

DEVELOPMENT
OF
LONG-RANGE GUIDED MISSILES
1945-1959



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I. World War II	1
II. The 1945-1950 Period	3
III. The 1950-1953-Period	8
IV. The 1953-1959 Period	12

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I. WORLD WAR II



A. Policy.

During World War II, the United States did not place major emphasis on the development of guided missiles, mainly because other weapons systems appeared to be sufficiently effective to achieve Allied military objectives within the established time schedule.

The same conditions did not exist in Germany, where the need for more effective and cheaper bombing systems for attacks on a broad target like the United Kingdom resulted toward the end of the war in the development of the V-1 and V-2 -- both rather primitive in comparison with current guided missile concepts, but relatively effective when production costs are compared to damage inflicted and resources required for defense.

B. Programs.

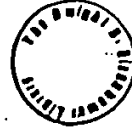
Although no major guided missile effort was undertaken during the war years, the 1941-1945 research and development effort of the military Services dealt with many of the component elements of future missile systems: (1) high-speed propulsion means (liquid and solid rockets, turbo and ramjet engines); (2) radar techniques (precision location and automatic tracking); (3) electronic fire control and bomb-sight systems (association of radars, computers, and servo-mechanisms); and (4) electronic components for severe military environmental conditions.

Numerous types of free rockets, both spin and fin stabilized, found extensive combat use. Rather limited employment was made of radio-directed glide and fin-control bombs, developed by both the Army Air Forces and the Navy. Pilotless aircraft and jet-propelled bombs (similar to the V-1) were also developed.

C. Management.

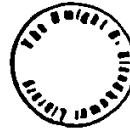
During World War II, each of the military Services carried on its research independently in accordance with its own mission requirements.

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To facilitate this research and effect some coordination, the Joint Committee on New Weapons and Equipment (JNW) was established by the JCS on May 6, 1942. On the suggestion of Dr. Vannevar Bush, Chairman of the JNW, a special Guided Missiles Committee was created on January 16, 1945, to recommend a national program and measures for better coordination of effort.

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ATOMIC ENERGY ACT OF 1954



II. THE 1945-1950 PERIOD

A. Policy.

Since no immediate operational requirements were anticipated during the early postwar years, the military departments initiated a broad investigation of the entire guided missile field but with no top priority projects. The accent was on research studies and test vehicles rather than on the production of operational missiles. Moreover, financial shortages made this approach the only realistic procedure.

On March 23, 1946, the JCS recommended the development of a broad research program in the field of guided missiles with special attention to be paid to basic scientific problems rather than the immediate development of new weapons systems. The research and development concepts to govern this program were stated by the JCS as follows:

"1. Emphasis will be placed on further basic information in both fundamental and applied science.

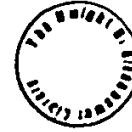
"2. Practical development is by far the most expensive part of the program. Consequently, practical development will not be rushed ahead of sound knowledge."

Among the studies undertaken at this time, long-range missiles did not carry a high priority. On October 26, 1949, the Joint Chiefs of Staff, on the basis of military requirements, placed surface-to-surface missiles in the last category -- after surface-to-air, air-to-air, and air-to-surface missiles. Among the 13 subcategories, long-range surface-to-surface missiles with atomic warheads held only eighth place.

B. Programs.

In accordance with approved policy, the military Services entered into broad research contracts with educational and industrial organizations during this period.

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In this broad research effort, almost all projects contributed to one another, particularly since the state of the art was not far advanced in the early postwar years. Substantial progress in the long-range missile field was largely dependent on the solutions developed for aerodynamic, guidance, and propulsion problems for missiles of shorter range.

Moreover, the lack of experimental data upon which to base decisions led inevitably to a multiplication of projects. These were reviewed again and again with the purpose of reducing their number, in view of the limited financial resources available. As a result, the total number of guided missile projects, which had amounted to 40 in July 1945, was reduced to 37 in April 1947, to 28 in January 1949, and to 16 missile projects plus 8 study projects in March 1950. These and separate Service reviews also brought frequent shifts in the objectives of programs.

In these circumstances, long-range missiles as such were usually thought of as eventual end products of research for shorter range missiles rather than as separate projects. Practically all of these long-range missile projects remained in the study stage, with only some of the components being developed for testing purposes.

Additional information on guided missiles became available with the transfer of about 100 V-2's and some of the German rocket scientists to the United States. In line with the established emphasis on broad research, these assets were used primarily to advance basic knowledge, particularly on removing the major shortcomings of the German missiles in guidance, range (200 miles), and reliability. (Of the 1,403 V-2's launched against the United Kingdom, 517, or 37 per cent, hit the London Civil Defense Region, an area of almost 700 square miles.)

1. Army. The most extensive of the Army's guided missile research programs in the immediate postwar years was the HERMES contract, initiated in November 1944 with General Electric. The objectives of the various subcontracts in the program were changed from time to time with the result that in June 1950 all that was left of the long-range surface-to-surface missile research was a ramjet propulsion study. Among the HERMES sub-programs dealing with missiles with a range of 1,000 miles or more were:



a. HERMES-B, initiated in July 1946 as a supersonic ramjet, 1,000-mile missile (B-1) and provided in May 1947 with an ultimate range of 1,500 miles (B-2). In May 1950, the B-2 study program was discontinued, and B-1 was changed from a test vehicle program to a ramjet propulsion research project. The obligations for HERMES-B through FY 1950 were \$2.5 million.

b. HERMES-C, which gradually developed into a program for a 500-mile missile and eventually into the 175-mile REDSTONE, started out in September 1947 as a project for a 3-stage missile with a 2,000-mile range. This original phase of the program, however, lasted only 1 month.

