GENESIS: NORTH AMERICAN MISSILE DEVELOPMENT

The development of the modern military and space missile is, to a very large measure, chronicled in the early events and accomplishments of North American Aviation’s missile project history.

Entering into the research and study of missile concepts at the close of World War II, North American founded projects in the areas of rocket propulsion, inertial guidance, vehicle design and construction, and operations and support that summary represent the nation’s pioneering missile development progress.

For example, at the moment of opening of the space age, rocket engine development conducted by North American Aviation represented virtually the entirety of America’s attainment in high-thrust propulsion for ICBM and space vehicles. The 75,000-pound thrust Redstone engine had been successfully fired—full thrust and full duration—as early as 1950. The liquid rocket engines used in the Atlas, Thor and Jupiter missiles as well as in the current Saturn types—evolved directly from this single development.

In the field of guidance, North American’s accomplishments have been equally precedent. The first complete inertial autonavigator was developed and tested flown by 1959; subsequent versions of this basic system have been used in such current air-, sea- and spaceborne systems as the GAM-77, A3J, the nuclear submarine fleet, and the Minuteman.

North American’s missile flight test programs first demonstrated flight capability in the Mach 1, Mach 2 and Mach 3 steady-flight regimes. These programs promoted the development of high-temperature materials and precision fabrication techniques that are now standard in missile system construction.

Missile development at North American can be characterized by three phases. The first phase occurred in the 1945-50 period; in this era, major efforts in experimental research—supported by German wartime materials—led to the initial definition and testing of fundamental configuration and systems for advanced missile weapons.

The particular circumstances of the time as well as the technical objectives merit discussion for their historical importance and to indicate the reasoning behind the decisions that have so strongly influenced the present-day state of missile technology.

The second phase in missile development covers the years from 1951 through 1957 and the highly significant Navaho program—the nation’s first full-scale missile system development and test project. The Navaho program was the major data source which enabled the U.S. to meet the Russian space challenge and to demonstrate its present tactical and strategic strength.

The third phase concerns the extension of missile capabilities to its present technological state. This portion is only briefly referenced because of the extent of involvement of North American Aviation in the current defense and space programs.

THE AEROPHYSICS PROJECT

North American Aviation’s missile activity began in 1945 when five engineers were assigned to study aspects of high-speed aerodynamics associated with air weapons typical of those used by Germany at the close of World War II. Germany displayed jet and rocket interceptors of astonishing performance; the V-1 rocket had been superseded by the supersonic V-2 missile—a weapon superior to the Allies’ most advanced concepts.

It was clearly demonstrated that the missile would become an increasingly important part of future U.S. military strength.

To concentrate its missile effort, North American established the Technical Research Laboratory which would be independent of the Company’s engineering organization. This group would pursue development on a theoretical basis and direct its research toward a single objective: specifications for an operational tactical missile. An exclusive team of scientists and engineers was being formed; the original five becoming ten—ten which grew to 100 at the end of the first year.

A primary decision had to be resolved; to attempt to develop a weapon vastly superior to any German armament, or to attempt to build a stockpile of tactical missiles of moderate performance with minimum development delay.
With the capitulation of Germany, North American and the other industry members began to receive data on their guided missile work. The German A-4 (V-2), and its successors in the A-series, offered an advantageous starting point for American missile development. The A-4, impressive as a tactical weapon, had been successfully mass-produced (3600 launched). Although the V-2 did not achieve intercontinental range, some 20,000 man-years of engineering research and development had been expended; that much of this enormous man-year fund could be utilized was an extremely attractive factor.

Preliminary studies indicated that satisfactory range and accuracy might be achieved with a winged version of the A-4, necessitating only a fraction of the engineering effort required for the development of a new type. Consequently, late in 1945—after a search of the limited data then available on German A-series missiles—North American decided that it would be feasible to combine the objectives of advanced design and reasonably early tactical availability.

North American submitted its initial missile proposal to the Air Force on 20 December 1945. As the first step in a three-year program, it was proposed to "...essentially add wings to the V-2 and design a missile fundamentally the same as the German A-9." It proposed to initiate its program of research and development "...approximately at the point where the Peenemunde group left off." The A-9—along with the "Wasserfall" model, an experimental supersonic, guided anti-aircraft missile which evolved from the earlier A-series weapons—were studied.

The proposed missile would possess characteristics which would generally satisfy all essential performance requirements set forth in a bid invitation issued by the Air Force earlier in November. These characteristics are listed below:

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<th>NAA Missile</th>
<th>German A-4 (V-2)</th>
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<tbody>
<tr>
<td>Range</td>
<td>375 miles</td>
<td>185 miles</td>
</tr>
<tr>
<td>Speed (Minimum)</td>
<td>Supersonic</td>
<td>Supersonic</td>
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<tr>
<td>Bomb Load</td>
<td>2,000 lbs.</td>
<td>2,200 lbs.</td>
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<tr>
<td>Thrust (Peak)</td>
<td>55,000 lbs.</td>
<td>55,000 lbs.</td>
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<tr>
<td>Weight</td>
<td>28,000 lbs.</td>
<td>28,000 lbs.</td>
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<tr>
<td>Fuel Load</td>
<td>17,000 lbs.</td>
<td>19,200 lbs.</td>
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<tr>
<td>Length</td>
<td>45 feet</td>
<td>46 feet</td>
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<tr>
<td>Fuselage Diameter</td>
<td>5.4 feet</td>
<td>5.4 feet</td>
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The North American proposal cautiously pointed out the following: "In order to fulfill the requirements for accuracy (i.e., 50 percent of the hits within 1000 feet of the target) and controllability in detail, further research and development work will be required." The A-4's 50 percent within 20,000 feet order of accuracy demonstrated that the German guidance system was of dubious value.

