The Flight of "BIG JOE"

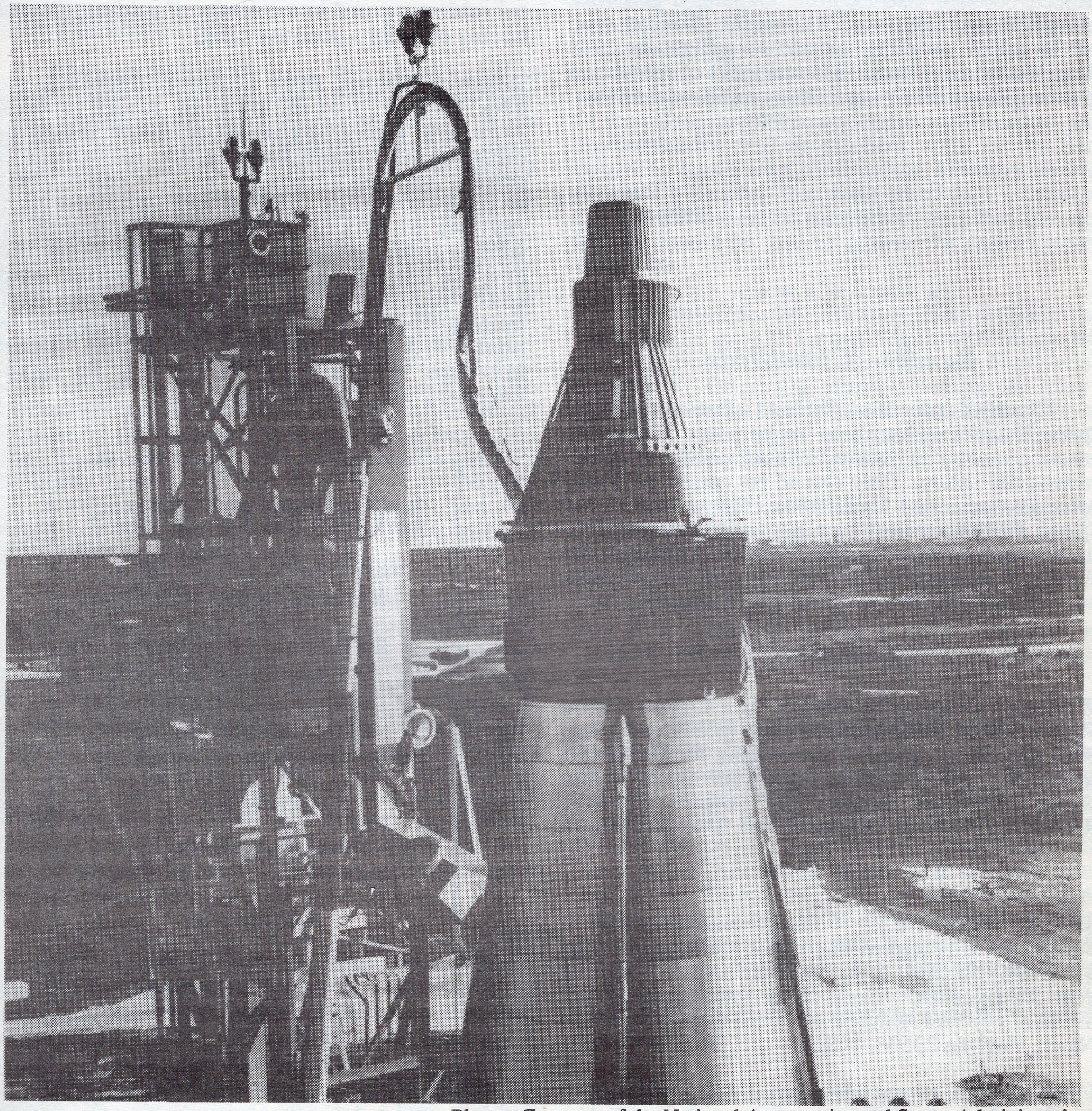


Photo: Courtesy of the National Aeronautics and Space Administration

The Flight of Mercury-Atlas "BIG JOE"

On September 9, 1959, an Atlas D rocket rocketed a boilerplate version of the Mercury capsule on a 1500-mile ride down the Atlantic Missile Range. This is the story of the first planned flight of this nation's manned space program -- thirty years after the fact.

Background to Mercury

Although Project Mercury, this nation's plan to place Americans in orbit, was formally approved by NASA Administrator Dr. T. Keith Glennan as a project on October 7, 1958, its beginnings date back much earlier. In March 1956, the U.S. Air Force had initiated Project 7969 with the stated task of recovering a manned capsule from orbital conditions. A conference was held at Wright-Patterson Air Force Base in Dayton, Ohio in late January 1958 to review eleven proposed manned orbital vehicle concepts received in response to the Air Force call (see sketches on page 4). The proposals ranged from a 1000-lb cannon ball shape offered by Convair to North American's stripped X-15 launched into orbit by a three-stage booster. Also offered informally were two Langley Aeronautical Laboratory (later Langley Research Center) concepts. One, by Maxime Faget, involved the use of a ballistic, high-drag capsule with heat shield on which the pilot lay prone during reentry. The McDonnell entry was similar to Faget's and was launched into orbit using an Atlas rocket with a Polaris upper stage.