2. Navy. The TRITON program for a supersonic ramjet missile with a range of 1,200 to 2,000 miles was the outgrowth of the BUMBLE-BEE project initiated in 1945. The TRITON program was focused primarily on the expansion of the knowledge being gained by the development of TERRIER and TALOS. In June 1950, it was carried as a research and design study project, including exploration of the possibilities of guidance by reference to the earth's magnetic field. The obligations for TRITON through FY 1950 were \$4.1 million.

3. Air Force. At the close of World War II all previous work on guided missiles was canceled, new military characteristics were developed, and 26 study contracts were initiated. Five of these contracts concerned surface-to-surface missiles with a range of 1,000 miles or more. Three of these were terminated within a year, mainly because of shortage of funds; two of them were still active in June 1950, but on a reduced scale.

a. The three terminated contracts were:

(1) MX-772, with Curtiss-Wright for a subsonic and supersonic 500-to-1,500-mile missile. The contract was initiated in August 1946 and terminated in June 1947. Obligations totaled \$1.8 million.

(2) MX-773, with Republic Aviation for a 600 m.p.h., 500-to-1,500-mile missile. The contract was initiated in April 1946 and terminated in May 1947. Obligations totaled \$2.0 million.

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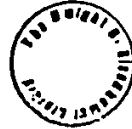
(3) MX-774, with Consolidated Vultee for a subsonic and supersonic 1,500-to-5,000-mile missile. The original contract, initiated in April 1946, was terminated in June 1949. Obligations totaled \$2.3 million. Three rocket test vehicles were constructed under the MX-774 contract and launched in 1948 providing information on the gimbaling of rocket engines for direction control; the design of lightweight, pressurized air frames; and the use of autopilots and command guidance.

b. SNARK. A contract with Northrop Aircraft, let on March 28, 1946, for study and research on a subsonic (SNARK) and supersonic (BOOJUM) "flying wing" missile with a range of 1,000 to 5,000 miles, including automatic celestial navigation. At the end of 1946 the subsonic SNARK study was canceled because of fund shortages, but reinstated as a development project for a 4,500-mile missile in October 1947. By February 1950 the procurement of 16 test vehicles (N-25) had been authorized. In March 1950 the JCS recommended, and the Secretary of Defense approved, the downgrading of SNARK to a "guidance system development" project with the N-25's to be used as guidance test vehicles. During the entire period, the supersonic BOOJUM was carried as a study project. The obligations for both projects through FY 1950 were estimated at \$22.3 million.

c. NAVAHO. A contract with North American Aviation, let on March 29, 1946, called for study and research of a 175-to-500-mile winged rocket missile (NAVAHO) with inertial guidance. In 1947 this contract was extended to include two follow-on phases for the development of a 500-to-1,500-mile and a 1,500-to-5,000-mile missile and 7 rocket test vehicles (NATIV) were authorized. In 1948 the project was redirected from rocket to ramjet for sustainer propulsion but retaining the rocket for booster purposes, and the range of the successive missiles was set at 1,000, 3,000, and 5,000 miles. In February 1950 a second reorientation, initiated to obtain an earlier delivery of missiles, shifted the project from surface-to-surface to air-to-surface missiles with ranges of 1,000, 1,700, and 5,500 miles; only the last retained an additional surface-to-surface capability. The obligations of the NAVAHO project through FY 1950 were estimated at \$26.0 million, including \$2.2 million for the 5,500-mile missile.

The possible use of atomic warheads was investigated by a special committee established in June 1949 at the request of the Secretary of Defense. Its proposals to establish close technical liaison with the AEC

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and initiate an intensive study in this field were approved by the JCS in December 1949.

C. Management.

The problem of effective coordination of guided missile programs was a matter of extensive discussion in 1945-1946 with the Army sponsoring 5 major programs with numerous subcontracts, the Navy backing 42 study programs, and the Air Force having entered into 26 study contracts.

A major change in centralized coordination was carried out on July 3, 1946, when the Joint Research and Development Board (JRDB), responsible to the Secretaries of War and Navy, replaced the Joint Committee on New Weapons and Equipment of the JCS. The Chairman of the old committee, Dr. Vannevar Bush, became head of the new agency, and the personnel, facilities, and functions, including the Committee on Guided Missiles, were similarly transferred.

On September 17, 1947, when the National Security Act of 1947 became effective, the JRDB became the Research and Development Board (RDB) in the newly established National Military Establishment and was made responsible to the Secretary of Defense. The assigned functions of the RDB included the allocation of responsibility for the conduct of specific research and development programs of joint interest.

Both the RDB and the JCS found it difficult to develop clear guidelines for the assignment of guided missile responsibilities, and the results of numerous reviews of guided missile projects proved unsatisfactory to the Secretary of Defense. A Special Interdepartmental Guided Missiles Board, composed of top civilian officials of the Army, Navy, Air Force, and RDB was established in December 1949 to recommend improvements in organization and reduce duplication of effort. One result of its report was the creation by the JCS on March 24, 1950, of a Guided Missiles Interdepartmental Operational Requirements Group.

7
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III. THE 1950-1953 PERIOD

A. Policy.

The outbreak of Korean hostilities in June 1950 brought a revision of guided missile policy. On February 2, 1951, the Joint Chiefs of Staff forwarded an approved program which based guided missile research and development on the assumption that the United States be prepared for a change from cold war to hot war prior to July 1, 1954. In general, long-range surface-to-surface missiles did not meet this prerequisite.

B. Programs.

Since the state of the art at the outbreak of Korean hostilities made it appear improbable that long-range missiles could become available by mid-1954, no special emphasis was placed on the development of such missiles. Additional funds, however, made possible the financing of additional research and the reinstatement of the subsonic SNARK as a weapons project.

