

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 non-participants.

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



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.

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



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.

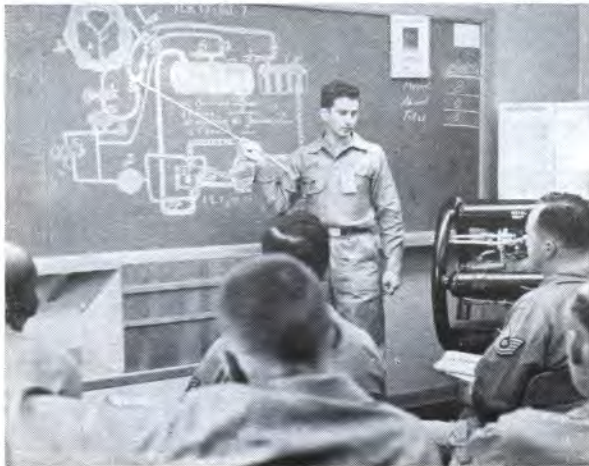


Since missiles don't come home like airplanes, all test data has to be extracted during short lifespan of vehicle in flight. Here, at AF Missile Test Center, Patrick AFB, Fla., specialist tracks flight using Fairchild Flight Analyzer, a camera resembling a helicopter.

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.

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



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.

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.

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



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.

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.

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



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.

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



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.

came back, but this time each wearing, a tiny halo.

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 ex-

change 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

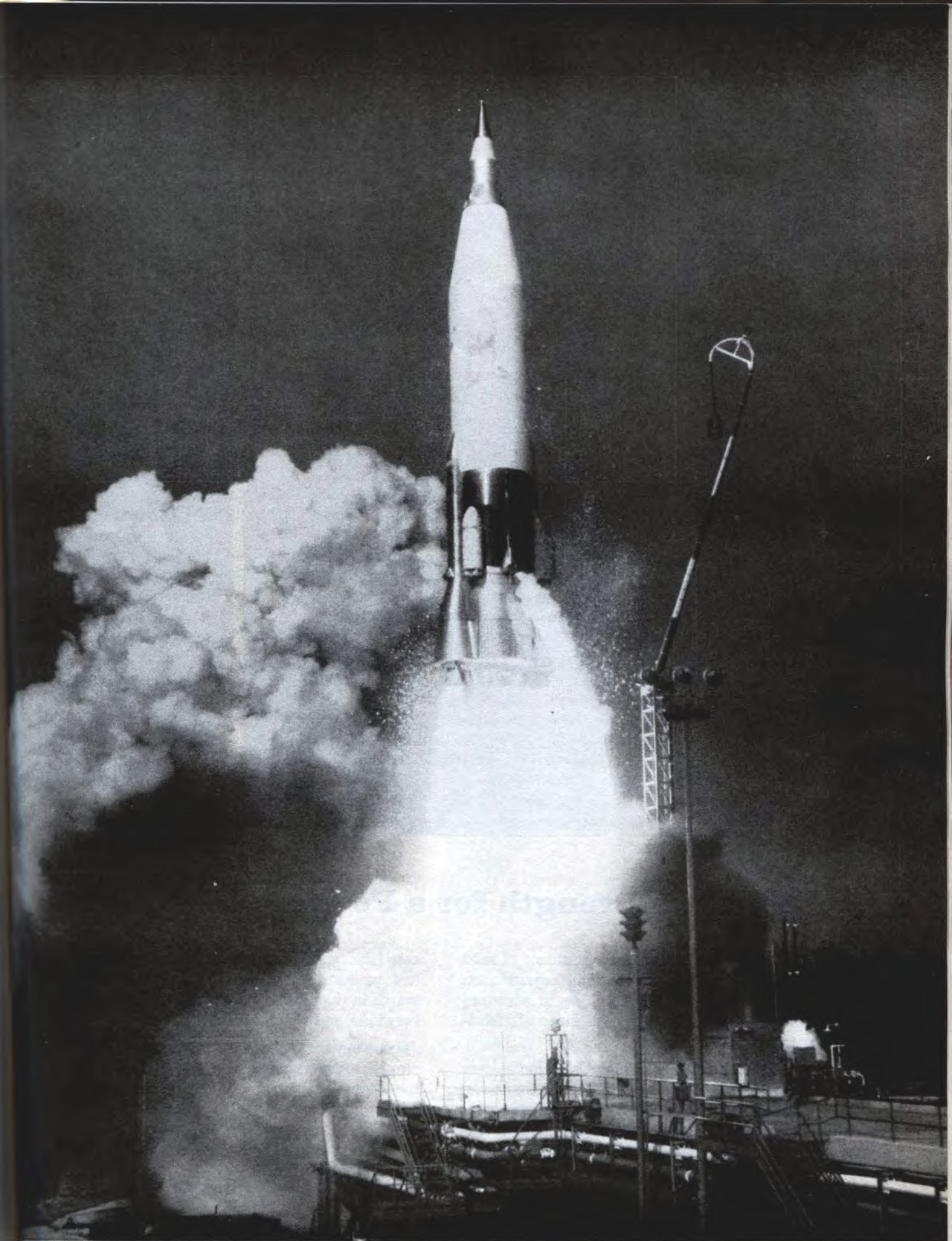
From the inception of the ballistic missile program, those in charge of its planning had a final goal or end product in mind. But they knew full well that they could only mount the ladder a step at a time. Because of the many technical problems to be solved, an operational missile