In March 1958 Faget presented a paper at the Ames Research Center in California called "Preliminary Studies of Manned Satellites -- Wingless Configuration: Non-Lifting". It was a very significant paper for it put forth most of the key items of the Mercury program. It described the ballistic capsule concept, the use of small retrorockets for deorbit, attitudes jets for on-orbit control, and parachutes for final descent and landing. By the summer of 1958 the early capsule shape had evolved to a more stable cone design. By August, factors related to structure and internal layout led to a domed structure, containing the man, topped by a cylinder (see sketches A, B, C on page 4).

With formal approval of the manned capsule program in October, a Space Task Group was formed at the Langley Research Center in Hampton Virginia to implement plans for the project. Following a contractor briefing on November 7, specifications for the manned spacecraft were issued and mailed to some twenty companies who had expressed a desire to bid on the project. The specifications included a form that had changed to a pure conical shape topped by a cylinder (see sketch D on the next page). Eventually, the winning company, McDonnell, was to come up with the modified final version shown in sketch E.

Beginnings of Big Joe

From the earliest concepts it had been well accepted that the Atlas rocket would be the launch vehicle for the Mercury orbital flights. During the early conceptual stages of Project Mercury, it was deemed necessary to include in the research and development program an early capsule flight test to investigate some of the many problems associated with satellite entry from orbit, as well as to check some of the basic concepts being employed in the Mercury capsule design. It was felt that none other than a full-scale capsule test would be satisfactory and that the Atlas booster should be used to achieve the desired reentry conditions.

On November 24, 1958, the NASA Space Task Group placed an order for one Atlas launch vehicle with the Air Force Missile Division in Inglewood, California. Originally, plans called for an Atlas C launch vehicle to launch a boilerplate capsule around May 1959. But plans were changed, and the Atlas actually delivered was to be a D model.

The capsule for this flight test was code named "Big Joe". The origin of the name "Big Joe" is attributed to Maxime Faget and followed as a logical progression from the "Little Joe" program, a series of suborbital test flights of the Mercury capsule that was also to be conducted starting in 1959. The Little Joe program will be the topic of another *Space Frontiers* article.

By December 1, the Space Task Group had completed the design of the Big Joe spacecraft. It had the same general lines or external configuration as the Mercury capsule, with the exception that it was not equipped with the Mercury escape tower. Lewis Research Center was responsible for construction of the lower part of the capsule and the control system while the Langley Research Center was assigned the upper capsule structure and parachute compartment. Many items were procured from outside vendors including the ablation heat shield, antenna and control system components, tape recorders, telemetry system, radar tracking and recovery beacons, the parachutes and the booster adapter.

Test Objectives

On February 12 - 13, 1959, discussions were held at Langley Field between the Space Task Group

	LOCK.	MARTIN	AERO-NEUT.	McDON	AVCO	GOOD-YEAR	CONV'R	BELL	NAA	REPUB.	NORTH'P.
MIN. MANNED SATELLITE	9' 14'	8' 14'	50° 7' 7'	[illegible]	7'	7'	5'	L/D·5	X-15B STRIPPED	[illegible]	L/D=6
WGT. LB.	3000	3500	2545	2400	1500	2000	~1000	18,000	~10,000	4000	11,000
BOOSTER	ATLAS + HUST.	TITAN	ATLAS + HUST.	ATLAS + POLARIS	TITAN	A or T + 3RD ST.	ATLAS + HUST.	[illegible]	4 G-26 + XLR-99	ATLAS + POLARIS	
ORBIT	150-300 3 REV	150 m. ~1 DAY	–	100 m. 1 REV.	120 m. 1 WEEK	200-400 5 DAYS	170 mi –	[illegible]	–	100-150 [illegible]	

Proposals By Industry for Air Force Project 7969

and the Air Force Ballistic Missile Division concerning the technical details of the first Atlas test flight and overall program objectives. The primary test objectives set for the Big Joe flight test were: (a) recover the capsule, (b) test the ablation heat shield and measure afterbody heating, (c) determine the capsule's flight dynamics during reentry, (d) test the adequacy of the capsule's recovery systems, aids, and procedures, and (e) educate NASA personnel on Atlas launch procedures. Secondary test objectives included: (a) evaluation of the loads on the capsule during flight, and (b) test of the capsule's control system.