1. Army. In June 1950, the only remnant of the Army's former long-range surface-to-surface programs was the ramjet study growing out of the HERMES-B program; research on this project was reduced in late 1950 and the study was terminated during the following year.

Important for the future development of long-range surface-to-surface missiles was the new emphasis placed in December 1950 on HERMES-C for the development, as soon as possible, of a ballistic missile with the greatest possible range, based on the V-2. This project, redesignated REDSTONE in 1951, started with an ultimate goal of a 400-mile range and a 150-yard accuracy. Because of increases in the weight of the warhead, the range was changed to 150 miles in April 1951.

2. Navy. The 1,200 n.m. TRITON continued to be carried by the Navy as a study project during the 1950-1953 period. The future of this missile, a member of the BUMBLEBEE family, depended to a large extent on the progress made on the aerodynamics, launching,

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ATOMIC ENERGY ACT OF 1954



and propulsion phases of other BUMBLEBEE missiles, such as TERRIER and TALOS. Studies specifically assigned to TRITON concentrated primarily on design and on mid-course and terminal guidance, with the latter providing the critical factor to be resolved before flight test programs could be justified. Obligations for TRITON for FY 1951 through 1953 were \$2.2 million.

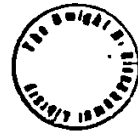
An additional project, capable of carrying out strategic missions, was started in March 1952, when the study program for REGULUS II was initiated. Conceived as a follow-up to the 500 n. m., subsonic REGULUS I, the successor missile was to have a maximum range of 1,000 n. m. and be capable of supersonic speeds. Total obligations for REGULUS II through fiscal year 1953 totaled \$9.4 million.

3. Air Force.

a. SNARK. During the summer of 1950, Northrop Aviation proposed to substitute for the 4,500-mile SNARK program and its 16 N-25 test vehicles a 5,500-mile super-SNARK to be operational in January 1954. As a result of this proposal, the Air Force reinstated SNARK as a weapons project during the fall of 1950 (approved by the Secretary of Defense in March 1951) and authorized the procurement of 65 super-SNARK (N-69) test vehicles during the following years. The 1946 study program for a supersonic version of the old SNARK missile, BOOJUM, was canceled in February 1952. Continued slippages, however, occurred in the SNARK program, and by the end of 1953 the date for research and development completion was expected to be not earlier than April 1957. The solution of the guidance problem represented the biggest stumbling block, and the September 1953 Keller report pointed out that, since SNARK was subsonic, "the time it becomes ready for operational usage assumes an important role in determining its ultimate value." Obligations for the SNARK program for FY 1951 through 1953 were \$207.2 million.

b. NAVAHO. With the outbreak of Korean hostilities, the NAVAHO program was accelerated on August 21, 1950, and reoriented from an air-to-surface missile to a surface-to-surface missile involving three phases: First, the development of an X-10 turbojet test vehicle, to be followed by a 3,500-mile experimental ramjet missile (XSM-64), and finally a 5,500-mile ramjet missile (XSM-64A) to be operationally available in 1959. During the 1950-1953 period, the construction of 13 X-10's

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ATOMIC ENERGY ACT OF 1954



and 5 XSM-64's was authorized and considerable work was undertaken on the development of launching rockets, improved ramjet engines, and celestial guidance systems. By the end of 1953, however, a slippage in the program of almost 2 years had occurred. In his September 1953 report Keller remarked that the 5,500-mile NAVAHO was "a promising, but long term approach with many technical problems still to be solved." Obligations for the overall NAVAHO for FY 1951 through FY 1953 were \$125.4 million.

c. ATLAS. As reports from industrial and scientific agencies pointed increasingly to the technical feasibility of using rocket propulsion in long-range missiles, the Air Force on January 16, 1951, established the ATLAS program (MX-1593) with Convair as the contractor for long-range ballistic and glide rockets. In September 1951, this study program was focused exclusively on a ballistic missile which, it was thought at the time, would require a 7-rocket motor to lift the 500,000-lb. vehicle. The September 1953 Keller report merely stated that ATLAS was "a highly complex and long term project still in the study stage." Obligations for ATLAS for FY 1951 through FY 1953 were \$5.0 million.

C. Management.

The increased urgency for operational missiles as well as the mounting impact of these programs on the Defense budget led to the appointment on October 24, 1950, of Mr. K. T. Keller as Director of the Office of Guided Missiles and special advisor to the Secretary of Defense on research, development, and production of guided missiles.

Mr. Keller, with a small staff, reviewed the plans and technical status of each major program and coordinated his recommendations with the established policy and review groups in the RDB and the JCS. He was successful in obtaining approval and funds for the establishment of production lines for some high priority missiles before the engineering evaluation had been completed (NIKE, TERRIER, and SPARROW) and for a major expansion of the flight test program.

Mr. Keller's office was abolished in the fall of 1953 at his suggestion. Reorganization Plan No. 6 of 1953, effective on June 30, 1953, had replaced the Research and Development Board with an Assistant Secretary of Defense (Research and Development) responsible

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ATOMIC ENERGY ACT OF 1954



for the development of policies and procedures for an integrated military research and development program. On November 12, 1953, the Secretaries of the military departments were authorized to approve guided missile programs in their departments. Mr. Keller's final report was dated September 17, 1953.