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 down-range. 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 down-range, 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



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.



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.

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.

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

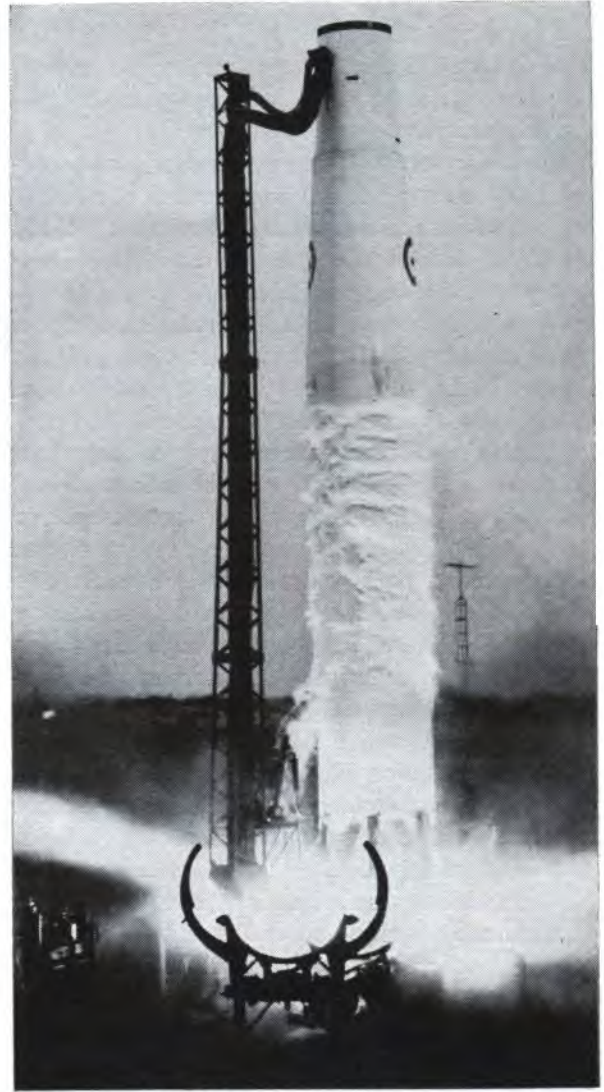
recovered within twenty-four minutes after impact. By the end of the year all research-and-development tests of the Atlas were completed, thus ending the five-year test program, but not the story of the Atlas. A spectacular chapter was written on May 15, 1963, when the Atlas (again a modified D Series) 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"



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.

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.

