10TH ANNIVERSARY

USAF's Ballistic Missiles — 1954-1964

A Concise History

BY DR. ERNEST G. SCHWIEBERT

From the Author . . .

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

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

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

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

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

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

About the Author . . .

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

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

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Chapter 1

Dawn of the Missile Age

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

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

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

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

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

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

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

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

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

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

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Chapter 2

Scientists, Too, Are Fallible

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

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

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

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

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

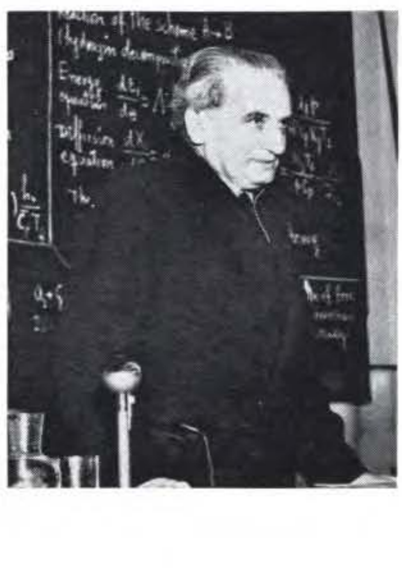
Wartime Air Force chief, Gen. H. H. "Hap" Arnold, was deeply concerned at war's end by demobilization and saw need for scientific study of strategic future.

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

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

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

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



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

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

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

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

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

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

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

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

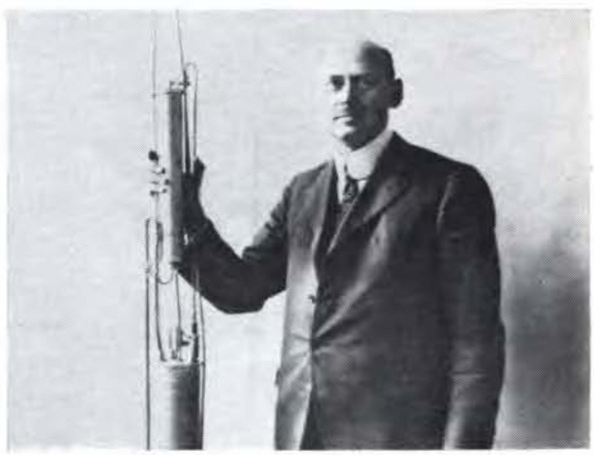
The same "Hap" Arnold who put the von Kármán group to work was the moving spirit behind the establishment of the RAND Corporation, a nonprofit organization staffed with the best available men in many scientific and related disciplines. As early as 1946 the Air Staff's Maj. Gen. C. E. LeMay called upon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

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

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

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

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



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

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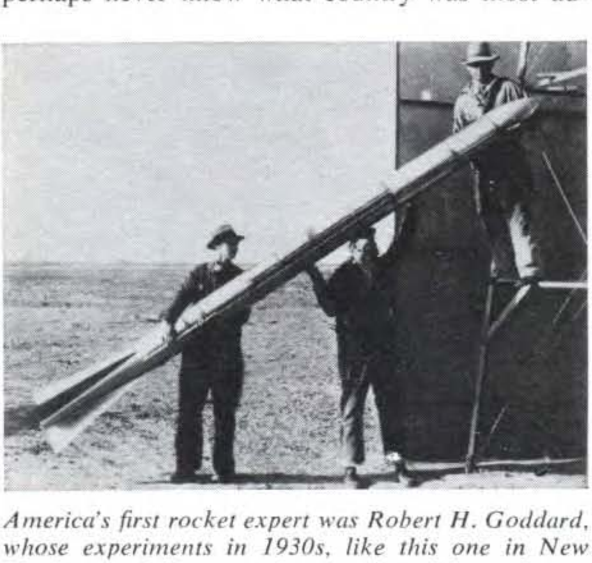
Chapter 3