11
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ATOMIC ENERGY ACT OF 1954



IV. THE 1953-1959 PERIOD

A. Policy.

On June 16, 1953, the Secretary of Defense initiated a review of guided missile programs with emphasis on eliminating duplication. Originally carried out under the supervision of the Secretary of the Air Force, this review was eventually divided into two parts -- one dealing with the long-range projects SNARK, NAVAHO, and ATLAS assigned to a group of civilian scientists (the von Neumann Committee or the Strategic Missiles Evaluation Committee), and the other dealing with the remaining guided missile programs assigned to a group of Defense officials headed by Mr. Trevor Gardner, Special Assistant to the Secretary of the Air Force (the Special Study Group on Guided Missiles). The von Neumann Committee reported on February 10, 1954, and the Gardner Group on January 25, 1954.

The conclusions of the von Neumann Committee were strongly influenced by the increasingly certain prospect in late 1953 that a high-yield, lighter weight warhead could be developed. The reduction in payload made possible by this development greatly reduced the power requirement for rocket engines, and the new high-yield warhead eased guidance problems by considerably lowering accuracy requirements. Simultaneously, progress in materials research indicated that the high-temperature re-entry problems might now be solvable. As a result, time estimates for the availability of long-range missiles could be greatly reduced.

These prospects, in the view of the von Neumann Committee, appeared to justify greater emphasis on all long-range missiles, but indicated above all a redirection and subsequent high priority effort for the ATLAS ICBM program. This redirection was approved by the Department of Defense in February 1954, and the highest Air Force priority was assigned to ATLAS in May, after the CASTLE tests in the Pacific confirmed the feasibility of the new warhead.

Additional and disturbing information on the Soviet effort in the ballistic missile field led to a further review of the U.S. ballistic missile effort in 1955.

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The January 4, 1955, recommendation of the Air Force's ICBM Scientific Advisory Committee for the development of alternate solutions for all major ATLAS components was approved by the Secretary of the Air Force on April 28 and resulted in the establishment of the backup TITAN ICBM program later in the year.

A review of the ICBM program by the President's Technological Capabilities Panel (the Killian Report, dated February 14, 1955) concluded that planning should not count on having a militarily significant ICBM capability before about 1965, and that therefore an urgent effort be made to develop a 1,500 n.m. ballistic missile (IRBM) -- a project believed to be easier and more certain of success in a shorter time than the ICBM. It was also recommended that consideration be given to both land-based and sea-based versions of the IRBM.

Before these recommendations could be implemented, a determination had to be made whether or not sufficient technical capability existed in the United States to carry out additional ballistic missile projects without interfering with approved programs. Moreover, since the time element was the critical factor, special management controls had to be developed to assure the fullest use of available talent and the quick removal of possible financial or procedural roadblocks. These matters were given thorough consideration during the following months.

In response to the March 17, 1955, NSC request for comments on the Killian report, the Department of Defense, on June 2, 1955, concurred in principle with the Killian recommendations. Also mentioned were the extensive effort currently devoted to the ICBM program and the desirability of awaiting the outcome of current discussions with the United Kingdom concerning British development of an IRBM before undertaking a U.S. IRBM program.

A full briefing on ballistic missiles was given to the President and the NSC on July 28, 1955, and a week later, on August 4, 1955, the NSC requested the Department of Defense to determine by December 1 which of the five IRBM plans it desired to carry out.

As for the ICBM effort, the President directed on September 8, 1955, that "the highest priority above all others" be assigned to the ICBM research and development effort and that it be carried out "with

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maximum urgency," in order to guard against the achievement by the Soviet of an operational ICBM capability substantially ahead of the United States.

The development of land- and sea-based IRBM's, as recommended in the Killian report, was approved by the NSC on September 13, 1955.

On November 8, 1955, the Secretary of Defense (a) decided that the latent technical capability in the United States was adequate to undertake the development of an IRBM concurrently with the ICBM effort; (b) established a special management organization to accelerate review and approvals within the Department of Defense; and (c) determined that two IRBM development programs be carried forward -- one an Air Force program for a land-based version (THOR) and the other a joint Army-Navy program, having the dual objective of achieving an early shipboard capability and of providing a land-based alternate to the Air Force program (JUPITER).

The actions taken by the Department of Defense were approved on December 1, 1955, by the President, who directed that the IRBM research and development programs carry the same priority as those for the ICBM and that major conflicts between these programs be presented for Presidential decision.

The probability of obtaining both a land- and a sea-based IRBM missile out of the joint Army-Navy IRBM program became increasingly doubtful during 1956. Efficient performance aboard ships, particularly submarines, pointed to the desirability for the development of a less bulky configuration, a less hazardous fuel, and simpler logistics. As early as March 20, 1956, the Navy was authorized to undertake a weapons system feasibility study for a solid-propellant IRBM missile (POLARIS). During the late summer of 1956, a major advance in weapon technology, the possibility of a warhead 2/5th the weight of a JUPITER warhead, increased the prospect of resolving the special shipboard requirements. On December 8, 1956, the Secretary of Defense formally approved the POLARIS Fleet Ballistic Missile effort as a separate program, assigning it high Department of Defense priority. In February 1958, the POLARIS program was moved into the highest national priority category.

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Rapid progress in the development of THOR, JUPITER, and ATLAS ballistic missiles during 1956 and 1957 greatly lowered the requirement for aerodynamic long-range guided missiles, particularly since the operational availability dates for the latter had to be stretched out as technical difficulties were encountered in the development of effective guidance systems and sustainer engines. In these circumstances, the aerodynamic programs were in no position to compete for funds with the ballistic missile programs and were either terminated or radically reduced in size.

The prospect of substantial improvement in solid propellants, promising a less costly and much smaller missile, led to the authorization in February 1958 of a second generation solid-propellant, 3-stage ICBM, the MINUTEMAN. This program was given the highest national priority rating (DX) as a research and development effort on August 18, 1959.