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,

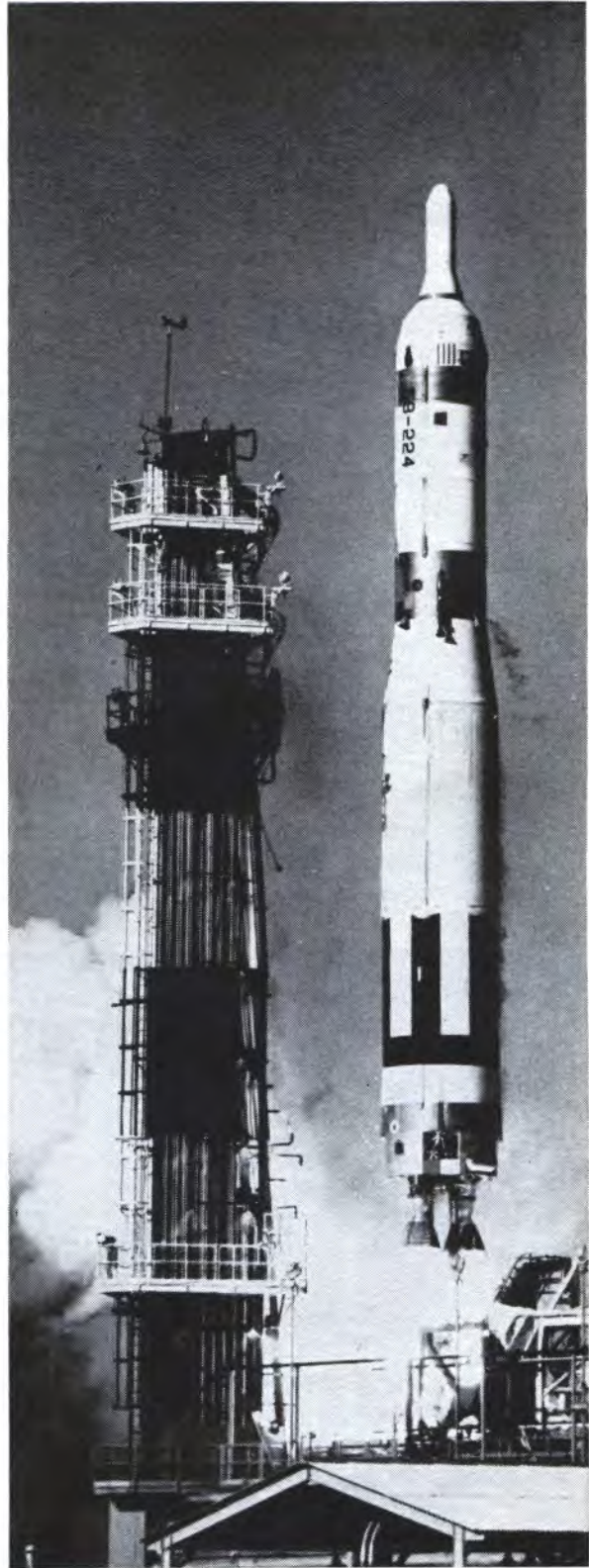
the all-inertial guidance system was added and the nose cone used toward the end of the five tests was separable. The next series of tests, begun in February 1958, was also comprised of five missiles which included all missile subsystems and a functioning reentry vehicle which, on some flights, carried 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,

