basis.

Then something happened behind the scenes which changed the whole picture. In what may have been the nick of time, a small group of alarmed Air Force leaders set the course for a tremendously accelerated ballistic missile program.

10TH ANNIVERSARY

## Chapter 5

# The Great Awakening

***The beginning of the breakthrough came when in 1952 disquieting intelligence reports suggested that the Soviets were working in deadly earnest on much more powerful ballistic missiles than had been used by the Nazis toward the end of the war. A small band of military men and scientists sensed an oncoming crisis . . .***

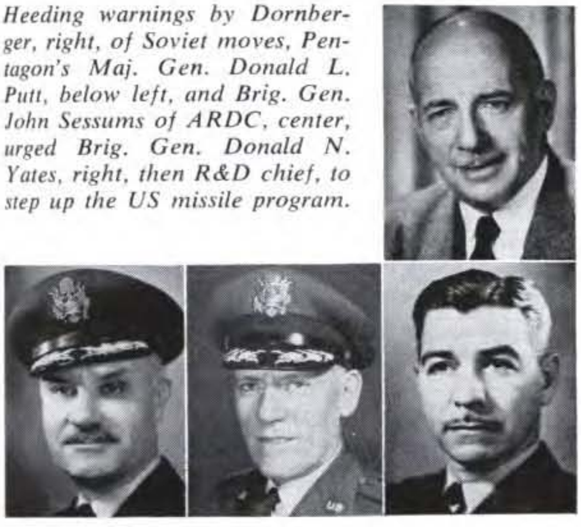
IT HAS been related how intelligence briefed a select group of leaders from the military, industry, and science at Dayton, Ohio, in August 1952 on an evaluation of Soviet vs. United States efforts in missile developments. The consensus was that there was no immediate cause for alarm. Perhaps too much thinking was predicated on assumptions that the Soviets would react to their problems in a manner similar to that followed in this country. On that basis it was concluded we were running about an even race.

*Director of Germany's Peenemünde rocket center, Maj. Gen. Walter Dornberger, in leather coat, and Dr. Wernher von Braun, arm in cast, who worked on the V-2, surrendered to US forces rather than be taken by Soviet troops who overran their laboratories. Later, assisting in US missile program, Dornberger expressed belief Soviets were working on huge rocket engines.*

But the reports of repatriated Germans had contained implications about which some people were not quite so complacent. One of these was Dr. Walter Dornberger, former director of the Peenemünde installation and subsequently employed by the Air Force at Dayton. He had interviewed many of his former colleagues on a return trip to Germany and learned that the Soviets had assembled a staff of some eighty men under the former Peenemünde propulsion expert, Werner Baum. They were assigned the task of designing and drawing up specifications for a 120-metric-ton-thrust rocket motor (more than 260,000 pounds) and a suitable test stand. Baum claimed the Russians had also displayed much interest in an even larger engine producing 250 metric tons of thrust. In 1952, when Dr. Dornberger brought these disquieting reports back to the US Air Force, his account was derisively dismissed by most of his hearers as just so much Russian and German boasting which could not possibly be based on facts. Even more disquieting should have been the report that the Soviets had built a separate factory building adjacent to that occupied by the German workers. No German was permitted to enter this separate building.

Some individuals intuitively sense danger and feel compelled to do something about it. They are the Paul Reveres of history. The Air Force had such an inner group which found no ground for complacency in the German reports of Soviet activities. Two of these were Maj. Gen. Donald L. Putt in the Pentagon and Brig. Gen. John W. Sessums, Jr., with the Air Research and Development Command. Both were trained engineers, and both were described by Dr. Dornberger as "bright and shining exceptions" to those who refused to heed his reports. In September 1951 General Sessums had written to Brig. Gen. Donald N. Yates, Director of Research and Development at Air Force Headquarters, stating that "it is feasible to undertake the development of the long-range rocket missile now." General Yates replied that Air Force Headquarters did not agree with the rate of development proposed by the contractor and believed the "proposed Atlas program should be revised . . . to provide completion of the preliminary test program in about five years."

By the following March (1952) General Sessums forwarded the views of the Air Research and Development Command in these words: "It is urgently recommended that a requirement be established for a long-range ballistic rocket missile" which, with adequate funding and priorities, could be operational by 1960. (It will be recalled that the Atomic Energy Commission had concluded from a laboratory test in May 1951 that a thermonuclear warhead was feasible, but the AEC declined to predict a date when it might become available. The "Mike" shot of November 1, 1952, demonstrated the validity of a new process in a thermonuclear detonation, but the problem of weight remained a deterrent to its adaptation to a ballistic missile warhead. The Air Force now asked the Scientific Advisory Board to examine the implications of the recent test results.



*Heeding warnings by Dornberger, right, of Soviet moves, Pentagon's Maj. Gen. Donald L. Putt, below left, and Brig. Gen. John Sessums of ARDC, center, urged Brig. Gen. Donald N. Yates, right, then R&D chief, to step up the US missile program.*

*Birth of the H-bomb. In 1952, experimental blast of thermonuclear device code-named "Mike" completely obliterated test island, Elubelab in the Marshall Islands. This shot of blast was taken from 50 miles off.*

An Ad Hoc Committee (the Millikan Committee) examined the evidence in December 1952. It did not recommend a basic program acceleration until after adequate components had been developed. However, it did recommend a relaxation of requirements for an ICBM. Then in the summer of 1953 another laboratory test established the feasibility of an advanced thermonuclear warhead and promised a weight reduction later verified by the "breakthrough" of the "Shrimp" shot of March 1, 1954. Prior to that time, however, still another committee reviewed the ballistic missile program.

The Millikan Committee Report was received with mixed reactions. Conservative elements, in and out of the Pentagon, supported the slow pace of development which it recommended. The pro-

*Air Force Secretary Thomas K. Finletter, left, received report in 1951 by Clark Millikan, center, here also with Dr. Lee DuBridge, that ICBM was feasible.*

*Harold Talbott, left, who became Air Force Secretary in 1953, named Trevor Gardner his assistant for research and development, and supported Gardner's demand for a "quantum jump" in attacking missile problem. Gardner was concerned about long lead times.*

gressives believed delay was dangerous. One of these was Trevor Gardner, who, early in 1953, was appointed Special Assistant for Research and Development to Air Force Secretary Harold E. Talbott. Mr. Gardner lost no time in attacking the missile problem. In April he asked for a review of Air Force missile programs, expressing grave concern about the estimate of seven to ten years before this country could have a ballistic missile with a satisfactory guidance system and atomic warhead. "In the light of existing knowledge," he said, "the final performance specifications for the Atlas missile are open to serious question." He believed the Air Force should generate more sensible specifications commensurate with recent technological advances.

The Air Research and Development Command, as the Command charged with responsibility for the missile program, was asked to provide information for the reply to Mr. Gardner's request. The Command admitted that the Air Force "had some dog-eared projects" which had been continued against its better judgment, and also that there were some "silly operational requirements" for the Navaho and Atlas missiles which could now be relaxed in view of the recent technological advances. As for the Snark, its survival capability was questionable unless means were found to increase its speed and altitude. The Navaho was still considered essential to the operational capability of the Air Force to provide an intercontinental, large-payload-carrying, supersonic, high-altitude pilotless aircraft at the earliest possible time. The Atlas should not be considered as duplicating the Navaho program, even though the programmed operational dates appeared to coincide.

*To get more funds for Atlas development Gardner urged cancellation of Matador and other air-breathing missile projects.*

The invulnerability of the Atlas made it a highly superior weapon, in spite of the many obstacles to its development. The Command was confident these could be overcome. In fact, "the ballistic rocket appears, at present, to be the ultimate means of delivering atomic bombs in the most effective fashion," and the Command urged again, as it had earlier, that Air Force Headquarters approve the Atlas program in order that the long-range ballistic rocket might be obtained as quickly as possible.

The new Administration had imposed stringent budget restrictions on all government agencies in its efforts to provide a balanced budget. As late as June 1953 General Yates replied to the Air Research and Development Command's proposed Atlas development program by requesting "a slowed-down budgeting plan," which would carry on "this expensive program" at a relatively slow rate. The initial program, he said, should not be aimed at a deadline of 1963, but must be based on "a logical series of developments" at a "considerably slower rate than previously contemplated . . . [and] under the most conservative ground rules for the use of production funds." In spite of these restrictions, however, the general climate surrounding the missile program was gradually changing. At about the same time General Yates was writing his letter, the Armed Forces Policy Council was recommending to Defense Secretary Charles E. Wilson that the missile programs of the three services be reviewed, both because of the changed conditions and the possibilities of duplication of effort.

## The 'Teapot Committee'

As a part of the requested review, Mr. Gardner established the Strategic Missiles Evaluation Com-


VON NEUMANN


WIESNER

*Nation's foremost scientists joined in "Teapot Committee" late in 1953, led by brilliant Dr. John von Neumann, to review missile programs of all services.*


LAURITSEN


KISTIAKOWSKY


DUNN


PUCKETT


RAMO


WOOLDRIDGE

mittee (SMEC), more popularly known as the "Teapot Committee." As chairman he secured the distinguished scientist, Dr. John von Neumann of the Institute for Advanced Studies. The membership roster included many well-known and highly respected figures in scientific and industrial circles, namely: Prof. Clark B. Millikan; Prof. Charles C. Lauritsen; Prof. Jerome B. Wiesner; Dr. Louis G. Dunn; Dr. Hendrik W. Bode; Allen E. Puckett; Dr. George B. Kistiakowsky; Dr. Simon Ramo; Dr. Dean E. Wooldridge; and Lawrence A. Hyland. The group held its first meeting on November 9, 1953, and submitted its report three months later.

Dr. von Neumann, a member of the General Advisory Committee to the Atomic Energy Commission, had studied the results of the recent laboratory tests, and from his own computations predicted the success of the later "Shrimp" shot.

The RAND Corporation was also continuously studying the problem and released a report almost simultaneously with that of the von Neumann Committee. The two groups had reached similar conclusions. Believing that the nation was in mortal danger and that only a "quantum jump" could avoid catastrophe in the 1959-60 time period, Trevor Gardner, with the two reports to support his views, advocated some type of Manhattan Project which would enlist the best brains of the nation toward a solution of the manifold problems. He recommended to the Chief of Staff, Gen. Nathan F. Twining, that the existing program be abandoned pending a restudy by a competent scientific-technical group, and that a centralized authority be established for a new program. By March 1954 he was ready with his proposed development plan for an ICBM.

As might have been expected, these reports were something of a series of bombshells in the midst of current thinking. Completely reversing the climate of the Millikan Report, instead of ten years, the von Neumann Report contained the "validation of the technical feasibility of accomplishing an Intercontinental Ballistic Missile System [IBMS] capability for the Air Force within a period of approximately six years," possibly less. However, this could not be accomplished under the existing Air Force organizational setup and Atlas program. Instead, if the preliminary Intercontinental Ballistic Missile System capability was to be achieved between 1958-60, the Air Force would have to "dramatize the acceleration of the program and simplify the normal controls and channels of coordination within the Air Force through the assignment of a high-ranking military officer to be placed in charge of the program with unusual channels of communication and a strong directive."

10TH ANNIVERSARY

## Chapter 6

# The Rejuvenated Missile Program

***Alarm in 1954—and the plus of the "smaller-warhead" breakthrough—spurred the "Teapot Committee" report which called for an accelerated ICBM program. The late, great, Trevor Gardner, pushing the program, urged a management arrangement that would allow centrality of decision-making and a minimum of red tape . . .***

WITH the report of the "Teapot Committee" and the recommendations of Trevor Gardner on his desk, Air Force Secretary Talbott faced a very important decision. Was the danger to the nation critical enough to warrant such an unorthodox approach? Should he approve the proposed "quantum jump" in missile building which would virtually bypass all normal, established procedures? He was not long in making up his mind. Less than a week after receiving the Gardner recommendations, Secretary Talbott sent a memorandum to the Air Force Chief of Staff, General Twining, directing the immediate acceleration of the intercontinental ballistic missile program within the general framework of plans and recommendations that were contained in the Teapot Report.

In his recommendations Mr. Gardner had proposed that "the active direction of the IBMS program should be the sole responsibility of a major general with the position of ARDC Vice Commander, backed up by a brigadier general of unusual competence to work directly with the contractors in supply of top-level support and technical supervision." At the Air Staff level he suggested that the Office of Assistant for Guided Missiles to the Deputy Chief of Staff/Operations be given the responsibility for coordinating all staff action required. The success of the program would depend greatly upon the abilities of the individuals chosen for the key managerial positions, therefore, they should be individuals of highest proven com-

*Farseeing Trevor Gardner, AF R&D planner, sparked decision to press ahead with an ICBM.*

*Air Force Secretary Harold Talbott saw significance of Teapot Report, ordered missile go-ahead.*

*Chief of Staff Gen Nathan F. Twining approved Air Council plan for missile management.*

*Maj. Gen. James McCormack, left, now MIT vice president, then, vice commander, ARDC, was given major responsibility in new program. Gen. Thomas D. White, right, was General Schriever's boss in Pacific, helped get the missile program started.*

petence. For these posts Mr. Gardner proposed the names of Maj. Gen. James McCormack, then Vice Commander of Air Research and Development Command, and Brig. Gen. Bernard A. Schriever, then Assistant for Development Planning to the Deputy Chief of Staff/Development in the Air Staff.

General Twining had already asked the Air Council to examine the recommendations of the "Teapot Committee," and on March 16 the Council, whose chairman was Gen. Thomas D. White, submitted its report. While not quite ready to abandon the Snark and Navaho, it recommended that the "CEP and payload requirements for the Air Force guided missile program be broadened . . . and . . . revised . . . in the light of latest projected warhead weights and yields." The Atlas program should be reoriented and accelerated, limited only by technical progress, not by funding. The Council declared that development of the intercontinental ballistic missile system should be a mission of the Air Force, specifically, the Air Research and Development Command, whose Commander should be directed to "establish within his organization a military-civilian group with the highest possible technical competence in this field." This group would be given a year in which to devise and recommend "in full detail a redirected, expanded, and accelerated program."

General Twining approved the Council recommendations on March 23 and the Air Force began to put into effect the recommendations of the "Teapot Committee." The von Neumann Committee, considerably augmented but minus the services of Doctors Ramo and Wooldridge, was retained as an advisory panel, the so-called Atlas Scientific Advisory Committee. Although official orders were not published until May 5 (to be effective June 1), General Schriever knew in April that he had been chosen for the monumental task of directing the intercontinental ballistic missile (ICBM) program and began handpicking a staff of military assistants. Assembly of the civilian scientists would be a more difficult undertaking.

## How Schriever Was Picked

There are many versions of why General Schriever was given the task of producing a ballistic missile system in record time. Some thought it couldn't be done, and that failure would put this opinionated young officer in his place. Others believed he was the best possible choice for the job. There were those who wouldn't have placed any large bets on the outcome of his career after he had argued nose to nose with Gen. Curtis E. LeMay over the future B-52. Schriever, then a colonel, had declared that the B-52 would not be needed to carry the improved thermonuclear weapons then being promised, that the job could be done much cheaper with a modified B-47. He lost that round, but he won the respect of General LeMay. Trevor Gardner learned to know him during the meetings of the von Neumann Committee, which was administratively supported by the Assistant for Development Planning (then General Schriever) under the Deputy Chief of Staff/Development. Gardner has been quoted as saying, "We created Bennie Schriever in 1953," and it is true that his promotion to brigadier general

*Both fighters, for a finally successful cause: Trevor Gardner, who as Special Assistant to the Air Force Secretary for R&D, sparked campaign for missiles, and General Schriever, who managed effort from the outset, rose in rank from a colonelcy to four stars.*

*Gen. Curtis LeMay, SAC chief and later USAF Vice Chief and now Chief of Staff, had known General Schriever as an imaginative young colonel. Lt. Gen. Laurence C. Craigie was then DCS/Development.*

came through in June of that year. But those who have followed his career believe he made his own decisions and was recognized as an independent and creative thinker.

The Schriever family had emigrated from Germany to the United States after the father, a German ship's engineer, had been interned here during the early years of World War I as a wartime belligerent prior to the United States' entry into the war. At the time of their entry in 1917, young Bennie was in his seventh year and had a younger brother Gerhard, then four. The little family lost its breadwinner in an industrial accident a year later and knew years of hardship and struggle.

Graduating from Texas A&M in 1931, the fledgling engineer could find no market for his talents. He was strongly attracted to the Air Corps, and, accepting a Reserve appointment in the field artillery, he entered flight training and earned his wings and commission in the Air Corps Reserve in June 1933. One duty assignment took him to the Panama Canal Zone as aide to Maj. Gen. George H. Brett, where he fell in love with the boss's daughter, Dora, but the uncertainties of life as a second lieutenant in the Reserves led the couple to delay their marriage. Reverting to inactive Reserve status, he became a pilot for Northwest Airlines, and the couple was married in 1938, the ceremony taking place in the home of General "Hap" Arnold. Obtaining a commission as a regular second lieutenant, he returned to the service where he later served as a test pilot. Attendance at the Air Corps Engineering School followed, then Stanford University where he obtained a master's degree in aeronautical engineering in June 1942.

In the Pacific theater, during World War II, he participated in eight campaigns, served under Gen. Thomas D. White, and rose in rank from major to colonel. At war's end he was assigned to the Pentagon, then to the National War College, then back to the Pentagon as Assistant for Evaluation, later Assistant for Development Planning, to the Deputy Chief of Staff/Development.

From the above sketch of General Schriever's career, it may be noted that he had come in contact with several of the leading influential figures of the Air Force. This studious, reflective young officer had come to the attention of General White in the Pacific and had earned the respect of General LeMay. General Arnold was a friend of long standing until Arnold's death in 1950. Schriever had been a member of the coterie of young officers who gravitated around Maj. Gen. Donald L. Putt when the latter was pleading for more emphasis on research and development and the implementation of the Ridenour Report, which resulted in the establishment of the Air Research and Development Command in 1950.

Dr. Darol Froman, of the Los Alamos Scientific Laboratory, recalled General Schriever as one of those constantly pushing for smaller atomic warheads which would make missiles practical. Trevor Gardner evidently believed this young officer would be unconventional enough to find new methods of operation, to short circuit official red tape and circumvent bureaucratic meddling, and to break through the barriers that stood in the way of the successful completion of the missile program.

## The Western Development Division

One of the directives pursuant to implementation of the missile program called for the establishment of a "military-civilian group with the highest possible technical competence in this field" within the confines of the Air Research and Development Command. In mid-April 1954, Lt. Gen. Donald L. Putt, who had commanded ARDC from July 1, 1953, relinquished command to Lt. Gen. Thomas S. Power and moved to the Pentagon as Deputy Chief of Staff/Development. Plans for the new missile management organization were already under way, but its exact format had not been established. On April 21 the Director of Procurement in ARDC wrote to the Air Materiel Command stating that, in consonance with the desires of the Air Staff, "it has been decided to establish a Project Office of the Air Research and Development Command on the West Coast" which would have "sole responsibility for

*Lt. Gen. Donald L. Putt, ARDC Commander, later DCS/Development, was focus of the school of young officers who urged greater research emphasis.*

the prosecution of research, development, test, and production leading to a successful Intercontinental Ballistic Missile System."