B. Programs.

The urgent military requirement for long-range ballistic missiles, combined with uncertainty of eventual success in view of the many major scientific and technological problems still to be resolved, made it advisable in 1955 to establish two programs for the intercontinental as well as the intermediate-range ballistic missile. While this procedure was costly, it brought major benefits, particularly in overcoming difficulties through the exchange of information and in creating a competitive spirit that greatly contributed toward meeting the established schedules.

Only 3 years were required to bring the IRBM from authorization in November 1955 to operational availability in December 1958. The ATLAS ICBM, started in its current version in February 1954, became operational in October 1959 -- a period of about 5 1/2 years. A 4 1/2-year research and development effort is scheduled for the solid-propellant POLARIS and a 5-year effort for the MINUTEMAN.

While research and development for all these weapons systems was carried forward with maximum urgency, the operational goals were submitted to many critical reviews, and adjustments were made reflecting changing military requirements and the progress made in the development of improved or more advanced systems.

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Obligations for the long-range ballistic missile programs totaled at the end of calendar year 1959 \$8.3 billion.

1. Intercontinental Ballistic Missiles (ATLAS, TITAN)

As the result of the report of the von Neumann Committee on February 10, 1954, and with the approval of the Secretary of Defense, the Air Force reoriented and accelerated the ATLAS program in the spring of 1954 and established special management procedures. In December 1954, the decision on the basic ATLAS configuration was made, reducing the gross weight from 500,000 lbs. to 240,000 lbs. and the number of engines from 5 to 3 -- 2 booster engines and 1 sustainer engine. The major contracts were let in early 1955.

The development of an alternate ICBM configuration was recommended in October 1954 by the Western Development Division and in January 1955 by the Air Force's Scientific Advisory Committee and approved by the Secretary of the Air Force on April 28, 1955. After a thorough review of bids, the contract for the development of TITAN, a 2-stage missile, was given to the Martin Company on October 28, 1955.

With the highest national priority assigned to the ICBM by Presidential decision on September 8, 1955, a maximum acceleration of the development program was initiated. No major problems were encountered in 1956 and both the ATLAS and the TITAN programs remained on schedule. On March 28, 1957, the President approved an initial operational capability of eight squadrons, four for each missile, to be achieved at the earliest practicable date -- considered at that time to be March 1959 for the first ATLAS missiles.

During the summer of 1957 a thorough review of the ICBM programs was initiated to determine the best means to reduce excessively high costs. As a result, the TITAN priority was reduced, overtime restrictions established, the maximum monthly production rate lowered, and the operational availability dates for the 8-squadron program extended to the period between June 1959 and October 1962.

A reexamination of all U.S. ballistic missile programs was undertaken during the winter of 1957-1958, taking into consideration increased Soviet capabilities, as indicated by Sputnik I, and the encouraging

16
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results of recent test flights. This review brought an expansion of the ATLAS goal from four to nine squadrons with initial operational availability still scheduled for June 1959. As for TITAN, its former priority was restored on April 10, 1958, but the decision on the Air Force's recommendation to expand the TITAN program from four to eight squadrons was temporarily postponed pending a review of the need for an alternate ICBM program.

In the meantime, the research and development effort was continued with maximum urgency.

In 1957, the first three ATLAS missiles were launched, with the last missile achieving all test objectives. In 1958, an additional 13 ATLAS missiles were flown; 7 of these test flights were considered completely successful and 3 of the 6 partial failures were caused by the same turbopump difficulties that plagued the THOR and JUPITER propulsion system. In 1959, 22 ATLAS missiles were launched, including 15 successful flights; all of the 7 launches that encountered trouble occurred in the first half of the year and caused the postponement of the operational availability date scheduled at that time for June 1959. Fourteen successful flights during the July-December period indicated that the difficulties in the fuel staging disconnect system had been fully resolved. Since mid-October 1959 the first ATLAS missile has been operationally ready at the Vandenberg Air Force Base.

The TITAN flight tests encountered initial difficulties, but during the first half of 1959 four successful flights were registered, employing only the first stage. During the second half of 1959, however, the TITAN program was plagued by a succession of accidents -- all attributable, as determined by careful review, to personnel errors during the shipment or launching of the missiles and not to any weakness in design or manufacture. This fact raised the expectation that most of the delay in the test program could be regained in 1960.

The operational force levels for both ATLAS and TITAN continued under review throughout 1958 and 1959, and on January 13, 1960, the President approved a 13-squadron goal for the ATLAS to be reached by December 1962, and a program for 14 TITAN squadrons to become operational between June 1961 and March 1964.

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By the end of calendar year 1959, obligations for the ATLAS amounted to \$2,545 million and for the TITAN to \$1,758 million.

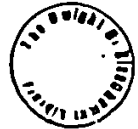
2. Land-based Intermediate-Range Ballistic Missiles (THOR, JUPITER)

The decision of November 8, 1955, to develop two IRBM's was based primarily on the requirement for both a land- and a ship-based missile and on the desirability of having an alternate effort to assure a successful solution for the many technical problems still to be resolved. The assignment to the Air Force of IRBM No. 1 (THOR) was made on the assumption that this missile would be a fallout from the ICBM program. The Army's Redstone Arsenal team entered the picture for IRBM No. 2 (JUPITER), the land- and ship-based version, because it had considerable experience with large ballistic missiles and no commitments in the ICBM effort.

Toward the end of 1956 the IRBM No. 2 program was modified when the requirement for a liquid-propellant, ship-based missile was canceled. Thus, by the beginning of 1957, the objectives of both the THOR and the JUPITER programs were identical -- a strategic, land-based, liquid-fueled missile with a range of 1,500 n.m. Although there appeared to be no "technical" reason to suppose at the end of 1956 that either program would fail, the Scientific Advisory Committee to the Secretary of Defense recommended on January 15, 1957, that both programs be continued on the ground that insurance against failure was desirable.