The proposal also recommended that theoretical and experimental studies be promptly initiated to increase the missile's range by replacing the rocket propulsion system with a ram-jet or turbojet power plant. Later, it was proposed that a huge starting rocket be developed as a booster for very long range missions.

While this proposal was in submittal, North American received a Navy BuOrd contract to conduct a one-year study of supersonic aerodynamics related to the "Bumblebee" program at the Applied Physics Laboratory at John Hopkins University.

**PROJECT MX-770**

On 22 April 1946, the Air Force awarded a letter contract (ac-14191) for a one-year study and research program for R&D of a supersonic surface-to-surface guided missile. Total value of the contract was $2,307,578. It was one of five contracts awarded to industry. It was the only one of the five that concerned progression from a relatively short-range tactical missile to an intercontinental weapon. The project was designated MX-770.

The initial Air Force contract contained certain military characteristics that were referenced as "desirable...and the Contractor will keep them in mind as a guide..." These characteristics included an explosive load equivalent to 5000 pounds of TNT; a range of 175 to 500 miles; and provisions to "insure maximum freedom of controls, propulsion unit and fuzes from natural, enemy or friendly interference." The accuracy requirement of 50 percent of hits within 2500 feet was to be met regardless of weather, target camouflaging, or enemy countermeasures.

Work was to proceed in the following areas:

- Comprehensive study and research of supersonic aerodynamics
- Comprehensive study and research of propulsion systems
- Comprehensive study and research in stabilizing and guiding systems
- Study of structures, metallurgy, launching systems and explosive warhead installation as required

Because the most critical problem was guidance, an intensive study was begun of the available concepts of automatic navigation. Radio or radar tracking, control from ground stations and radio, or radar navigational lattice methods were rejected because of susceptibility to enemy jamming. Magnetic and celestial navigation systems were too far in the future.
NATIV missile launching

Although only sketchily defined, a preset-inertial system seemed to offer the best hope of success. The Germans had been working along these lines for about six years and, although their most advanced experimental devices fell far short of meeting the Air Force specification requirements, the limitations they encountered were more subject to change than the other systems considered. It was decided to concentrate research in the field of guidance on a concept identified as a Supervised Path Governor. As envisioned, this system would consist of the following: a gyroscopically stabilized platform carrying instruments capable of measuring accelerations and computing missile position; a radio supervision system; and auxiliary equipment—such as high-precision time standard and servo-control equipment.

In addition to the Supervised Path Governor, a high-power automatic piloting with an extremely short reaction time was needed. To develop a workable guidance system required new techniques—extremely sensitive laboratory equipment, highly complex flight simulators, and a new family of miniaturized electronic components.

There were aerodynamic unknowns as well. Supersonic wind-tunnel testing was needed. Aerodynamic heating was an unfamiliar subject. There were no facilities for testing rocket power plants; extensive research in fuels and structural materials was indicated. Ram-jet development was not emphasized for the 175-500 mile missile because rocket power alone would be adequate for the mission.

Late in June 1946, the plan for construction testing facilities and the testing approach had been formulated and submitted to the Air Force. By this time, the NAA Technical Research Laboratory had been renamed the Aerophysics Laboratory; its complement had increased to 43 persons (12 having doctorate and 18 with masters degrees in science or engineering); it comprised 3000 square feet of floor space.

The propulsion section initiated the redesign of the A-4 power plant and small rocket engine experimentation at a temporary test station near Inglewood. The guidance and control section was involved in several related pursuits: determining allowable inaccuracies in the components of the Supervised Path Governor; continuing the study of German guidance systems; and formulating the design of a complete flight simulator with six-degrees-of-freedom.

All sections of the Aerophysics Laboratory—aerodynamics, guidance and control, propulsion and preliminary design—collaborated on the final project; the design of a small rocket test vehicle. This was proposed by letter in June 1946. At the end of August 1946, work had already progressed beyond the design stage.

NATIV

The small rocket missile was designated NATIV (North American Test Instrumentation Vehicle). Three basic series were planned. The first series—unstabilized, unguided missiles—were used to develop handling, launching, and tracking techniques and to gain aerodynamic data. The second series included guidance and control equipment. The third series were to be scale models of an ultimate 500-mile missile.

The NATIV configuration was similar to the "Wasserfall" missile: 13 feet long, 11½ feet in diameter, and 1070 pounds. Powered by an Aerojet acid-aniline rocket motor of 2600 pounds static thrust, the NATIV was designed to attain supersonic speed, a maximum altitude of more than 10 miles, and a range approaching 100 miles.