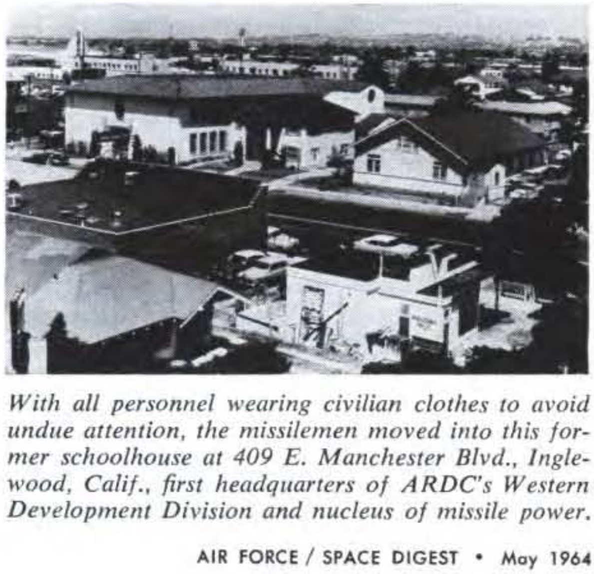
Official authorization was transmitted to the Command from General Putt on June 21, 1954. He notified the ARDC Commander that the Atlas program had been given the highest program priority in the Air Force, and all major air commands had been instructed to support the program in accordance with this priority. Direct responsibility for accomplishing the reorientation and acceleration of the Atlas program had been assigned to ARDC, which would establish a "field office on the West Coast" under command of a general officer who would have authority and control over all aspects of the program, including the "development of the complete weapon system including ground support and the development of recommended operational, logistic, and personnel concepts." The Atomic Energy Commission was also being contacted to provide priority support to the Atlas program.

On July 15 Air Research and Development Command published general orders establishing the Western Development Division, effective July 1, with duty station at Inglewood, Calif., as an extension of Command Headquarters. The following week Air Force special orders transferred General Schriever and four staff officers to the West Coast, where General Schriever assumed command on August 2, 1954. Headquarters of the Western Development Division was established in a former schoolhouse at 409 East Manchester Boulevard. All personnel wore civilian clothes to avoid attracting attention or exciting speculation as to their mission. This group provided the nucleus of what was to become in a few months a beehive of activity.

## The Role of Ramo-Wooldridge

When Trevor Gardner formed the "Teapot Committee" in October 1953, he sought some established organization which would provide technical support on a continuing basis. His first thought was that it should be the RAND Corporation, but RAND was already heavily burdened with Air Force projects. He then tried unsuccessfully to interest the California Institute of Technology and the Massachusetts Institute of Technology, but both already had heavy government commitments.

In September 1953 a number of scientists and executives resigned from Hughes Aircraft Corporation to form an independent company. Principal organizers were Dr. Simon Ramo, formerly vice president in charge of operations at Hughes, and Dr. Dean Wooldridge, formerly vice president in charge of research and development. Their names provided the title of the new Ramo-Wooldridge Corporation. Seeking financial support, the new corporation approached the Thompson Products Company and was successful in obtaining its aid. Dr. Ramo was a long-time acquaintance of Mr. Gardner, who was also highly impressed with the work done by the pair on the Falcon missile while at Hughes. Ramo-Wooldridge was persuaded to undertake the technical advisory role to the Strategic Missile Evaluation Committee (the von Neumann Committee), and the two men became



*With all personnel wearing civilian clothes to avoid undue attention, the missilemen moved into this former schoolhouse at 409 E. Manchester Blvd., Inglewood, Calif., first headquarters of ARDC's Western Development Division and nucleus of missile power.*

members of the Committee. A letter contract [AF 18(600)-1002] was issued as of October 15, 1953, to the Ramo-Wooldridge Corporation for "Long-Range Analytical Studies of Weapons Systems." The task was more specifically defined on December 3 by Task Order No. 1, which called for "a research study of certain means of delivering atomic warheads by intercontinental missiles and preparation of related recommendations on development programs." Termination date was February 28 or sooner.

After the first von Neumann Committee was officially disbanded, it was reconstituted, as we have seen, as the Atlas Scientific Advisory Committee. This group, as had its predecessor, felt the need for the assistance of a technically competent organization which would offer guidance in the extremely complex project of building ballistic missiles. On May 4, 1954, a new contract was promulgated with Ramo-Wooldridge [AF 18(600)-1190] to "conduct research studies, experimental investigations, and consultations with others as . . . necessary to properly carry out technical evaluations and systems analysis in connection with conclusions and recommendations resulting from the performance of the research accomplished" under the previous contract.

The Scientific Advisory Committee met in July to review progress to that date. Of particular concern to the Committee members was the question of whether General Schriever's authority over both requirements and contract matters was sufficiently strong.

*A meeting of the Scientific Advisory Committee at Western Development Division headquarters in 1955. Some of the luminaries present were Dr. John von Neumann, seated at the center. At his right, Trevor Gardner, Gen. Thomas S. Power, Charles Lindbergh. At Dr. von Neumann's left, General Brentnall, Col. Donald P. Blasingame, Dr. Clark Millikan, Col. Donald Latham, Dr. Milton Clauser, Colonel Morris. General Schriever is at the podium. Scientific advice played a significant role in the successful program.*

*Famed scientist missile duo, Drs. Simon Ramo and Dean Wooldridge, who formed Ramo-Wooldridge Corp. and aided Air Force in planning and integration of missile effort, view selves on* Time *cover.*

Considerable disappointment was expressed by the Committee members after having heard the Convair proposals, particularly with their continued espousal of their previous design plan. In the Committee's view the old design took little advantage of the fact that major changes could be made in the missile specifications in view of progress attained in several technical areas. It was also doubted that the Convair organization was strong enough for systems responsibility and management, nor did the Committee consider any other airframe contractor as capable of assuming this task.

Explaining the proposed relationship between Western Development Division and Ramo-Wooldridge, Dr. Ramo stated that his organization would have a small, but highly competent, technical staff, which would provide studies and advice on program planning and program direction. The actual development would be performed by contractors, including one prime systems contractor, presumably Convair or some other airframe manufacturer. In addition to conducting initial systems studies which would determine some of the basic technical systems engineering decisions and outline the basic approach to the problem, Ramo-Wooldridge would support the systems contractor and assist the Western Development Division in its evaluation of the contractor's performance.

Among its several conclusions the Committee stated that an early decision must be made as to the extent of systems responsibility to be retained in the Western Development Division as against the amount to be placed with any one contractor. Until such a decision was made, care should be exercised not to encourage any one contractor to assume that it would be the systems contractor. The Committee also expressed concern that the existing organizational arrangement (consisting of the Western Development Division with Ramo-Wooldridge as technical staff, and industrial organizations, including Convair, in various roles) was much too cumbersome to ensure early attainment of the goals of the program. It urged a strengthening of the organization "with a clear and single allocation of authority and responsibility for systems engineering." General Power, ARDC Commander, resolved some of the indecision when he issued a directive to General Schriever as of July 29 assigning to him full responsibility for the Atlas program and directing him to exercise "complete control and authority over all aspects of the program, including all engineering decisions." All elements of the Command were further directed to support the Atlas project with a 1-A priority, which meant giving the Atlas program precedence over all other command projects. General Power further directed General Schriever to restudy the role of Ramo-Wooldridge and the airframe contractor in the Air Force ballistic missile program and to submit recommendations on the most desirable type of management organization.

General Schriever's study of the Development Management Organization for the Atlas Program was submitted on August 18, 1954. He pointed out that the Air Force had three possible approaches to the problem of missile management: (1) award a single prime contract to one industrial organization to manage and provide the complete development, as strongly recommended by Convair; (2) create a new large laboratory within a university; or (3) have Ramo-Wooldridge supply a staff for the project office to provide and be responsible for technical direction and systems engineering for the project, with actual hardware development to be accomplished by direct contracts with industry.

Each possibility was carefully weighed. There were grave doubts as to whether Convair or any other single industrial organization possessed the across-the-board competence in the physical sciences to perform the complex systems engineering required, nor was it likely that they could attract the caliber of scientific personnel needed. As for a university laboratory, while it might be able to attract prominent scientists, it was doubted that such a group could provide the vehicle for the control and management of such a major industrial operation as would be needed for the extensive hardware development and production necessary, nor was it likely that any university would wish to undertake a project of such broad scope. The recommendation adopted was for the Western Development Division to assume direction of the program, utilizing the services of the highly competent Ramo-Wooldridge staff to provide the necessary strong technical direction and systems engineering skill. Actual hardware development would be accomplished by direct contracts with the aircraft industry. Principal contractors would be responsible for "structure and physical system assembly," and associate contractors for major subsystems development. The Ramo-Wooldridge organization would provide technical planning, evaluation, and supervision of the various contractors.

Advantages of this proposal were that over-all management control would reside within the Air Force, the use of associate contractors would provide the broad industrial base and permit the degree of control considered essential by the Air Materiel Command, which would administer the contracts, and the flexibility of organization and administration would attract the best brains of the nation to the project. The Ramo-Wooldridge Corporation appeared to be highly qualified to perform these various functions, but would not be permitted to benefit from either development or production projects related to the program. Based upon this extensive analysis of all facets of the situation, General Schriever recommended that Ramo-Wooldridge, working directly for the project office (consisting of the Western Development Division of ARDC and Special Aircraft Project Office of AMC), be made responsible for technical direction and systems engineering for the intercontinental ballistic missile system. The recommendation was approved by commanders of both Commands and presented on September 3 to the Assistant Secretary of the Air Force for Materiel, Mr. Roger Lewis, who also gave his tentative approval pending concurrence of other members of the Secretary's staff. Formal approval and authority to proceed with the organization was issued on September 8, 1954.

*Roger Lewis, then Ass't AF Secretary for Materiel, helped speed approval of plan for Ramo-Wooldridge to provide systems engineering.*

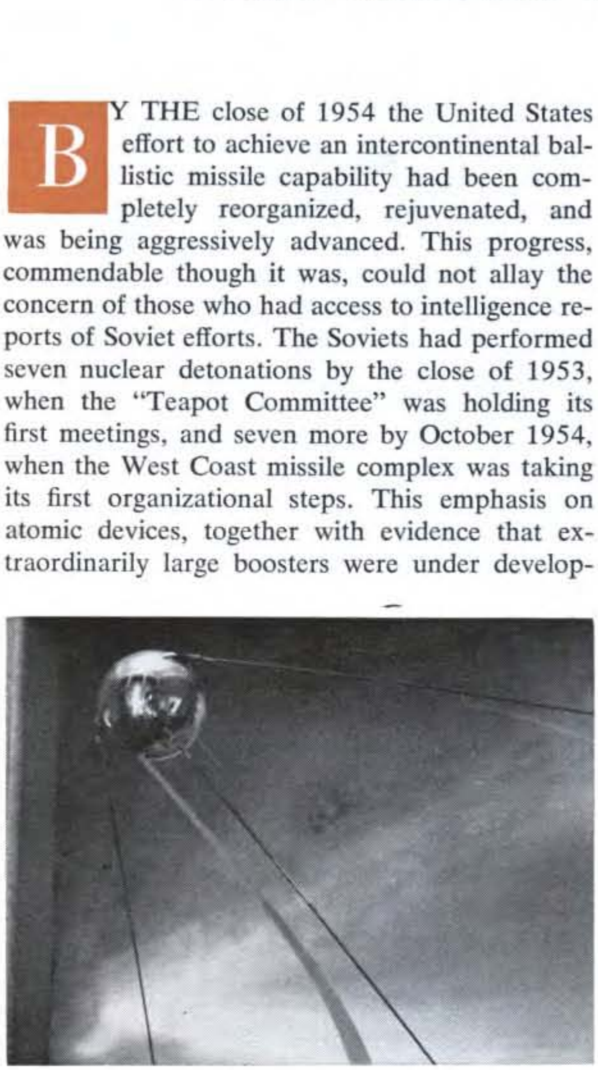
10TH ANNIVERSARY

## Chapter 7

# The Race With Time

***Having decided to go for an ICBM capability, which after all was an obvious path to space prowess, too, why didn't we also give thought to astronautics in the 1950s? Trevor Gardner suggested, after Sputnik, that, while working on missiles, the Soviets had "dared to imagine" and as a result "their space program led ours." . . .***

BY THE close of 1954 the United States effort to achieve an intercontinental ballistic missile capability had been completely reorganized, rejuvenated, and was being aggressively advanced. This progress, commendable though it was, could not allay the concern of those who had access to intelligence reports of Soviet efforts. The Soviets had performed seven nuclear detonations by the close of 1953, when the "Teapot Committee" was holding its first meetings, and seven more by October 1954, when the West Coast missile complex was taking its first organizational steps. This emphasis on atomic devices, together with evidence that extraordinarily large boosters were under development by the Soviets, could lead only to the conclusion that the Soviets had at least the rudiments of a ballistic missile in the making.



*Soviet success in October 1957 in orbiting Sputnik I, shown in display model, presented chilling evidence of the Soviet booster and guidance capability.*

Other straws in the wind might have been found in announcements made at various times by Soviet scientists, as, for instance, that of the president of the USSR Academy of Sciences in November 1953 when he said, "Science has reached a state when it is feasible to send a stratoplane to the moon [and] to create an artificial satellite of the earth." There was also the significant announcement in September 1954 that the Presidium of the USSR Academy of Sciences had established the Tsiolkovsky Gold Medal to be awarded "for outstanding work in the field of interplanetary communications, to be awarded every three years beginning in 1957." When one recalls that the first Russian Sputnik was launched almost exactly three years later, it is clear that the Soviets were calling their shots pretty accurately.

Reminiscing about those early efforts almost a decade later, Trevor Gardner deplored the fact that in the early 1950s no one had dared even to think about space. It was even venturesome to think about the ICBM, and it was feared that any discussion of space, however exploratory, might prejudice the climate for the the ICBM. His instructions had been to eliminate some strategic missiles, particularly the ICBM, and he considered it a notable achievement, as indeed it was, to reverse the climate of opinion and, although "slow in getting off the pad," achieve an ICBM only a few months later than had the Soviets.

*One of the first members of General Schriever's staff at Western Development Division was Col. Ben Blasingame, MIT-trained in inertial-guidance systems.*

*Another was Col. (now Brig. Gen.) Otto J. Glasser, an expert in electronics who had earlier served a tour with the US Atomic Energy Commission.*

*Maj. Paul L. Maret handled personnel recruiting, scouring nation for key specialists. Not shown is fourth initial member, Lt. Col. Beryl L. Boatman.*

Paying tribute to those who had made such an achievement possible, Mr. Gardner said the effort had included "a lot of people, many tens of great scientists and many hundreds of fine engineers and managers, and a few dedicated individuals like General Schriever and Dr. von Neumann and Dr. Ramo" (to which list his own name might well be added). And he made the chilling prediction that, had this nation not begun the concentrated effort when it did, the Soviets would have had a decisive weapons edge in 1957.

Contrasting this nation's outlook with that of the Soviets, he said, "they dared to imagine," and as a result "their space program led ours," as evidenced by the fact that in August 1960 the Soviets had orbited a 10,000-pound satellite and landed it at a predesignated spot. Mr. Gardner pointed out that this satellite could have contained a thermonuclear weapon, against which there was, at that time, no defense.

Who were the hundreds of people to whom Mr. Gardner referred and where had they been recruited? It has been noted that when General Schriever reported to the West Coast he had a nucleus of four staff officers. They were: Lt. Col. Benjamin P. Blasingame, Lt. Col. Beryl L. Boatman, Lt. Col. Otto J. Glasser, and Maj. Paul L. Maret. By September the nucleus had grown to fifteen, by November the number was twenty-seven, exclusive of office staff support elements, and by January 1955 the professional "blue-suit" staff totaled fifty-five. General Schriever had been given sweeping authority to select his staff, not only within the confines of Air Research and Development Command but also throughout the Air Force. At one time he had a list of some 1,500 names from which to select the Air Force's best-trained officers in propulsion, guidance, airframes, and atomic aspects of the program. The men whom he selected were released from other vital programs to lend their talents and energies to the urgent ballistic missile program. Major Maret, as Personnel Officer, made many flights around the country in a B-25 or C-47 borrowed from Edwards Air Force Base, Calif., to recruit designated personnel. These men were the "quarterbacks" of the ballistic missile team.

As for the other half of the team, Dr. Ramo later estimated that in 1954, when the program was taking form, his staff contained about fifty very exceptional people working on the von Neumann assignment, ranging from skilled scientists to practical engineers, many of whom had had much executive and practical experience. In many cases these men were national figures with enviable reputations in their fields who had been recruited from technical and engineering schools and industrial laboratories, each specially chosen for his unique capabilities in this highly complex program. Many of them were on "leave of absence" from their academic or industrial employers in order to facilitate a program designed to mitigate the nation's peril. It was clear that such an array of talent could not have been recruited by any single manufacturer or government agency.

Dr. Ramo, himself a brilliant engineer and executive, served both as vice president and executive director of his corporation and as Deputy for Technical Direction to General Schriever. Dr. Ramo had originally estimated the maximum size

*Headquarters buildings of what is now Aerospace Corporation, El Segundo, Calif., nonprofit advisory group to AFSC's Space Systems Division, previously housed Space Technology Laboratories. Both grew out of original Ramo-Wooldridge organization, created to provide technical direction and systems engineering for USAF's missile programs.*

of his ballistic missile staff at 400. However, that number was predicated on the assumption that the Ramo-Wooldridge Corporation would act only as an advisory body to the Western Development Division. When the wider role of responsibility for technical direction and systems engineering was given to Ramo-Wooldridge, in lieu of a prime contractor, it was necessary to enlarge its staff accordingly. In this capacity the Ramo-Wooldridge organization functioned as a line organization when dealing with contractors, while retaining its advisory technical staff relationship with the Western Development Division. Through succeeding years the size of the staff, assigned to the ballistic missile program, increased as follows:

| | | |
|---|---|---|
| At year's end: | 1954 | 170 |
| | 1955 | 760 |
| | 1956 | 1,557 |
| | 1957 | 1,961 |
| | 1958 | 2,580 |
| | 1959 | 3,877 |
| | 1960 | 5,182 |

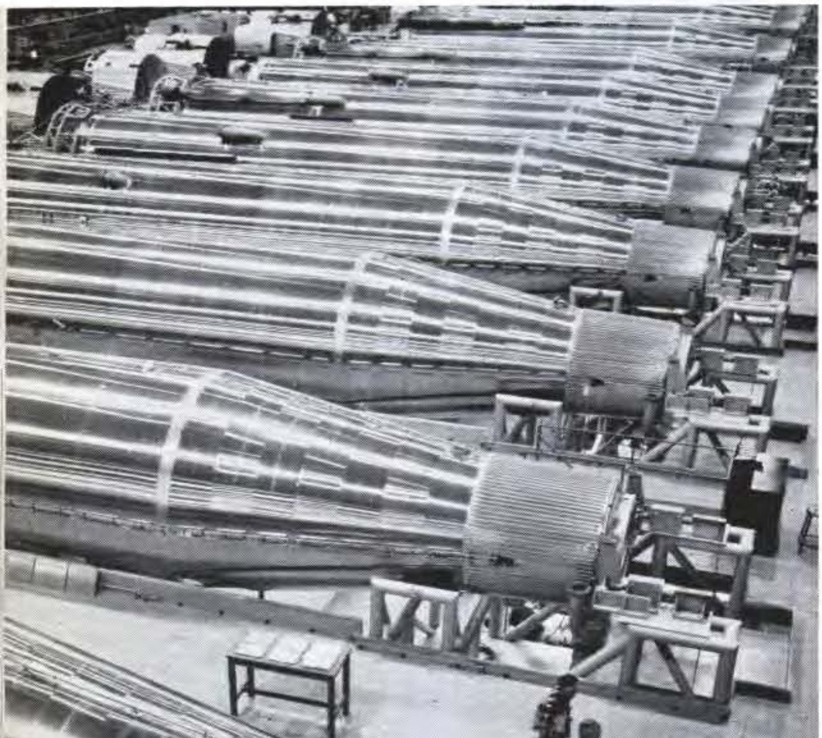
An evaluation of these increases must take into account, however, the added assignments to the Western Development Division of management responsibility for the intermediate-range ballistic missile (IRBM), Advanced Reconnaissance System (ARS), and a second ICBM and Minuteman.