Early Efforts Toward Missiles

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

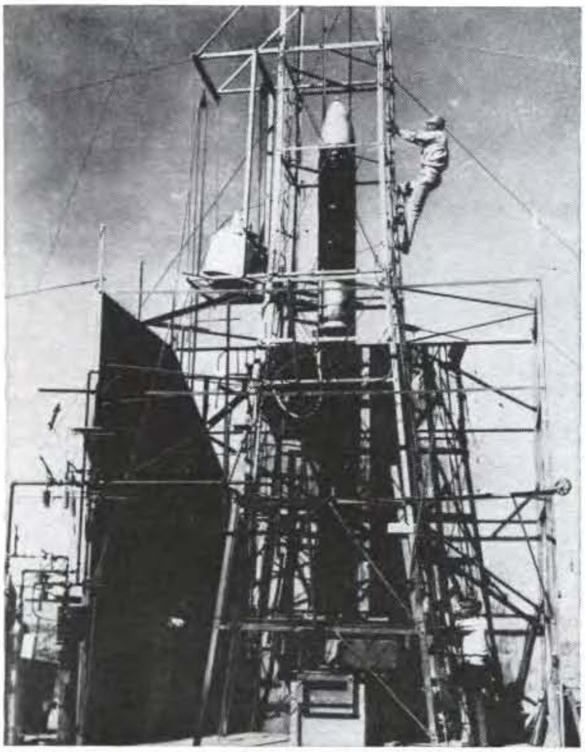
SEMINAL thinkers often live far in advance of their times. Leonardo da Vinci envisioned his flying machine centuries before science could build an engine which would have enabled his aircraft to leave the earth. Albert Einstein evolved the formula leading to the exploitation of atomic energy some three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

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



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

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



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

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

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

Exploiting the V-1 and V-2

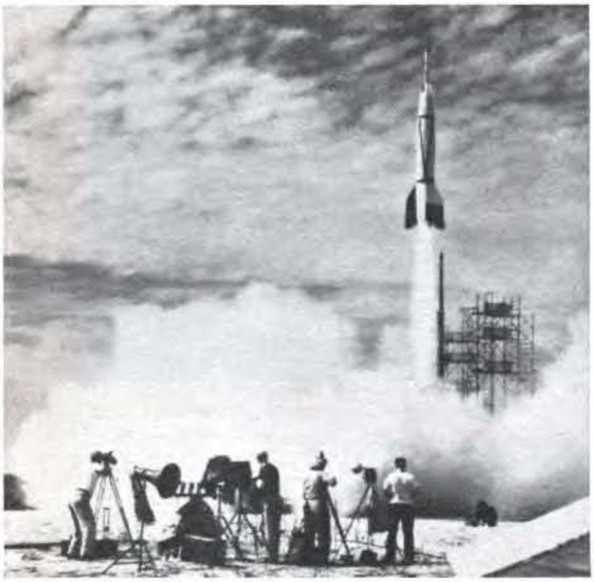
The story of our efforts to duplicate the V-1 and V-2 programs is also a dramatic one. Colonel Arnold, who was active in the V-1 program which had been assigned to the Air Force (the V-2 went to the Army), tells how we had optimistically entered into the program in the hope of turning the weapon against the Nazis. But when we tried to reproduce the weapons, we encountered all manner of difficulties, chief of which was that the missiles would not fly! A "Chinese copy" of a German V-1 became the United States' JB-2. Testing was performed at Eglin Air Force Base, Fla., but inferior components, lack of autopilot reliability, great launching difficulties, and the low priority accorded the program all contributed to failure to

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

get the JB-2s off the ground. According to Colonel Arnold we did learn something, if only what not to do. But the V-1s were never used against their inventors, nor against the Japanese as had been hoped. The program was, however, the precursor of the Snark, a pilotless, air-breathing missile.