The size of the IRBM effort as well as the deployment schedule became increasingly dependent in 1957 on agreements with allied nations rather than on the progress made in the research and development effort. Without assurance of the timely availability of foreign bases, the crash development of the land-based IRBM was difficult to justify. The first breakthrough came at the Bermuda Conference, March 21 to March 24, 1957, when a broad agreement on the deployment of U.S. IRBM's in the United Kingdom was concluded. On the strength of this agreement, the President approved on March 28, 1957, a 4-squadron force structure for the IRBM.

During the mid-summer 1957 review of the ballistic missile program, special attention was paid not only to the high cost



of the THOR and JUPITER programs but particularly to the modification problems caused by the substantial production of missiles in advance of the completion of various test schedules. On July 31, 1957, the Secretary of Defense proposed to establish a single IRBM program and, pending the selection of either THOR or JUPITER, to suspend production except for flight tests and drastically reduce overtime costs. It was recognized that this action might cause some delay in the IRBM development program, but such delay was not expected to be significant in the light of the time required to achieve operational use and deployment abroad. On August 1, 1957, the President approved this proposal, and on August 13, the Secretary of Defense appointed a 3-man Special Committee to work out a single land-based IRBM program and reduced, for the interim, the production rate of THOR to a maximum of 2 missiles per month and of JUPITER to 1 per month.

The selection of a single IRBM proved a difficult task. By the beginning of October 1957, the IRBM flight tests included 5 THOR launchings, of which 1 was a complete success, and 4 JUPITER flights with 2 a complete success. The nose cone re-entry problem, considered the most critical factor in 1955, appeared to be on the way to solution with the recovery on August 8, 1957, of a scaled-down JUPITER nose cone which had traveled 1,168 n.m., reached speeds of Mach 14, and showed ablation of only 1/4 to 1/3 of that expected. Similarly, neither propulsion nor guidance appeared to present any insolvable problems. Still, no concrete assurance could be given that operational IRBM's would be available within a year and a half.

With both the Army and the Air Force claiming superiority for their respective programs, the Special Committee, composed of OSD, Army, and Air Force representatives, could come to no agreement. With the increased urgency created by the launching of Sputnik I, the Department of Defense recommended the continued use of both the THOR and the JUPITER production line in order to obtain the largest number of missiles in the shortest time. The President approved this recommendation on October 10, 1957.

During the following weeks, the existing restrictions on procurement were removed, and the Secretary of Defense approved on November 25, 1957, an initial operational capability of four THOR and four JUPITER squadrons between December 1958 and early 1960, with production facilities for a maximum of 6 and 5 missiles per month respectively.

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Both programs were pursued with maximum urgency during 1958 and met established schedules, despite the difficulties encountered with the turbopump gear box in the propulsion system of both missiles. Assurance that the JUPITER would meet all operational requirements was obtained on July 17, 1958, with the ninth JUPITER flight test, which demonstrated the reliability of the inertial guidance system as well as the adequacy of the nose cone construction and separation mechanism. The THOR program reached the test stage of the operational configuration in November 1958 and in December scored three successful flights -- one of them was the first launch from the Pacific training site at Vandenberg AFB by a SAC military crew. By the end of December 1958, 15 THOR missiles had arrived in England of which 7 were on launchers. JUPITER missiles would also have been operationally ready but for the delay in negotiating base agreements.

This delay had been the major reason for the NSC action of April 24, 1958, reducing the JUPITER program from four to three squadrons. With maximum THOR production raised at the same time from six to eight missiles per month -- to support the THOR-ABLE program for ICBM nose cone testing -- various plans were made to meet possible emergency requirements by expanding the THOR program from 4 to 5 and possibly 9 squadrons. None of these plans, however, was implemented.

Negotiations with the French Government for the deployment of JUPITER squadrons collapsed in May 1958.

Since the agreements provided that the launching sites be manned by native personnel, the date for the full operational capability of the oversea IRBM squadrons had to be extended to permit the training of British crews. The first THOR squadron was turned over to the Royal Air Force on June 22, 1959; the installation for the last of the four squadrons is scheduled to be ready for turnover in May 1960. The two JUPITER squadrons are scheduled for turnover in September 1960 and March 1961.

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By the end of calendar year 1959, obligations for the THOR amounted to \$897 million and for the JUPITER to \$824 million.

3. The Fleet Ballistic Missile (POLARIS)

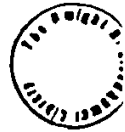
The POLARIS development became officially a separate ballistic missile program on December 8, 1956, when the Secretary of Defense authorized the Navy to end its participation in the liquid-propellant JUPITER program and to proceed with the development of the solid-propellant POLARIS.

Since the first joint Army-Navy planning in November-December 1955 regarding the development of a ship-based ballistic missile capability, the Navy had stressed its eventual requirement for a solid-propellant missile suitable to submarines, pointing to the hazards of liquid fuel on shipboard and the difficulties of logistics, handling, storage, and design inherent in a ship version of the JUPITER. In February 1956 the Defense Scientific Advisory Committee recommended that the Navy's solid-propellant IRBM development be given equal priority with the other IRBM's. In April 1956, the Navy was authorized to pursue system studies and component development, but not a full-scale missile program for a solid-propellant ballistic weapon. The turning point came in mid-September 1956, when the Atomic Energy Commission forecast the possibility of a 600-lb. warhead by 1965, and possibly by 1963. In November 1956, the Secretary of the Navy proposed to substitute a submarine-based, solid-propellant ballistic missile in place of the liquid-propellant one launched from a merchant ship, and it was this proposal which was approved on December 8, 1956.