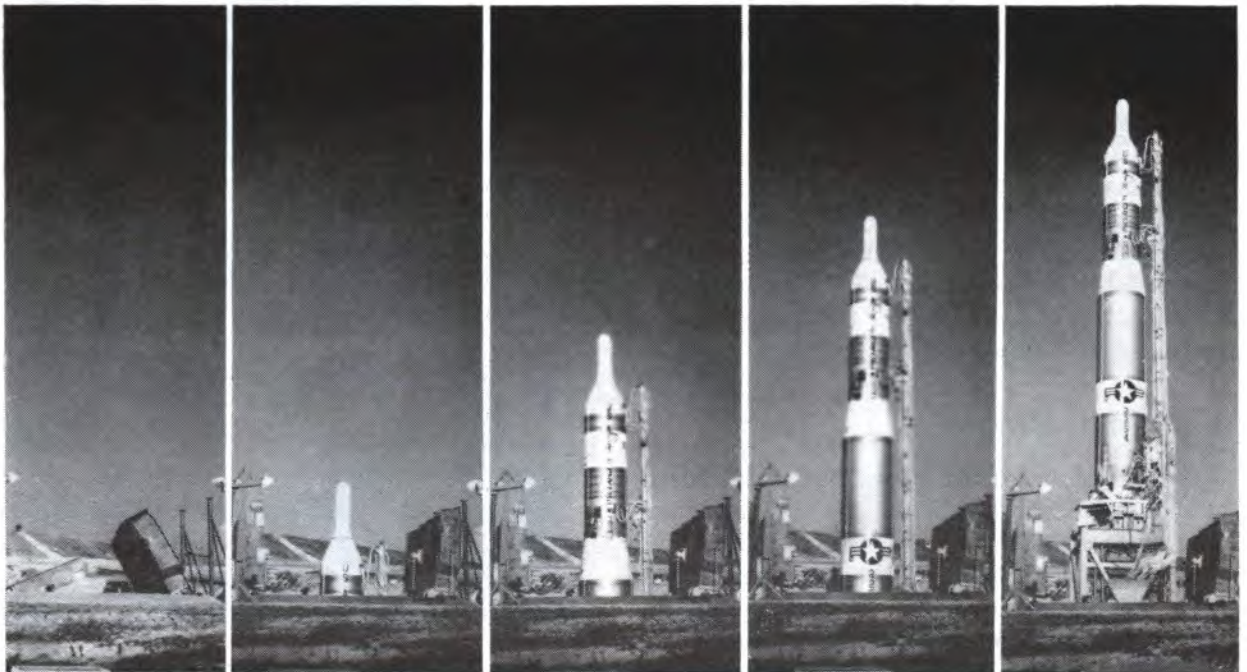
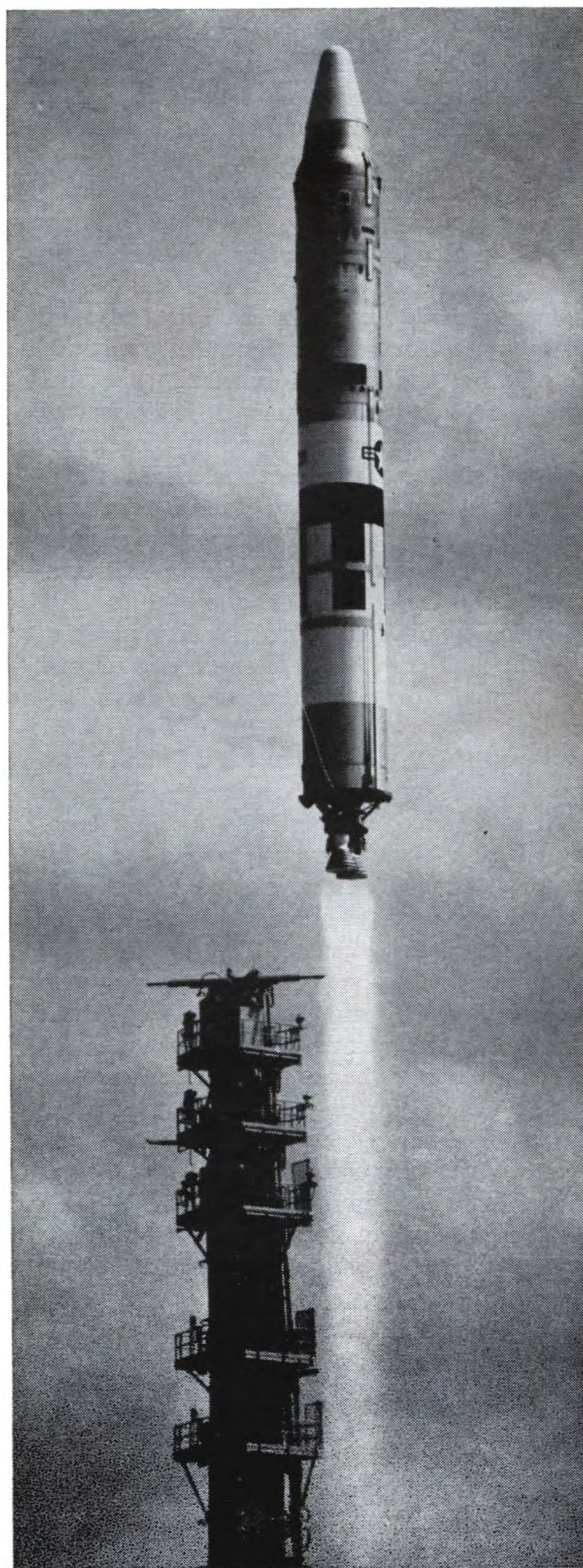


Photo sequence at Vandenberg AFB, Calif., shows Titan I from time launch controller initiates action until missile is ready to be fired. Two-hundred-ton doors open and weapon rises from concrete and steel underground silo hardened against nuclear attack. Fueled with refrigerated propellant, the Titan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

