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Chapter 17

ROCKET RESEARCH AND TESTS AT THE NACA/NASA WALLOPS ISLAND FLIGHT TEST RANGE 1945-1959: A MEMOIR[*]

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The launching of the 100th Scout space vehicle which placed a satellite in Earth orbit on June 2, 1979 from the NASA Wallops Island flight test range was another reminder that an economical and reliable space launch vehicle could be produced with multistage solid rocket motors. The Scout was developed by following the rocket-staging concepts used so successfully in flight research with rocket-propelled models at Wallops by the Pilotless Aircraft Research Division (PARD) of the Langley Research Center, Hampton, Virginia. Langley was the first research laboratory of the National Advisory Committee for Aeronautics (NACA), the forerunner of the National Aeronautics and Space Administration (NASA). The Scout was considered by PARD as the logical step in its program to obtain research data in flight at ever-increasing speeds that started with the high subsonic Tiamat guided missile for the Army Air Forces in 1945 and evolved into the supersonic and hypersonic range with multistage solid rocket motors of increasing size and efficiency and eventually at satellite speeds.

But, to return to the beginning, in late 1944 the Army Air Forces[1] asked NACA to assist in the development of an air-to-air rocket-propelled guided missile through flight test, while the Navy Bureau of Aeronautics[2] asked NACA to expedite high-speed aerodynamic research and suggested the use of rocket-propelled models. NACA asked Langley to respond to these requests. Langley researchers were aware that military airplanes had been encountering severe problems in high-speed dives that appeared to limit the speed attainable. These problems were violent buffeting and longitudinal trim changes of such magnitude that recovery from such dives was difficult, if not impossible. There were no transonic wind tunnels, and special techniques had been devised for studying these problems. First among these was the "free-falling body" technique in which heavy instrumented models were dropped from high altitudes to allow study of high-speed conditions as

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the body accelerated to the Earth as described by Thompson[3]. A second technique for studying transonic phenomena was the "wing-flow" technique invented by Gilruth[4] in which small half-span models were mounted on a balance with the test model extending from the curved upper surface of an airplane wing for test in the local flow field which became transonic as the airplane dived to its highest speed. The opportunity to add a third technique for high-speed research that had no speed limitations (rocket-propelled models) was eagerly accepted, and Langley leaders recommended to NACA Headquarters that such a program be implemented with funds requested from Congress. The request for approval cited the need to develop a guided missile for the Air Forces as the justification.

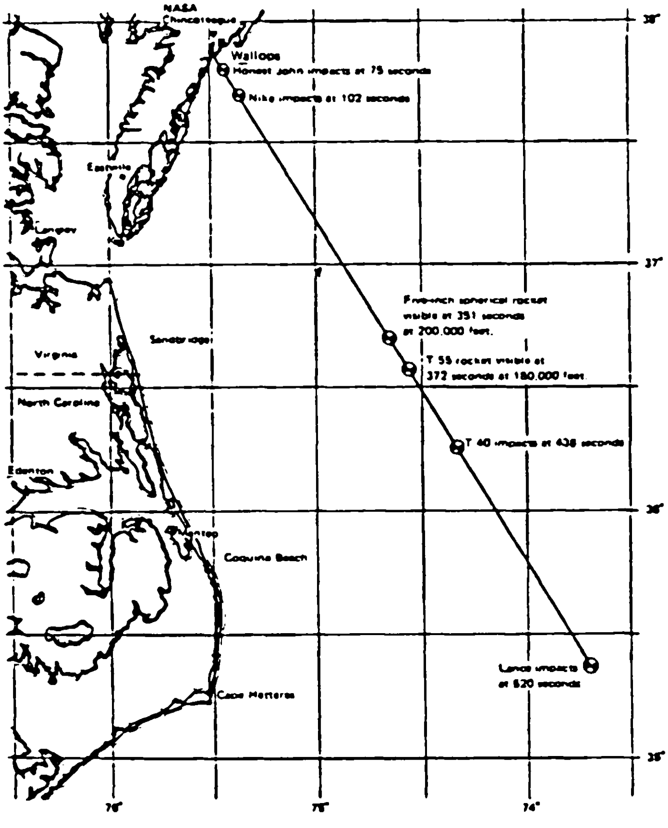

Figure 1 Wallops Island Test Range showing path of a Trailblazer 6-stage rocket.

Langley officials recommended that such tests be conducted at a remote flight test range to be established under the supervision of a new division to be formed within Langley and to be called Pilotless Aircraft Research Division (PARD). With the approval of Congress this was done and such a test range was located on the southern part of Wallops Island, a small barrier island on the Atlantic ocean side of the Eastern Shore peninsula of Virginia near the Maryland border as may be seen in Figure 1. This figure also shows the range used in a flight test of a Trailblazer vehicle as well as the impact points of its six stages, as will be discussed later. Wallops continued as a test station under Langley until 1959 when it became a separate Flight Center under NASA Headquarters. PARD and the Wallops range were headed by R. R. Gilruth from the beginning in 1945 until 1951 when J. A. Shortal succeeded him. In 1959, when Wallops was separated from Langley, R. L. Krieger was named Director. Krieger had been in charge of Wallops operations as a PARD branch head since 1948.

Although NACA was an independent agency of the U.S. Government during World War II, it was the aeronautical research agency of the military services and all research had to be related to the war effort. Such research was conducted with funds appropriated for NACA without any transfer from the military. In turn, the military services transferred to NACA any equipment or special supplies needed. In this category were airplanes, boats, trucks, radars, and solid rocket motors needed for operations at Wallops. This simple transfer of equipment made it possible for PARD to begin flight operations at Wallops within a couple of months after approval by Congress.

Langley had an SCR-584 radar on loan from the military for use in the tracking of airplanes and bombs and adapted it for use at Wallops to track ground-launched rockets. In addition, a Doppler radar, TPS-5 was obtained from the Signal Corps to measure velocity. Radiosonde equipment to measure atmospheric conditions was likewise acquired from the Signal Corps but all other instrumentation had to be developed by Langley. This was done by the Instrument Research Division headed by E. C. Buckley. Measurements of such items as accelerations, pressures, temperatures, and control position were transmitted from the free-flying models by radio telemetry especially developed by IRD with the accuracy and reliability required for research. This telemeter system was an FM/AM system with continuous transmission of data.

The rocket motors used in the initial program were principally small-diameter aircraft rockets with high thrust which could accelerate the test models to supersonic speed. PARD kept abreast of new developments in solid rocket motor technology and added advanced types of rockets to its inventory as they became available.

The material in this paper was taken from a much more detailed history of the first fifteen years of the range covering the complete development of facilities and techniques as well as the accomplishments during the period[5]. A preliminary draft of this detailed history was used extensively by Gilruth when he prepared his memoir[6] for delivery at the Sixth History Symposium of the International Academy of Astronautics, Vienna, Austria, October 1972.

EARLY FLIGHT TESTS

Wallops island was separated from the mainland by water and marsh, and all equipment needed for the initial operations was transported by boat. A concrete slab was poured on the sands just back of the ocean beach and a small area in the rear was enclosed with sandbags to serve as a blockhouse. The first rocket launched occurred on June 27, 1945 as shown in Figure 2. It was a small aircraft rocket obtained from the Navy. This first rocket at launch simulated the path to be taken by the first test missile. The Atlantic Ocean was the test range and the test models were not recovered.