Design work on both the missiles and the launch equipment progressed rapidly during the summer and fall of 1946. Detail drawings were released to the tooling and fabrication departments in December, and the manufacturing of 15 NATIV missiles was begun. Arranging for static test and launching site evoked some delay; eventually, in March 1947 the Alamogordo Army Air Base (Holloman AFB) near White Sands was selected. It was necessary to design the complete test facilities—the blockhouse, a tilt-table 125-foot tower, the telemetry system, and the optical and electronic tracking equipment. Tracking accuracy required was 2/100th of one per cent, or approximately one foot to a mile.
Work on range instrumentation and communications continued through 1947 and into early 1948. The first tracking tests employing a NATIV beacon installed in an airplane were made in March 1948, and cinetheodolite tracking of a Boeing ground-to-air missile was successfully accomplished the following month. Complete tests of the telemetering installations were made 10 days later. Static firings and hydrostatic tests produced structural failures which involved the propellant tanks of the first two NATIV missiles.

The third NATIV was successfully launched on 26 May 1948. The telemetering and tracking equipment functioned almost perfectly. Wind shift at launch caused the missile to change course and move toward a nearby town, necessitating fuel cut-off after 18 seconds flight.

Other successful launchings were made in September, October, and November of 1948. The highest altitude reached was 59,000 feet; the highest speed was Mach 2.23. The November launching concluded the NATIV testing program.

The NATIV program had made valuable contributions to the nation’s missile development program. It provided practical experience in the launching and handling of rocket-powered missiles with advanced stabilization and control systems. It provided specific aerodynamic data on transonic and supersonic flight regimes. It sponsored the successful design of a 32-channel telemetering system, including the airborne and ground units that proved adaptable to a number of different types of missiles. The field test instrumentation capable of tracking and recording with unprecedented accuracy and reliability was an important bonus of the NATIV program.

**TEST FACILITIES**

NATIV development prompted the construction of extensive testing facilities that were to significantly benefit future missile programs. In November 1946, NAA made a capital investment of $124,000 for facilities to support the aerophysics program. A water towing tank was constructed to obtain flow patterns simulative of supersonic speeds. The second facility was a small supersonic wind tunnel which utilized a compressed-air supply system to produce air streams up to Mach 3.0. A Schlieren optical system was utilized for studying the shock waves, and a sting balance system was developed by North American to measure all six of the standard forces. The small wind tunnel proved valuable for fundamental research on such subjects as boundary layer conditions, pressure distributions and heat transfer. It also pointed up the need for a larger tunnel with intermittent flow capability.

In 1947, NAA authorized a capital expenditure of one million dollars for the construction of test facilities to support work in the advanced technologies. This decision was made in the face of a financial loss in the overall NAA operation.

With Air Force cooperation, NAA designed a larger, 16-inch tunnel; in June 1947, NAA authorized an expenditure of $287,000 of the allotted capital funds for its construction. The tunnel was completed in October 1948—the first privately owned facility of its kind in the U. S. It immediately began yielding data on speeds up to Mach 5.0.

In the summer of 1946, the hazards of rocket motor testing made it necessary to plan an isolated test station. A proposal was presented to the Air Materiel Command's Laboratory for a large test stand to conduct static tests of complete propulsion systems up to 100,000 pounds thrust. This stand included associated component test facilities, a heat transfer laboratory for atomic power research, and a liquid hydrogen plant.

However, Air Force funding complications arose; consequently, late in 1946, the Air Force decided to proceed with plans for two 60,000-pound thrust test stands at Muroc Dry Lake, California—one of which would be used by North American.

Meanwhile, North American had found an ideal site for rocket testing in the Santa Susana mountains—only 42 miles from its Los Angeles plant. Exercising a 90-day option to lease, North American—following notification that the ultimate 500-mile missile end-goal of the
MX-770 project would be continued into the component development phase—committed itself to undertake the construction of permanent facilities at the Santa Susana site. NAA authorized the remaining $713,000 of the one-million dollar 1947 capital expenditure for the propulsion test facilities, provided that the Air Force would agree to supply valuable equipment and instrumentation. A two-year plan for the development and erection of a test facility was submitted in June 1947.

Approval was gained during December 1947, and construction was begun. By the end of 1949, the field laboratory at Santa Susana was complete.

The expansion of the guidance and control portions of the aerophysics program created the need for larger facilities. It was found that Air Force Plant No. 16 in Downey, California (operated during the war by Consolidated-Vultee) was available. In July 1948, the Aerophysics Laboratory personnel moved from Los Angeles to the Downey plant—now occupied by the Space & Information Systems Division. Employment of the independent Aerophysics Laboratory at that time was 700. A total area of 168,000 square feet was set aside for the offices, laboratories, shops and special facilities—e.g., environmental laboratory, flight simulators, and an orientation and drift test chamber equipped with an equatorially mounted star-tracking telescope.

500-MILE MISSILE

The third phase of the NATIV program was to be devoted to the development of the configuration for a 500-mile missile. Structural analysis had been started early in the program, and major design innovations were being made to the basic A-4 missile. The use of the integral tank principle provided a 32 percent increase in propellant volume and a 35 percent decrease in structural weight. Supersonic aerodynamics research produced formulas for wing lift and drag at supersonic speeds as well as for the prediction of downwash effects. Trajectory analyses methods were mathematically simplified in these pre-computer days.

The first MX-770 design was presented in the fall of 1946; essentially, it was a modified A-4 missile with swept wings and large aft control surfaces. The design had been selected in preference to two other types: a triangular-winged rocket missile, and a two-stage rocket-boost ramjet sustainer missile.