Describing his organization before a congressional committee in 1959, Dr. Ramo pointed out that, from the first, it was clear that "a crash program of unprecedented size would be required, marshaling the resources of industry, government, and science on a broader scale than had ever been previously attempted in peacetime." Of its function he said, "We had to extend every phase of the technical art—propulsion, electronics, materials, and structures—by factors of ten or more, simultaneously and on a schedule half or less of the time usually allowed for relatively modest advance in military weapon systems technology." At the same time it was necessary "to create major government facilities, widespread geographically, and start parallel development approaches to be sure that every problem was solved at the earliest possible moment." In other words, "the scientific state of the art, the military problems, and the industrial capability" had to be merged into a tightly knit machine to move at twice normal speed.

Direction of the Air Force ballistic missile program within the Ramo-Wooldridge Corporation was vested in the Guided Missiles Research Division which was subdivided into five general areas: Guidance and Control, Aerodynamics and Structures, Propulsion, Flight Test and Instrumentation, and Weapons Systems Analysis. This Guided Missiles Research Division was made a subsidiary in November 1957 and renamed Space Technology Laboratories. STL worked under a hardware ban and was forbidden to enter production. STL was in business for profit and closely allied to its parent, now called Thompson Ramo Wooldridge. In June of 1960 a new nonprofit firm was organized to provide USAF with technical direction and systems engineering. Aerospace Corporation, the new firm, did not replace

STL entirely. STL retained its place in the systems engineering and technical direction of the Atlas, Titan, and Minuteman programs.

By December 1954 the company reported that five contractors were competing to furnish a second propulsion source (recommended by the ICBM Scientific Advisory Committee in its July meeting). These contractors were: General Electric, Reaction Motors, Inc., Aerojet-General Corporation, Curtiss-Wright Corporation, and Bell Aircraft Corporation. In the guidance and control area, competing organizations were: Sylvania Electric Products, Inc., Radio Corporation of America, General Electric, Raytheon Company, Westinghouse Electric Corporation, and Sperry Rand Corporation. Actively competing in the computer field were: International Business Machines, Monroe Calculating Machine Company, Remington-Rand Corporation, Raytheon Company, and Burroughs Corporation. Although directing the work of these contractors, the Ramo-Wooldridge Corporation staff members were not permitted to sit on the evaluation boards to determine the recipients of final contracts.



*Atlas production line at San Diego plant. Missiles were nested in elevated docks. At upper left, booster sections have been pulled back to install rocket engines. By December 1955, fifty-six major contractors were engaged in the Atlas program alone.*

*Thin welded bands of gleaming stainless steel are formed into tanks for the Atlas ballistic missile at General Dynamics/Convair plant in San Diego, Calif. Collapsible rings kept sections in circular form until missile was assembled and pressurized.*

By December 1955, one year later, the official list of contractors on the Atlas program alone totaled fifty-six large contractors, in addition to the support afforded by eight centers of Air Research and Development Command.

By December 1957 the AF Ballistic Missile Division and the Ramo-Wooldridge Corporation were supervising over 150 first-line contracts. At lower levels, in the subsystems area the count was infinitely complex. It has been estimated that the ballistic missile program in the late '50s was employing some 2,000 contractors with more than 40,000 personnel in a broad industrial base to accomplish the many tasks attendant upon the ballistic missile program, which had by that time grown to encompass the Atlas, its follow-up missile the Titan, the intermediate-range ballistic missile Thor, the solid-propellant Minuteman, initial operational capability for these missiles, and the advanced reconnaissance system. This composite program far exceeded, both in complexity and magnitude, the earlier Manhattan project.

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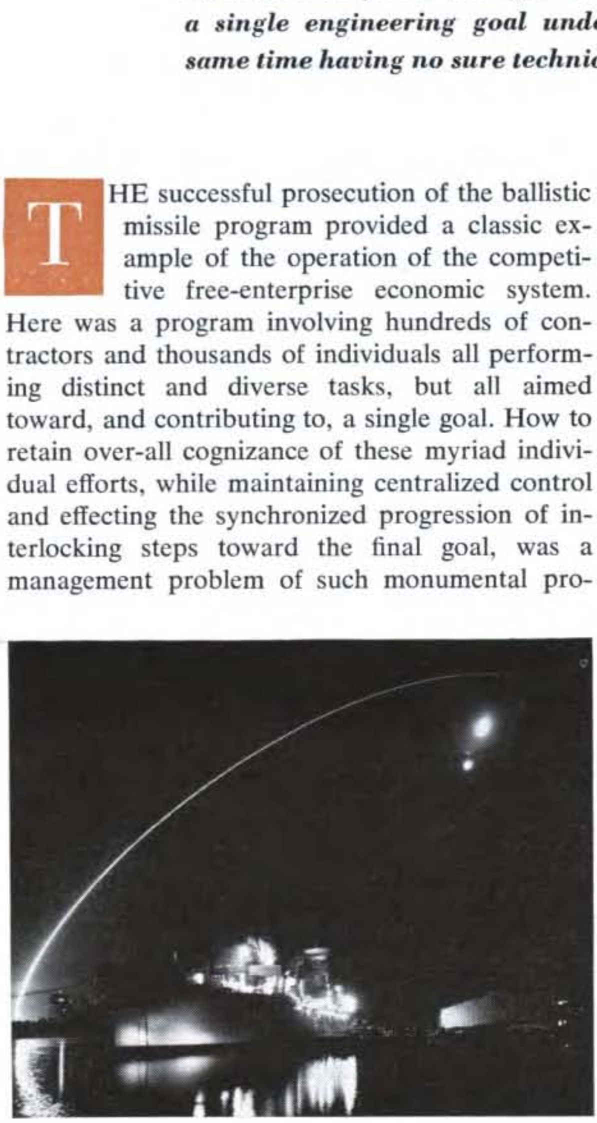
## Chapter 8

# Command and Control

***The USAF ballistic missile program provided a unique peacetime challenge to American industry and to military planners. The problem: how to focus the efforts of hundreds of contractors toward a single engineering goal under centralized control while at the same time having no sure technical solutions to the problem at hand?***

THE successful prosecution of the ballistic missile program provided a classic example of the operation of the competitive free-enterprise economic system. Here was a program involving hundreds of contractors and thousands of individuals all performing distinct and diverse tasks, but all aimed toward, and contributing to, a single goal. How to retain over-all cognizance of these myriad individual efforts, while maintaining centralized control and effecting the synchronized progression of interlocking steps toward the final goal, was a management problem of such monumental proportions as to strain the comprehension of nonparticipants.



*Spectacular night launch of Minuteman solid-fueled ICBM from Cape Kennedy, Fla., silo in February to more than 5,000 miles downrange is dramatic symbol of USAF missile program's success. What was once visionary, as anniversary approached, now is routine.*

One of the first steps taken by the missile management complex was to formulate an operating program based upon a threefold policy: First, all aspects of the program would be thoroughly studied; second, a multiple approach would be followed toward the development of system components; and, third, selective industrial competitions would be employed to determine the most competent contractors for system development. In the case of areas of high risk, either from a technical standpoint or a performance point of view, dual development programs were pursued to ensure that no promising avenue was overlooked which offered a solution of the difficult engineering problems to be solved.

This operating program was based upon the conviction that only by such means could the entire scientific talents and industrial capabilities of the nation be tapped, resulting in the best possible solutions to difficult technical problems and the assurance of the availability of the necessary system components when needed. This method would ensure the attainment of the best possible weapon-system components and, hence, an operational ballistic missile at the earliest possible date.

To avoid a "shotgun" approach to selection of competing contractors, and thus exclude wasted effort both in preparing and reviewing unlikely proposals, the procurement office established by the Air Materiel Command assisted the Western Development Division in compiling lists of qualified industrial sources that should (on the basis

*Airmen at ATC's Lowry Technical Training Center, Lowry AFB, Colo., learn to mate a reentry vehicle to a Thor. Missile training began at Lowry in 1951.*

of such criteria as past performance, technical competence, and availability) be invited to enter competition for specific system components. The various proposals received in response to the invitation to bid were then considered by a Joint Evaluation Committee, established for each area of competition and composed of representatives of all the management agencies, except Ramo-Wooldridge personnel. These latter provided technical advice but had no voice in the final selection. The industrial firms thus chosen were awarded contracts.

As early as October 1954 a calendar of "decision dates" was devised for the various tasks to be accomplished leading to an operational missile. Under the principle of "concurrency," all components were programmed into the calendar, along with ground installations for testing and a handling and training program, in order that each article or capability would be available at the precise time when it must be added to the progression. One such calendar was subdivided into six areas: nose cone, guidance and control, propulsion, engine test vehicle, fully guided missile, and general. This last category included such items as plans for a training program, handling equipment, determination of the location of the first operational base, and its construction.

*Ingenuity has helped cut test costs via simulation, as illustrated by use at Air Force Missile Test Center of this modified F-94 on which missile components have been flown, their performance tested, and information turned in by pilot at completion of the flight.*

*Since missiles don't come home like airplanes, all test data has to be extracted during short lifespan of vehicle in flight. Here, at AF Missile Test Center, Patrick AFB, Fla., specialist tracks flight using Fairchild Flight Analyzer, a camera resembling a helicopter.*

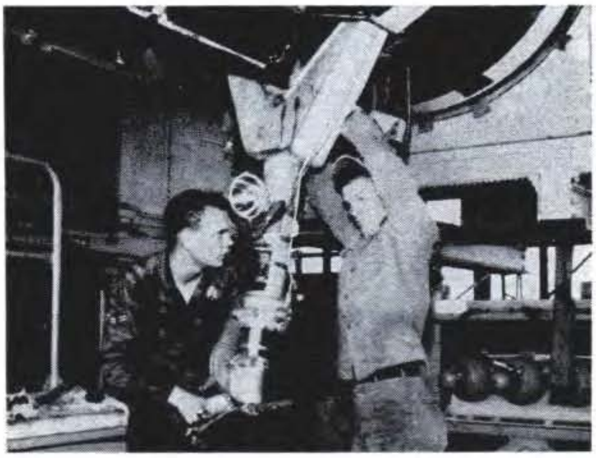
In the nose cone area, for example, before the end of 1954 decisions would be made as to its gross weight and the design of a reentry test vehicle. In January 1955 a contractor would be selected for the reentry test vehicle, its design frozen in February, followed by the freeze of the nose cone design in October in consonance with development of the engine test vehicle. In January 1956 the first flight of the reentry test vehicle was programmed, and September 1956 was the decision date for design freeze of the nose cone for the fully guided missile.

In the area of guidance and control, the final months of 1954 saw the initiation of design study contracts and a research program, among others, to study the effects of rocket exhaust gases on the propagation of electromagnetic radiation. By July 1955 detailed specifications for the guidance and control system to be used in the fully guided missile would be ready. Tests of the radar-tracking system would begin in May 1956 using airplanes. By July the final design of the guidance system would be determined. Ground installations necessary for tests of the fully guided missile would be readied in January 1957, with first tests of the complete guidance loop, still using airplanes, programmed for March at the Air Force Missile Test Center, Fla. Although all-inertial guidance was planned for the final version of the missile, it was realized that a massive research program would

*From the start, the missile business has been a learning business, not only for the R&D people who created the weapon systems, but for the thousands of officers and airmen, like these at Chanute AFB, Ill., who have learned the intricacies of Atlas, Thor, and follow-ons.*

first be required. Therefore, the guidance system which had been under development by Convair from the beginning, requiring ground tracking and guidance stations, was continued in order to hasten the test programs of other components.

In propulsion the guidelines called for selection of a contractor for the vernier rockets and selection of a second-source contractor for the rocket boosters by December 1954. During 1955 the configuration design would have been determined and the propulsion tasks revised accordingly, a method decided upon for obtaining vernier thrust, and consideration given to a superfuel hardware contract. February 1956 called for first delivery of the engine-test-vehicle propulsion system, and by July 1957 the first delivery of the flight-approved propulsion system for a fully guided missile was expected.



*While Atlas was nearing its initial operational capability back in 1957, SAC personnel who helped fill the time gap between air breathers and ballistic missiles were trained for operational Snark units. In a few years, Snark gave way to the ICBMs.*

*Even the now-defunct air-breathing intercontinental Snark, a lot less complex than the ballistic systems that succeeded it, took a lot of training. Above, an airman learning the operation of a guidance-simulation analyzer at Northrop plant in Hawthorne, Calif.*

These "decision dates" were continually revised to reflect the situation as the program advanced. This cursory description of the tasks involved in only three major development areas provides a rough idea of the magnitude and complexity of the management and technical problems faced by the missilemen. Centralized control of the total program was lodged in a Program Review Committee, of which General Schriever was chairman. In monthly meetings, attended by the System Program Officers and contractor representatives, each director reported upon the status of his particular system or component. One participant said these early sessions came to be labeled "Black Saturday" for obvious reasons.

Another management device was the Configuration Control Board, which had responsibility for assuring that any necessary changes in component design would be immediately reflected throughout the total missile configuration. Responsibility for immediate and final decision was vested in the chairman. Still a third management tool was the Production Control Board, which exercised complete control over allocation of equipment and resources with authority to move scarce items of equipment or to reprogram funds to that area most in need at a given point in time.

Another instrument designed to assist in "management visibility" was a Project Control Room, created in August 1955 "to serve as a nerve center for all project information, including hardware delivery schedules, test schedules, and operational planning schedules." In the early days, while the attendance was still small, the "Black Saturday" program reviews were held in this room, one feature of which was a keyed system embracing the use of "red flags" on any item which might lead to program delays.

These, then, were a few of the management devices established as the program progressed. Not all of them were used on every missile finally developed. Rather, they were devised and instituted as management experience matured along with the expanding missile program. For example, another management principle, designated "management by exception," was tried. By this was meant that, as long as progress was going smoothly and schedules being met, the contractors were left pretty much on their own. It was only when some difficulty was encountered that the "red flag" went up and the Air Force managers stepped in to solve the problem.

Based on experience gained on the early Atlas and Thor "installation and checkout" programs, a new management approach was devised which sought to profit by the lessons learned. For good management, it was found, the whole future task had to be more precisely laid out. It was not enough just to chart the progress of a program. Future goals must be very carefully defined. In a football game, the players must always know where the goal line is and also exactly how they plan to reach it. In laying out a railroad the engineers must plan for each station in advance of the terminal. The whole program, therefore, was laid out in a series of "sequence and flow" charts, familiarly called the "bed-sheet method." Definite base lines were established for the military-civilian management team, the contractors, and the using organizations. To this end the using commands were also involved in the planning stages, and agreements were reached in advance as to the turnover point in the program. For this purpose, Technical Approval Demonstrations were arranged preceding formal "sell-off" agreements. This preplanned program was predicated upon a very high level of efficiency and background experience in the System Program Offices, on people who now knew from experience how to anticipate roadblocks in advance.

*Plumbing and electrical operations are key items in successful missile operations. Intricacies of these arts have been taught virtually from the start of the program at Air Training Command centers such as this school at Chanute AFB, Ill. Today's lesson: wiring.*

*The missilemen learned from failures, but the failures were expensive and heartrending each time they happened. This was the scene at Cape Canaveral during the early ICBM development era on a night when a missile test vehicle went awry and had to be destroyed.*

These management techniques were not necessarily new or invented specifically for the missile program, but they were harnessed into a smoothly operating system on a scale untried prior to the ballistic missile program. Additional experience continually strengthened the management techniques. Thus, Titan benefited from the lessons learned on Atlas and Thor. For Titan II the entire route was laid out in advance, and Minuteman went forward steadily almost without problems under the guidance of a team which by now knew its task thoroughly, as did the contractors who were involved.

But the picture was not always as rosy as it may appear in retrospect. How General Schriever, upon whose shoulders rested the final staggering responsibility, retained his equanimity through those first trying years was an enigma, because, as one participant put it, he heard nothing but problems. That he was not only an able administrator but something of a psychologist as well is demonstrated by the following episode. At one of the "Black Saturday" reviews, after a particularly disheartening string of delays, misfirings, and other mishaps, General Schriever handed each of his missile program directors a small figurine whose face had a most woeful expression. "This is the way you guys look," he told them. "Take these for company, and don't bring them back until your missile has had a successful flight and you're smiling." One by one, as Atlas, Thor, and Titan roared off the launching pads, the figurines came back, but this time each wearing, a tiny halo.

*General Schriever's idols, awarded to haggard missile project officers, earned halos after successful flights. They're now part of ICBM, IRBM lore. Above, Thor project officer Col. Richard K. Jacobson, now working on MOL, keeps his idol on his desk.*

If one were to single out any one factor of the complicated management program which contributed most to its effectiveness, that factor would be the decision-making process. Because of delegation of authority to the working level, everyone concerned knew exactly where to go to get an immediate and final decision. However, there still existed time-consuming delays in gaining higher approval in certain areas, chiefly in financial procedures, procurement policies, and, particularly, in facilities acquisition. For example, in the last area the procedure followed as late as September 1955 was as follows:

Specific requirements and justifications were required to follow a circuitous and tortuous process from Western Development Division to Headquarters, Air Research and Development Command to Air Force Headquarters to the Office of the Secretary of Defense to the Bureau of the Budget to Congress, undergoing review at each station. Then, after the facilities were authorized and funding provided, action proceeded, generally, from the Western Development Division (or other center, as the case might be) where the design criteria were established to Headquarters, Air Research and Development Command for review and on to the Air Force Installations Representative of the Corps of Engineers at whichever District Office had jurisdiction and where the construction contracts were let. All concerned realized that this cumbersome process should not be tolerated.

After the first year of operation of the ballistic missile organization, and as a result of a briefing presented to the National Security Council at the White House in mid-1955, the ballistic missile program was accorded the highest national priority, above any and all other federal programs. In consonance with this increased emphasis on, and support of, the program, Trevor Gardner sought to increase the effectiveness of program management. In September 1955, the same month in which the top priority was allocated, Gardner appointed a committee "to evaluate the administrative management and control procedures incident to this program," with the objective of reducing administrative interference and delays. Originally called the "ICBM Administrative Procedures Evaluation Group," it was more familiarly known as the Gillette Committee from the chairman, Mr. Hyde Gillette, Deputy for Budget and Program Management under the Assistant Air Force Secretary for Financial Management. As a result of the Committee's recommendations, sweeping changes were made through the Department of Defense to expedite the ballistic missile program.

The Commander of Air Research and Development Command was delegated primary authority and responsibility for actual development of an initial operational capability of the intercontinental ballistic missile system, to be exercised through the Western Development Division, already an integral part of the Air Research and Development Command. At the Air Staff level, the Office of the Assistant Chief of Staff for Guided Missiles provided the focal point for central control and direction of all ballistic missile matters referred from the field.

At the Air Force Secretariat level, a Ballistic Missile Committee was established to consolidate review actions of all matters related to the program. The Secretary, the Assistant Secretaries for Research and Development, Financial Management, and Materiel, and the Assistant Chief for Guided Missiles were members of the Committee and the Assistant Secretary of Defense (Research and Development) was asked to attend meetings as appropriate.

Close liaison was maintained between that Committee and a similar group established in the Department of Defense, the OSD Ballistic Missiles Committee. This was the single point of contact to which the Secretary of the Air Force reported and the agency which acted as a single program and review authority at the Secretary of Defense level. This Committee included the Deputy Secretary of Defense, other interested Assistant Secretaries, and a representative of the Bureau of the Budget. In this manner the separate justifications and clearances by five Assistant Secretaries was combined in one committee action, and review by the Bureau of the Budget was accelerated. Although the OSD Ballistic Missiles Committee exercised final review and guidance, the management responsibility for the missile program was delegated to the Secretary of the Air Force and encompassed unusual authority in regard to facilities, procurement, funding, and the composition of the technical program.

The ICBM Scientific Advisory Committee, established previously by the Secretary of the Air Force, expanded its membership and operations to act in an advisory capacity also to the OSD Ballistic Missiles Committee. Effective liaison was also established with other major air commands, the other services, and other government agencies, such as the Atomic Energy Commission, for exchange of information and resolution of interrelated problems.