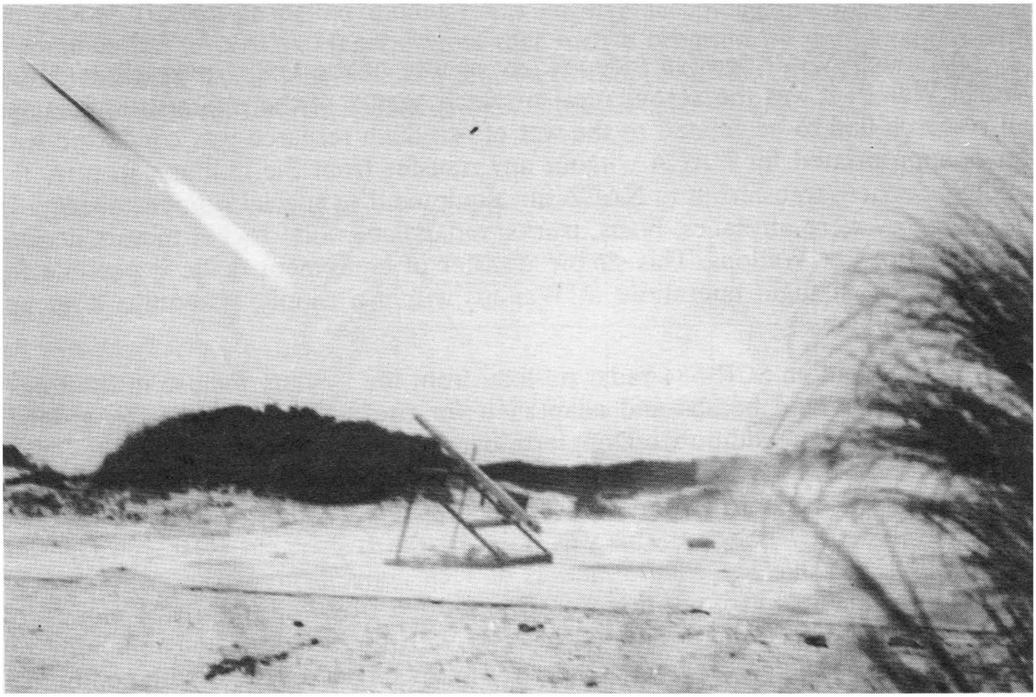

Figure 2 Launch of first rocket at Wallops, June 27, 1945.

The first research program at the new Wallops range was to develop the subsonic air-to-air guided missile as requested by the Army Air Forces[1]. R. T. Jones of Langley proposed a design for this missile that consisted of a simple body with three tail fins which was named "Tiamat". The Air Forces accepted this design and contracted Hughes Aircraft Co. to build the production version. At the same time Langley was constructing a quantity of full-size models of the missile for test at Wallops and such models were ready for launch by the time the range was ready. One of these Tiamat models is shown in Figure 3 with its booster rocket thrusting. This booster accelerated the missile to its operating speed and, following separation of the two, an internal rocket motor maintained this speed over the test course.

Three important things were learned about rocket-booster technology in these first tests. First, it was found that a successful launch could be made at a relatively flat angle with a "zero-length" launcher provided a high-acceleration booster was used. The need for a launching ramp as used with the German V-1 missile was not necessary. Second, it was demonstrated that a booster could be attached to a missile with rods which could be released by explosives. Third, it was found that the booster as well as the missile had to stable after separation to prevent the booster from disturbing the missile as it separated. Before a completely successful flight was obtained, however, World War II was over and the urgency of this program ended. Emphasis now shifted to research at supersonic speeds.

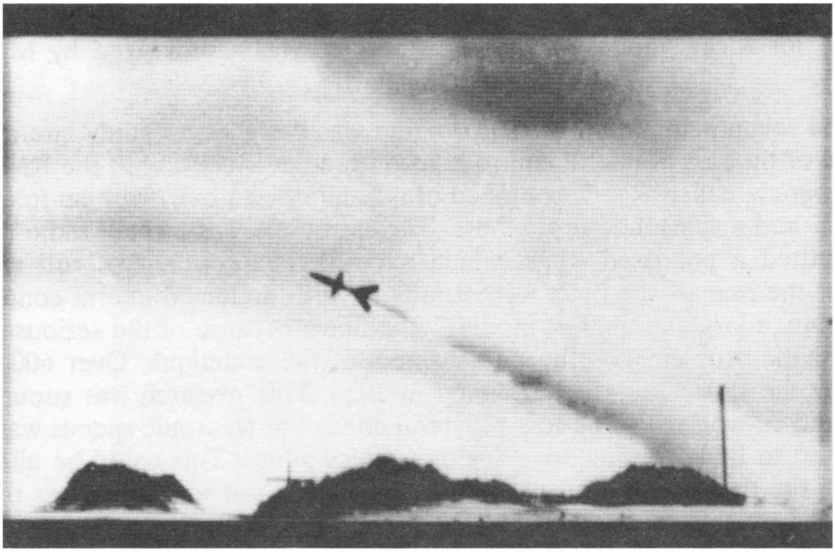

Figure 3 Launch of boosted Tiamat missile at Wallops, 1945.

Even before the war ended, a supersonic missile designated RM-1 was designed as a follow-on to the Tiamat and as an all-purpose test missile to study various wing and control arrangement into the supersonic speed range. This research missile had an automatic stabilization system in the roll plane to avoid coupling with pitch or yaw motions. This missile was smaller in diameter than the Tiamat and a Mach number of 1.4 was attained with a 2-stage system. The first instrumented missile was launched in May 1946 and a new aerodynamic problem at transonic speeds was revealed, that of aerodynamic control reversal. Now it was evident that basic research in this speed range was needed before such a complicated device as a complete guided missile could be tested. To accomplish this the various research problems were attacked individually with specialized research missiles.

The first of these specialized missiles, RM-2, concentrated on aerodynamic drag. It was found that the Doppler radar had sufficient accuracy in the measurement of velocity that accelerations could be deduced from it, enabling a determination of drag as the model decelerated from its maximum speed after burnout of the rocket motor. Short-burning rockets were used to keep the model close to the radar during the test period. Because of the simplicity of this technique it was not possible to test a large number of models quickly. In 1946, for example, 150 were launched and by the time the program ended over 800 had been launched. Because there were no transonic wind tunnels at this time, this rocket technique was used to collect basic drag data for wide variations in wings, bodies, and nacelles.

As the desirable low-drag wing forms began to materialize, much larger models were flown with an internal Deacon rocket motor. The Deacon rocket motor was the first high-performance motor used at Wallops, and its development at Alleghany Ballistics Laboratory (ABL) was sponsored by NACA. Initial work on this rocket had been halted when the war ended. With these large models, full-scale flight conditions for airplanes flying at high altitudes could be attained and even after large transonic and supersonic tunnels were available there still was a great demand for rocket-model data, some of which was summarized by Morrow and Nelson[7].

The second simplified model program was designed to study lateral control--because of the loss of lateral control encountered at Mach 1 with the RM-1 missile. This program, called RM-5, consisted of a standardized body with an internal rocket motor and a spinsonde in the nose. The spinsonde was a small radio transmitter that emitted a polarized signal which allowed measurement of roll rate. Three wings at the rear of the body were equipped with deflected lateral controls under test. Again, a large number of models were flown because of the seriousness of the aerodynamic problem and the effectiveness of the technique. Over 600 had been flown by the time the program ended in 1956. This research was summarized by Strass and co-workers[8]. The loss of lateral control at transonic speeds was found to be related to large trailing-edge angles of thick wings. This could be alleviated by blunting the trailing edge or, preferably, by making the wing thin, less than 5-percent of the wing chord.

For research into transonic problems of longitudinal trim changes encountered earlier in dives with high-speed airplanes, it was necessary to test complete models. A small floating vane was used to measure angle of attack in flight while lift and drag were recorded by accelerometers located near the center of gravity. Such a model provided data on trim lift and drag over the speed range, and by flying successive models with different control settings a complete map of control position for trim over the speed range could be developed. A more sophisticated program involved moving the longitudinal control between stops in a square-wave pattern in flight. The pulse time was set to allow several oscillations of the model so the stability and damping could be determined. Variations of lift, drag, damping, stability, and control effectiveness as related to angle of attack could then be determined over the speed range. Any buffeting would also be shown.