On April 16, Space Task Group, Langley, and Lewis Research Center personnel met to discuss the construction and instrumentation of the Big Joe test vehicle. Later that same month a meeting was held at Langley to coordinate the activities of individuals who would be engaged in handling, reducing, and analyzing the data received from the Big Joe spacecraft. Most of the data reduction task fell to the Space Task Group and Lewis Research Center. Construction of the spacecraft proceeded quickly followed by delivery of the capsule to Cape Canaveral on June 8. Meanwhile, the Navy practiced capsule recovery operations. On June 25, off the coast of Jacksonville, Florida, a mockup spacecraft was airdropped 40 miles away from a simulated impact point and 45 miles from the nearest ship. Yet, the Navy was able to affect a recovery in just 2-1/2 hours.

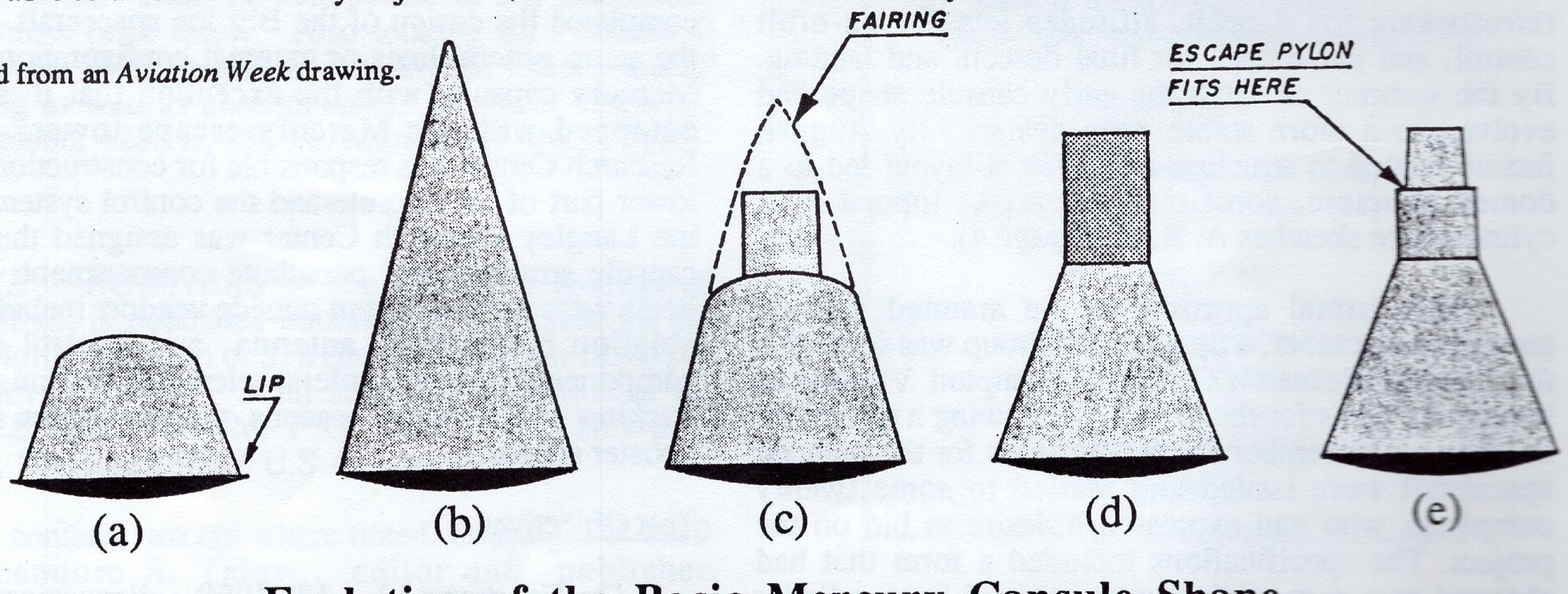
<u>Capsule Description</u>

The configuration of the Big Joe capsule is shown on the facing page. The overall external dimensions were basically identical to those of a full-scale Mercury spacecraft although the external appearance was different. The structure of the capsule consisted of four major assemblies:

<u>Heat Shield</u>. At the base was a massive heat shield constructed of a fiberglass cloth weave impregnated with resin. Under high heating conditions, this resin would volatize and carry heat away from the capsule, a process known as ablation.