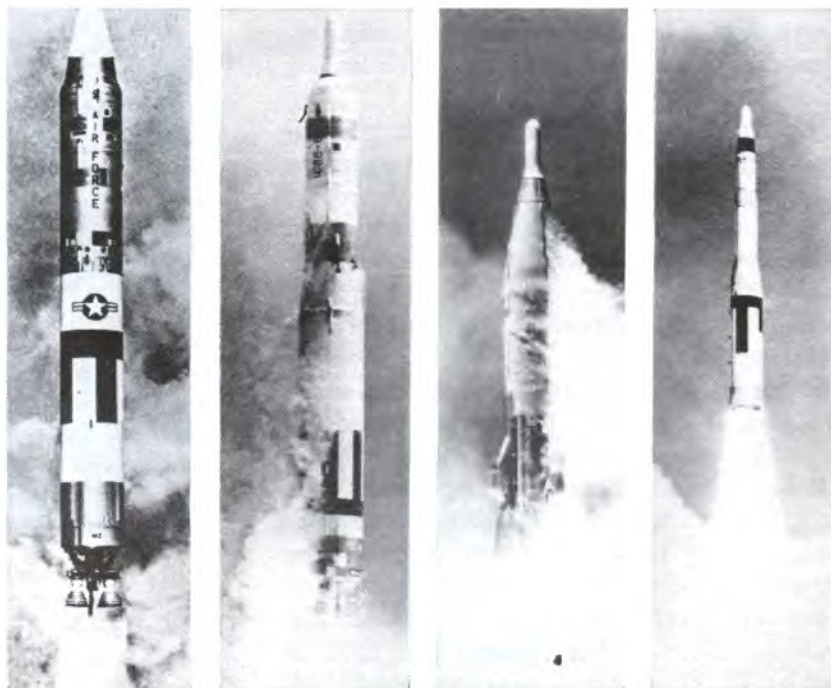
The following March, Air Force Headquarters was ready to explore the many significant advantages offered by the solid-propellant rocket for IRBM propulsion, but funding difficulties were still a dominant factor. Among other things, Headquarters USAF asked Air Research and Development Command to furnish 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.

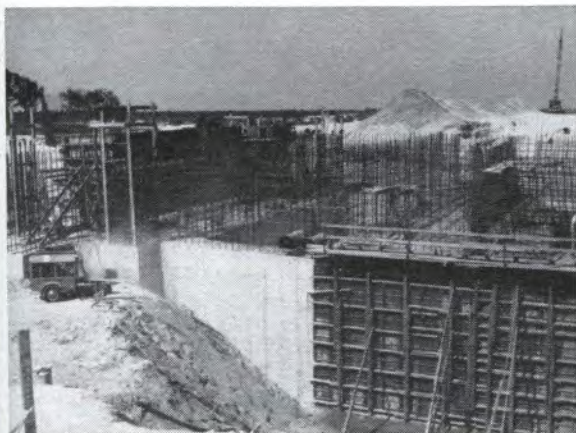
The Colossal Facilities Task

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

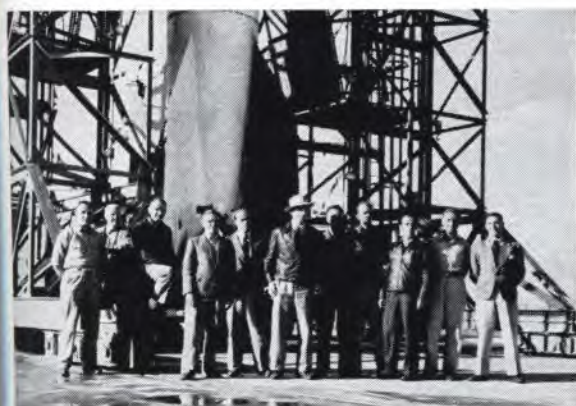


Concurrency concept in site construction is demonstrated in this view at Cape Kennedy, Fla., where workmen are preparing railbeds leading from Titan III booster assembly area to launch pad, while the components of Titan III are still under development.

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.

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 main-



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.

tenance 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.