As better aerodynamic data became available, the configuration changed considerably. The most important change was the transition to a canard configuration. The new canard configuration was developed during late 1947 and early 1948. By March, the configuration for the 500-mile missile had been fixed. There was confidence that the guidance system could be worked out within the weight and space allotments, and the preliminary design of an approved propulsion system was well advanced—backed up with interchangeability of the proven operable A-4 propulsion system. As the design of the 500-mile missile reached completion, however, changes introduced in the development goals made it necessary to reorient and reschedule the entire program.

XSSM-A-2

The Armed Forces Unification Act of July 1947 delineated the roles of the Air Force and the Army in the field of guided missile research and development. The Air Force was to be assigned programs leading to the development of missiles with more than 1000 miles range; the Army's interest would involve missiles having shorter range. Accordingly, the range requirements for the first North American tactical missile were changed from 500 to 1000 miles. Among the other changes introduced was a warhead increase to an explosive equivalent to 5000 pounds of TNT. The 1000-mile missile was designated the XSSM-A-2.

The first step taken in the design of the 1000-mile missile was the addition of two ramjet cruise engines and the structural and fuel provisions for their employment. The power of the rocket propulsion system had to be increased. These modifications amounted to a newly designed missile.

The redesign of the North American rocket power plant to attain 75,000 pounds of thrust—an increase of 34 percent over the 56,000-pound thrust version contemplated for the 500-mile missile—involved substantial structural weight decreases, higher rated turbo-pump speed, and more efficient cooling.
The development of a suitable ramjet, however, was critical. Although the study of ramjet propulsion was initiated early in the aerophysics project under the Bumblebee study—and while some valuable wind tunnel data had been accumulated—study had proceeded on a very low priority basis.

Radio supervision would be less effective, requiring greater inertial accuracy. Otherwise, the guidance system was little affected by the doubling of range to 1000 miles.

The initial external configuration of the 1000-mile range missile was investigated. A configuration which featured the addition of ramjets at the wing tips was rejected because of wing flutter. Underwing installation of the ramjets was studied. Eventually, it was decided to attach the ramjets to the vertical afterburners; consequently, wind tunnel testing provided data which resulted in the size reduction of the forward elevators and the elimination of the sweep in the wing plan. Early in 1949, a complete control analysis of the XSM-A-2 resulted in the addition of ailerons to the wings. Also, the sweepback of the vertical tail was eliminated and the ramjets were moved forward. Other than these, few external changes were made to the 1000-mile range missile during 1948 and 1949.

The dimensions of the circular cross-section body were as follows: length, 47 feet; diameter, 5 feet, 10 inches; wing span, 22 feet, 7 inches; ramjet nacelle length, 8 feet, 4 inches. Weight empty, 14,000 pounds; takeoff gross weight, 44,000 pounds.

Fabrication of the first three XSM-2 missile structures began in late 1948, and the basic engineering release came in April 1949. A manufacturing department was organized at the Downey plant to assemble the missile components fabricated at the Los Angeles facility. Production was well underway with the completion of the first missile airframe scheduled for July 1950. Again, in the spring of 1950, the program was reoriented and the airframe design was superseded.

GUIDANCE SYSTEM DEVELOPMENT

Previous to 1950, the development of guidance and control components evolutionary to a fully automatic inertial navigation system had made excellent progress. Functional tests could be scheduled. The originally planned radio supervision system to monitor the initial portion of the trajectory consisted of four ground-based UHF transmitters and missile-borne receivers and computers capable of converting the signals into highly accurate velocity and position information.

This information was to be compared with data supplied by the inertial guidance system to the maximum line-of-sight distance. A novel method of phase multiplication was successfully applied to the tracking of the NATIV missiles in 1948. As a result of other developments the radio supervisory function was deleted because only the inertial guidance system could achieve the required accuracy for the 1000-mile range requirements.

The supervisory guidance system developments, however, had valuable application in other projects. From the design and experimentation work in connection with microwave propagation, frequency, phase modulation, and antenna operation, NAA was able to utilize this experience in subsequent flight test operations. The early guidance system development promoted related system and component advances. A novel system of celestial supervision was conceived; a dust-free electronics research laboratory was set up; gyros, far more precise than any existing at that time, were designed and produced.
A thorough study was carried out through the late '40s on accelerometers. The study was directed at the further development of existing German devices and the application of new concepts. The key problem in developing the inertial guidance system lay in the development of devices capable of accurately measuring and then double-integrating the accelerations experienced by the missile to find the distance travelled in each direction of a chosen three-dimensional coordinate system. Intensive studies of three German types of accelerometers revealed that each would require separate computing devices for performing the required integrations. Thus, the total error arising in this portion of the guidance system would be the result of both accelerometer and integrator errors.

An important breakthrough was achieved by the development of the kinetic double-integrating accelerometer; this device combined the functions of the accelerometer and double-integrator into one instrument, providing accuracies well beyond the initial goal. Air-bearing gyro development was instrumental in the achievement as was the progress made in the design of such components as servomechanisms. Servo control improvements in turn applied to autonavigation systems.