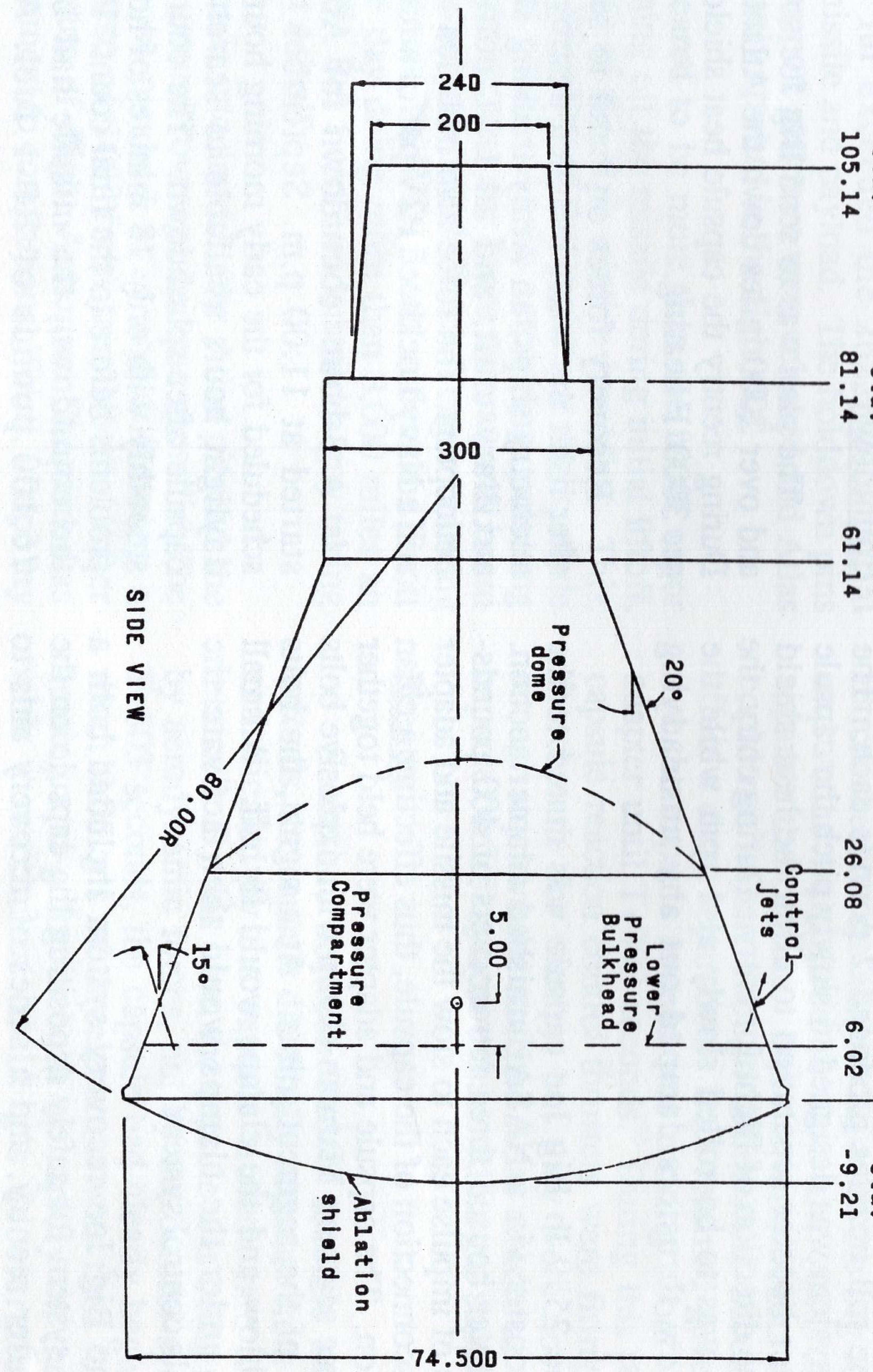
<u>Pressurized Instrument Compartment.</u> The pressure compartment consisted of the frustum of a cone extending from the heat shield up about two feet and capped by an internal, pressure dome. Extensive use was made of Inconel, a heat-resistant nickel-steel alloy. The pressurized compartment housed instrumentation and was lined with two inches of insulation to keep heat away from the interior. An interior open volume between the heat shield and instrument compartment was designed to flood after landing to increase the stability of the capsule in the water. Also, a dye marker and shark repellent was to be released (the repellant was for the benefit of ensuring the recovery crew was not attacked by sharks!).