In addition to the usual aerodynamic, guidance, and re-entry problems associated with the development of all ballistic missiles, the POLARIS program had to overcome additional hurdles, such as the development of an efficient solid propellant for a 1,500 n.m. range, the design of a submarine and of an underwater missile launching system for a still nonexistent weapon, and the development of new electronic techniques to permit accurate positioning as well as effective command communications for submerged submarines. Operating under special management procedures, rapid progress was made in all these areas.

On April 19, 1957, the Secretary of Defense approved the POLARIS effort as a part of the over-all IRBM-ICBM program, but provided

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ATOMIC ENERGY ACT OF 1954



that it should not interfere with programs having earlier capability dates. As a result of the review of all ballistic missile programs in the summer of 1957, the POLARIS effort was reduced in August by 5 percent and overtime was limited to 5 percent. These limitations were lifted in October and December 1957 respectively, and the possibilities of accelerating the established schedules were investigated.

The original Navy program of November 8, 1956, had looked forward to achieving a submarine IRBM capability by 1963, with the warhead development believed to be the major delaying factor at that time. In October 1957, it was estimated that a "crash" warhead development program might meet POLARIS requirements in 1960, and on December 9, 1957, a new schedule was approved which moved the date for an initial operational submarine capability from January 1963 to October 1960 and provided for three FBM submarines by June 1961. In February 1958, the President approved the highest national priority for POLARIS.

Various proposals for further acceleration of the program were considered in 1958 and 1959, but a construction program of 3 FBM submarines per fiscal year was adhered to. Recommendations for the installation of POLARIS on surface ships were not approved.

As the result of Presidential action on January 13, 1960, the over-all POLARIS effort called for 12 FBM submarines with long-leadtime items authorized for 3 more. Of these 12 submarines, 2 were scheduled to be operationally ready in calendar year 1960, 3 in 1961, 4 in 1962, and 3 in 1963. The range of the missiles for the first seven submarines was set at 1,200 n.m. and for the remainder at 1,500 n.m. The shorter range missiles will be retrofitted at a later date.

Progress in the development of the missile as well as the submarine delivery system indicated by the end of 1959 that the established schedule would be met. At that time, obligations for the POLARIS program amounted to \$1,851 million.

4. Solid-Propellant ICBM (MINUTEMAN)

While the effort to develop a liquid-propellant ICBM was being pursued with maximum urgency, studies were initiated in 1955 looking toward the development of a "second generation" ICBM that would be smaller, cheaper, and quicker to react in case of emergency.



It was planned that such a weapon would take advantage of the experience gained with the guidance system and re-entry vehicle of the "first generation" missiles and, above all, would rely on solid instead of liquid fuel. It was the latter requirement for effective large solid-propellant engines that appeared to present the major hurdle in 1955, but such rapid progress was made in this field that by the end of 1957 the development of a solid-propellant ICBM within a 5-year period appeared to be well within the state of the art.

In February 1958, the Secretary of Defense approved the research and development program for a solid-propellant ICBM, the MINUTEMAN, which was to be a 3-stage, 65,000-lb. missile with a range of 5,500 n.m. and a CPE of 1 n.m. During the following year the problems related to the manufacture of effective solid propellants and the control and termination of thrust were well on the way to solution, and the availability of production facilities rather than research progress became the critical factor.

On December 8, 1958, MINUTEMAN was approved as a weapons system for research and development, and planning for production, training, and operation was authorized. In line with a JCS recommendation of February 19, 1959, the President assigned the highest national priority to the MINUTEMAN research and development program on August 18, 1959.

At the close of 1959, the MINUTEMAN program was progressing essentially on schedule. Although no full-scale flight tests had as yet been made, a substantial operational capability in 1963 appeared to be readily attainable. In early 1960, approved budget requests called for an IOC of 150 missiles by mid-1963 with 135 of these assigned to hardened fixed squadrons and 15 to mobile squadrons. //

Obligations for the MINUTEMAN amounted to \$433 million on December 31, 1959.

5. Aerodynamic Long-Range Missiles

When the feasibility of long-range ballistic missiles became apparent in 1954, four aerodynamic long-range missile programs were being pursued: The Air Force's SNARK and NAVAHO

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and the Navy's TRITON and REGULUS II. Since the rapid progress in the ballistic missile field met to a large extent the military requirements that these aerodynamic weapons were supposed to fill, the latter programs were terminated or drastically reduced in 1957. The further high cost of the full development of these missiles was not justified by whatever advantages would be gained through a greater diversification of our weapons arsenal.

a. SNARK. The February 1954 report of the von Neumann Committee recommended the continuation of the SNARK program, but on a simplified basis in order to achieve an operational availability as a decoy, drone, or reconnaissance vehicle in 1958. The major change proposed involved the substitution of autopilot and command guidance for the planned celestial guidance. Slippages, however, continued to occur in the program. In June 1955, difficulties encountered in terminal dive tests led to the addition of a ballistic nose cone to be ejected near the target and, at about the same time, the celestial navigator was re-introduced. As flight tests continued to reveal difficulties, the program was reduced from the 8-squadron goal, established in November 1956, to 2 squadrons in December 1957 and to 1 squadron, with 30 missiles, in early 1959. Simultaneously, the operational date for the squadron slipped from 1958 to 1960, and is currently scheduled for September 1960. The SNARK is expected to be phased out in 1963. Obligations for the program through fiscal year 1960 are expected to be \$695.4 million.

b. NAVAHO. The capability of the NAVAHO to carry larger warheads led the von Neumann Committee in February 1954 to recommend the continuation of this program as a supplementary, rather than an interim, effort and to propose emphasis on the 3,500-mile version to be available in 1960-1961 instead of on a 5,500-mile missile at a later date. Expansion of facilities for ramjet, rocket booster, and guidance equipment was also recommended. These recommendations were followed until December 1955, when an accelerated program for a 5,500-mile version, with an operational date in 1960, replaced the 3,500-mile NAVAHO program. Serious slippages, however, occurred in the program during 1956, and the Secretary of Defense and Secretary of the Air Force agreed on December 6, 1956, to delete all NAVAHO funds from the budget for fiscal year 1958. Continued test failures during the first half of 1957 confirmed this decision, and the program was officially terminated on July 9, 1957. The total cost of the terminated



NAVAHO program is estimated at \$679.8 million. While producing no new weapons system, NAVAHO made important contributions to the ballistic missile programs, particularly in the propulsion and guidance fields.