In addition to gyro and accelerometer development, the important advance in guidance system development was the computers used for converting the output of accelerometers into signals for the autopilot. Both analog and digital computers were investigated. The analog computer proved more adaptable to the type of signals obtainable from the kinetic double-integrator accelerometer; it consequently received the greater development project emphasis. However, the first transistorized airborne digital computer, the NATDAN, was developed and operational by 1949.

The primary problem in the design of the early guidance system components (particularly the computers) resided in the difficulty in reducing the size of complex electronic devices to dimensions suitable for airborne vehicles and still retain their functions. Printed circuitry, miniaturization, and other techniques were introduced at this time; this rapidly lessened the size and weight problems.

By the end of 1949, the basic design features of the XSSM-A-2 missile guidance and control systems were well established, and most of the components had undergone extensive laboratory testing. The stabilized platform—with its precision gyros, kinematic double-integrator accelerometer, large-scale computing equipment, power supply, and associated devices—were assembled into a flight test model.

Arrangements were made to test a complete inertial autopilot in a specially equipped C-47 transport. The first flight was made on May 2, 1950 and six additional tests were made during May and June. While performance did not match laboratory accuracy (as expected), the flights indicated areas where improvements could be made. Seventeen additional flights were made in 1950 with generally satisfactory results for the stage of equipment development. The basic system would only require minor modifications.

PROPULSION TEST

In November 1948, with a propulsion test group established at the Santa Susana field test laboratory, two complete A-4 propulsion systems had been assembled supplemented with several new component developments. Of the major test installations, however, only the preparation stand was ready. Consequently, although a large number of systems qualification tests were run with the A-4 system and their components, no firing tests were conducted in the large motor test stand until late in 1949. By that time, the large rocket motor—rated at 75,000 pounds of static thrust—had been constructed. Since this propulsion system had evidenced success in preliminary tests, it was decided to short-cut the original program, which called for the progressive firing of the A-4 motors.

Early REDSTONE firing

On 30 November 1949, the first static firing test of a large rocket motor was conducted with an uncooled version of
the 75,000-pound thrust booster. The first step was made at 10 percent of maximum propellant flow; it lasted 11 seconds and was successful in every respect. Six more starting tests were conducted before the end of the year.

During the first quarter of 1950, 24 additional starting tests were conducted, and five other tests followed at progressively increasing rates of flow. On March 2, an average thrust of 75,750 pounds was attained over a period of 45 seconds.

Full-thrust, full-duration static tests of the rocket during May and June of 1950 were highly successful. The actual performances met and exceeded all rated performances. Using the design ratio of 1.275 parts of oxygen to one part of 75 percent alcohol fuel, maximum thrust attained was 80,900 pounds—specific thrust of 225 pounds for every pound-per-second of propellant flow was attained. The greatest duration of firing at full thrust was 64.5 seconds. In addition, design improvements were indicated in various areas during the testing; these were accomplished and checked out in later tests.

Highly satisfactory results were returned on the adequacy of the combustion chamber design. The cooling system was effective. A solid catalyst gas generator was developed to replace the liquid-catalyst system used on the A-4. The tests offered the opportunity to test turbines under actual loads and aided in the development of better turbopump low-temperature seals and bearings. Valves, control systems, test instrumentation, procedures received the benefits of analysis and refinement during this testing period.

Testing continued during 1950 and into early 1951. In October 1950, the rocket engine (now designated by the Air Force as the XLR43-NA-1 system) was subjected to a complete system, full-thrust firing. Rough combustion problems encountered with the complete system were solved by early 1951, and the requirement for continuing the tests to late summer 1951 as originally scheduled was eliminated.

There were a number of successful design innovations introduced in the XLR-43-NA-1 employed by early tactical missiles. Weight-saving was accomplished via the first use of an aluminum injector; the injector weighed about one-third of the 180-pound steel injector used in the 1950 static testing program. A tubular thrust chamber reduced chamber weight by 50 percent.

AIR-LAUNCHING

During the fall of 1949, the Air Force, Research and Development Board, and North American decided to thoroughly study the possibility of launching the 1000-mile range XSSM-A-2 missile from a B-36 bomber. This would extend the range of the first tactical missiles to approximately 4575 miles plus an additional 1500 miles with each in-flight refueling of the carrier aircraft. The air launching significantly increased missile range and promised an earlier tactical availability via the use of supersonic turbojet engines (ramjet development had lagged).

The air-launch version required several modifications: an enlarged missile; star-tracking equipment to correct the gyro-stabilized platform during long flights; and modification of the rocket propulsion system for horizontal start and various other missile position alterations. The B-36's bomb bay also required considerable modification.

A design for an air-launched missile was submitted in January 1950. Although the proposal was not accepted, the Air Force authorized extensive component development.

Considerable aerodynamic, structural, and preliminary design work was conducted on the air-launched version as well as work in propulsion and guidance. During the last quarter of 1950, however, the air-launching study had an important effect on the progress in the development and testing of major missile components; these greatly influenced its successor—the WS-104A NAVAHO experimental flight test program.

NAVAHO

In July 1950, the Air Force authorized North American Aviation to proceed with the Navaho program (Weapon System 104A). The end objective of this program was the development of a guided, intercontinental range missile capable of delivering large yield warheads against strategic targets. The Navaho was the only missile weapon system under development at that time with such future goals.

More than any program in the formative period of the modern missile system, the Navaho development and flight test projects advanced the techniques and procedures which were so vital in meeting the Russian space challenge and in answering this country’s defense needs.