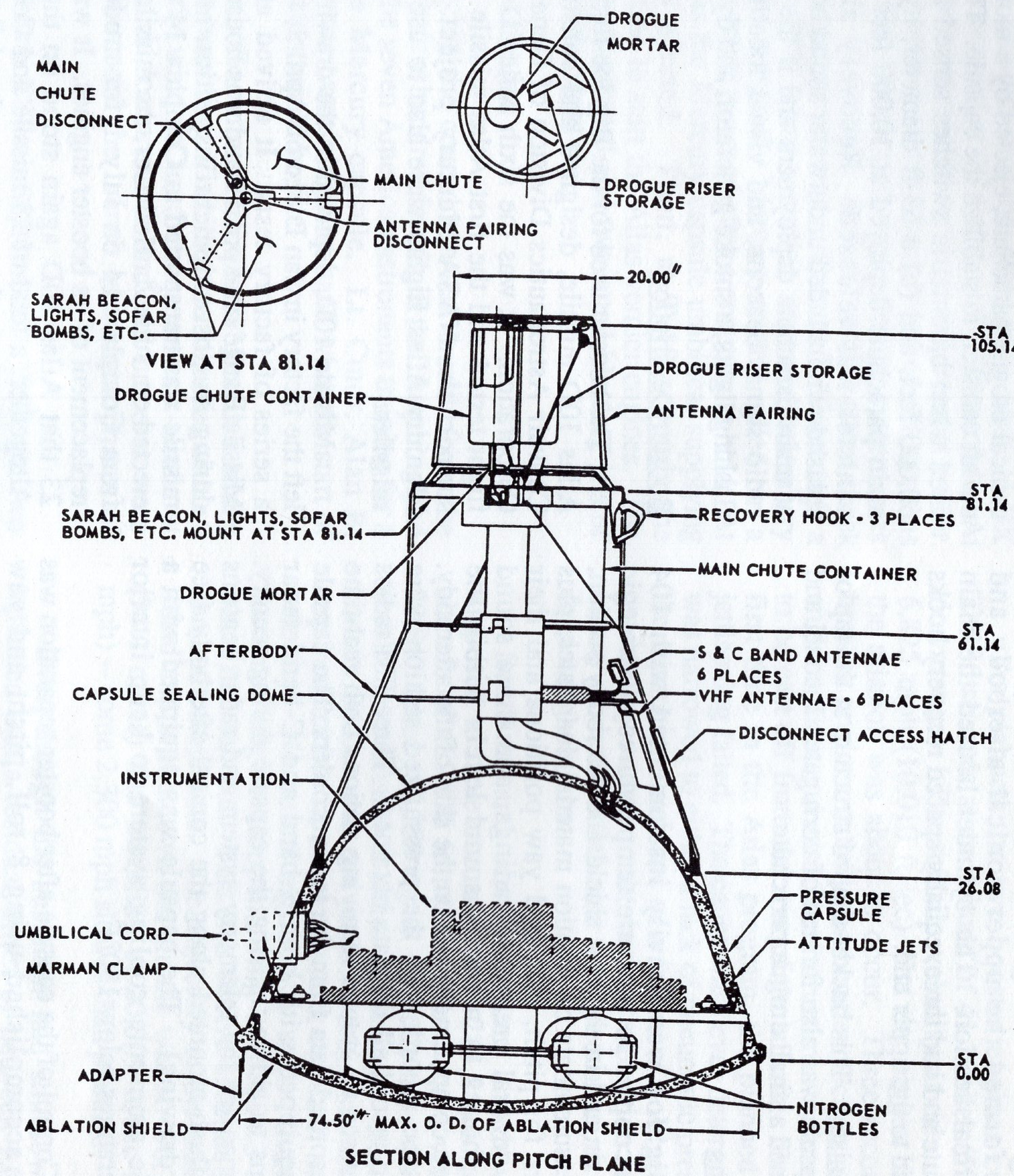
Adapted from an *Aviation Week* drawing.



Evolution of the Basic Mercury Capsule Shape

Big Joe Mercury R&D Capsule





Conical and Cylindrical Afterbody. Inconel, stiffened by longitudinal corrigations and braced by internal rings, formed the upper conical afterbody and cylindrical section. The cylinder housed the main parachute and had three, equally-spaced recovery hooks attached to the upper end.

Aft Canister. This bucket-shaped structure at the top of the capsule was also formed of corrugated Inconel and contained a small drogue parachute.

Systems

Big Joe was heavily instrumented with 104 thermocouples to measure temperatures at strategic points on and in the heat shield and afterbody section, 13 measurements of ablation material char rates, plus sensors for pitch, roll, and yaw positions and their rates, several pressure readings, and three sound microphones to measure sound levels within the pressure compartment and on the skin of the afterbody. Four tape recorders in the pressurized section were used to record all the data obtained. Three FM radios telemetered to ground receiving stations both real-time and recorded data from the tape recorders. The capsule was equipped with both S-band and C-band radar beacons to aid in tracking the capsule during reentry. Antennae for the telemetry system and radar beacons were flush-mounted along the conical afterbody (see scale drawing). The capsule was equipped with a simple ammonia cooling system to keep interior temperatures below 150°F.

Control of the capsule after booster separation was to be accomplished using 8 roll, pitch, and yaw thrusters that used high pressure nitrogen gas as a propellant. The thrusters were located peripherally near the lower portion of the pressure compartment. Pitch and yaw nozzles produced 10 pounds of thrust each, while the roll nozzles produced 2 pounds each. The control system was designed to slowly pitch the capsule over after booster separation to align the heat shield along the direction of flight for entry. During entry, the capsule was to be rolled slowly at 1 rpm while the pitch-yaw thrusters damped out any unsteadying motions.

The 2579-lb Big Joe capsule was mated to the Atlas booster via a NASA-furnished adapter section. The adapter housed three retrorockets of 400 pounds-seconds of impulse each to slow the missile and adapter after disconnection of the capsule, thus effecting a clean separation. The capsule and adapter were held together by a three segment Marman clamp with explosive bolts at each of the segment joints. At a signal, the bolts would blow and the clamps would fly off. A small switch under the clamps would then activate the capsule's control system.