Lack of facilities was a primary concern of the Gillette Committee, and it took unprecedented action to eliminate the former complicated procedures and to acquire maximum flexibility in meeting unforeseen requirements. The development plan to be prepared and submitted annually for the ballistic missile programs was to include budget requirements and facilities needs, both industrial and military. This plan was to be reviewed and approved as one package. With respect to industrial facilities, the Committee recommended that Air Force review be limited to approval of the industrial facility program addendum of each development plan. In the area of military construction, it was recommended that construction programs be included in the yearly development plans as a single package for lump-sum authorizations. Additionally, in order to ensure prompt approval of construction programs requested by Western Development Division, detailed line item scrutiny of the construction program during the fund apportionment process was waived. The Air Force was given wide latitude in determining design criteria and standards, in designating construction agencies (other than Army or Navy) for specialized missile requirements, and in shortening facility completion dates, even though higher costs might be involved.

This, then, was the unique organization and its management procedures which brought to a successful fruition the ballistic missile program and provided a powerful deterrent arsenal to ensure the nation's security. These procedures proved to be applicable, not only to the ballistic missile programs, but also in the lunar space program conducted by the National Aeronautics and Space Administration. More recently, the Department of Defense has adapted many of the ballistic missile management principles to its larger role of managing the weapons of the future.

Thus had the nation proved that it could adapt itself to new methods and realign its organizational elements to meet the threat of an implacable foe and under the pressure of a timetable not of its own choosing but established by the enemy. The consummate faith which Trevor Gardner and General Schriever had when they staked their reputations and future careers on the professional abilities of the scientific and technical personnel of this country, coupled with the competency of the industrial foundation, had been eminently sustained.

## Chapter 9

# The Growing Missile Program

***Atlas-A and -B and -C . . . Thor . . . the Titans I and II . . . Minuteman. What was meant by this riot of nomenclature? The answer: The USAF missile program was climbing, from the outset, the ladder of capability a step at a time. Not one missile, but a series of systems—each better than its predecessor—was being developed . . .***

THE numerous missile programs and their various stages and nomenclatures are somewhat confusing. What is the difference between an Atlas-A, or -B, or -C? And why, if an Atlas-A had a successful flight, did one bother to build an Atlas-B? Also, what were the Thor, Titan, and Minuteman designed to do that the Atlas could not do? And why a Titan I, II, and III?

Perhaps it would be well at this point to recall what the ballistic missile was designed to accomplish, namely, the delivery on a distant target of a warhead capable of neutralizing that target. Obviously, then, the efficiency of the warhead was the final determinant in the size of the vehicle needed to carry it, in the amount of propulsion required to reach the target, and the degree of accuracy which it would require to hit that target. With these requirements in mind, we can understand more readily the various stages of the program as it developed. As General Schriever has stated, "We did not develop just one missile, or just one family of missiles, but a series of missile systems, each of which was more advanced than the one before."

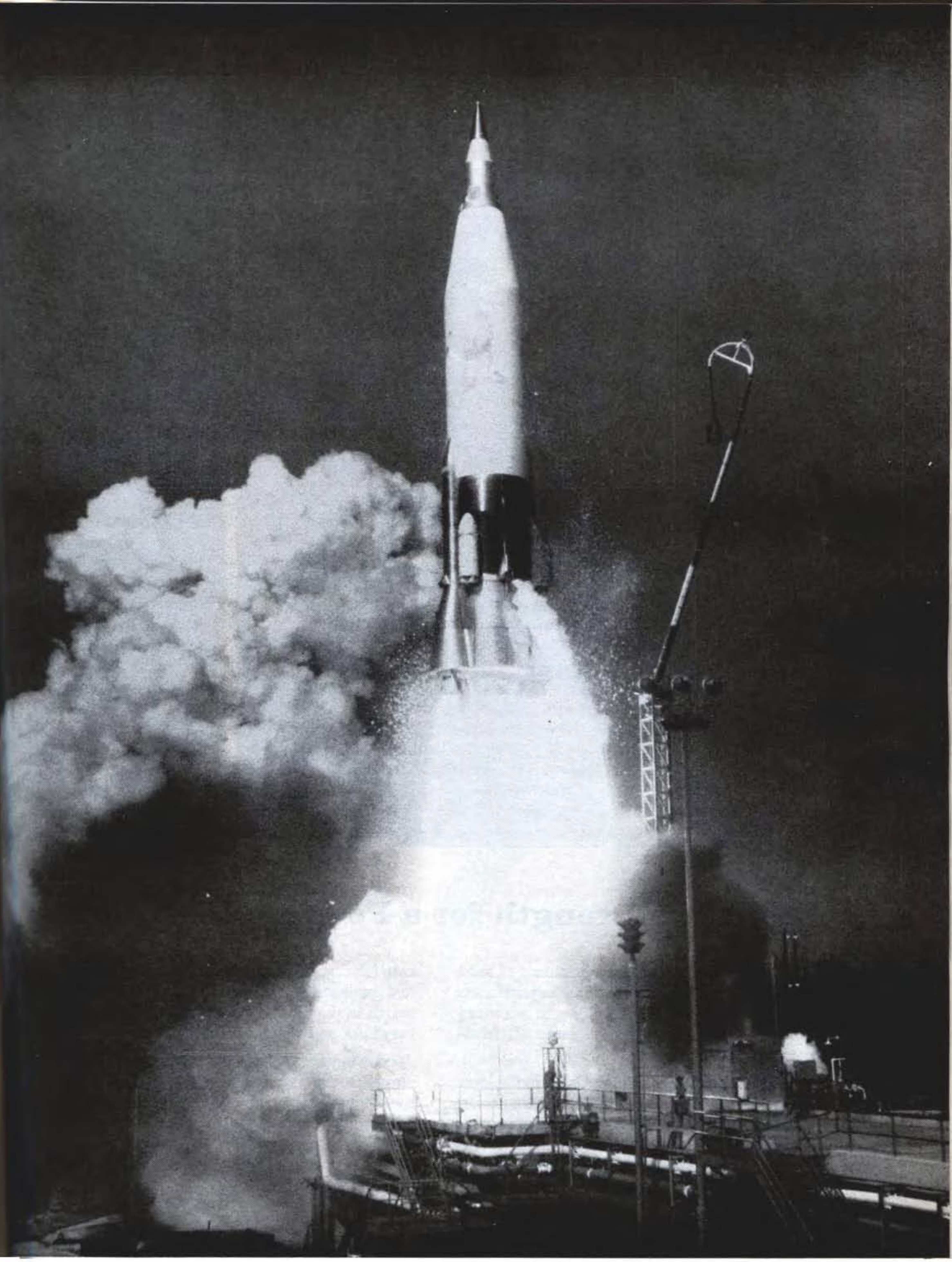
## The Evolution of the Atlas

From the inception of the ballistic missile program, those in charge of its planning had a final goal or end product in mind. But they knew full well that they could only mount the ladder a step at a time. Because of the many technical problems to be solved, an operational missile was many months, if not years, away, but, in the meantime they could take some of the steps up the ladder and hope to find solutions to other problems along the way.

It must also be remembered that testing a ballistic missile is not like testing an airplane. In the latter case, a pilot puts the aircraft through its tests and returns it to its base to be further refined or modified on the basis of accumulated test data and the pilot's judgment. In the case of a ballistic missile the test vehicle is irretrievable after the test. Flight testing is also very expensive, estimated at something like a million dollars a shot; therefore, all possible information on reliability of the many parts had to be sought from ground tests.

As for the flight tests, several methods were considered. One possibility would be to test a whole series of unrelated, separate vehicles, one to test guidance, another propulsion, and so on, with the idea that these subassemblies, after their defects had been discovered and corrected, could be put together into a final missile that would have a good chance of working. However, experience in other programs had taught that this approach was not valid because of the additional problems which appeared only when the subassemblies functioned together as a complete system. Another approach might be to start the flight tests

*Opposite, an Atlas leaves pad at Cape Canaveral in reentry-vehicle test. Missile testing posed many problems differing from flight tests of manned aircraft. Several methods were considered before evolutionary approach was adopted, starting with basic structure.*



with the complete missile, but this would delay the start of any flight tests until all subassemblies could be ready. Another disadvantage of this approach was that, because of the enormous complexity of the missile and its various components, comprising over 10,000 major parts, it would be difficult to locate particular defects, especially since, in the case of a malfunction, the test period might not be longer than a few seconds.

The dominating idea of the flight-test plan that finally evolved was an evolutionary approach, moving gradually from the simple to the complex, until the operational missile was realized. Beginning with a mental picture of the completed missile, it would then be stripped of its components, one by one, until the simplest possible vehicle capable of leaving the ground was obtained. The Series A, attached to the Atlas missile, designated the most rudimentary missile that could be tested in flight. It employed the booster and vernier engines, but not the sustainer. Only the autopilot of the guidance system was aboard but was not operating. The reentry vehicle was only a dummy. No range or altitude requirements were programmed. When the "bird" met the requirements of a particular test, it was rated as a satisfactory flight. Tests of the Series A began in June 1957 and with the third try on December 17, a missile landed near the designated impact area with all systems performing satisfactorily.

While this first version was being tested, a second version was being readied. This one added the sustainer engine and a complete propellant utilization system. It also had an improved guidance system aboard and working, as well as a test reentry vehicle. Several answers were sought. Would the sustainer engine feed properly during the initial boost and maintain the desired thrust throughout the powered portion of the flight? The guidance unit would determine whether the ground installations were functioning properly in conjunction with the missileborne components during the vital rise of the missile from the vertical into its programmed trajectory. Ten flight tests of the Atlas-B were conducted between July 1958 and February 1959. A measure of its success may be found in the fact that it was the Atlas-B which boosted into the skies "Project Score," from which was relayed President Eisen-

*Mirrored in canal which carries away water used to cool pad at launch, Atlas booster employed in Project Score, conveying President Eisenhower's Christmas message to world in 1958, is poised before launch. It marked first broadcast of human voice from space.*

hower's Christmas Message in December 1958, giving the nation a "first" in relaying a voice from space and also a much-needed boost to its morale. It was also the nose cone lofted by an Atlas-B which was photographed from an airplane in the target area.

Further sophistication was achieved in Atlas-C. Although still using the same propulsion system as the B Series, the propellant-utilization system operated as a complete flight unit; the missile carried an operational test reentry vehicle; an improved and refined guidance system was aboard and guiding; and the vehicle achieved increased altitude and range. These tests provided further data on the boosters, separation of both stages, and the copper heat sink applied to the nose cone. Tests of the Atlas-C began in December 1958 and by March 1959 it was testing the improved ablating nose cone.

The Series D Atlas was the first prototype of the final operational Atlas. It employed the operational configuration and was designed for maximum range depending upon the warhead aboard. The missile still operated with the ground-based, but much-refined, guidance system, but it also carried the all-inertial guidance for (Atlas-E) testing. The propulsion system had also been improved to provide greater thrust. All subsystems were aboard and operating. Tests of the Atlas-D began in April 1959, and by July it had made the first full-range flight. By August 1959 the Atlas-D had met all R&D test objectives.

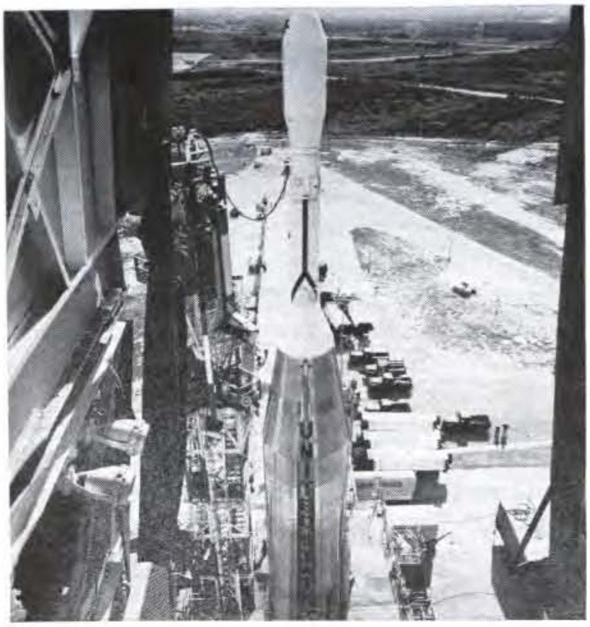
September 1959 posted two spectacular scores for the Atlas-D. It was the booster for the first Project Mercury test-flight vehicle ("Big Joe I") developed by the National Aeronautics and Space Administration, and, although the booster section did not separate at engine shutdown, all Mercury test objectives were met with recovery of the data capsule approximately 1,500 miles downrange. Success of the flight caused cancellation of the next scheduled test. On the same day, September 9, a launch from the Pacific Missile Range by a crew from Strategic Air Command (with backup by the Air Force Ballistic Missile Division and contractor personnel) marked the beginning of an initial operational capability, thereby considerably bettering the six-year prognostication made by the Strategic Missiles Evaluation Committee

*Test of first Mercury vehicle, Big Joe I, launched September 9, 1959, and recovered 1,500 miles downrange, was so successful that NASA was able to cancel a second such test. Same day on West Coast SAC crew achieved initial operational capability.*

in February 1954, and also exceeding the original specifications as to range, warhead-yield capability, and accuracy.

But these accomplishments, though commendable, still left small room for relaxation of effort in view of Soviet achievements. On August 27, 1957, the USSR announced successful tests of an intercontinental ballistic missile capable of carrying a powerful nuclear weapon to any point of the globe. On September 13, 1959, they successfully hit the moon with Lunik II, followed on October 4 by a circumnavigation of the moon which obtained photographs of the hitherto unseen side of the moon. A further disappointment was the failure of our November 26, 1959, Pioneer shot, an attempt at a "moon orbit," but the failure of a payload shroud fairing was no fault of the Atlas-D booster. The following May the Atlas-D heartened its backers by making a 9,000-mile flight, carrying the ablative reentry vehicle redesigned to overcome the stability problem previously encountered.

The Series E and F Atlas also had the operational configuration but had advanced to a still more powerful propulsion system, the all-inertial guidance, and the operational reentry vehicle. The all-inertial guidance now made unnecessary the extensive ground stations, and the missile was immune to ground control except for the "destruct" signal in case of malfunction. The Series E missiles had advanced to the point where the missile could be installed in semihardened sites, and the missile program was well along the path toward underground installations. The first of the Series E missiles was fired from Cape Canaveral (now Cape Kennedy) in October 1960 with the objectives of testing the performance of all subsystems and evaluating the flight control and the all-inertial guidance system. After three failures, the fourth attempt in February 1961 successfully landed its reentry vehicle at near-ICBM range. By May the Atlas-E had demonstrated that all primary objectives could be met.



*Soon after Soviets hit moon with Lunik II and followed with successful effort to photograph moon's dark side, US attempted to put this Pioneer into lunar orbit in November 1959 with Atlas booster, but mission failed when payload shroud fairing came apart.*

*Navy Cmdr. Walt Schirra leaves on six-orbit mission aboard* Sigma 7 *capsule October 3, 1962. In a virtually perfect flight, marred only by a problem with his spacesuit temperature control, he splashed down in Pacific just four miles from his carrier pickup.*

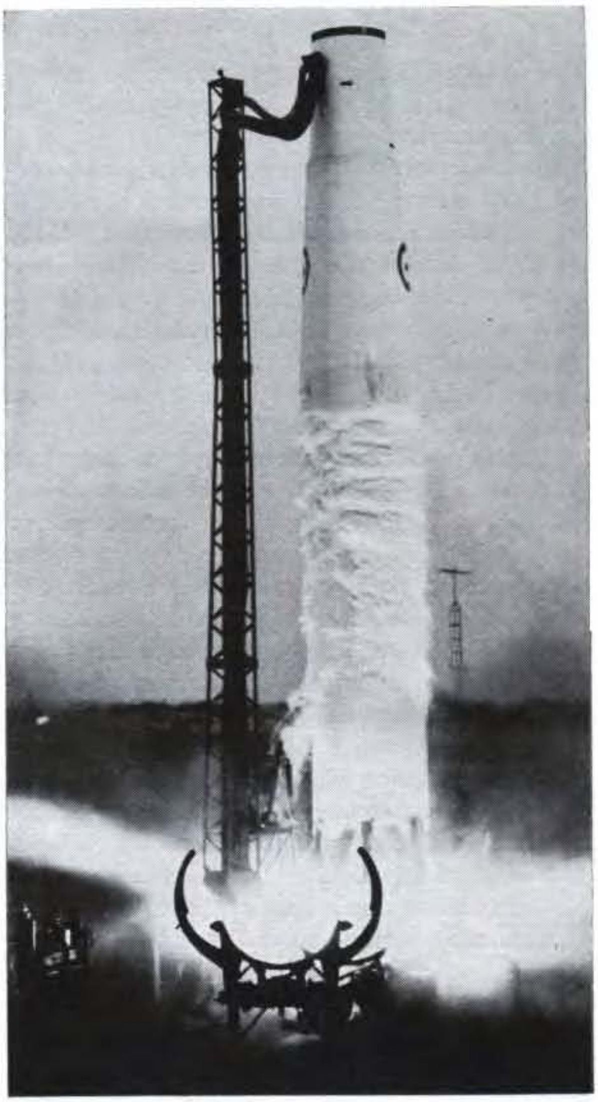
Testing of the Atlas-F began in August 1961. Although the first flight was successful, except for loss of the data cassette, or capsule, subsequent flights uncovered shortcomings. In a test on December 12 the guidance system failed; on December 20, there was a malfunction in the sustainer engine pumps; on April 9, 1962, the vehicle was destroyed by an explosion in the thrust section followed by an explosion in the propellant tanks. But a flight on August 13, 1962, launched by an all-Air Force crew, followed the planned trajectory throughout the flight, and the data cassette was recovered within twenty-four minutes after impact. By the end of the year all research-and-development tests of the Atlas were completed, thus ending the five-year test program, but not the story of the Atlas. A spectacular chapter was written on May 15, 1963, when the Atlas (again a modified D Series) propelled into orbit the sixth manned spaceflight under Project Mercury, carrying Air Force Maj. L. Gordon Cooper for twenty-two orbits of the earth to a pinpoint recovery in the Pacific Ocean.

So the mind's-eye missile which had been foreseen from the beginning was achieved after years of effort, years that at times were marked by crushing disappointment but eventually crowned by high achievement.