These early flight tests with different techniques provided solutions to the problem of flight at transonic speeds, namely, longitudinal trim changes, buffeting, loss of lateral control, and high drag and made possible the design of safe and efficient supersonic aircraft. The use of thin wings and all-moving horizontal tails were the main contributing factors in this solution.

SPECIFIC AIRPLANES AND MISSILES

Despite the fact that basic research programs in many areas were carried out with simplified models or generalized configurations, the military services requested that models of their specific supersonic airplanes and missiles be flown at

Wallops. With the acquisition of the Deacon rocket motor it became possible to fly rather large complete models to Mach 1.6. For heavier models 2, 3, or 4 Deacons were strapped in a cluster as a booster. For higher speeds or heavier models, Nike booster rockets were obtained from the Army in 1953. These were quite large, being equivalent to about seven Deacons. One of the Nike boosters being used to launch a model of the Navy McDonnell XF4H-1 airplane is shown in Figure 4.

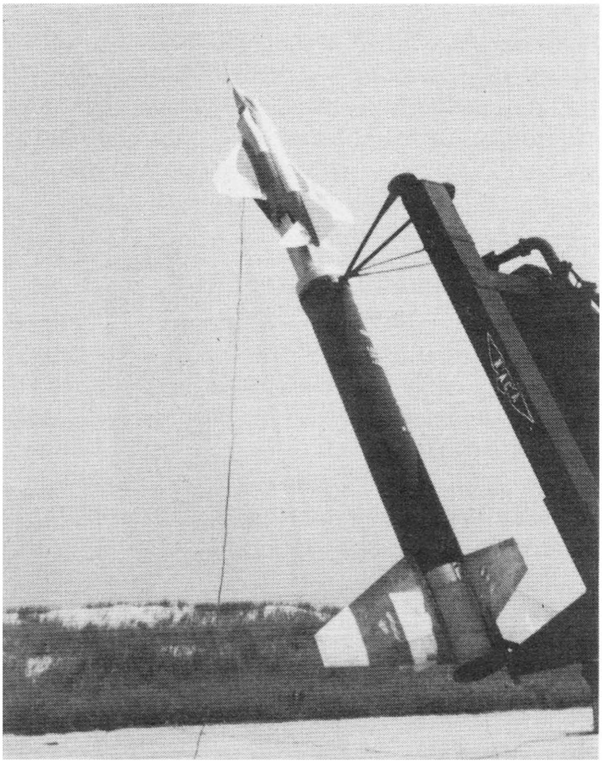

Figure 4 Rocket model of McDonnell XF4H-1 airplane with Nike booster, 1957.

In addition to this XF4H-1 model, the following airplane models were tested: Douglas D558-II, Bell X-2, and Douglas X-3 research airplanes; Republic XF-91, Convair XF-92, Convair XB-58, North American YF-100, Convair F-102, Lockheed XF-104, McDonnell XF-101, and Republic F-105 Air Force airplanes; and Grumman XF10F-1, Douglas F5D-1, Douglas XF4D-1, McDonnell XF3H-1, Chance Vought CF8F-1, and Grumman XF9F-9 Navy airplanes. With most of these models, the flight tests supplied data on drag, inlet performance, lateral control, stability, and in some cases flutter information. In reality for two of the airplanes the flight tests led to a redesign. For the Convair F-102 the fuselage was reshaped in accordance with the Area Rule of R. T. Whitcomb of Langley to form a "coke-bottle" shape to reduce peak drag at Mach 1. For the Convair XB-58 airplane an even more drastic redesign in accordance with the Area Rule was made. In both cases, the redesigned airplanes were then able to achieve their specified performance.

In the case of specific guide missiles beyond the Hughes Tiamat already mentioned, the following models were tested: Bell Rascal, Northrup Snark and Boojum, North American Navaho, Hughes Falcon, Martin Titan, General Electric Atlas nosecone for the Air Force; Sperry Sparrow, Navy Lark, Eastman Kodak Dove, Grumman Rigel, Sidewinder, Chance Vought Regulus II, Martin Bullpup, and Lockheed Polaris for the Navy and a few Hermes tests for the Army.

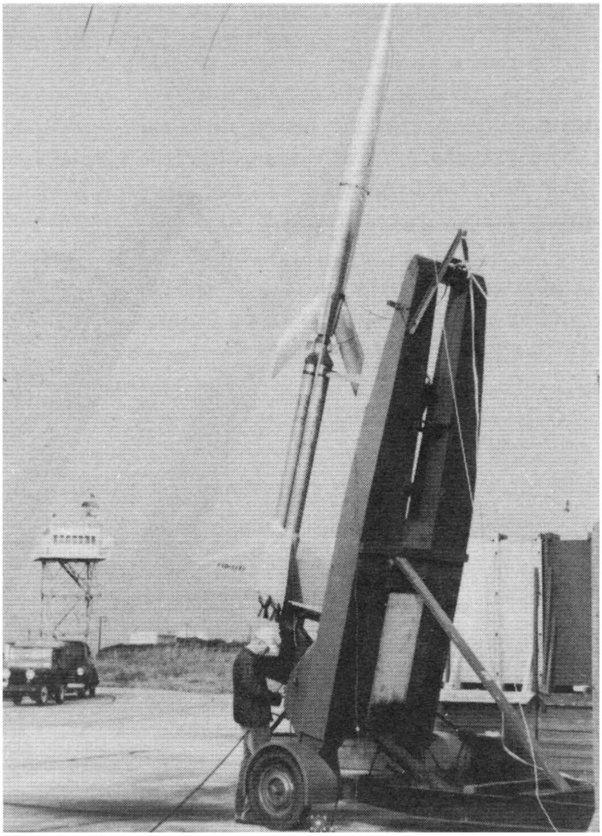

Figure 5 RM-10 aerodynamic heating model with double-Deacon booster.

HYPERSONIC HEAT TRANSFER

The subjects of aerodynamic heat transfer and skin friction were especially suited for rocket model research because of the ability to reproduce near full-scale conditions. Heating under turbulent flow could be as much as seven times that under laminar flow conditions, and it was vital to know which condition would exist. The initial flight measurements were made with a standardized body selected by PARD researcher W. J. O'Sullivan. This body with four stabilizing fins was called RM-10, and one is shown ready for launch in Figure 5. It was later used in wind tunnel calibrations and was adopted by the NATO Advisory Group for Research and Development as their AGARD Model I. RM-10 models were flown at speeds up to Mach 4 and skin friction over this range was analyzed by Loposer and Rumsey[9].

In 1952 the military services and the aircraft industry through the NACA committees requested that the PARD rocket model program be extended as quickly as possible to Mach 10, and even higher, to provide data for the new ballistic missiles under development. Of greatest importance was heat transfer since survival of the reentry structures depended on accurate knowledge of such heating. At that time the Atlas ICBM was designed for a 10-degree conical nose and PARD began research with such a shape. Some tests were made with multiple Deacon rockets, but it was quickly seen that a larger motor was needed. A Nike booster was therefore used with a Deacon as the second stage and launched for the first time on November 19, 1953. This vehicle reached a Mach number of 5.6, somewhat lower than expected. A third stage was then added in the form of another Nike and launched on April 24, 1954. A Mach number of 6.9 was reached. Plans were made to replace the Deacon motor with the more efficient Thiokol T40 motor developed for the Army Hermes missile program.