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

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



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

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

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

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

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

First proposed in January 1946, the Snark sur-

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

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

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

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

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

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

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

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

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Chapter 4

Scientific Barriers to Missiles

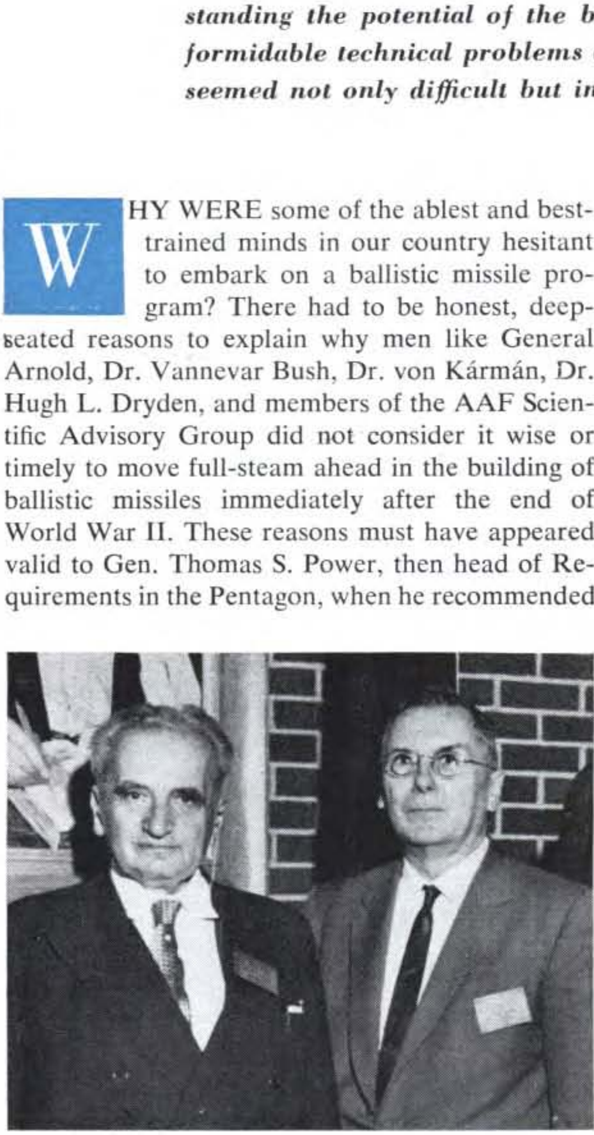
In the beginning there was a real "mental barrier" in the late 1940s that prevented the best scientific and military minds from understanding the potential of the ballistic missile. But there were also formidable technical problems associated with ballistic missiles that seemed not only difficult but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

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

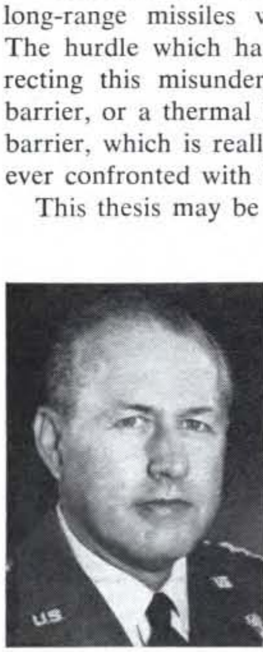
The climate surrounding the thinking of that day has been succinctly described as follows:

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

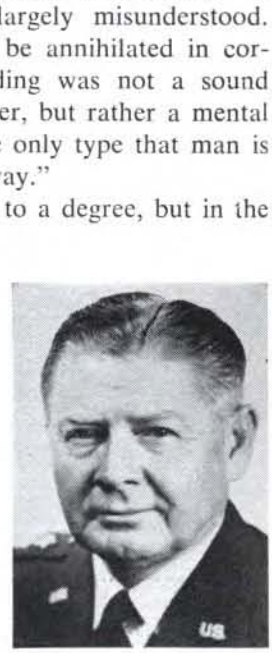
This thesis may be true to a degree, but in the