During the latter part of 1950, program decisions were established which defined the intermediate and ultimate
vehicles and performance. The final Navaho missile was to be capable of carrying a heavy 7000-pound special warhead over a maximum range of 5500 nautical miles. The missile was to be supersonic (Mach 2.75 or greater) with demanding CEP accuracies.

The design concept of the Navaho missile system was a two-stage vehicle which consisted of an expendable booster powered by alcohol-oxygen rockets; it was to be powered by two ramjet engines mounted in the aft fuselage. Its guidance system was a stellar-supervised, inertial autonavigator.

Navaho development was to be evolved in three stages. An unboosted experimental flight test vehicle was to be produced and used to verify the aerodynamic and control characteristics of the basic configuration; it would also aid in the flight test of the inertial guidance system. The second vehicle was to be the prototype for the Navaho operational missile; it would have verified the feasibility of the Navaho concept and aided in the development of prototype hardware for building the third vehicle series—the operational Navaho.

The MX-770 program and company investment, the feasibility of the intercontinental supersonic guided missile could be technically supported.

However, technical feasibility is one-dimensional. The Air Force's decision to schedule the development of a missile system of the intricacy and complexity of the Navaho at such an early stage of the technology was a courageous one. It presumed the timely and successful solution of a great number of technical problems that had not even been approached. The basic system composition was largely unproven. The propulsion and guidance units existed only in elementary form in laboratory test stands and racks; the structural and dynamics aspects of sustained high supersonic flight had not been demonstrated. The development effort required to progress efficiently to an operational system with objectives so advanced of the state of technology demanded a whole new management approach.

It was determined that the then new weapon system management procedure would be employed. In the weapon system concept, the prime contractor would be responsible for the total program—including the coordination and monitoring of the overall research effort and the subcontractor activities.

In view of the scope of the Navaho development and the onrushing technology of the missile, North American Aviation in 1951 issued a new charter to the Downey operation. This established a new division of the corporation. Named Missile and Control Equipment Division, this facility would operate independently of the parent NAA organization and be exclusively dedicated to missile airframes, guidance and related electronics equipment, and atomic research—a project that had branched off from the early propulsion system studies.

**X-10**

At the end of 1950, the experimental flight test vehicle—the X-10 (RT-V-A-5)—had been in detailed design and construction for three months. The X-10 was designed for early availability and to minimize configuration changes in the more advanced missiles. Booster launch would not be used; instead, normal field take-off and landing would be employed. Two Westinghouse J40 turbojets with afterburners were to be used; these were used in lieu of the ramjet engines originally scheduled for development by the Wright Aeronautical Corporation for the second (prototype) Navaho vehicle.

The X-10 was approximately 70 feet long and had a gross take-off weight of 46,000 pounds. The canard design X-10
had a 28-foot delta wing; small, all-movable forward control surfaces; and a Vee-type tail surface with elevons. Primarily, the surfaces were constructed of aluminum alloy, while stainless steel was used in the fuselage. A conventional tricycle landing gear and a radio command system were employed to recover the missile. During the early flight tests, the missile was to be directed from the ground system. Later tests were made with the missile completely controlled by the autonavigator.

In February 1951, the preliminary design of the X-10 had been firm. At the end of the following month, model testing at speeds up to Mach 2.87 had been completed. One-hundred percent design release was obtained in September 1951, and the X-10 flight vehicle was completed and flown in October 1953 at Edwards Air Force Base. The duration of flight was 32 minutes. The missile attained a speed of Mach 0.72 and an altitude of 20,000 feet. Missile recovery was successful and all objectives were accomplished.

**X-10 test flight**

**NAVAHO AUTONAVIGATOR DEVELOPMENT**

The development of the automatic navigation system for the Navaho missile was scheduled for a three-step progression. The first would involve the proving-out of a pure inertial system in a piloted aircraft. The second step would entail the development of a stellar-supervised autonavigator using a star-tracker telescope sensing system which would orient the gyro-stabilized platform. The third step was visualized as a design refinement period—during which the experience gained in earlier development would be used to redesign the system in order to obtain suitability with the Navaho missile or production convenience.

Guidance engineering under the Navaho project proceeded from the flight testing of the basic system in 1950. The major deficiencies discovered in this testing resided in the platform and the gyro; these problem areas were traced to gyro-bearing corrosion, a factor which accounted for position errors of the same order of magnitude as those recorded in the flight tests. Correction of this condition led to two advances: (1) development of autolubricated (gas or liquid) bearings for gimbal support, and (2) the use of gas spin bearings in certain critical areas for simplicity, reliability, and constancy of properties over extended periods of time.

One of the most important advances resulting from the Navaho guidance development program was the method of pairing gyro's. This method was invented by guidance personnel during the latter part of 1950. This system,
called NAVAN, used two gyros rotating in opposite directions for each of the three sensitive axes of the space reference system. In principle, the sense of spin of each gyro is periodically reversed, cancelling out the inaccuracies of the other. The N6 autonavigator series based on NAVAN and the new digital computer techniques developed into one of the most accurate contemporary guidance systems.