In the meantime, R. O. Piland realized that to attain a Mach number of 10, a smaller upper stage would be required. A Thiokol T55 motor developed as a part of the Falcon missile program was selected, and it was mounted as a fourth stage atop a Nike-Nike-T40 booster system. Such a 4-stage system was launched on October 14, 1954 and a Mach number of 10.4 was reached[10]. This missile was fired in a climbing trajectory and reached an altitude of 350 km and a range of over 600 km. This was a speed, altitude, and range record for Wallops, but the long range introduced problems of range clearance. In addition, the test model was climbing rapidly during the important high-speed test period and the altitude became too high to simulate missile reentry. For these reasons, the flight trajectory was changed.

With the multistage rocket, the flight trajectory can be changed without the use of a control system. In the case of the 4-stage system just described, the first stage was ignited with an instantaneous squib while the second stage had a 13-second delay squib. Each of these rockets dropped away after burnout. The upper two stages were then allowed to coast to the top of the trajectory at about 30 km and then the third stage was fired with the aid of an onboard timer and battery. The setting of the timer could be varied to provide any type of trajectory of the last two stages from a climbing one to one of steep reentry from the peak altitude.

As mentioned, the Tiamat missile tests showed that all parts of a rocket system had to be aerodynamically stable to prevent disturbances at separation, and that explosive charges could be used to break connecting tierods. While the need for stability always existed, a simpler way of connecting stages was found. For a 2-stage system, the second stage was simply placed atop the first stage with the nozzle fitting over a plug attached to the front end of the first stage. This plug transmitted the thrust to the second stage directly to the nozzle end, while bending was prevented by the front end of the plug being in close contact with the nozzle throat. At burnout of the first stage, the spent rocket simply fell back out of the way. Blowout diaphragms were sometimes used for connectors in upper stages.

When it appeared that the Nike booster, even in a 4-stage system, would limit the program to about Mach 10, a search was made for a larger first stage. The Army had the Honest John missile under development and agreed to transfer a number to NACA. This motor had about twice the impulse of the Nike and was suited for a multistage system. In addition, the Air Force transferred a number of Recruit motors. This Thiokol motor had the same high efficiency as the T40 but was longer and produced over ten times the thrust. With a Recruit substituted for the T40 motor of the Mach 10 system, and an Honest John added to the bottom of the stack, a large 5-stage system was developed with which Mach 15 was obtained. One of these vehicles is shown in Figure 6. The first launch was on August 24, 1956. By this time the Air Force had changed the shape of the ICBM nosecone to a blunt shape, and this 5-stage vehicle was used over the next two years to obtain heat transfer data for many such shapes. As before, the "over-the-top" trajectory was used to keep the test range close to Wallops[11].

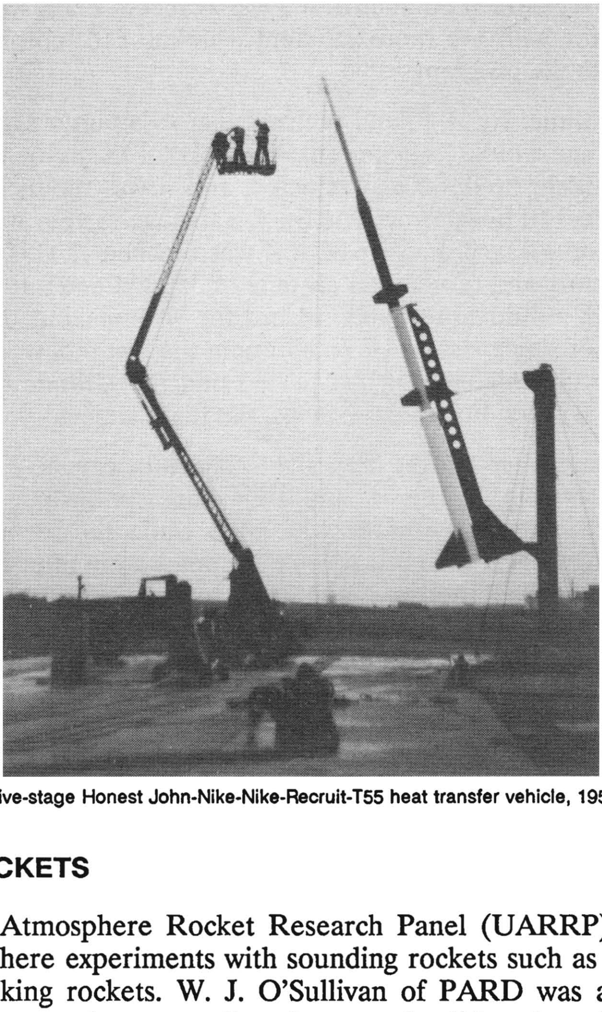

Figure 6 Five-stage Honest John-Nike-Nike-Recruit-T55 heat transfer vehicle, 1956.

SOUNDING ROCKETS

The Upper Atmosphere Rocket Research Panel (UARRP) was responsible for upper atmosphere experiments with sounding rockets such as the German V-2, Aerobee, and Viking rockets. W. J. O'Sullivan of PARD was a member of this panel and made suggestions regarding the use of solid rockets for such research. Funding for this research was provided by the armed forces. The Air Force Cambridge Research Center (AFCRC) was particularly involved and their representative asked O'Sullivan at the meeting on April 29, 1953 if NACA had a solid rocket launch system that would do the job more cheaply than the Aerobee.

O'Sullivan recommended the Nike-Deacon system which was being readied for the hypersonic heat transfer program at Wallops. He calculated that such a vehicle could carry a large payload to 120 km in a vertical launching. Although many members of the panel hated to see their liquid sounding rocket displaced, a budget cut of 40 percent forced the issue, and AFCRC contracted the University of Michigan to adapt the PARD vehicle for use as a sounding rocket. L. M. Jones and W. H. Hansen of the Dept. of Aeronautical Engineering were assigned the task and Jones was to be the initial user with his "falling-sphere" experiment.

The conversion of the basic Nike-Deacon vehicle into a sounding rocket was a cooperative effort by University of Michigan and NACA personnel, with the University serving as the prime contractor. The first such rocket is shown in Figure 7. It was launched on April 8, 1955 and the expected altitude was reached[12]. The UARRP panel was impressed with simplicity of this system and the minimum equipment required for launching, which would make possible its use from ships all over the world. When informed that the cost was less than one-fifth of that of an Aerobee, 34 Nike-Deacons were added to the International Geophysical Year (IGY) program to begin in 1957. By the time these rockets were needed PARD had contracted Thiokol to develop an improved version of the Deacon. This new motor, named Cajun, replaced Deacon at PARD as well as the Deacon in the Nike-Deacon. In 1956 another use was made of the Nike-Cajun rocket at Wallops when the Weather Bureau created Project Hugo to develop a system to keep track of hurricanes by photography from sounding rockets. The Nike-Cajun became one of the major sounding rockets used by NASA afterwards[13].

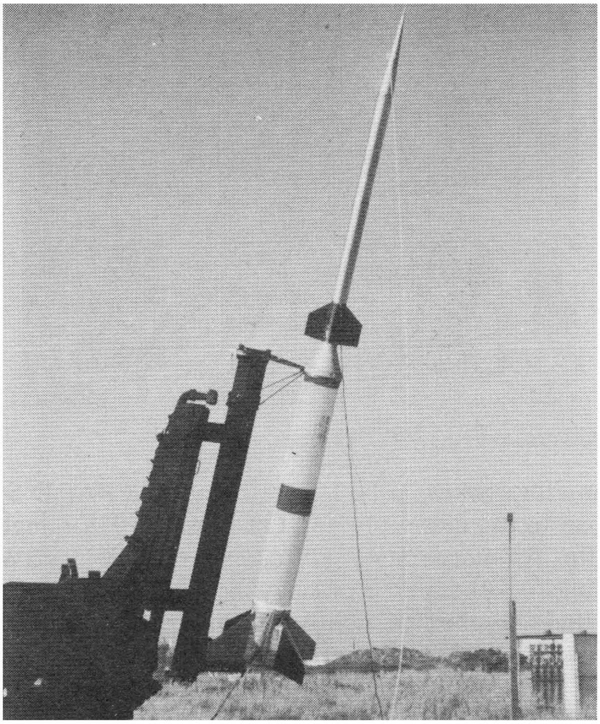

Figure 7 First Nike-Deacon sounding rocket at Wallops, 1955.