## The Intermediate-Range Thor

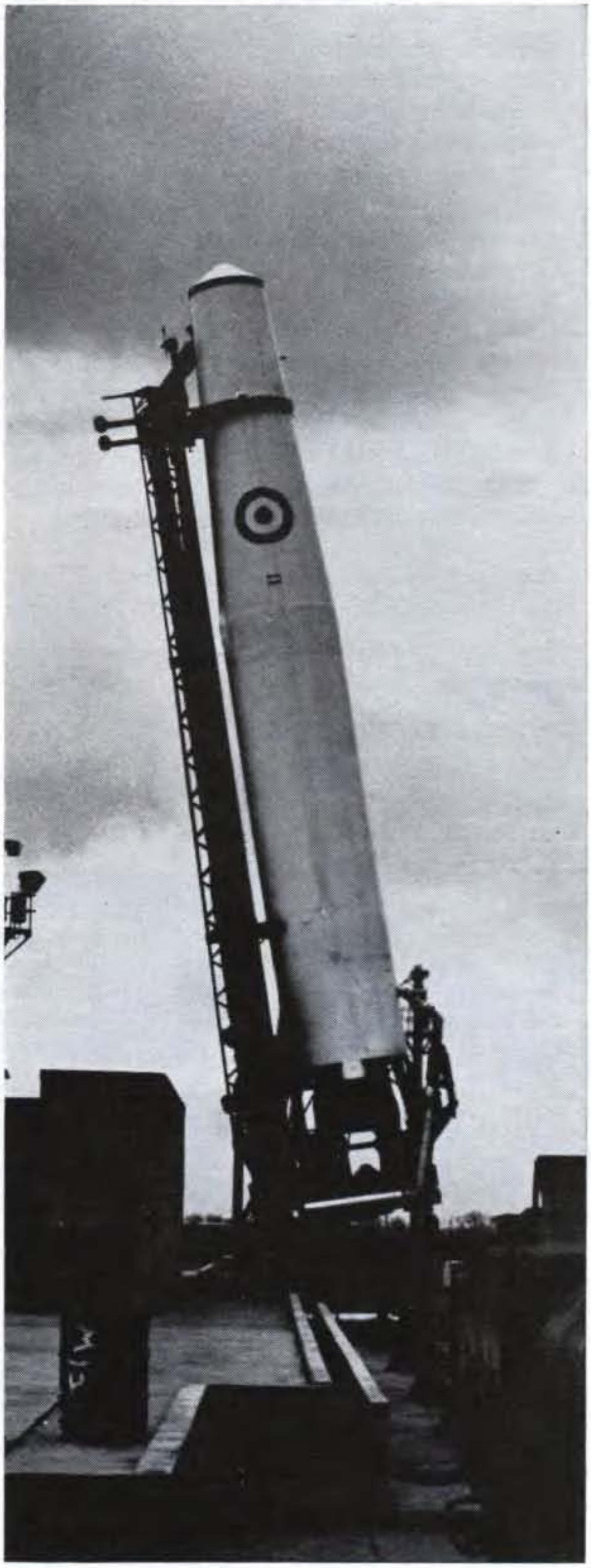
Air Force interest in a medium-range missile dated from the 1940s and from its early experiments with various types of missiles, as was evident from the earlier Snark and Navaho programs. Serious consideration was given to a tactical ballistic missile (TBM) by the Scientific Advisory Committee in its meeting of January 1955. The group had already advised that an alternate configuration for the Atlas be developed as a backup to the Convair program, and it was believed that the TBM might result from that effort. General Schriever advised against the undertaking at that time for the reason that it might dilute the scope of the effort directed toward the intercontinental-range Atlas. Even the discussion of such a program, he said, was causing possible contractors to hold back from becoming involved in Atlas contracts in the hope that they would get large contracts for the TBM.

After the Gillette Committee had submitted its report on administrative management of the ballistic missile program, the Secretary of Defense issued several memoranda designed to put into effect many of the Committee recommendations. Among these was a memorandum for the Secretary of the Air Force, dated November 8, 1955, which stated that the Department of Defense, based upon studies of the problem and acting upon the advice of the National Security Council, had decided to "initiate the IRBM program with a priority equal to the ICBM but with no interference to the valid requirements of the ICBM program." Its studies had "indicated that an IRBM capability could be achieved at an earlier date than the ICBM capability," and it proposed to pursue "these research-and-development programs at the maximum rate" permitted by technological advances. The intermediate-range missile program was further subdivided into land-based development, for which the Air Force was made responsible, and a joint Army-Navy program "having the dual objective of achieving an early shipboard capability and also providing a land-based alternate to the Air Force program." These programs were to share equal priority.



*Flight testing of the Thor intermediate-range missile, which began only thirteen months after Douglas signed production contract in December 1955, was routine by the time an RAF crew conducted this training launch at Vandenberg AFB, Calif., in 1959.*

This new Air Force responsibility was quickly reassigned to the Air Research and Development Command, with the proviso that the same "command relationships and administrative procedures relating to the ICBM development will apply to the IRBM." All actions related to the dual efforts



*Thor missiles, like this one on launcher at an RAF base, were operational in Britain by June 1959, just three and a half years after the program was initiated, a remarkable achievement compared with previous eight- to ten-year weapon development cycle.*

were to receive top precedence and priority and "any insurmountable situation of a delaying nature" or any "inability to obtain complete cooperation from other government agencies" would be reported by priority means to the Assistant Chief of Staff for Guided Missiles at Air Force Headquarters.

By December 9, 1955, a revised Operations Order was transmitted to the Western Development Division assigning responsibility for the intermediate-range ballistic missile. In anticipation of this probability, that Division and its advisory body, Space Technology Laboratories, had already performed preliminary studies and were ready to proceed rapidly. Before the end of December a contract had been awarded to Douglas Aircraft Company to build the airframe. An all-out effort was to be made to compress the complete development cycle from program initiation to operational deployment, with a goal of first launch within twelve months. This effort presented a double challenge. Although many of the components of the Atlas could be modified for use in the Thor, the latter system still required further technical advancement in the missile art itself, and while the process of creating a new missile was under way, it was also necessary to proceed simultaneously with the creation of a new ground environment, new facilities and equipment, and a new operational force.

The Thor, as originally designed, was a single-stage, liquid-propellant, ballistic rocket, approximately sixty-five feet tall and eight feet in diameter, powered by a gimballed rocket engine and two gimballed vernier engines. Since the Thor range was limited to 1,500 nautical miles, the warhead weight could be the same as that carried by the Atlas-D, and therefore the nose cones could be identical. The Thor propulsion system was also borrowed from the Atlas booster, and the inertial-guidance system under development for Atlas was reoriented for Thor, as were many vital components in the electrical, hydraulic, and pneumatic systems. It was confidence in these building blocks which permitted the early "all-out" beginning of the Thor program.

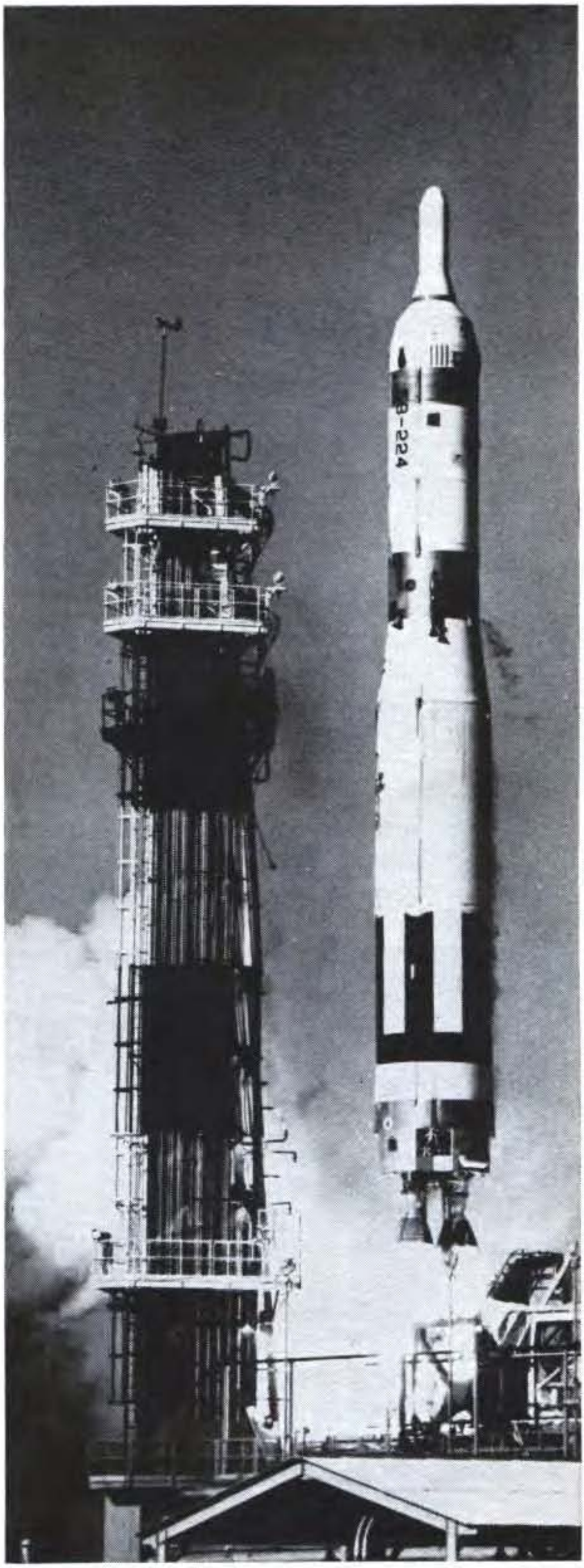
Testing of the first phase of the Thor program began as early as January 25, 1957. The first series of tests, during which seven missiles were launched (one burned on the pad prior to launch), employed a configuration consisting of the airframe, propulsion system, control system, and a nonseparable dummy nose cone. During the second series of tests, begun in December 1957, the all-inertial guidance system was added and the nose cone used toward the end of the five tests was separable. The next series of tests, begun in February 1958, was also comprised of five missiles which included all missile subsystems and a functioning reentry vehicle which, on some flights, carried a dummy warhead. Delivery of the first operationally configured missile occurred on May 31, 1958, with first launch from an operational launcher on June 4, 1958.

The final series of tests, begun in November 1958, launched twenty-eight missiles of an operational configuration (less the warhead, although a dummy warhead was carried on eight of the flights) with the final improved propulsion system. By June 1959 the first operational squadron of Thor missiles had been turned over to its British operators, just three and one-half years after program initiation, a remarkable achievement when compared with the traditional eight- to ten-year development cycle under previous management procedures. By April 22, 1960, the final squadron was in place in Britain, and from that time on the Thor missiles were poised on their launching pads guarding the security of the West.

Commenting on the Thor program before Congress in July 1961, General Schriever pointed out that, although there had been trouble with the early Thor, as in any new program, after the shakedown period the program had scored twenty-three successes out of twenty-six attempts, a record that surpassed all expectations. The confidence placed in the Thor was evident in its wide use as a space booster in the Pioneer, Discoverer, and Explorer space programs, and for the Tiros, Transit, and Echo satellites. On October 4, 1960, the 100th launch of a Thor boosted into orbit the Courier 1B, the world's first active communications satellite. As of April 15, 1964, 140 Thor launches have had only nine failures, giving it a better than ninety percent reliability score.

## The Titan Program

Origins of the Titan program can be traced to the early deliberations of the von Neumann advisory committee in its 1954 and subsequent reports. A RAND report of the same vintage had suggested the feasibility of a two-stage ballistic missile configuration, but at that time the one-and-one-half-stage ballistic missile proposed by Convair seemed to offer better promise of early availability. Nevertheless, those who favored the alternate approach thought there were great risks



*Titan I, nation's first two-stage ballistic missile, blasts off Cape Kennedy, Fla., launch pad on 5,000-mile test flight. Decision to develop it as separate weapon system was made in 1957, but the program had to overcome criticism that it duplicated the Atlas.*

attendant upon the Convair airframe because its thin, inflated fuselage might not withstand the rugged "G" loads forced on the missile in the early lift. Other factors considered were the possibility that an element of competition might have a stimulating effect on airframe contractors generally, and that such an approach might produce substantially superior design offering great advancement in the state of the art if it were oriented around greater technical risks.

In March 1955 the missilemen forwarded a formal proposal to Air Force Headquarters for an alternate long-range missile program, requesting authorization to initiate competition among possible contractors for a two-stage ICBM configuration. The required approval was forthcoming from the Secretary's office in late April 1955. By October the airframe contract was awarded to the Glenn L. Martin Company (later the Martin Company). Selection of subsystems contractors was simplified by the fact that the possibilities had been thoroughly explored for the Atlas, and in many cases contracts had been given as second sources for Atlas components. Now these "back-up" sources were generally diverted to the Titan program.

The decision to develop Titan I as a completely separate weapon system was made in early 1957. It suffered the customary cutback and production stretchout when caught in the 1957 budget austerity program. Principal criticism was that the Titan program duplicated the Atlas program, thereby doubling the basic cost of the ballistic missile effort without significantly contributing to total improvement of the national defense posture. Proposals that the program be canceled were offset, however, by the still-valid original arguments in its favor—that it provided the most practical means of testing several alternate approaches to the resolution of technical uncertainties, offered the preferable two-stage configuration (which would probably have been adopted for the Atlas had not the factor of "earliest possible operation" been a dominant consideration), broadened the industrial base in the vital missile area and provided a competitive element in the total program, and had a far greater growth potential than any other discernible alternative.

Early in 1958 General Schriever was convinced that too much emphasis was being placed on Atlas when the attractiveness of the two systems was compared. The Scientific Advisory Committee supported his stand, but by this time another competitor had appeared, the Minuteman, a solid-propellant version ballistic missile which seemed to offer a decrease in size and cost per squadron. Minuteman advocates argued that, instead of putting too much money on an enlarged Titan force,

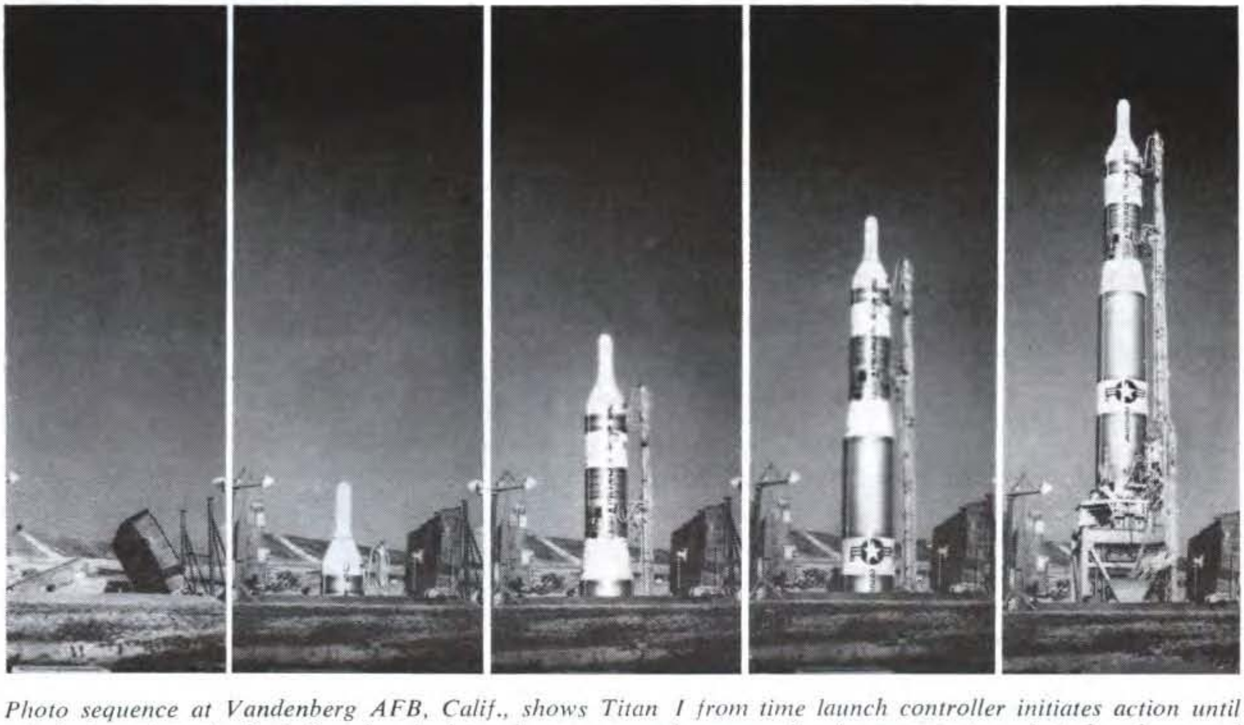
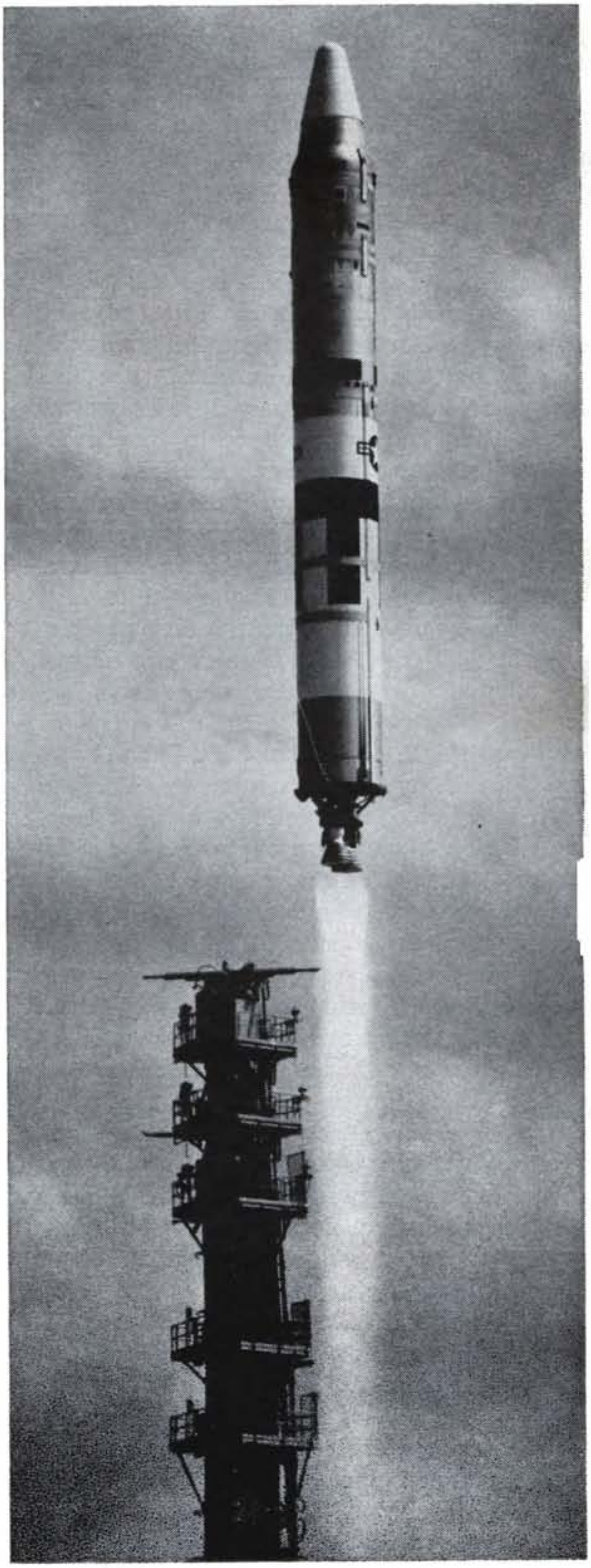


*Photo sequence at Vandenberg AFB, Calif., shows Titan I from time launch controller initiates action until missile is ready to be fired. Two-hundred-ton doors open and weapon rises from concrete and steel underground silo hardened against nuclear attack. Fueled with refrigerated propellant, the Titan can be launched in minutes.*

it would be wiser to expend it on Minuteman, which could be available very shortly after Titan. However, in view of the critical nature of the threat to the nation's security posed by Soviet accomplishments, the view prevailed that the Minuteman, a high-risk program, should first be proven before other promising systems were abandoned.

In January 1959 Titan men were heartened by a Department of Defense decision to release funds to enlarge the number of Titan squadrons. By the end of the year the Titan II program had been authorized. Titan I was the designation given to the first phase of the operational weapon system. It was equipped with radio-inertial guidance, fueled by liquid oxygen which required refrigeration, and was launched from the surface after being elevated from its underground silo. Titan II was the second-phase operational system. It incorporated all-inertial guidance, noncryogenic propellants which could be stored internally, a higher-thrust second stage, and heavier warhead, which could be launched from within its silo in a highly invulnerable underground installation. The advanced Titan clearly offered notable advantages, both technical and operational, over earlier missiles. The tandem configuration was more compatible with the planned silo launch and hardened operational sites. The all-inertial guidance enhanced dispersion and thereby increased survivability from surprise attack. Development of the ablation-type nose cone reduced missile weight, permitting a larger warhead. The more powerful single-booster first stage and independent propulsion system in the second stage permitted complete separation of the first stage as a unit. Development of noncryogenic propellants which could be stored in the missile simplified the whole process of maintaining the missile in a readiness state in its silo, reducing critical reaction time.