The stellar-supervised inertial system was first considered in 1946 for the MX-770 program. In 1948, this system was proved feasible by an NCAA innovation which utilized a single telescope with two six-degrees-of-freedom. Intermittent, rather than continuous, star tracking was utilized. The telescope and sensing element as well as the platform structure for the stellar-supervised system were fabricated and initially tested before the end of 1950.

Guidance development achievements and events came quickly. In March 1951, 28 flights of the XN-1 pure inertial system had been completed. In the summer of that year, the flotation-bearing gyro and the daylight star-tracker techniques were in laboratory test. The first daytime flight test of an XN-2 stellar-supervised system occurred in March 1952 with 22 additional flights made in the following year.

The X-10 autopilot was constructed and installed in an F-86D aircraft which served as the test bed. Performance was successfully demonstrated in 1953. Aircraft flight test of the advanced XN6 autonavigator for the X-10 missile was initiated in 1954. The autonavigator's performance earned the recommendation for its use in the subsequent Navaho missiles. Improvements to the system were continuing to be made. In 1955, functional tests were begun on the first transistorized airborne digital computer.

**XSM-64 AND SM-64A MISSILES**

The prototype Navaho missile (XSM-64) closely followed the X-10 experimental research vehicle in development. The XSM-64 was 70 feet long with a take-off gross weight of 60,000 pounds. The ramjet-powered missile was launched with a booster vehicle system powered by two 120,000-pound thrust, liquid propellant rocket engines.

Preliminary design and test of the 120,000-pound thrust rocket engine began in June 1951. The first static firing taking place in December 1953. The first static firing of the 240,000-pound thrust chamber occurred seven months later. With the success of the rocket booster development, the XSM-64 cruise missile was entered into production.

Air Force acceptance of the first flight article was recorded in April 1956. The first XSM-64 launch occurred in November 1956; during the next five months, three additional flights were made.

Development of operational Navaho (SM-64A) was first planned to be paced approximately one year behind the XSM-64 prototype program. The SM-64A final Navaho design was 90 feet in length and had a gross take-off weight of 135,000 pounds. It was designed to fly 3500 nautical miles at an altitude of more than 80,000 feet. The booster was powered by a cluster of three liquid oxygen and RP-fueled engines which developed more than 415,000 pounds of thrust.

Development of the SM-64A missile was proceeding efficiently on the example of the XSM-64 prototype. In the middle of 1955, the full-scale firing of the 415,000-pound booster had been accomplished, and static tests of the missile structure were underway at the start of the following year.

In July 1957, the WS-104A Navaho program was cancelled by order of the Department of Defense for reasons of Government economy and its decision to devote full effort to the ballistic missile program.
At the time of program termination, nine XSM-64 missiles and 13 boosters had been completed. The first SM-649 operational missile was well into production. Additional flights with the XSM-64 missiles that had been completed were authorized. This follow-on test program, identified as Fly Five, was highly successful. On the sixth flight, a 19-minute, 500-nautical mile flight was made at Mach 3 cruise—the highest steady flight speed by a winged vehicle until flight of the X-15. On the eighth flight, a distance of 1075 nautical miles was flown with completely successful autonavigator operation. The R&D flight program was concluded in 1958.

CONTRIBUTIONS OF THE NAVAHO

Although cancelled before completion, the Navaho is generally recognized as the key program in advancing the nation’s large missile and space capability. It is difficult to assess its full value. It was a program that foreran a broad order of technology. Certainly, the inertial guidance and propulsion accomplishments were the founding factors of our present missile and space stand; in addition, there were innumerable other valuable contributions.

Large liquid propellant power plant development carried out under the Navaho program alone would have justified the program’s value. It is estimated that it would have taken four years of intensive design and development to duplicate NAA’s technical position at the start of the Atlas program if Navaho developments had not been utilized. A thrust of 460,000 pounds achieved in a 1956 firing of the SM-64A booster engine was not exceeded until the Saturn firings.

Much of what is now standard in the fabrication of high-strength steel and titanium was developed for the Navaho program. The method of large machine-extruded, integrally stiffened panels as structural unit—which eliminated the conventional skin-frame-longeron construction—was applied to the XSM-64 booster. This method has been utilized in nearly all high-performance aircraft and missile vehicles.

Automatic tungsten, arc fusion welding was perfected for the stainless steel sections of the XSM-64 missile. The basic industry handbook for forming and welding titanium was written from the techniques developed for the SM-64A missile. The Chem-Mill process for chemically etching metals to critical dimensions was introduced by NAA during the Navaho program. A stretch-age process for fabricating stainless steel was conceived. Honeycomb sandwich construction techniques were advanced. Novel missile and space structure methods evolved from the production development projects associated with the Navaho made it possible to keep missile and booster manufacturing direct hours expenditure per pound comparable with the industry average for fighter aircraft.

Electronics, including guidance, were immensurably advanced in the Navaho development. Universal automatic ground checkout equipment and ground operational support systems for the Navaho flight test program contributed significantly to current operations programs. Early in 1955, the XN4 autonavigator became the nation’s first lightweight, starlight-supervised autonavigator; it was the only one of a new series of autonavigators and related equipment for a host of later generation aircraft and missile systems.

The Navaho program prefaced high supersonic and hypersonic aerospace flight. The efficiency of its canard configuration led to its application in the GAM-77, B-70, and other designs. Dynamic and thermal characteristics of Mach 3 flight were returned, and the feasibility of the modular space vehicle and high-altitude separation was exhibited.