Following the success of the Nike-Cajun sounding rocket, the Air Force asked the University of Michigan to develop a sounding rocket to carry an air-density payload to an altitude of 480 km. As before, AFCRC supervised the contract and again Jones and Hansen of Michigan were in charge. Jones and Hansen visited Langley on March 20, 1957 and asked for advice on rocket motors for such a sounding rocket and for assistance in its development as had been provided with the Nike-Deacon. PARD recommended an Honest John-Nike-Recruit 3-stage combination of motors. This sounding rocket was named Exos and one is shown in Figure 8 ready for launching on June 26, 1958. Millstone Hill radar near Boston, Massachusetts tracked the upper stage to a peak altitude of 400 km when launched at an elevation of 80 degrees.

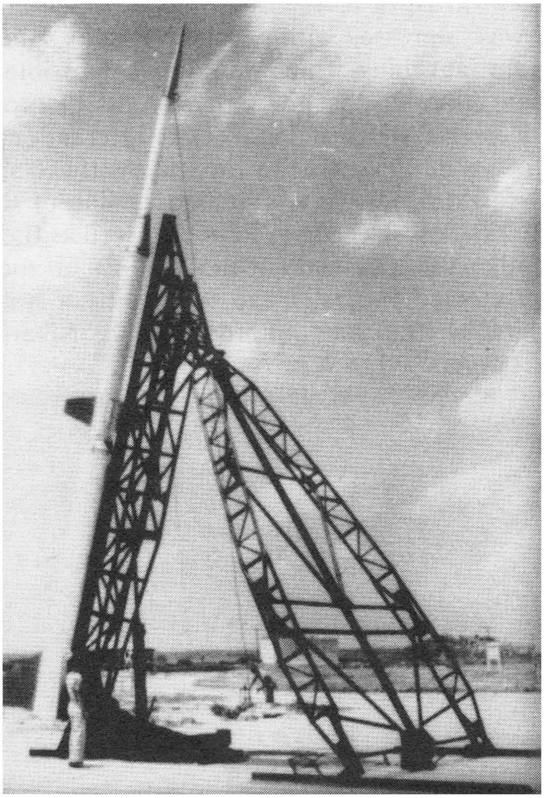

Figure 8 First Exos sounding rocket at Wallops, 1958.

The next sounding rocket, to be adapted from the PARD 5-stage heat transfer vehicle, was for use in the Jason project. On May 6, 1958 Langley was visited by a contingent from the Air Force Special Weapons Center (AFSWC) regarding their need for a sounding rocket capable of carrying a radiation-measuring payload to at least 500 km altitude as part of the Argus program of the Advanced Research Projects Agency (ARPA) of the Department of Defense. Twenty-one such vehicles were needed to be launched before September 1958 simultaneously from three different sites on the East coast: Wallops; Cape Canaveral: and a new launch site in

Puerto Rico. Small nuclear bombs were to be carried to a high altitude in the South Atlantic and exploded. The sounding rockets were to measure the radiation in space before, during, and after the explosions to determine if such radiation would become entrapped in the magnetic field of the Earth. AFSWC planned to launch the nuclear bomb with a modified X-17 vehicle under contract with Lockheed Aircraft Co. In addition, Lockheed was to provide radiation-measuring packages to be carried by the sounding rockets. AFSWC had concluded that the PARD 5-stage heat transfer vehicle was the "most feasible and economical for the job". AFSWC planned to procure all of the rockets needed for the program and planned to contract Aerolab Development Co., whose president, E. G. Crofut, was well acquainted with the PARD activity through earlier component contracts. Aerolab was to construct all the fins and connecting hardware and to provide the field crew at the two sites other than Wallops.

The vehicle was redesigned with the joint efforts of NACA and Aerolab and successfully proven ready by the time needed. All phases of the program were successful. The final vehicle of the Jason project is shown in Figure 9 after launch on September 2, 1958. These sounding rockets were remarkable for their success because they contained no guidance, control, or destruct system, and were launched at an elevation of 80 degrees. The Millstone Hill radar tracked on of the rocket to an altitude of 750 km. PARD activities in the development of this sounding rocket were directed by A. G. Swanson[14]. NASA later identified this sounding rocket by its project name, Jason, while Aerolab produced it under their designation, Argo E-5.

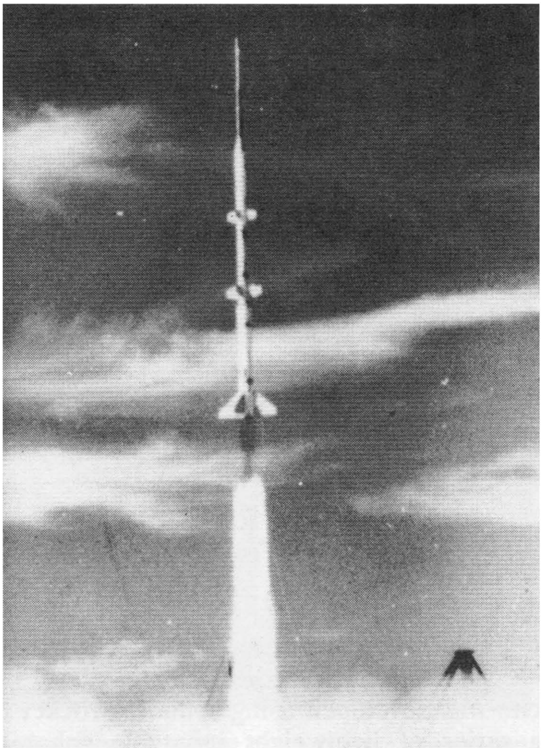

Figure 9 Final launch of the Jason project at Wallops, 1958.

As a follow-on to the Jason project, AFSWC wanted a sounding rocket to measure radiation to an altitude of 1600 km in a project called Javelin. In September 1958 the Air Force asked that A. G. Swanson be assigned on temporary duty at AFSWC to provide assistance. Swanson proposed that the upper two stages of the Jason system be replaced with an X-248 motor. He calculated an altitude of 1450 km for it. The X-248 was a new motor developed by Alleghany Ballistics Laboratory (ABL) for use as the upper stage of the Navy Vanguard satellite launch vehicle and could be operated outside the atmosphere with spin stabilization. The first launching was at Wallops on July 7, 1959 with successful results. The rocket is shown on the launcher in Figure 10. The payload was provided by Lockheed, as before, and measured radiation in space. After NASA was formed, its Goddard Space Flight Center was given responsibility for sounding rockets and the Javelin was added to the Goddard inventory of sounding rockets.