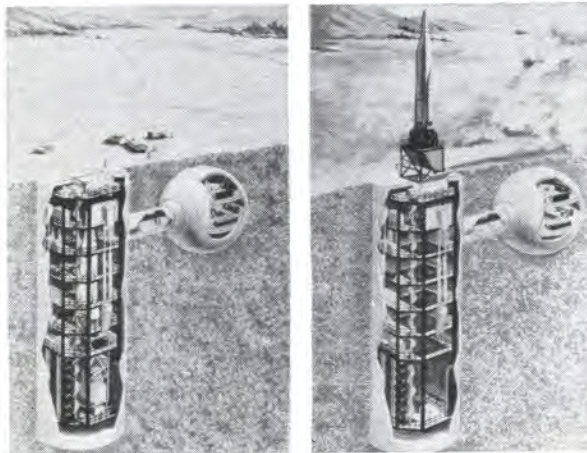


Illustration shows principal features of hardened Atlas silo with underground spherical blockhouse. At left, maintenance, checkout, and fueling operations are carried out underground in the silo; at right, the Atlas has been raised and engines ignited.



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.

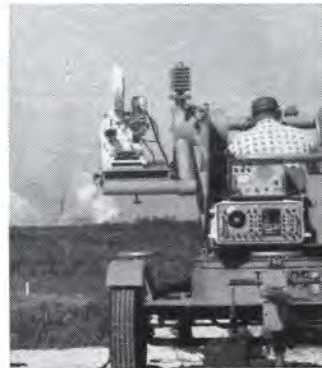
shell, ready for instant firing. The operational launcher could be unmanned, underground, and hardened to withstand the surface burst of a nuclear weapon. Each launcher housed a single weapon and the equipment necessary to support and fire it, and required only periodic maintenance. The missiles could 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 Bal-

listic 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.

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 counter-



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.

part: 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).

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



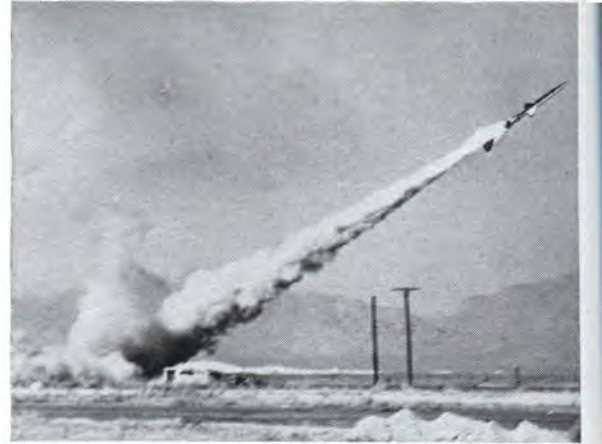
Potential significance of antimissile defense has been underscored by Army research-and-development efforts with Nike-Zeus AICBM. Here is a Nike-Zeus rising from its R&D launch site at Pt. Mugu, Calif.

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.

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 missilery, 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.



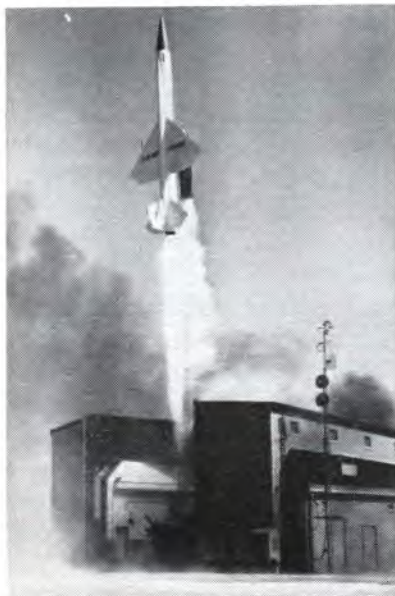
A GAPA firing at Alamogordo, N. M., in 1953. Photo shows angled takeoff of supersonic research vehicle, capable of reaching speeds of 1,500 mph. But the GAPA was never placed into production.

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.