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



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



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

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

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

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

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

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

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

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

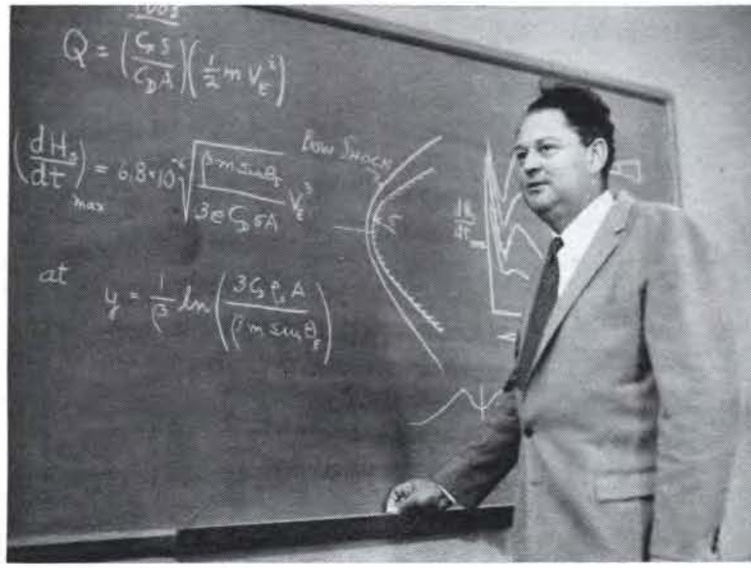
Although definite progress had been made in refining the atomic bomb since Hiroshima and Nagasaki, bomb weight was still a major problem. Dr. Darol Froman of the Los Alamos Scientific Laboratory has reminisced about those early days from a perspective of some fifteen years. He said the question most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

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

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

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

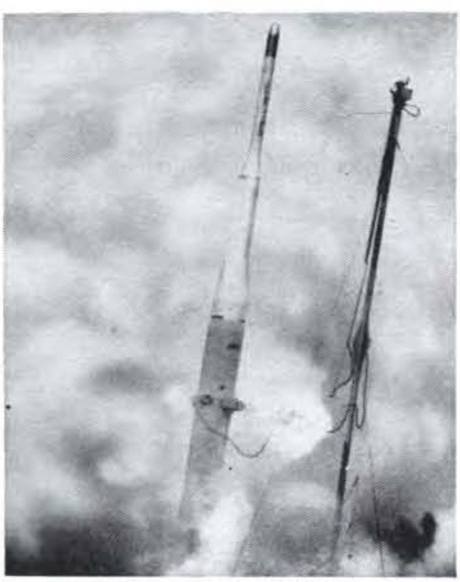
Development of nose cone to withstand terrific heat of reentry was a major problem. Wind-tunnel tests at Mach 20 conditions proved this configuration superior to spear shape.



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

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

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



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

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

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

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

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

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

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

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

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Chapter 5

The Great Awakening

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The 'Teapot Committee'

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

VON NEUMANN

WIESNER

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

LAURITSEN

KISTIAKOWSKY

DUNN

PUCKETT

RAMO

WOOLDRIDGE

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

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

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

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

10TH ANNIVERSARY

Chapter 6

The Rejuvenated Missile Program

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

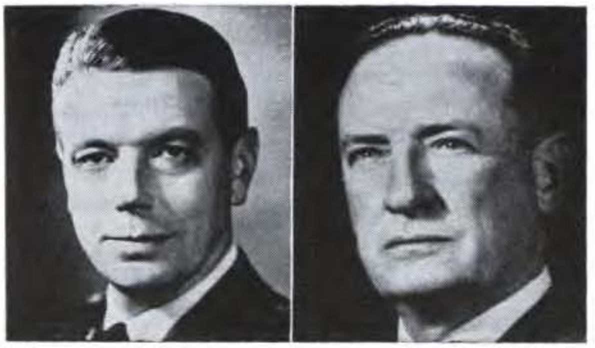
WITH the report of the "Teapot Committee" and the recommendations of Trevor Gardner on his desk, Air Force Secretary Talbott faced a very important decision. Was the danger to the nation critical enough to warrant such an unorthodox approach? Should he approve the proposed "quantum jump" in missile building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

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

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

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

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



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

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

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

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

How Schriever Was Picked

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

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

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

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

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

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

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

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

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

The Western Development Division

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

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

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

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

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

The Role of Ramo-Wooldridge

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Chapter 7

The Race With Time

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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