The Big Joe recovery system included both a landing system for safely depositing the capsule on the water after reentry, and a series of recovery aids to assist in locating the capsule after landing. The landing system consisted of: (a) a six-foot diameter ribbon, conical drogue parachute, ejected by a mortar located in the aft canister, to stabilize the capsule. The mortar was fired when barometric switches sensed an altitude of 60,000 feet, and (b) a 63-ft diameter, nylon, ring-sail main parachute deployed at 10,000 feet when the aft canister was released. Recovery aids for after splashdown included underwater sound bombs released at main parachute deployment and if the capsule sank, radio signal beacons, and visual locating devices -- flashing lights, a smoke generator, and dye marker.

Booster Description

The booster used for the Big Joe flight test was the Atlas 10D missile, designed and constructed by the Convair Astronautics Division of General Dynamics Corporation. It was the sixth series D missile to be flight tested and the first Atlas missile designated to support the NASA Mercury project. Subsequent Mercury-Atlas flights were also to use the Series D missiles.

Missile 10D, depicted in the drawings on page 8, left the factory in San Diego on April 3, 1959 following a series of factory tests. It arrived at the Atlantic Missile Range on April 19 and was housed in Hangar J during its post-shipment inspection and tests. The missile was transported to Complex 14 on June 1 and erected on June 2. However, the missile was removed from Complex 14 on July 1 for modifications and replacement of its booster engines. It wasn't until July 23 that Atlas 10D again stood on the launch pad. Altogether, a total of 28 missile and Complex 14 tests were conducted to prepare the missile for flight included two flight readiness firings which occurred on September 1 and 3, 1959.

Countdown

The plan was to send Big Joe some 90 miles high and over 2000 miles down the Atlantic Missile Range. During reentry the capsule heat shield was expected to see 3000°F heating.

Recovery forces on hand to search for Big Joe after it hit the water included destroyers, missile range telemetry ships, an Army tracking ship, several small auxiliary craft, and an LST converted to handle helicopters. The force also included an Air Force C-54 and a Navy Lockheed P2V patrol aircraft.

A 3-hour countdown for Atlas 10D-Big Joe started at 11:00 p.m. September 8. Launch was scheduled for the early morning hours to ensure ample daylight hours available to search for the Big Joe capsule after splashdown. The countdown proceeded smoothly with only 18 minutes of hold time for minor problems before to the final count. Prior to the start of the countdown, the missile had been loaded with 76,100 pounds of RP-1 fuel. At 1:43 a.m. on

September 9, liquid oxygen loading commenced. Over the next thirty minutes, 175,200 pounds of the frosty liquid were pumped into the Atlas main tank. LOX tanking was secured at 2:16 a.m. at T-130 seconds. At T-100 seconds the missile went on full internal power. At T-75 seconds a status check verified all systems were go. The launch pad water deluge system was activated at T-60 seconds. At T-40 another status check reported all systems were go. Then at T-19 seconds a hold was called when a station reported telemetry coverage was marginal. Mercury control called out a GO, and the count resumed after a one minute hold. At T-26 seconds the Mercury capsule umbilical supplying power was ejected. Then, at T-18 seconds the command came to start the Atlas vernier engines. The start button was pressed and two small blinding jets of flame pierced the night sky.

The Flight of Big Joe

Monitoring the countdown and launch from the block house a few hundred feet from the launching pad was one of the seven American astronauts training for a flight in the Mercury capsule. Lt. Cmdr. Alan B. Shepard, Jr. was examining first-hand what the start of a such a mission would be like.

At launch the temperature was 74° F with a heavy 97 % relative humidity. Visibility was 10 miles with a 3 knot northerly wind. Cloud cover was six-tenths at 10,000 feet. A dozen movie and still cameras were positioned to record the launch and initial phases of flight.

At 2:19 a.m. EST on September 9, 1959, the two XLR 89-NA-3 booster engines and single XLR 105-NA-3 main sustainer engine on Atlas 10D fired up bringing the total thrust on all engines (including the two vernier engines and turbine exhaust) to 361,900 pounds. This far exceeded the 262,372-lb initial weight of the missile and payload. The holddown pins of the missile support structure were released and Atlas 10D moved cleanly upward in the night sky.

There appeared to be more than the usual vapor and frost sloughing off the missile during initial liftoff, probably a result of the high relative humidity. This, combined with the glare of the engines at night, made for a spectacular liftoff. As the screeching, pulsating Atlas rose straight up, one Air Force veteran was heard to comment: "I can understand Chuck Yeager breaking the sound barrier in the X-1. I can understand Scott Crossfield some day doing more than 3,000 miles an hour in the X-15. But I can't understand a guy taking off on top of that Atlas!"