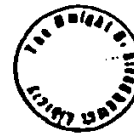
c. TRITON. The Navy continued to carry the TRITON as a study program until the summer 1957, when, as a result of the review of all guided missile projects, the program was canceled on September 17, 1957. The total cost of the TRITON effort has been estimated at \$19.4 million.

d. REGULUS II. The acceleration of the POLARIS program, resulting in the establishment of a 1960 operational availability date, became the major reason for the termination of REGULUS II, which had the same schedule but as an aerodynamic weapon could not compete with the more effective ballistic missile system. The decision to end the project was made by the Secretary of the Navy on December 12, 1958. The total costs for REGULUS II were estimated at \$146.5 million.

C. Management.

In 1953, the management of long-range missiles was carried out as an integral part of the overall research and development effort of the Department of Defense in accordance with the framework established by Reorganization Plan No. 6 of 1953, effective on June 30, 1953. Under the direction of the Secretary of Defense, policy guidance was formulated by the Assistant Secretary of Defense (Research and Development) with participation by other Assistant Secretaries as the programs entered the fields of application engineering, procurement, and construction. The Secretaries of the military departments remained responsible for operational management.

The urgency of the ATLAS program, as the result of the von Neumann report in February 1954, brought a streamlining of the Air Force organization for this project, including (a) the establishment of a special ICBM Scientific Advisory Committee; (b) the establishment of the Western Development Division in Los Angeles as a field office of the Air Research and Development Command (ARDC) with participation by the Air Materiel Command (AMC); and (c) the assignment to Ramo-Woollridge Corporation of responsibility for systems engineering and



technical direction of the contractors. In general, this 1954 special organization -- extended later to the TITAN, THOR, and MINUTEMAN -- continued in effect in subsequent years, except that responsibility for initial operational capability of these programs was transferred from ARDC to SAC on January 1, 1958.

As a result of the 1955 Presidential review of ballistic missiles and the assignment of the highest national priority to ATLAS, TITAN, THOR, and JUPITER, special management procedures were established throughout the Department of Defense. In accordance with recommendations made by the Gilette Committee of the Air Force, the Secretary of Defense directed on November 8, 1955, the establishment of special Ballistic Missile Committees in his own office and the military departments in order to expedite and facilitate decisions by key officials in these agencies. At the same time, Scientific Advisory Committees were established to provide technical advice on scientific problems in the ballistic missile field.

Since the early JUPITER program aimed at a dual land- and ship-based capability, it was supervised during 1956 by a Joint Army-Navy Ballistic Missile Committee. The establishment of the POLARIS program on December 8, 1956, resulted in the formation of separate committees for the Army and Navy. Within both departments special administrative procedures for operational management had been previously established. In the Navy, a Special Projects Office was created on November 17, 1955, to handle the technical problems associated with a ship-based ballistic missile, and on February 1, 1956, the Army Ballistic Missile Agency was established at Redstone Arsenal, Huntsville, Alabama.

To assure full-time direction and coordination of the ballistic missile programs, the Secretary of Defense established on March 27, 1956, the position of Special Assistant to the Secretary of Defense for Guided Missiles, and on May 3, 1957, extended the responsibilities of this official to the aerodynamic long-range missiles. A few months later, on November 17, 1957, the Special Assistant became the Director of Guided Missiles, responsible for authoritative direction of all guided missile activities.

The Department of Defense Reorganization Act of 1958 had among its major objectives the strengthening of the Defense

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organization in the fields of science and technology. To meet this objective, the position of Director of Defense Research and Engineering was established with the incumbent being authorized not only to supervise all research and engineering activities in the Department of Defense but also to direct and control those that might require centralized management. The new position was filled on December 24, 1958, and its charter issued on February 10, 1959. The statutory authorities vested in the new Director made unnecessary the position of Director of Guided Missiles, which was abolished on April 8, 1959.

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ATOMIC ENERGY ACT OF 1954



LONG-RANGE MISSILES

OBLIGATIONS
(Millions of Dollars)

	<u>1945-1950</u>	<u>1951-1953</u>	<u>1954-1959</u>	<u>Total</u>
<u>Army</u>				
HERMES-B & -C	2.5			2.5
JUPITER			824.1	824.1
<u>Navy</u>				
TRITON	4.1	2.2	13.1	19.4
REGULUS II		9.4	137.1	146.5
POLARIS			1,851.0	1,851.0
<u>Air Force</u>				
MX 772	1.8			1.8
MX 773	2.0			2.0
SNARK	22.3	207.2	468.9	698.4
NAVAHO	26.0	125.4	528.4	679.8
MX 774	2.0			2.0
MX 1593		5.0		5.0
ATLAS			2,545.2	2,545.2
TITAN			1,758.0	1,758.0
THOR			897.0	897.0
MINUTEMAN			432.7	432.7
 TOTAL	 <u>60.7</u>	 <u>349.2</u>	 <u>9,455.5</u>	 <u>9,865.4</u>