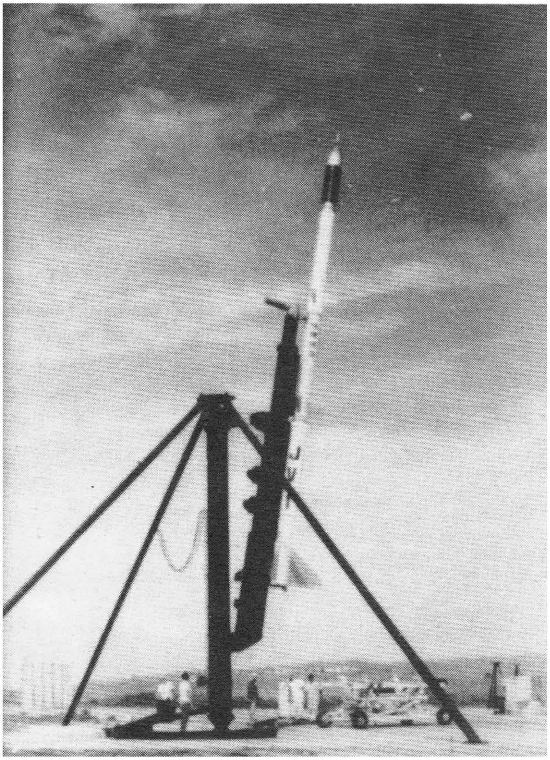

Figure 10 First Javelin sounding rocket at Wallops, 1959.

SPACE FLIGHT

The most famous unmanned satellite to be launched by NASA was undoubtedly Echo, the 30 m inflatable spherical communications balloon. Launched from Cape Canaveral in 1960 it remained in orbit and visible in the night sky for more than eight years. Echo was developed using sounding rocket launchings at Wallops and was one of a series of lightweight inflatable spheres invented by W. J. O'Sullivan.

O'Sullivan's first proposal, in January 1956, was a 50 cm balloon to be launched as a companion to a much heavier spherical satellite of equal diameter in the Vanguard program. Air density was to be determined by analysis of the relative motions of these two objects. This first inflatable sphere was constructed of thin aluminum sheet glued to a thin Mylar plastic sheet. When the finished package weighed less than allowable, the diameter was increased to 75 cm in February 1957. It was not until April 1959 that an attempt was made to put one in orbit, but then the Vanguard vehicle failed.

While waiting for the Vanguard launching of the 75 cm sphere as a secondary payload, O'Sullivan in late 1957 developed a 360 cm sphere which could be carried by Vanguard as a sole payload. Then came the Russian Sputnik on October 4, 1957. Now, national interest in this 360 cm sphere became intense because it would be visible evidence that the United States was also in the satellite business and plans were made to launch one in a 51 degree orbit so as to cover a large area of the globe.

Both a Vanguard and a Jupiter C launch vehicle were considered, but neither became available. This sphere is shown in Figure 11 inflated and as rolled into a compact bundle at the base of a simulated Jupiter C nosecone. The "high-kick" rocket motor used to put the Jupiter C into a circular orbit may be seen in the top of the nosecone.

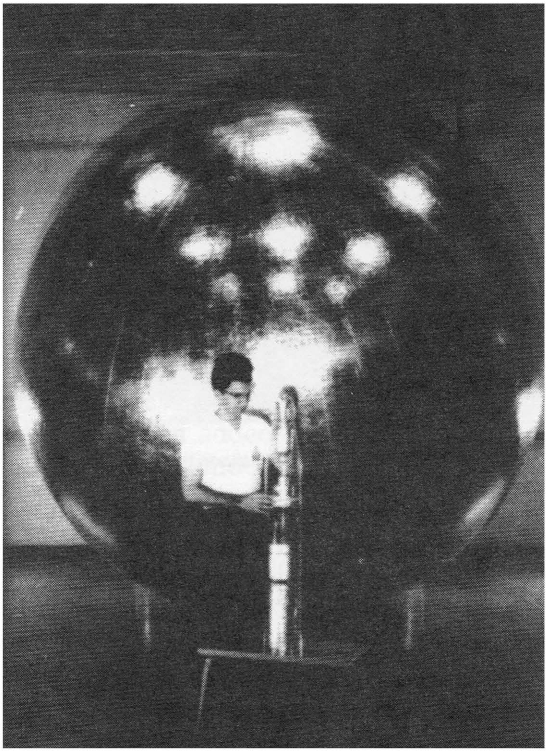

Figure 11 Jupiter C nosecone with inflated 360 cm inflatable sphere behind it.

In the meantime developmental tests of the 360 cm sphere were successfully conducted at Wallops in April 1958. Several such spheres were launched by Nike-Cajun rockets at Wallops, but it was not until later that one was placed in orbit by a Scout launch vehicle, as Explorer IX. It remained in orbit for several years and provided astronautical data, not only on air density, but also on solar radiation pressure[15].

The Echo inflatable satellite that followed the 360 cm sphere was an outgrowth of a suggestion in 1955 that a large sphere in orbit could be used in passive communications. Early in 1958 NACA was asked to develop such a satellite for possible launching by an ARPA satellite in October 1958. O'Sullivan was assigned the task. Whereas the earlier spheres were constructed of sheet aluminum and could maintain their shape without internal pressure, the 30 m sphere was constructed of thin Mylar covered with only a molecular film of aluminum to provide a radar reflective surface and required internal pressure to preserve its shape. The Echo balloon was assembled at Langley and taken to a large balloon hangar for a test inflation as shown in Figure 12.

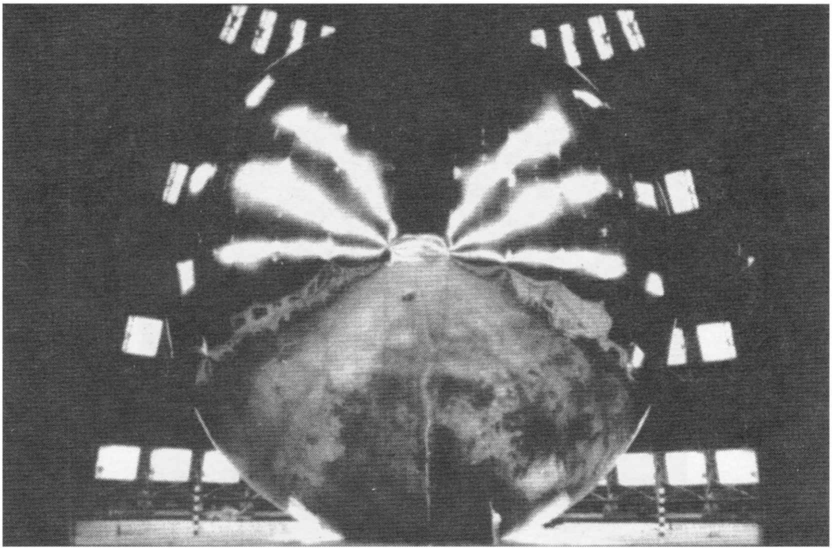

Figure 12 Echo 30-meter inflatable sphere in balloon hangar, 1958.

A special sounding rocket named Shotput, and shown in Figure 13, was developed for testing the inflation of Echo in a space environment at Wallops. Langley designed the package for launch by a Thor-Able launch vehicle belonging to ARPA, but after the creation of NASA it became strictly a NASA launch. Eventually it was launched by a Delta satellite vehicle. The payload was designed to be attached atop an X-248 rocket motor. The Shotput rocket likewise had an X-248 motor as its upper stage with a Sergeant as the first stage. This was the Thiokol motor from the Army Sergeant missile, and had been used in the X-17 and other research projects. To increase the acceleration at launch, two Recruit motors were strapped to the sides of the Sergeant. The upper stage was stabilized by spin imparted by small rocket motors. Similar motors stopped the spin before the large payload was ejected.