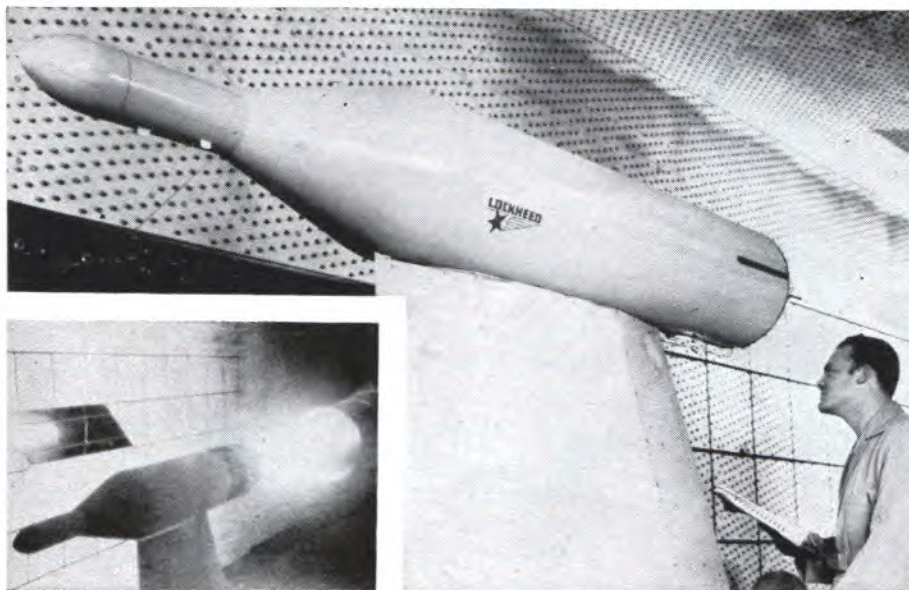
Antimissile technology after 1945 grew quite naturally out of aircraft defense problems in the postwar years. In the late '40s, as we have seen, this country placed so much stress on the bomber that antiaircraft ground-to-air missiles were given

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.

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.



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.



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 De-

partment 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 . . .

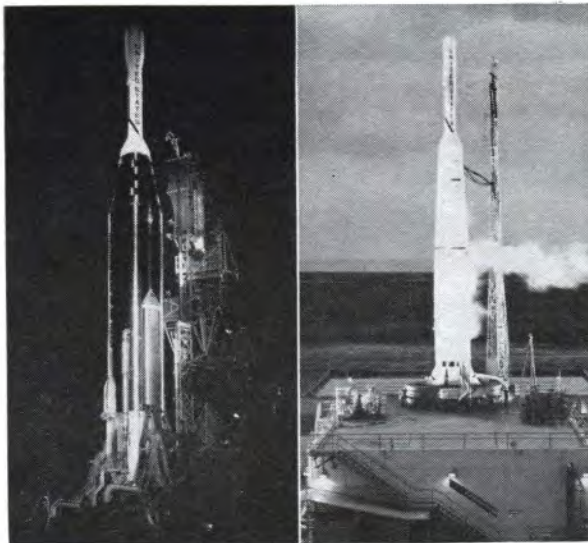
ALTHOUGH the primary objective of the intercontinental ballistic missile program was development of a weapon system, mention should be made of its contributions to the space effort. The full treatment of the United States' role in space belongs to another story. This account relates only to ballistic 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).

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



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.



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 mini-

mize 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.

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

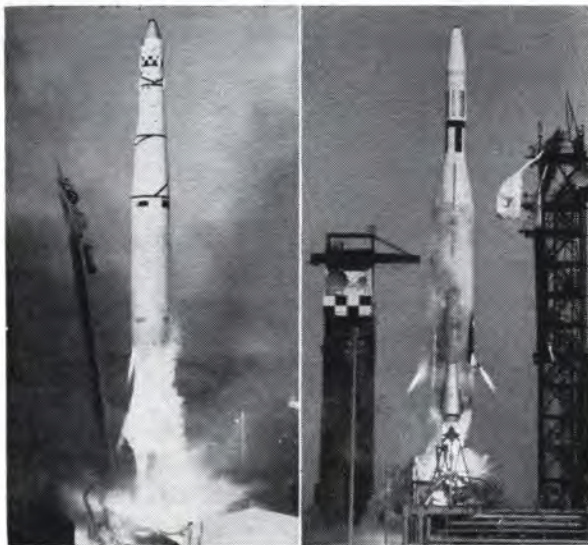


Air Force and National Aeronautics and Space Administration have cooperated in successful X-15 rocket-airplane program which has produced vitally needed data on high-speed, maneuvered reentry.

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