At 40 seconds into launch, the Atlas pierced the cloud deck and ground coverage became sporadic. The missile was now pitched over and following a downrange course of 108° from true North. After about two minutes of flight Astronaut Shepard was overheard to comment to companions: "Well, I hope my (pressure) suit is ready."

As planned the two booster engines cut off at T+136 seconds at an altitude of 41.5 miles (59.4 miles downrange). The missile velocity at this time was 6,825 mph (10,010 ft/sec). But the biggest failure of the mission was about to occur. Three seconds after booster engines cutoff, the booster section -- its two engines, skirt and associated structure -- was supposed to be cast off from the rest of the missile. But for the first time in the Atlas program, the planned booster jettisoning failed. The cause was never determined, but was narrowed to either a lack of pneumatic pressure for the separation hardware or a failure of a valve, switch, or circuitry related to the booster separation sequence. In any case, the Atlas now struggled onwards with its dead weight burden.

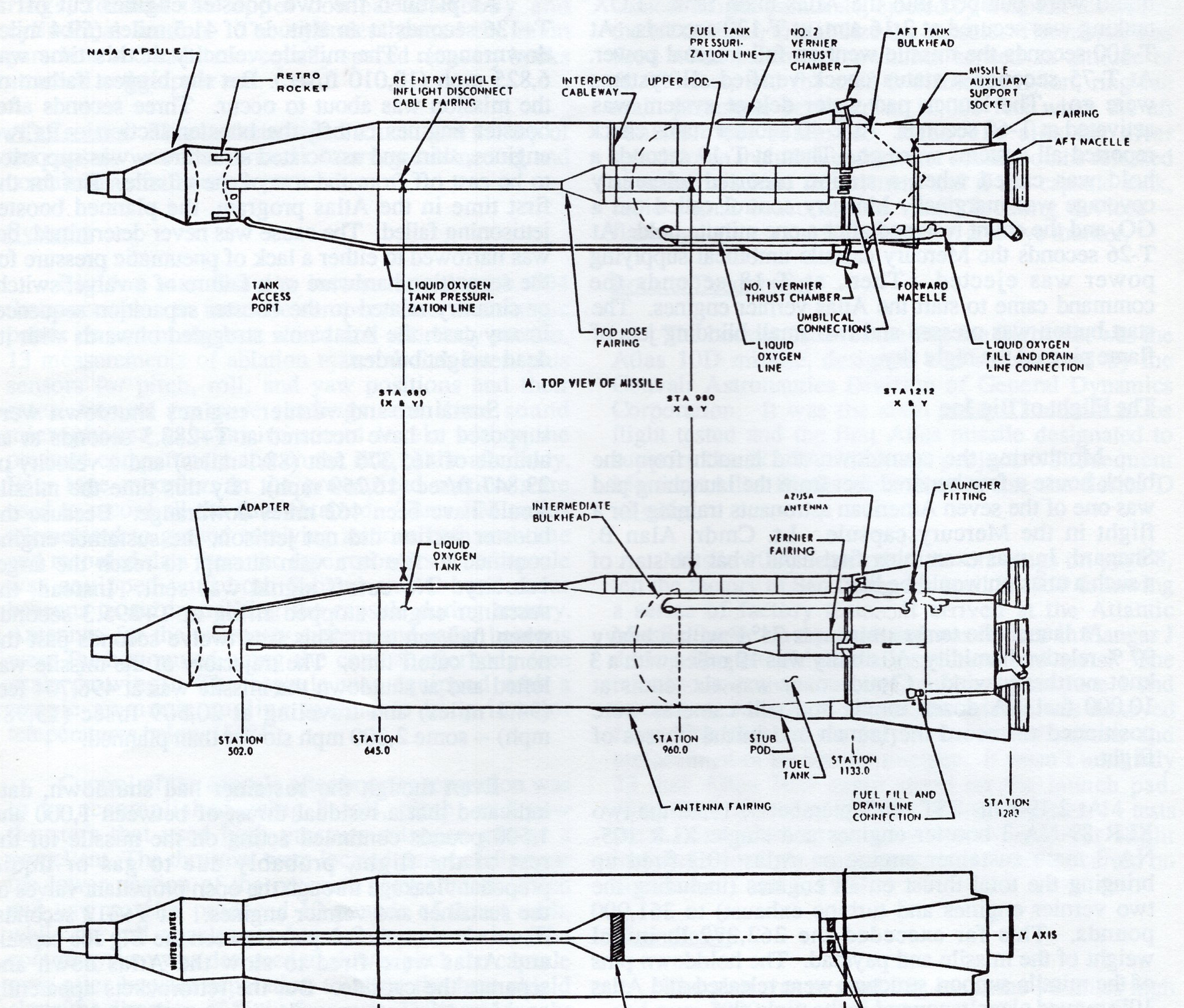
Sustainer and vernier engines shutdown were supposed to have occurred at T+283.5 seconds at an altitude of 465,376 feet (88.1 miles) and a velocity of 23,847 ft/sec (16,259 mph). By this time the missile would have been 462 miles downrange. Because the booster section did not jettison, the sustainer engine continue to fire in a vain attempt to reach the target velocity. No cutoff signal was sent. Instead, the sustainer engine stopped firing at T+295.3 seconds when fuel ran out. This was twelve seconds past the nominal cutoff time. The trajectory of the missile was lofted and at shutdown the missile was at 496,704 feet (94.1 miles) and traveling at 20,509 ft/sec (13,983 mph) -- some 2,300 mph slower than planned.