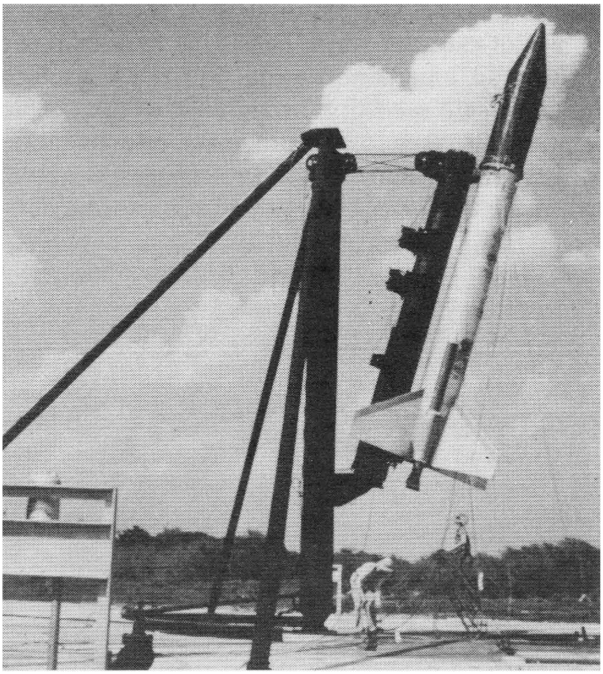

Figure 13 First Shotput vehicle on launcher at Wallops, 1959.

In the first tests of Shotput at Wallops on October 28, 1959 everything went as planned except for the inflation of the balloon. After burnout of the X-248 motor the spinning motion was stopped and the spherical container separated from the motor at an altitude of 135 km. Then linear shaped charges separated the container into two halves and pushed them apart while a taut rubber band expelled the compactly-folded balloon from the container. Immediately the balloon was torn apart. At packaging the balloon was evacuated but some residual air was left to aid inflation. In addition, water had been added inside the balloon for the same purpose. The water was supposed to turn into vapor and ice crystals which would sustain inflation. Moreover, a small amount of subliming powder was added to maintain inflation over a long period. It was conjectured that in the flight test the water was so heavy as to cause the thin balloon to be torn apart at separation. Some modifications were made without success until, at the fourth attempt on April 1, 1960, the balloon was punctured with 240 pin-sized holes to allow complete evacuation during packaging. For inflation only a subliming powder was used. This time all went well and the packaged sphere awaiting launch at Cape Canaveral on a Delta vehicle was modified accordingly. On the second try at the Cape on August 12, 1960 Echo was placed in orbit and its usefulness as a passive communications device demonstrated.

One of the largest developmental programs in astronautics at Wallops in this period was that associated with the first manned satellite, Project Mercury. Many small-scale models were tested, dummy capsules were dropped from the air, and even a paraglider was flown at Mach 2 for possible use. The most extensive program, however, was test of the full-scale capsule on the Little Joe launch vehicle. The Mercury capsule, invented by M. A. Faget, a branch head at PARD under NACA, contained a pilot-escape feature consisting of a solid rocket motor attached to it, which in case of an emergency could pull the capsule away from its large launch vehicle and allow safe recovery through use of the normal parachute landing system. The Little Joe tests were to determine the effectiveness of the abort-escape system in early stages of the launch. The first full-scale Mercury capsule used in these tests is shown in Figure 14.

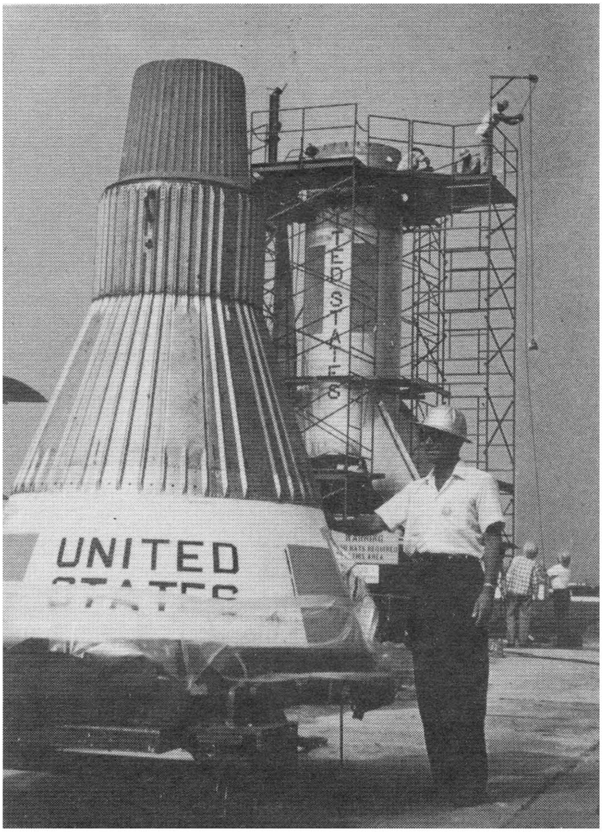

Figure 14 PARD Chief J. A. Shortal examines Mercury capsule at Wallops, 1959.

The Little Joe system at launch is shown in Figure 15. Four Sergeant motors plus four Recruits were contained within a fin-stabilized cylinder with the capsule mounted on top. An improved Sergeant named Castor was used in some of the tests. While no astronauts were onboard in these tests, two small monkeys were successfully launched and recovered in separate tests. The experience at Wallops with Little Joe was the very important first-flight step in the evolution of the Mercury manned satellite.

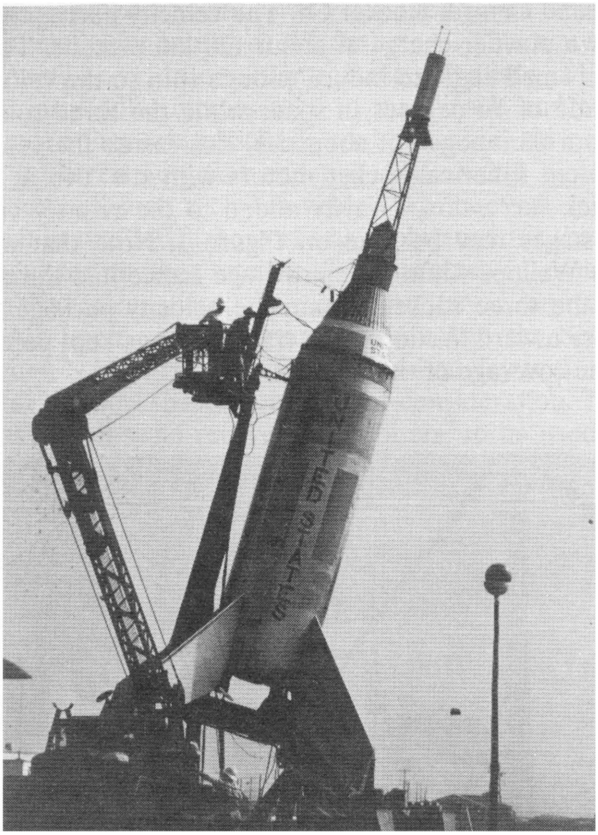

Figure 15 Launch of Little Joe vehicle with Mercury capsule at Wallops, 1959.

In January 1958 an idea led to a new project at Wallops to provide a reentry object that could simulate reentry of an ICBM nosecone for use in development of a detection radar system. Such a system was under development by the Lincoln Laboratory of the Massachusetts Institute of Technology under contract with ARPA, and two of these radars were positioned at Wallops. W. N. Gardner of PARD proposed a 6-stage solid rocket system which had a 12.5 cm spherical rocket as its last stage which could be made to reenter the atmosphere within radar range of Wallops at speeds of up to Mach 26. Construction of this system was authorized and fifteen were launched, mainly after NASA was formed in 1958.

The program was named Trailblazer, and one of the first series is shown in Figure 16. One of the variables in the program was the material on the front surface of the spherical motor exposed to reentry conditions. In addition to aluminum, phenolic nylon, copper, titanium, and steel were tested to determine radar enhancement of the burning target during reentry.