As with the Atlas, testing of the Titan missile proceeded from the simple toward the complex. All subsystems were thoroughly tested before their incorporation into the airframe, and the whole system was put through a rigorous "captive" test series in the Martin Company's "backyard" test facility located at its Denver plant. As airframe contractor, the Martin Company was responsible for the installation, checkout, and operation of the airframe, the autopilot, and the propulsion components. Then, as each subsystem was added, having been first thoroughly tested by the subsystem contractor, the airframe contractor assumed responsibility for the entire missile configuration.



*Titan II, shown in Cape Kennedy test launch, improved upon Titan I in that it employs all-inertial guidance, storable fuels, higher-thrust second stage, and heavier warhead. It can be launched from within its silo, giving it extremely short reaction time.*

The scope and complexity of the test facilities required for such an extensive program stagger the comprehension. At the Denver facility alone were four test stands, two blockhouses, and a cold-flow laboratory, plus support equipment to supply liquid oxygen, helium, and water to the missile during the captive tests.

Captive testing on the Denver stands began in March 1958, and the first Titan research-and-development missile was fabricated, tested, and accepted by the Air Force in June 1958, only one month behind the original schedule. The first launch of a Titan I on February 6, 1959, met all test objectives, and was followed by three more successful launches. In spite of some failures during the last half of 1959, tests of the B Series, including both stages, powered by prototype engines, and carrying a dummy reentry vehicle, had been completed satisfactorily by February 1960.

Problems continued to harass the Titan program during the next year, but hard work paid off and there followed a period of heartening accomplishment.

On April 1, 1961, the Titan I and Titan II programs became separate developments. Early in the Titan program, responsibility for initial operational capability was transferred to the Strategic Air Command. An Operational System Test Facility was constructed at Vandenberg Air Force Base, Calif., but in December 1960 the failure of a hydraulic flow valve in the elevator system caused the missile to drop into the silo five times more rapidly than intended. The impact ruptured the fuel tanks, and the resulting explosion damaged the facility beyond economical repair (an example of how an otherwise insignificant component can negate an entire undertaking). The operational launch test program was moved to a training facility where the first successful operational test of the completely integrated Titan I weapon, its ground equipment, and facilities took place on September 23, 1961. Titan I was declared operational in April 1962.

The first flight test of a complete Titan II on March 16, 1962, also met all test objectives with impact in the target area. In a program of steady progress, a Titan II was launched on December 12 carrying an operational autopilot. A night launch was carried out on January 12, 1963, but failure of a sustainer engine marred the flight. On February 6 an all-Air Force crew launched Titan II, but again depletion of sustainer oxidizer caused impact a few miles short of target. By May 1963, however, an accuracy within less than two miles of target was achieved more than 5,000 miles downrange, with all systems performing as planned. Titan II was declared operational in June 1963.

With renewed interest in, and increased funding for, space projects in early 1961, a series of studies and recommendations made by the Air Force, the Department of Defense, and the National Aeronautics and Space Administration during the spring and summer of 1961 established the need for a second-generation standardized space-launch system. The Air Force version of such a system, designated Titan III, was designed around the Titan II missile with the addition of powerful solid-propellant engines which would form the first stage, with the Titan II missile becoming the second and third stages. This system would meet the requirements of all known and projected payload missions within the 5,000- to 25,000-pound range.

## The Minuteman

It might be said that the successful first flight of a Minuteman missile on February 1, 1961, was the culmination of all the previous composite of research efforts, management techniques, and industrial participation which had produced the earlier missiles. The idea of using solid, instead of liquid, propellants for rocket motors was not new. It had been considered at the time the Atlas was being conceived, but the concept was abandoned as impractical for the size missile then required to boost the payloads available for effective target destruction. The rocket pioneer, Robert H. Goddard, had experimented first with solid fuels, but turned to liquid propellants as the more promising for attainment of the high and sustained thrust required. The Germans, too, in their early experiments with the V-2 depended upon liquid propellants to achieve the long range desired, but they continued to develop the solid fuels for possible application to shorter ranges and smaller payloads.

When the Atlas missile was first conceived, the problems attendant upon solid propellants appeared insurmountable under the stringent timetable then scheduled. It was generally understood, however, that their use was feasible for short-range ballistic missiles, but their development would require an extensive research effort. It was not until the Air Force authorized the development of a second intercontinental missile (the Titan) in April 1955 and included in its directive the evaluation of all possible approaches to a

Tactical Ballistic Missile that it appeared justifiable to examine any and all technological approaches relating to such a development. The possible use of a solid propellant for the shorter-range missile was also stimulated by advances in other technological areas, such as warhead weight-reduction and improved guidance, as well as promising gains in metallurgy, chemistry, and high-temperature materials.

Admittedly, there were formidable obstacles to be overcome. Among them were how to obtain a specific impulse large enough for a missile, how to ensure stability in combustion, how to control the termination of thrust at the exact split second directed by the computer and inertial guidance, how to control volatility? And if these problems were solved, the certainty of obtaining uniformity in solid-propellant mixtures by production methods had not been demonstrated.

Consultation with experts in the field produced the conclusion that rapid advances in solid-propellant technology were possible and impending. With these assurances, and with the background of experience accumulated by having surmounted other "insurmountable" obstacles in previous missile development, the missilemen decided to undertake a comprehensive research program to include the development of higher specific impulse, a practicable means of thrust vector control, and improvement in mass ratio (increase in thrust, reduction in weight, increase in payload), a requirement which demanded drastic improvements in materials and design which would yield high-strength, lightweight nozzles, more favorable propellant densities, and improved volumetric loading efficiencies.

By early 1956 the Western Development Division briefed the Scientific Advisory Committee on its appraisal of solid propellants. In its report to the Secretary of Defense the Committee stated that the "Air Force presentation outlined an imaginative research program that would provide new basic information that could be used for subsequent optimization of the Navy's [Polaris] missile, or possibly even for the design of a solid-fuel ICBM." The proposed program was approved, and the Western Development Division initiated feasibility studies and development programs with four contractors in April 1956. However, it recommended that responsibility for the programs be transferred to the Power Plant Laboratory at Wright Air Development Center of the Air Research and Development Command as soon as possible. By December it was concluded that

*Smoke ring created by silo launch precedes Minuteman missile as it takes off on 5,000-mile flight. Concept of concurrency development was epitomized in three-stage solid-propellant Minuteman; all stages and all systems worked perfectly in its first launch.*

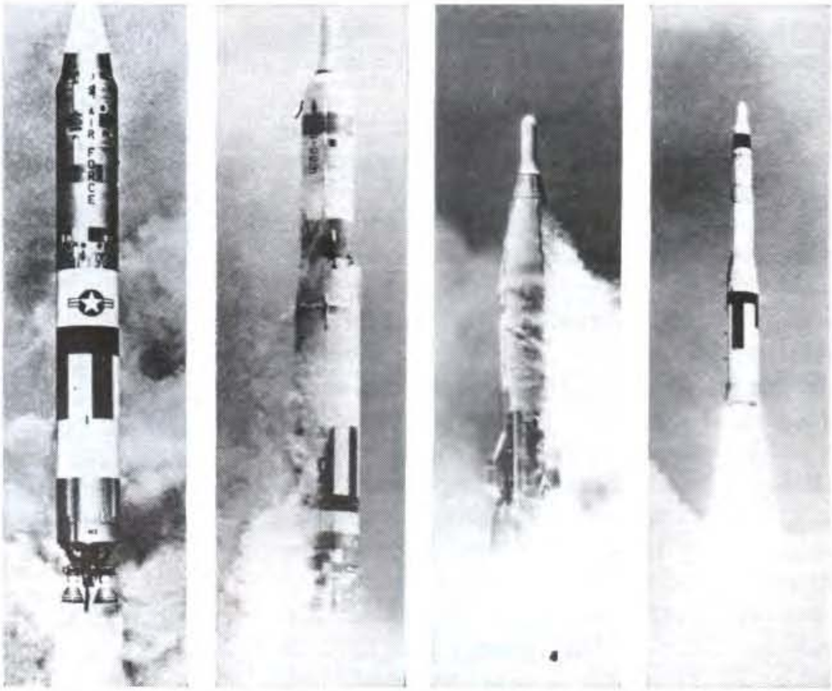
advances in solid-propellant technology had been so significant that a smaller, lighter, and more mobile weapon system was possible. The solid-rocket engine, without the complex gears, valves, and complicated plumbing that characterized liquid-fueled engines, was making rapid strides toward a simple, reliable, propulsive device.

The following March, Air Force Headquarters was ready to explore the many significant advantages offered by the solid-propellant rocket for IRBM propulsion, but funding difficulties were still a dominant factor. Among other things, Headquarters USAF asked Air Research and Development Command to furnish an estimate of the date on which development of a solid-propellant IRBM weapon system could be undertaken without undue interference with the initial operational capability of the Atlas and Thor weapon systems, a comparison of cost of operation of the liquid versus the solid IRBM, and information on which to base an estimate of the development cost of alternative designs taking full advantage of adapting or using existing components. Air Research and Development Command promptly passed on to the Western Development Division (renamed Air Force Ballistic Missile Division in June 1957) "responsibility for weapon-system planning and management for the solid-propellant IRBM."

By July Air Force Headquarters issued a formal requirement for a "quick reaction Short Range Ballistic Missile Weapon System employing solid or stable liquid propellant." Before the end of the year the Division had prepared a complete weapon system development plan for a solid-propellant missile which would not only meet the requirements for the IRBM but gave promise of becoming a "second-generation" ICBM as well. It would be a completely new weapon system employing all advancements in guidance, nose cone, and warhead areas as well as the new solid-propellant propulsion units. When Air Force Headquarters on February 12, 1958, directed submission of a definite program for the development of a solid-propellant weapon system "as soon as possible," the Division dispatched the first Minuteman Development Plan three days later. (Prior to this time it had been known as Weapon System "Q," but the name Minuteman, foretelling its state of constant readiness, seemed more apt.)

Minuteman was designed as a three-stage missile, whose airframe consisted of the solid-propellant rockets. Consequently, the results of engine development would decide the validity of the Minuteman concept. The first stage required a larger solid-propellant rocket engine than any yet produced; the second stage was of intermediate size; the third stage would be smallest and least costly to develop but possessed the greatest inherent response to improvements in weapon capability. Contracts for all three stages were

*The four Air Force intercontinental ballistic missiles developed under executive management of AFSC's Ballistic Systems Division pass in review in this composite scale photo. From left, they are the liquid-fueled Titan II, with longest range and payload of any US operational ICBM; Titan I, five feet shorter than Titan II; Atlas, the nation's first ICBM, and highly reliable launch vehicle for NASA's Mercury flights; and the solid-propellant Minuteman, barely half as long as the Titan II, but already the mainstay of USAF's missile deterrent strength.*



awarded in mid-1958, and by the end of the year all contractors reported satisfactory progress.

Another critical area was the research and development of the guidance and control system. While the accuracy and reliability of all-inertial guidance had been repeatedly demonstrated in the Thor, its application to Minuteman required further refinement and miniaturization of an already complex and highly refined engineering system. Contracts in this area and for the reentry vehicle design were also awarded by mid-1958. Other contracts were awarded for ground and handling equipment and for studies of thrust vector control of solid-propellant engine nozzles. But the most sought-after contract, for assembly and test of the completed missile, was not awarded until October 1958, with the Boeing Airplane Company receiving the award, based on the superiority of its competence and experience in the assembly and test areas. The contract called for "planning, studies, design, fabrication, component and subsystem tests, integration and coordination, system tests, evaluation redesign, documentation, and services as required to deliver complete missiles." Boeing was to confirm missile design, fabricate airborne and test-support equipment, assemble and check out missiles, and conduct ground, captive, and flight-test programs.

Meanwhile the Air Force had revised its earlier operational requirement to specify the intercontinental-range Minuteman which it defined as "an economical solid-propellant intercontinental ballistic missile capable of destroying any selected target," and calling for a quick-reaction solid or storable-liquid missile available in large numbers and in hardened configurations. Other objectives were simplified maintenance and operation, a high degree of reliability, and the best possible yield and accuracy, with availability hopefully set for sometime prior to July 1962.

Testing of the Minuteman components and subsystems proceeded generally along lines followed in earlier missile tests with the added capability of "captive" testing a full-scale missile. The test program was supported at various other Command centers. Missile flight testing would be done at Air Force Missile Test Center, Patrick Air Force Base, Fla., as had been the case with the earlier flight tests. The guidance system would be tested on the experimental sled at Air Force Missile Development Center, Holloman Air Force Base, N.M., which would also be the location of high-altitude environmental testing. And the Air Force Flight Test Center, Edwards Air Force Base, Calif., would provide the site of silo-launcher development testing, missile captive testing, and some specialized engine-static testing. The first firing of a full-scale solid-propellant missile of intercontinental range from an underground silo took place on September 15, 1959, at Cape Canaveral, Fla. The test missile contained a live first stage, only partially charged, a dummy second and third stages, and the missile was tethered by a nylon and steel cable to control impact. From these tests the compatibility and operational configuration of the silo were determined as well as the optimum type of flame deflector. By May 1960 the captive tests had accomplished their purpose and were terminated, although ten additional tests had originally been scheduled. Data gathered from these tests were invaluable in the design of the launch facility at Patrick AFB, where the first flight test was made on February 1, 1961.

As mentioned above, this test was a culmination of the many lessons learned from the earlier efforts at building intercontinental ballistic missiles. It was the first attempt to launch an initial ballistic missile flight with all stages and systems operating. The results were sensational. All stages worked perfectly, the guidance system performed accurately, and the instrumented reentry vehicle made a very near miss on a target some 4,000 miles downrange.

First attempt to launch from its underground silo simulating operational conditions ended in a spectacular explosion in August. However, damage to the silo was minor, and evaluation of telemetry data indicated premature ignition of the second-stage engine and not any inherent weakness in the silo-launch concept. This conclusion was verified in a November flight where a perfect flight resulted from an underground silo launch, a flight substantially duplicated the following month. By December 1962 the operational Minuteman took its place among the other ballistic missile sentinels. The successful execution of the Minuteman program gave increasing assurance that the end of the ten-year period of missile development would find the nation's deterrent capability no longer resting exclusively in the bomb bays of its manned aircraft, but also in the warheads of Minuteman missiles, concealed and protected in hundreds of silent but lethal underground silos dispersed across the vast breadth of the United States, ready to react instantly and decisively to any enemy threat. The missiles thus became full partners with the bombers in providing the nation's deterrent strength.

10TH ANNIVERSARY

## Chapter 10

# The Colossal Facilities Task

***Building the missile facilities complex, the sites, the command and control facilities, and all the rest has been compared in magnitude to construction of the pyramids of Egypt. But the comparison pales when the complexities of electronics, changing configurations, and need for protection are considered . . .***

ATTEMPTS have been made to compare the vast missile facilities construction project with other great building feats of history. One writer chose for comparison the building of the Khufu Pyramid at Gizeh, which Herodotus reported took 100,000 men and twenty years to construct. There is simply no common denominator of comparison between the two accomplishments. The Gizeh construction, according to Egyptian records, was done with slave labor, men working in eight-hour shifts, often under intense heat, with women standing by to fan them during rest periods. The stones were not cut with saws, but by the slow process of hand-drilled holes into which wooden pegs were inserted and the holes then filled with water. The subsequent swelling of the wood split the stones which had been floated on barges down the Nile River, in some cases 700 miles, unloaded, and presumably dragged up huge earthen ramps to as high as 480 feet. The stones were fitted, polished, and placed with such precision that engineers today find the base lines to be off no more than a quarter inch in 755 feet. In that day the Great Pyramid was one of the seven wonders of the world, but it is dwarfed by comparison with the gigantic undertaking of missile installations.

Nor do comparative figures have relevance to the lay reader. So many cubic yards of earth moved, how much concrete was poured, or tons

*The enormous job of building ICBM missile sites and launch facilities easily surpasses Egypt's efforts in erecting its pyramids, but size of construction project is secondary to the intricate specifications involved.*

*In our age, bulldozers, earthmovers, and cranes are taken for granted, but burly workmen came to respect very close tolerances demanded in different site configurations.*

*Blockhouse at Cape Kennedy seems to be of relatively simple construction, but besides safeguarding occupants it houses vast quantity of complex communications, telemetry, and surveillance equipment to assure complete record and evaluation of every aspect of missile test flight from the pad to downrange.*

of steel used, convey small meaning as to the magnitude of the two tasks. In our age bulldozers, earthmovers, cranes, and other mechanical extensions of human power are taken for granted. It is not so much the size of the holes dug, or the number of missiles installed, which determines the criteria for understanding the enormity of this task. The problem of missile installations was made infinitely more complicated because of the demands of intricate scientific and technical considerations beyond the mere physical construction.

As the missile program expanded, so did the problem of specialized installations, because each advanced type of missile demanded a specific facility to launch it properly. For example, the Atlas, as it advanced in series from Atlas-D emplacements at Vandenberg Air Force Base, Calif., to the Atlas-F at Schilling Air Force Base, Kan., over a period of several years, progressed through three operational missile configurations and many different site configurations. But this seemingly haphazard growth was not due to any lack of preliminary planning. Rather, it was conditioned by the threat to the nation's security offered by Soviet missile developments, a threat which it had been estimated would reach its most critical point in the late '50s.

Because Atlas was the first ICBM authorized for operational deployment, it was only to be expected that it would undergo the greatest evolution in development of its operational facilities. Although its planners had in mind from the beginning the type of Atlas which would eventually evolve, they could not wait for the final article. For example, the radio guidance used on the Atlas-D required highly sensitive ground-based facilities for its operation which in turn demanded a certain type of terrain. Therefore, technical considerations were the determining factors in the location and design of the installation. Because of these above-ground requirements, the installation was described as "soft." In other words, it was extremely vulnerable to attack.

As booster capability increased, it was possible to add more weight to the vehicle; likewise, the guidance system advanced to the all-inertial, which could be carried in the missile and was independent of ground-based equipment. These developments permitted underground installation, but the early Atlas, with its thin skin and flaring skirt, was not suited to the silo-lift type of launch, still less the in-silo launch. This latter type of installation had to await the later configurations of the two- and three-stage missiles with rigid structures and storable propellants, such as Titan II and Minuteman. Only then could the missiles be installed completely underground in "hardened" sites, practically invulnerable to anything except a near hit of considerable magnitude.

But that is an oversimplification of the many problems to be solved before such a goal could be realized. In the race for survival the "soft" bases had to suffice. As for some of the problems, there existed but very limited data on the environmental effects of high-yield nuclear weapons. Such effects as nuclear radiation, electromagnetic pulse, thermal radiation, ground shock, and air blast had to be considered in relation to missile installations. Such factors as levels of exposure, tolerance level of personnel, and needed shielding were unknowns.

By pooling the nation's brainpower in these many areas some answers were obtained, others could only be inferred; but basic decisions had to be made. The repository for most of the information known in this country on weapons effects phenomena, gathered from nuclear tests and many study contracts with universities and industry, was the Air Force Special Weapons Center at Kirtland Air Force Base, N. M. That Center worked very closely with the Ballistic Missile Division toward solutions of specific problems. Beginning in January 1960 all nuclear weapons effects research was funded by the Department of Defense Atomic Support Agency (DASA) which established a Weapons Effects Board, composed of different effects panels, to coordinate the research efforts of all the services. In addition, symposia were jointly sponsored by the Air Force Special Weapons Center and the Ballistic Systems Division (successor to the Air Force Ballistic Missile Division after the major reorganization of April 1961) which brought together experts in various weapons effects to compile and consolidate accumulated data and explore methods of protective construction. The installations as they finally evolved were based upon the composite of information obtained from these many sources and combined with that of the architectural engineers and construction contractors.