Possibly the most significant contribution of the Navaho program was the weapon system management approach
that was fostered and tested by the Navaho program. A system-oriented organizational structure, established at the start of the program, enabled separate development efforts—vehicle, propulsion guidance, ground support equipment, test plan—to proceed simultaneously. These efforts were coordinated to arrive at pre-determined time. This method permitted concentration on project tasks unaffected by the other activities; it also permitted progressive product improvement.

The Navaho-inspired acceleration in the advanced fields of rocket propulsion, electro-mechanical systems, missile development—plus that portion of effort attending atomic research—led to the creation of separate and specialized North American operations. By the middle 50's, these endeavors resulted in the forming of the Rocketdyne, Autonetics, Missile Development, and Atomics International corporate divisions.

The missile airframe and Air Force systems management activity remained at Downey with the Missile Division; following the ending of the Navaho program, the technical and production force was directed to the next Air Force missile program—the GAM-77.

In conclusion, the Navaho program provided North American with an exceptionally well-trained management and a peerless technical and production organization. These forces were immediately applied to a host of new research and study projects which evolved from the log of the Navaho; these included 80,000 hours of offshore studies which were exploited to continue state-of-the-art advancements of specialized components.

DIVISIONAL EXPLOITATION OF THE MISSILE TECHNOLOGY

The laboratory research and development for the launch system portion of the Navaho program was continued at the Missile Division; this was the project which yielded such airframes as the Little Joe booster vehicle for the NASA Project Mercury flight test program and the Saturn S-I interstage fairing.

In December 1960, the Missile Division's name was changed to the Space & Information Systems Division. This operation was reorganized and realigned to accommodate new program roles in both manned and unmanned spacecraft, advanced launch vehicles, space science research; it also focused on the data, sensing, and communication areas associated with information systems.

S&ID is now processing a host of vital programs and projects which projected the Navaho accomplishments—including the Project Apollo spacecraft and the Saturn S-II stage which will hurl it on its lunar mission.

The advanced proprietary developments in electromechanical systems which were created out of the Navaho's broad research base sponsored the establishment of the Autonetics Division. Today, Autonetics is one of the ten largest electronics companies; it has major representation as an associate and subcontractor for guidance, flight control, GSE and other systems for a large representation of current manned and unmanned weapon systems. Some of these systems include the GAM-77, A3J, F-104, F-105, Polaris, and Minuteman.

Rocket propulsion programs of North American were also placed within separate divisional cognizance in 1955 with the forming of the Rocketdyne Division. The liquid rocket engines for the Atlas, Jupiter, and Thor missiles were produced by Rocketdyne. With the national space program coming into full definition, Rocketdyne is producing 1.5 million-pound thrust, H-1 cluster and F-1 single chamber types for the Saturn launch vehicles. This division is also advancing the development of all categories of rocket, electric and nuclear propulsion.

Nuclear research introduced in the original 1946 propulsion evaluation studies (judged not adaptable at that time) was redirected to other applications—primarily to the application of commercial power reactors. North American's atomic research, which led to the design of the first sodium graphite reactor, ultimately will concern non-military electric power installations. The Atomics International Division has added to its responsibilities several other tasks, nuclear effects research and the development of small reactors for space application as an electrical subsystem power source.

Elsewhere in the North American corporate activity, the technological advancements that had sprung from the early missile development programs were introducing the aerospace projects of the Los Angeles and Columbus Divisions. The materials research and production developments of the advanced missile found application in the high-supersonic designs of the F-107, F-108, A3J, and the XB-70. The XB-70 extensively employs the brazed honeycomb sandwich construction first approached for the Navaho. The X-15, with its hypersonic flow and severe re-entry requirements, capitalized on the materials that had been in progress for Navaho.
With the Divisional apportionment that occurred within North American Aviation in the middle '50's, the responsibility for Navy and Army missiles was assigned to the Columbus (Ohio) Division. Here, accelerated advances were being made in electronics and structures capability in support of the A3J and other advanced concepts. Building on the experience base of the Corporation, NAA-Columbus quickly came to the fore in its industry missile assignment. Concentrated research studies led to a series of highly competitive missile system proposals and to the award of the Redhead-Roadrunner target missile program. Columbus' competence in missile technology is evidenced by its selection as a prime bidder for such programs as Typhoon, Missile "B," and SPRINT.

The defense and space programs of today and tomorrow call for a scientific and industrial vigor that far exceed the capabilities of single specialized companies or the standard division of large members of the defense industry. North American Aviation has invested its major long-term development planning effort to the application of the corporate resources that would effect all-systems capability and the full industrial and technical strength to efficiently process national responsibilities.

The early assembly of missile system capabilities at North American were effectively distributed throughout the corporation by the development planning that established specialized divisional pursuits. Repetitive and complementary divisional roles were carefully planned. For example, GSE assignments are undertaken at all NAA Divisions—each directed to the requirements of the particular product or using agency. Under its present structuring and alignment, the corporation is able to collect and consolidate its total missile skills (including manpower, data fund, and equipment and facilities) to accomplish the demanding tasks of modern procurement.

The significance of North American's heritage in missile development is not only that it was a prime mover in the original establishment of the nation's missile weapon and space program, but also in the capitalization of its early accomplishments to meet the nation's present and future needs.