The Trailblazer provided a reentry target close to Wallops by firing three stages backwards from a "velocity package" making up the upper stages of the vehicle. The first three stages were Honest John-Nike-Lance and were fin-stabilized and launched as before in the multistage systems. The Lance motor was a new one obtained from Grand Central Rocket Co. The velocity package was separated from the third stage by a powder charge at about 120 km altitude. The fins on the third stage were set at a small angle to induce enough spin so the velocity package would maintain its attitude of 70 degrees in space while the three rockets inside it were fired rearward from the apogee of about 300 km. Inside the velocity package were the T40-T55-12.5 cm spherical rocket motors with the T40 at the top. All three were fired in quick succession. Gravity added to the reentry velocity. The splash points of all six stages may be seen on Figure 1. Note that the first two stages impacted close to Wallops while the third stage Lance had the greatest range. The impact points of the three rockets within the velocity package may be seen back along the trajectory toward Wallops. The trajectory was kept parallel to the coast to allow photographic coverage of the reentry.

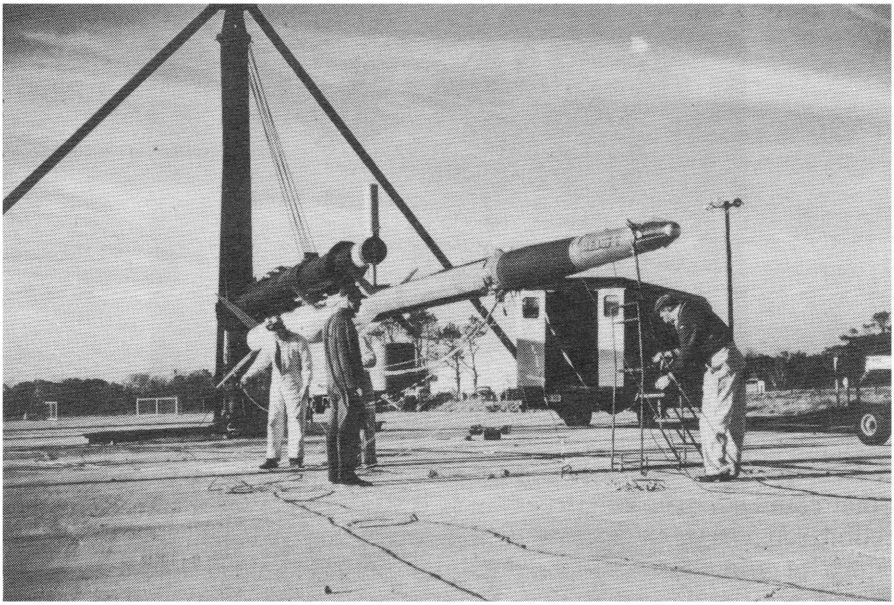

Figure 16 Trailblazer on launcher at Wallops before elevation for flight.

The small spherical rocket motor was developed by J. G. Thibodaux and his co-workers at PARD. It was an outgrowth of the 25.4 cm spherical motor invented and patented by Thibodaux, Swain, and Stiles in 1955. These were but two of the many different sizes developed in the PARD rocket test area at Langley. These spherical motors were used in many space programs under NASA.

The 5-stage vehicle, described earlier, provided a means for obtaining aerodynamic data at Mach 15 but even higher speeds were needed. A second 5-stage system was developed with a Sergeant motor replacing the Honest John, and two Lance motors replacing the Nike boosters in the second and third stages. A Mach number of 18 was attained, but by the time it was ready the development of an even higher speed vehicle had begun.

This vehicle, named Scout, was designed with the Aerojet-General Corporation's Jupiter Senior motor as the first stage. This motor was developed in 1957 for joint Army-Navy Intermediate Range Ballistic Missile and was the forerunner of the large solid motors used in the Polaris and Minuteman missiles. Calculations indicated that orbital speeds could be obtained with a 4-stage system consisting of an improved Sergeant and two ABL X-248 motors added atop the Jupiter Senior. Although such a launch vehicle was needed by PARD to continue its reentry research in late 1957, the cost was prohibitive for that purpose only. The timing was not right for another satellite proposal since it would be in direct competition with the Navy Vanguard, the Army Jupiter C, and the new Thor-Able proposal of the Air Force. An opportunity to propose the Scout came in March 1958, however, when NACA Headquarters asked Langley to prepare a Space Technology program for the new space agency under consideration. The Scout was listed in this program as "Small-scale recoverable orbiters" to be used in development of the Mercury capsule and 4 million dollars was listed to provide five such vehicles. Studies of such a vehicle were continued and coordinated with those of the Air Force, which wanted a larger sounding rocket to extend the Javelin program. When NACA changed into the space agency (NASA) in October 1958 contracts were placed separately for the rocket motors, the guidance system, and the airframe and launcher. Langley served as the prime contractor and initially handled the assembly and launching. All Air Force vehicles were procured as part of the Langley contracts.

Some changes in the rocket motors were made. The first stage remained the same, but was renamed Algol. The second stage was the Thiokol Sergeant redesigned with an improved propellant and renamed Castor. For the third stage, instead of the X-248 motor, a similar but larger motor was designed and named X-254 bu ABL and Antares by NASA. The fourth stage was the X-248 renamed Altair.

The Scout was designed after the same concepts as the earlier PARD multi-stage vehicles, but it was more complicated. The solid motor cases were the main structural members as before, but a guidance and control system was used instead of aerodynamic stabilization. The first stage was controlled by fins at the rear attached to vanes within the jet, the second and third stages were controlled by small reaction jets while the fourth stage was spin-stabilized. The different stages were held together until separation was desired by blowout diaphragms of the type used in the earlier 5-stage vehicle. Heat shields protected the payload and upper two stages during the initial part of the flight.

The first Scout is shown immediately after launch at Wallops in Figure 17 on July 1, 1960. It was to be used very successfully as a satellite launch vehicle, as a sounding rocket and a a reentry test vehicle.

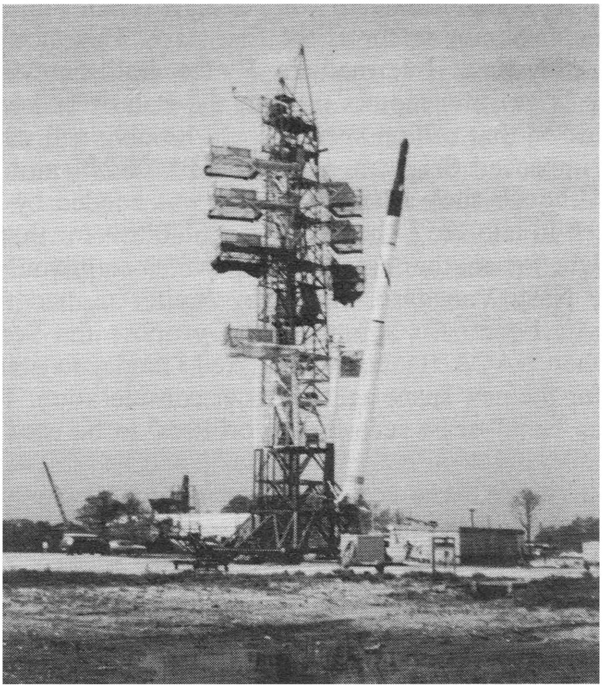

Figure 17 First Scout vehicle at Wallops, launched July 1, 1960.

CONCLUDING REMARKS

In this brief paper I have described only a few of the many astronautical projects at Wallops. Although Wallops started out as a test range for guided missiles, it quickly became a research range for rocket models of supersonic airplanes as well, and by 1955 it had expanded into sounding rockets and space flight programs. The success of the programs was due in large part to the flexibility afforded the researchers by the use of multistage solid rockets. Their simplicity and reliability made possible the development of the many different propulsion systems required by the programs. The rocket-model program would not have received the national recognition accorded it as a powerful research technique, however, without the highly accurate instrumentation that kept pace with the requirements.

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