Another concept that affected the location and installation of the missile launchers was dispersal, both of geographical location and on a given base. But dispersal, too, depended upon such developments as the all-inertial guidance system and storable propellants, among others. With the early Atlas, several missiles were governed by the same ground-based guidance control facilities which required their reasonably close proximity. It was not until each missile could operate independently of all others that optimum dispersal tactics could be employed. As technology progressed through the advanced Atlas, Titan, and Minuteman, missile sites could be widely dispersed in isolated areas affording maximum concealment.

*German scientists who moved to US after World War II, shown here before test structure at White Sands, N. M., in 1946, helped develop launch facilities for V-2 rockets tested by Army, marking the beginning of missile site construction technology in the US.*

*Concurrency concept in site construction is demonstrated in this view at Cape Kennedy, Fla., where workmen are preparing railbeds leading from Titan III booster assembly area to launch pad, while the components of Titan III are still under development.*

As with the building of the missiles, the magnitude of the task of installation can only be fully realized by those who participated. It involved at least four major configuration and assembly contractors, twenty-five major associate contractors, 400 subcontractors, and about 2,000 small contractors and suppliers in a multibillion-dollar program. At its peak the program required approximately 700 "blue-suit" technical officers in addition to the large staff of the advisory organizations, Space Technology Laboratories and, later, Aerospace Corporation.

When planning the first ballistic missile sites, the experts were faced by a myriad of interrelated factors. They knew they were lagging behind the Soviet missile capability which posed a threat never before experienced by this country. This fact spurred them into a highly compressed time table. In this race with time the first site configuration was designed to meet that threat and comply with the requirement for an operational capability at the earliest possible date within the confines of the existing state of the art. Developed from knowledge obtained from test facilities at manufacturers plants and at the Atlantic Missile Range launching sites, the design placed the missile in a vertical position, each with a large gantry tower for maintenance and servicing. One guidance control station serviced three missiles, and the system then employed required a large, level land area. Construction of the initial installation began in the spring of 1958 and continued into the summer of 1959. As noted earlier, the first launching by a Strategic Air Command crew in early September 1959 marked the initial operational capability of the Atlas-D.

Primary objective of the follow-on design was protection of the missile and its related equipment from the elements. A horizontal launcher (the "coffin") was developed which permitted servicing of the missile while in a horizontal position, considerably alleviating the maintenance and servicing tasks. Advancements in guidance permitted simplified ground equipment and a considerable reduction both in the amount of land and the topographic limitations of the previous guidance system. This facility, also constructed at Vandenberg Air Force Base, Calif., was built primarily to meet the operational command's training requirements. Additional similar installations were built at Warren Air Force Base, Wyo.

Availability of the all-inertial guidance system permitted the combining of the launch operations building and guidance station in a single structure. It was now economically possible to "harden" the installation, but since funds were limited to those available for the "soft" or unprotected sites, the resulting design provided protection only to a limited degree. The coffin-type missile housing was sunk to ground level and the operations center was completely underground.

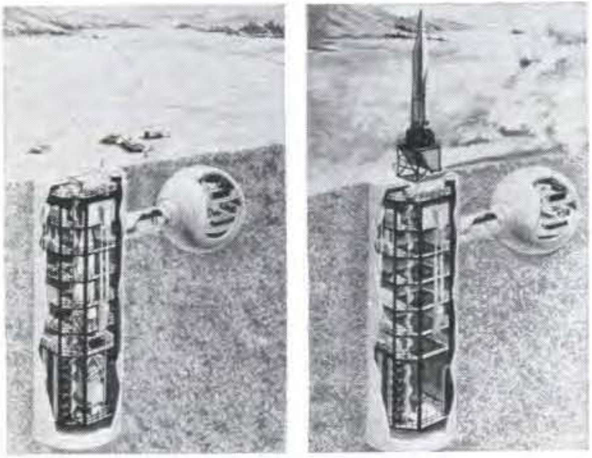


*Illustration shows principal features of hardened Atlas silo with underground spherical blockhouse. At left, maintenance, checkout, and fueling operations are carried out underground in the silo; at right, the Atlas has been raised and engines ignited.*

*Unlike Atlas sites, each of which stores its own missile fuel, groups of three Titan I launchers are served by a central tank, while portable tankers fuel Titan IIs. Here construction begins on the still more advanced fuel storage system for the new Titan III.*

By mid-1960 studies were completed and design criteria determined for a more advanced, improved operational Atlas configuration of increased size and capability. Data were now available from the 1958 Operation Hardtack nuclear tests, and Atlas-F moved to an underground silo with greatly increased hardness levels and reduced surface exposure time.

The construction effort, like the missile program, was made more complicated by the fact that several missiles were "in process" at the same time and their site installations also had to be provided concurrently. While the Atlas concept evolved from soft to semihard to hard-type installations, the Titan was originally designed to fit into a hardened silo. As originally designed, each Titan launcher was to have a fuel-loading system similar to the Atlas. (All Atlas and Titan I missiles used a highly volatile and explosive cryogenic propellant which required an immaculate propellant-loading system.) With advancements in propellant development, however, first operational installations were designed with a centralized fuel tank serving three launchers with fill and drain lines running through interconnecting tunnels to load and unload the missiles. With Titan II, as we have seen, the on-board storage of propellants made possible a faster countdown and simplified installation construction. All required tankage could be above ground and portable.

All of these advancements, stupendous as they were, were leapfrogged by the Minuteman. With the successful utilization of solid propellants, the Minuteman could hide in its lethal lair like a shotgun

*Mockup launch control facilities, accurate in all essential details, are employed by Air Training Command in preparing airmen and officers for launch crew assignments. Whenever modifications are made in operational systems, ATC mockups must follow suit.*

shell, ready for instant firing. The operational launcher could be unmanned, underground, and hardened to withstand the surface burst of a nuclear weapon. Each launcher housed a single weapon and the equipment necessary to support and fire it, and required only periodic maintenance. The missiles could be fired individually or in salvos of any number at a moment's notice. They are to be found in mountains, in deserts, and in prairies, standing "at the ready" to ensure the security of the nation.

Today the nation's arsenal of intercontinental-range ballistic missiles includes some forty squadrons of Atlas, Titan, and Minuteman missiles in sites stretching from Plattsburgh, N. Y., to Marysville, Calif., and from Abilene, Tex., to Spokane, Wash., encompassing a total area of more than 100,000 square miles. The enormity of the task accomplished may be comprehended when it is realized that at most of these locations there was constructed what was essentially a compact, underground city with built-in atmosphere, water, power, fuel, access roads, and communications.

This monumental achievement is a testimonial to the tightly integrated team which brought it to fulfillment. In the early stages of ballistic missile development the entire operation was directed by the Ballistic Missile Division of Air Research and Development Command and the Ballistic Missiles Center of the Air Materiel Command. In 1960 complete responsibility for activation of these sites was assigned to BMC, from initiation to the point of turnover to Strategic Air Command. The Army Corps of Engineers as construction agent established the Corps of Engineers Ballistic Missile Construction Office located in close proximity to the other agencies (Atlas-D and -E sites had been constructed by District Offices in their respective areas). At each location a highly qualified Air Force officer was "hand selected" as commander of the Site Activation Task Force (SATAF). Through all stages of planning and construction the Strategic Air Command, as the operational command, and the Air Training Command, responsible for certain aspects of crew training, were in continual consultation with the other agencies. Following a major reorganization in 1961, all site-activation responsibilities were assigned to the new Ballistic Systems Division of the Air Force Systems Command.

While the construction of the various missile sites was by far the largest financial outlay of the ballistic missile program, mention must also be made of the considerable financial investment in other facilities, an investment shared by industry. Across the nation a whole new complex of industrial and military resources for research, development, production, and testing was created. These included facilities for producing liquid and solid propellants, and electronic guidance and control systems; entire factories were built for individual missile airframe systems and propulsion units; vast test complexes arose for testing rocket engines of over a million pounds thrust and captive test of full-scale missiles; not to mention the far-flung ranges with their complicated and extensive systems for tracking and controlling the flight tests of the various missiles. When the Atlantic Missile Range requirement was established, some people thought the Air Force was "way out in the blue," but as it turned out it was barely ready in time. Total investment in government facilities for the ballistic missile program is estimated at around $2 billion, to which figure industry has added another $200 million. Total costs of the ballistic missile program have been estimated at approximately $17 billion.

*Indicative of new complex of industrial and military resources developed to meet missile program's research and testing requirements is this tracking camera recording a Titan II launch at Cape Kennedy.*

10TH ANNIVERSARY

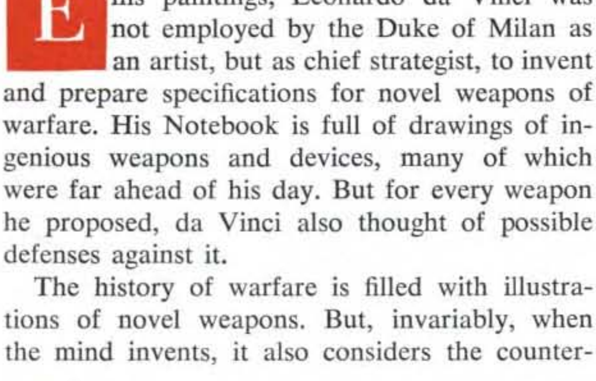
## Chapter II

# Preserving the Delivery Capability

***Since the dawn of warfare, against every offensive system there has eventually been developed a defense. And despite obvious difficulties in a hypersonic age, this will probably be true of the ICBM too—a fact which the Air Force and its sister services are keeping well in mind as they look to the future . . .***

EVEN though he is best remembered for his paintings, Leonardo da Vinci was not employed by the Duke of Milan as an artist, but as chief strategist, to invent and prepare specifications for novel weapons of warfare. His Notebook is full of drawings of ingenious weapons and devices, many of which were far ahead of his day. But for every weapon he proposed, da Vinci also thought of possible defenses against it.

The history of warfare is filled with illustrations of novel weapons. But, invariably, when the mind invents, it also considers the counterpart: What can the enemy do to circumvent this? Even a great breakthrough like the atomic bomb does not long remain the monopoly of the inventor. Nor is it long until offense is matched by equally effective defense. In its initial stages the ICBM, with its fantastic speeds and long-range striking power, was regarded by some as the "ultimate weapon." But even then men of science, though they admitted that great difficulties must be overcome, predicted that a ballistic missile defense could be evolved (the anti- or AICBM).



*Even a great breakthrough like the atomic bomb, originally a US monopoly, did not remain so long. At the time of the 1948 US nuclear tests at Eniwetok, the monopoly-shattering Russian demonstration of a nuclear device was but a short year away from display.*

Now that the nation has moved further into the ballistic missile age and has acquired a tremendous residue of scientific and technological skill in the services, in industry, and in scientific and academic institutions, the point has been reached at which defensive capability is beginning to overtake the offensive capability of the earliest operational ballistic missile.

Nor is the Nike-Zeus performance record the only basis for this statement. The Soviets have themselves been quite vocal as to the strides they have made in the AICBM field. Khrushchev has boasted that they now have the capability of shooting most of our reentry vehicles out of the air before the trajectory threatens a Soviet target. Lest his remarks be dismissed as empty boasts, there is supporting evidence of intense USSR interest in this field.

Of course, both military men and scientists fully realized that the establishment of a ballistic missile striking force did not ensure permanent retention of its role as a defender of the

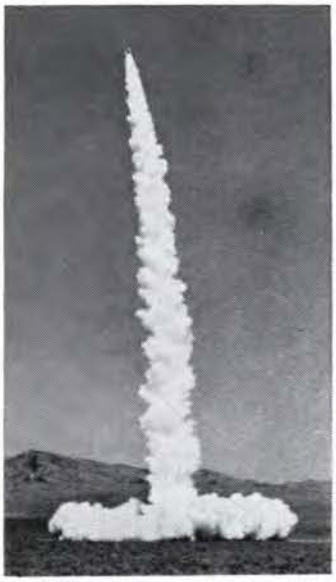
*Soviet boss Nikita Khrushchev, pensive in his Kremlin office, has been vocal on Russian technological prowess, and has even boasted of a Soviet capability of being able to shoot down American ballistic missiles.*

free world once that force became operational. Science and technology move too rapidly for that. The missilemen were fully aware of the fact that a Thor, Atlas, or Titan are far from constants. Their effectiveness is only relative. Thus, as missile capability developed in the United States, the Atlas-E and -F followed the first operational "soft" installation Atlas-D; the Titan I "silo-lift" launch was followed by the "in-silo-launched" Titan II and by the second generation of still more advanced Minuteman with its superior quick response and great reentry capabilities. Therefore, as the ballistic missile program progressed from 1956 through 1958, the planners were increasing the emphasis on survival capabilities and also the ability to penetrate enemy defenses. As missile striking power matured into the 1960s, there was no longer any question of having produced some remarkable weapon systems in the fully matured Atlas-F, Titan II, and Minuteman.

*Potential significance of antimissile defense has been underscored by Army research-and-development efforts with Nike-Zeus AICBM. Here is a Nike-Zeus rising from its R&D launch site at Pt. Mugu, Calif.*

The building of a large ballistic missile capability, which included the complete systems of missiles, installations, and operational organizations, involved an immense financial outlay, an investment which meant that the country could not afford to permit such fine installations to sink into early obsolescence. Particularly is this true of the fully matured systems of Atlas-F, Titan I and II, and Minuteman deployed in greatly hardened, scattered sites which now, in large measure, provide the nation's deterrent force against a nuclear war. These installations need not become obsolescent for many years to come. The boosters, though improvements continue, are already capable of hurling effective payloads at enemy targets. More mandatory is increased sophistication of the reentry vehicles. In this aspect of the program, present capability might well be compared to that of the nation's bombers of an earlier day.

Aviation as an instrument of combat was born in World War I. Since the day of the Spad, both the types of planes and their capabilities have undergone enormous evolution. But bombers or fighters were not abandoned when one individual type became obsolete because of superior enemy capability in speed, altitude, range, or firepower. Rather, newer and better aircraft were built, using all the science and technology available in the state of the art. Similarly, ballistic missiles will remain in being a long time. While improved radar, better accuracy, and increased penetration capabilities will be developed, the enemy will be engaged in similar efforts, and the race will continue on both sides of the Iron Curtain. There is presently a massive capability in missilry, like the B-52 in its prime, but that area most likely to advance deals with the two aspects of warfare. On the one hand, simultaneous efforts will be made to improve our ballistic missile penetration capability as Soviet technology advances its detection devices and its AICBM ability to prevent destruction of its targets; and, on the other hand, this country will continue to develop



*Boeing-Air Force GAPA (ground-to-air-pilotless aircraft) program started in 1945 was an early effort to study interception problem, and antecedent of the later Bomarc program. Program was phased out after JCS decision to transfer short-range missiles to the Army.*

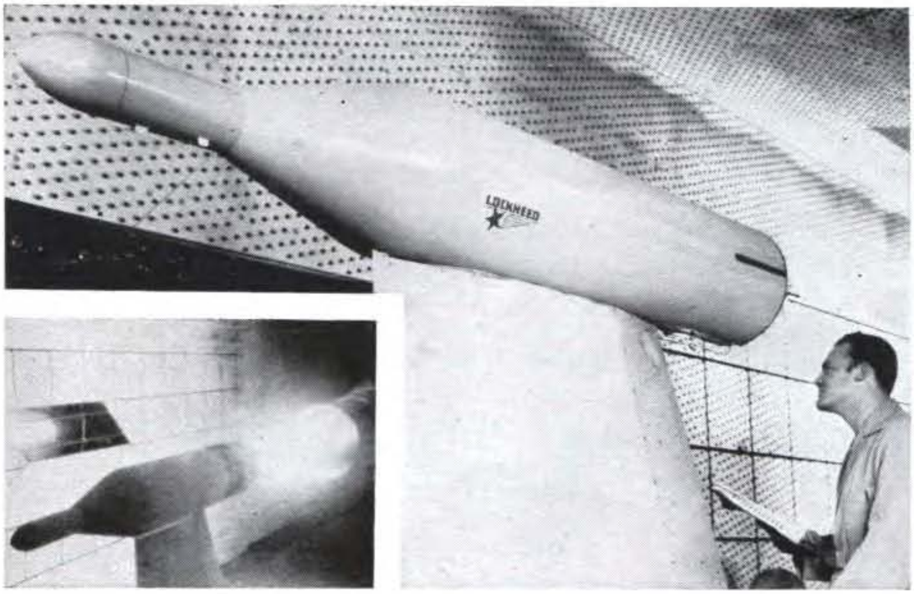
*A GAPA firing at Alamogordo, N. M., in 1953. Photo shows angled takeoff of supersonic research vehicle, capable of reaching speeds of 1,500 mph. But the GAPA was never placed into production.*

the AICBM capability already notably advanced through joint working relationship with the Army's Nike-Zeus program. As our AICBM capability advances, we will, at the same time, improve our penetration aids. The more that can be learned about shooting an enemy ballistic missile out of the air, or even a number of missiles fired simultaneously in salvos, the greater will be our knowledge in developing techniques to neutralize their defenses. Thus, maintaining a current ICBM capability will be a continuing future problem.

Antimissile technology after 1945 grew quite naturally out of aircraft defense problems in the postwar years. In the late '40s, as we have seen, this country placed so much stress on the bomber that antiaircraft ground-to-air missiles were given a higher priority than ballistic missiles. The Navy's "Bumblebee" project to deal with *kamikaze* attacks affords a good example of the requirements. The Boeing-Air Force GAPA program in 1945 was another early attempt, until phased out by the Joint Chiefs of Staff decision which assigned short-range missiles to the Army. The V-2 firings during those years aroused General Electric to work on the "collision interception" of a ballistic missile. This project was known as the Thumper program and by June 1949 was merged with the Wizard program then under development in the Aeronautical Research Center of the University of Michigan. This was a fairly sophisticated program hopefully aimed at producing a prototype by 1955-56. As is common knowledge, out of this background came Boeing's Bomarc.

*Out of Boeing-Air Force studies, GE Thumper effort, Univ. of Michigan Wizard program, and other studies emerged the Bomarc program. At left, a Bomarc rises from a research site during a test run.*

The Army's strong emphasis on the development of an anti-ICBM capability has already been well publicized. It might be pointed out, however, that the development of Nike-Zeus and its ability to hit a target vehicle during reentry not only added credence to Khrushchev's threat but also indicated that our early reentry vehicles might become obsolete. By way of additional contributions, the Army program offered an excellent opportunity to observe problems in radar, computations, and target hits, and on the basis of that information to increase the fund of knowledge needed to improve reentry capabilities. Especially since 1957 the Nike-Zeus program has served in the double role of developing our capability to destroy incoming Soviet missiles while at the same time assisting in the development of penetration aids.



*Polaris, the Navy's submarine-launched solid-fueled nuclear deterrent weapon system, got some of its testing in Air Force labs. Left, a one-fifth scale model of the Lockheed-built missile is run through Propulsion Wind Tunnel at Arnold Engineering Development Center, Tullahoma, Tenn., during research investigations that helped decide nose-cone selection.*

In one sense the Army antimissile program serves as a war game for the study of ballistic missile reentry problems comparable to those encountered by our missiles when entering their terminal dive upon enemy targets. Through exchange of information, these data have been incorporated in the many contracts which have been launched to develop future penetration of target areas in the event of war involving ballistic missiles.

This nation's leaders, from the President on down, have not looked upon present ballistic missile installations as a kind of Maginot Line which now is completed and behind which the nation can bask in permanent security. Rather, top officials have recognized that the ICBM program is admirable for the present. The excellent installations and the advanced missile performance have far exceeded original expectations. But that is for today. What about tomorrow? Or 1967? Or 1970?

Keeping ahead of this program demands constant alertness to enemy capability and to possible obsolescence of equipment which has been outdated by technology. Of what use are superb missiles which can reach enemy targets with great speed and accuracy if the enemy can detect them in time to destroy them before they can carry out their mission? The propulsion system and other subsystems may be further improved from the angle of hurling larger payloads into the trajectory; however, the main field of emphasis, both on our part and that of the enemy, will be the improvement of target destruction by greatly improved and much more sophisticated penetration aids for the reentry vehicle.

The Air Force has been directed by the Department of Defense to devote considerable effort to updating the ballistic missile reentry program both for AF and Navy weapon systems and for the Navy Polaris. The Advanced Ballistic Reentry System Office (ABRSO) examines the enemy "threat posture" on a continuing basis to define our requirements and determine possible depar-

*Laboratory tests were only the beginning. Then followed pad launches from the Cape and crucial sea launches like the one dramatically shown here. Polaris is now an integral, significant part of national deterrent posture, aboard many missile subs.*

*Handle with care is watchword as technicians at White Sands Missile Range, N. M., join component parts of the Nike-Zeus nose cone in the missile assembly building prior to a research firing. Each section is handled separately and joined before firing.*

tures from prejudiced approaches. It is also engaged in very fundamental research in the physics involved in ICBM flight, the intrinsic signature characteristics to build up a reservoir of knowledge, and feasible means to improve reentry. Critical items are first tested on a reduced-scale model, and eventually on full-scale range tests, to study flight characteristics, radar backscatter, and the need for radar improvement to observe the newly created electronics problems.

Because this is both a scientific and a technological problem (to keep reentry systems ahead of enemy capability by observing, identifying, and computing how to destroy incoming reentry vehicles), the ABRSO, though directed from the Department of Defense, is heavily laboratory- and industry-oriented. Project Officers at Air Force Ballistic Systems Division direct the program, assisted by the highly competent Aerospace Corporation which provides them with systems engineering and technical direction. In fact, Aerospace Corporation reviews the entire program from the viewpoint of existing systems and its Nike-Zeus target vehicle experience in support of the Army. Strategic Air Command, Air Force Systems Command, Headquarters USAF, and the Department of Defense look over the shoulders of these organizations and constantly review what is being developed in laboratories in industry and universities.

One does not need to be cleared for military secrets to grasp some of the major problems involved in keeping penetration capability of missile systems ahead of defense capabilities. Nor is the enemy unaware of the main areas where advancement and breakthroughs will improve offense or defense. Thus, three areas are under intense study on both sides: the warhead itself, its defense by hardening, miniaturization, and ever-increasing yield for weight ratios; the reentry system is equally vital, as its size, shape, backscatter, and visual pattern are related to its contents, enemy identification, and possible destruction; and, finally, penetration devices, used both in existing reentry vehicles and in future, more sophisticated designs, are likewise potent factors in the reduction of the enemy's potential number of AICBM kills.

But the scope of the program goes even further. Systems analysis considers the total problem of missiles, tracking systems, computer techniques, and advances in radar capabilities. This is especially true from the angles of confusion or saturation of Soviet detection devices by means of sophistication and deceptive and reentry vehicles which would make it difficult to discriminate between the warhead and its penetration aids and which would disrupt calculations, thus depriving the enemy of sufficient time to destroy the warheads in their terminal dives. The future will doubtless reveal many kinds of deceptive measures on both sides.

One other factor of the ballistic missile program might be mentioned. Those responsible for keeping ballistic missiles current in their accurate delivery capabilities have also calculated the optimum expenditures for this many-sided program and have estimated that, with but a small added percentage of the original investment already made, the missile capability can be constantly improved and modernized mainly by this new emphasis on reentry systems. Instead of becoming obsolete in a few years, ballistic missiles will continue to be our main defensive deterrent force for a long time to come.

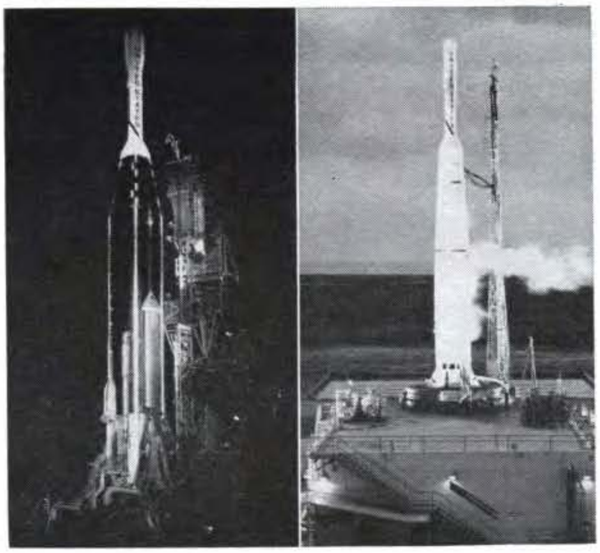
*A 1960 test firing of an early model Nike-Zeus from White Sands Range, N. M., with missile sent on an unguided ballistic trajectory. AF cooperated in tests.*

## Chapter 12

# USAF and Space

***The burgeoning missile power that was beginning to emerge from the USAF ICBM and IRBM programs by 1957 provided—when national policy finally gave the green light—a major boost to the national space effort. To missile planners, the crossover between missiles and space was obvious. They had spelled out space capabilities available from the missile effort long before Sputnik, but their voices were unheeded . . .***

ALTHOUGH the primary objective of the intercontinental ballistic missile program was development of a weapon system, mention should be made of its contributions to the space effort. The full treatment of the United States' role in space belongs to another story. This account relates only to ballistic missile technology in a supporting role, and describes how the massive missile capability, nurtured by science, industry, and the military, provided the point of departure for the programs now under the direction of the National Aeronautics and Space Administration (NASA).



*A night shot of Atlas-Able, carrying a lunar probe, on the Cape Canaveral pad, November 26, 1949* (left). *At right, ready for launch is Pioneer 5, which in 1960 set multimillion-mile distance record for space communications, relaying data from 17.7 million miles out. It was boosted by an AF Thor-Able.*

In February 1957, after the ballistic missile program was well on its way, and some seven months prior to the Soviet's Sputnik 1, General Schriever addressed a Space Flight Symposium on the implications of the ICBM development for the conquest of space. He pointed out that the ballistic missile program had created a highly competent industry-science-government team, many specialized facilities, and an enormous reservoir of industrial capability and production know-how.

The same system which would hurl a nuclear warhead over 5,000 miles to a predetermined target could provide the springboard for a whole gamut of follow-on projects. For example, the same rocket engine which could boost a heavy warhead to 25,000 feet per second could boost a comparatively lighter body to escape velocity into an orbital path around the earth. The same guidance system that enabled the warhead to reach its target with permissible accuracy would also be sufficiently accurate to guide a vehicle to the moon. These same propulsive and guidance components could also be used for surface-to-surface transport vehicles for rapid delivery of mail or strategic materials. At that early date General Schriever estimated that some ninety percent of the unmanned follow-on projects then visualized could be undertaken with the propulsion, guidance, and structural techniques then under development for the ballistic missile program.

Certain scientifically minded individuals in the

*On top of R&D responsibilities, General Schriever is veteran witness on Capitol Hill. Above, a Schriever post-Sputnik appearance before House space panel. Left to right, Rep. John McCormack, Democrat of Mass.; Rep. James Fulton, Republican of Pa.; Rep. Kenneth Keating (now Senator) Republican of N. Y.*

United States had been interested in space for many decades. The active interest of the Army, its Air Corps, and the Navy began with the World War II German missiles, especially the tests of the V-2. RAND had also continued its studies of earth satellites and reaffirmed their feasibility. But few people, outside the military, could see any compelling reasons for space exploration; and the military planners were in the same position with regard to space as they were at the close of World War I trying to anticipate the applications of aircraft to future military uses. General Schriever told his audience that several decades hence the important battles might not be sea, land, or air battles, but space battles, and that over the long term the nation's safety might depend upon achieving superiority in space.

General Schriever recently recalled those early efforts. "In space," he said, "I can recall pounding the halls of the Pentagon in 1957 trying to get $10 million approved for our space program. We finally got the $10 million, but it was spelled out that it would be just for component development. No system whatsoever. I made a speech in February of 1957 . . . on space. I pointed out that the work . . . done in the ballistic missile program would really create the foundation and the base for the US to move into space. The very next day I got a wire saying that from now on we were forbidden to use the word 'space' in any of our speeches."

This same taboo extended to all echelons. All references to space were ordered deleted from Department of Defense budget requests, and in the Air Research and Development Command Headquarters, for example, such seemingly innocuous titles as "Director of Astronautics" had to be changed to "Director of Aeronautics." But, as General Schriever went on to say, after Sputnik 1 in October 1957 to the end of 1958, he seemed to spend more time in the air traveling from the West Coast to the East Coast to "testify before Congress and talk to people in the Pentagon about why we couldn't do things faster to get on with space" than he spent in his office running the ballistic missile program.

*Low-budget Vanguard IGY program lagged behind Soviet effort, was dogged with failures. This launch June 22, 1959, from Cape Canaveral, failed to orbit as did all but three Vanguards. Policy choice to use nonmilitary boosters for IGY was unfortunate.*

*US got back into space race after shock of Sputnik, thanks to successful launch January 31, 1958, of Jupiter-C-boosted Explorer I satellite. Above, Army's Maj. Gen. John B. Medaris, Dr. Wernher von Braun, examine model of satellite and rocket before launch.*

*After the jolt of Sputnik, the White House directed the Army Ballistic Missile Agency to launch its satellite as soon as possible. And, happily, up it went. Explorer 1, launched from Cape Canaveral, Fla., on January 31, 1958, was boosted by a Jupiter-C, adapted from the Redstone missile designed by the Army team.*

The repeated disappointments this country suffered in its attempts to emulate the Soviet feat are well remembered. The reasons behind the failures may be more obscure. All three military services had made proposals for launching satellites. The Navy had begun studies in 1945, and the Army Air Forces study of 1946 has been mentioned, but there was little top-level interest in or support of any space efforts. The services, however, continued their campaign to gain approval of the proposals. In July 1955 President Eisenhower announced the intention of the United States, as part of its contribution to the International Geophysical Year, to launch a number of satellites without the use of military boosters. The decision that military rockets could not be used had been enunciated by the National Security Council the previous May and was in consonance with the President's doctrine of "peaceful uses of space." This restriction ruled out both the Army and the, by now separate, Air Force proposals, leaving the Navy's Vanguard program as the only one based on a nonmilitary vehicle. It also foretold the fate of the satellite launch attempt, since the Army's Redstone or Air Force's Atlas or Thor were the only high-thrust rockets that could conceivably become available during the period.

So the prestige of having launched the first earth satellite went to the Soviets by default. In the midst of the consternation aroused in this country, high government officials sought to minimize the Russian accomplishment. It was variously referred to as a "neat scientific trick," an "outer-space basketball game," a "silly bauble"; and even the further shock of the Soviet second launch of the 1,118-pound Sputnik 2 with a live canine passenger only one month later was billed as "no surprise." By the following January, however, the President, in his State of the Union message, admitted that "most of us" had underestimated the psychological impact of the Soviet feat upon the world and our ensuing loss of national prestige.

But the United States still was not in the race. Between Sputniks 1 and 2 the White House announced that the United States would not engage in a space race and that Project Vanguard would not be accelerated. First attempt to launch Vanguard on December 6, 1957, resulted in a malfunction which consumed the vehicle in flames. It was not until January 31, 1958, that Explorer 1, a thirty-one-pound, pencil-shaped, eighty-inch satellite, was successfully launched by the Army's four-stage Jupiter-C rocket. Its cosmic-ray and micrometeorite experiments, plus its discovery of the Van Allen radiation belts, were some consolation.

The studied surface calm belied considerable activity behind the scenes. A committee of eminent scientists was convened under the leadership of Dr. Edward Teller to suggest possible projects that would regain space primacy for the United States and recoup its international reputation. Its recommendation for a closely unified program was disregarded. Major reorganizational efforts were also under way to give increased emphasis to space programs. Of primary impact on the military space

*Physicist Dr. Edward Teller, shown here in White House ceremony, received AEC's Enrico Fermi Award for 1962. President Kennedy makes the presentation as Mrs. Teller looks proudly on. Dr. Teller has warned of Soviet technological efforts, has called for an increased astronautics program for the US.*

*As Vice President and as President, Lyndon B. Johnson has firmly supported a vigorous national space program. Mr. Johnson headed National Aeronautics and Space Council prior to succession as Chief Executive.*

program was the establishment in October 1958 of the National Aeronautics and Space Administration (NASA), which became the official agency for all exploratory and scientific programs in space. To these projects the massive boosters of the ballistic missile program have been large contributors.

During 1961 the space effort of the nation was reoriented. President Kennedy challenged the Soviets in a race to the moon, informing the world that this nation did choose to run. The Soviets subsequently announced their withdrawal from that race. Vice President Johnson called for a "fully cooperative, urgently motivated, all-out effort toward space leadership," and pointed out that "no one person, no one company, no one government agency has a monopoly on the competence, the missions, or the requirements for the space program. It is and must continue to be a national job."

That cooperative effort includes primarily, in addition to NASA, such government agencies as the Department of Defense, Atomic Energy Commission, and Department of Commerce, particularly its National Bureau of Standards and Weather Bureau. Universities contribute basic research activity and qualified scientists and engineers. Industry designs and fabricates boosters, spacecraft, launch facilities, and worldwide tracking stations.

*Air Force and National Aeronautics and Space Administration have cooperated in successful X-15 rocket-airplane program which has produced vitally needed data on high-speed, maneuvered reentry.*

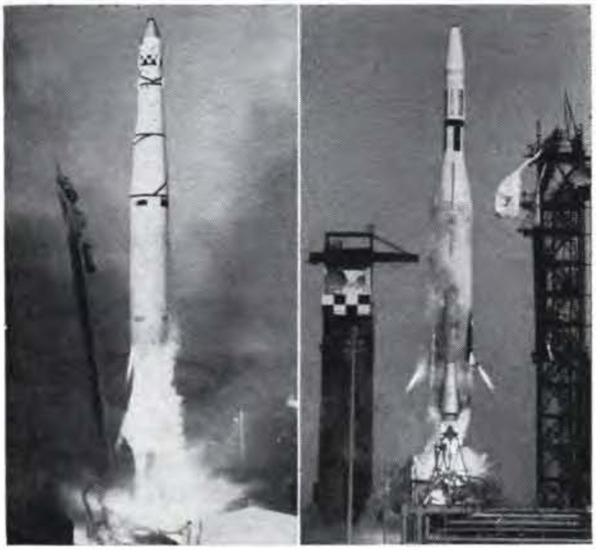
Such cooperative effort is not new. The National Advisory Committee for Aeronautics, the predecessor of NASA, worked intimately with the armed services from its inception in 1915. Its personnel made significant contributions, and it provided numerous specialized facilities; for example, extensive wind tunnels. The close association between NACA and the Air Force culminated in the remarkable X-15 rocket program, wherein the Air Force provided funding and contract management for such basic hardware as the airframe, engine, and guidance and control systems; while NACA (now NASA) provided the basic aerodynamic design for the vehicle and now supervises the research and experimentation program.

A system of interlocking management maintains continuing cross-fertilization throughout the space effort. At the highest level, the National Aeronautics and Space Council, whose chairman ordinarily has been the Vice President, includes in its membership the Secretary of Defense and the Administrator of NASA. Cochairmen of an Aeronautics and Astronautics Coordinating Board are NASA's Associate Administrator and the Director of Defense Research and Engineering of the DoD. This agency reviews major programs and coordinates budgets and support agreements. Several senior staff officers from the Deputy Commander for Space of Air Force Systems Command Headquarters join their counterparts in NASA's Office of Manned Space Flight in reviewing and managing the many program matters of common concern. Specialized personnel of various agencies are intermingled at the working levels. For example, the Space Systems Division of Air Force Systems Command maintains at NASA's Manned Spacecraft Center a detachment which manages DoD experiments to be flown on Gemini spacecraft. NASA has a specialist in aerospace medical research attached to the Air Force Aerospace Medical Division.

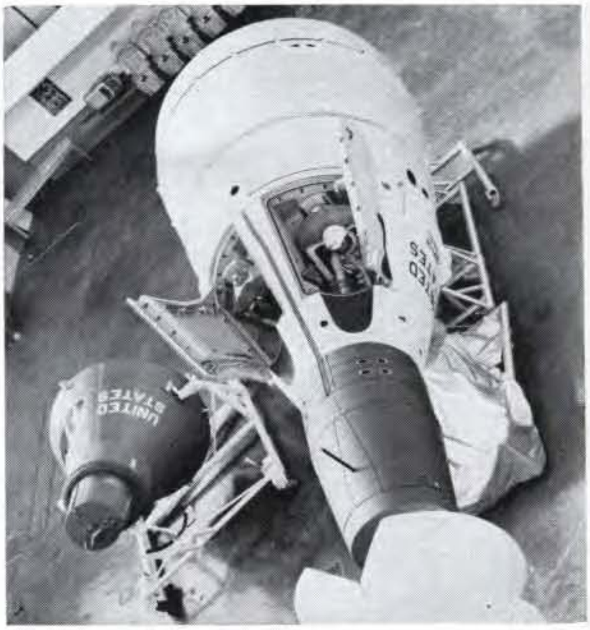
The effectiveness of this interplay is enhanced by the backgrounds of many of NASA's people, a substantial number of whom are former armed forces officers, or civilians formerly employed by the services. In addition, there are 262 active Army, Navy, and Air Force officers, from major general to captain, and including twenty-three of the twenty-seven astronauts, presently detailed to NASA to perform a variety of important tasks for which they possess unique qualifications. NASA has recently established a requirement for forty-eight more. There is also an interchange of use of facilities. To name them all would be too tedious. Suffice it to say, all Air Force agencies and facilities are giving maximum support to NASA space programs.

Mention has been made of the contributions of the Atlas-D to Project Score and the first manned Mercury flight. Ten Mercury flights were successfully boosted by the Atlas-D specially adapted to assure required levels of safety. The Thor-Able and Thor-Agena combinations successfully launched numerous exploratory scientifically instrumented satellites in the Pioneer and other programs, including Explorer launches. Thor also lofted the Transit and Tiros vehicles and the Echo inflated balloon which sought to establish new capabilities in communications and weather forecasting. August of 1960 was a banner month for space efforts beginning on August 10 when, after a Thor-Agena launch, the data capsule was recovered the next day from the ocean, the first such recovery of a man-made object from orbit.

The Air Force also furnished the Gemini launch vehicle, an adaptation of the proven Titan II, also extensively modified to ensure the extreme reliability associated with "man-rating." Air Force crews and facilities have also played an important role in the actual launching of many space efforts.



*Thor-Agena combination, left, blasts off carrying Air Force Discoverer 1 satellite, February 28, 1959. Atlas-Agena, which took Ranger 4 to crash landing on the moon, leaves the pad April 23, 1962. Agena spacecraft mounted on both Thor and Atlas missiles, modified for space jobs, have done yeoman service.*



*Space capsules, still not luxury sized, are growing larger, as witness this comparison between Gemini* (right) *and Mercury* (left) *on display at McDonnell Aircraft plant, St. Louis, Mo. Gemini spacecraft will weigh three tons, nearly double the Mercury craft.*

Military space programs are necessarily shrouded in security. However, the Department of Defense, which named the Air Force as its agent, has recently embarked on its most ambitious manned space program to date, an orbiting laboratory called MOL (for Manned Orbital Laboratory). This program seeks to provide an early, comprehensive evaluation of the military role of man in space. The MOL system will consist of a modified Gemini spacecraft mated to a pressurized "can" which is the laboratory. A Titan III will launch the system, capable of remaining in orbit for thirty days with a two-man crew. The Gemini will provide return to earth.

The Department of Defense is also committed to full support of the national lunar program. This program, by establishing specific, time-phased objectives, as was done in the development of the atomic bomb and the ballistic missile, will provide answers in an orderly fashion in a large area of common interest to NASA in furthering its mission of space exploration and technology and to the DoD in discharging its responsibility for ensuring national security. No one has a mastery of space, but we must acquire a proficiency there which will not only permit the exploration of that new environment but which will also ensure our capability to defend against any aggressive use of space. —END