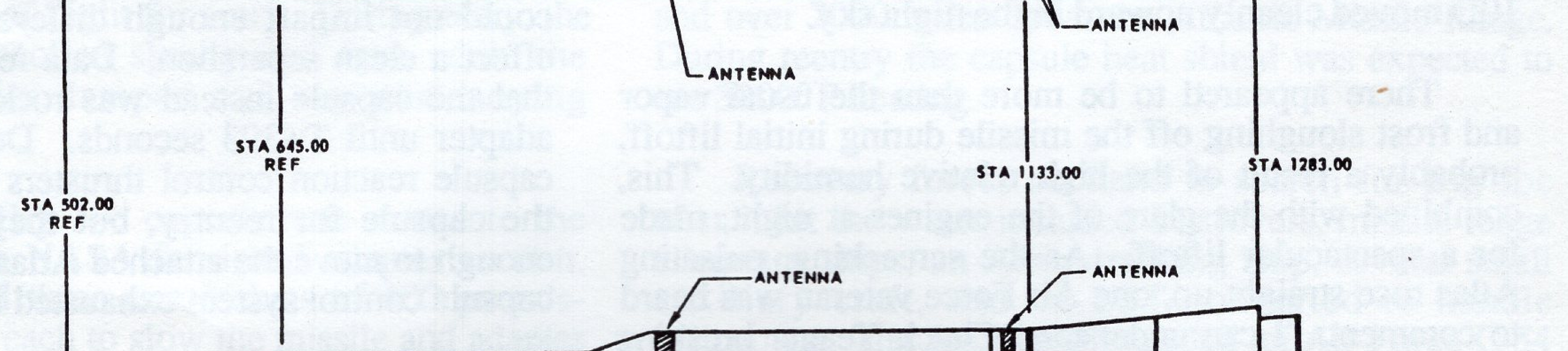
Even though the sustainer had shutdown, data indicated that a residual thrust of between 1,000 and 1,500 pounds continued acting on the missile for the rest of the flight, probably due to gas or liquid propellant leakage through the open propellant valves of the sustainer and vernier engines. At T+312 seconds, retrorockets on the adapter between the Big Joe capsule and Atlas were fired to slow the Atlas down and separate the capsule. But the retrorockets apparently could not impart enough differential acceleration to effect a clean separation. Data returned gave evidence that the capsule instead was rocking about within the adapter until T+393 seconds. During this period, the capsule reaction control thrusters were firing to orient the capsule for reentry, but they were not powerful enough to move the attached Atlas missile as well. The capsule control system exhausted its gas supply.

Reentry

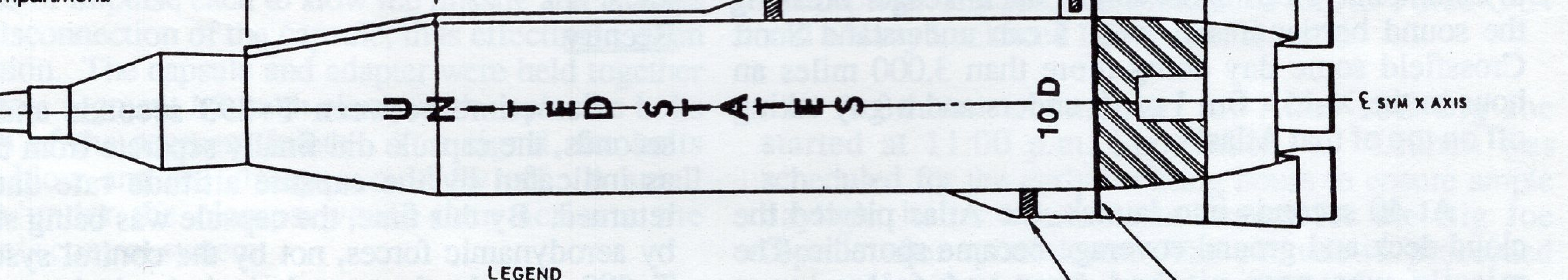
Sometime between T+393 seconds and T+448 seconds, the capsule did finally separate from the Atlas as indicated by the capsule attitude rate data being returned. By this time, the capsule was being stabilized by aerodynamic forces, not by the control system. At T+503 seconds, the capsule had clearly begun reentry when 0.05 g's of deceleration was first felt. Both heating and g forces built up rapidly on the capsule with a maximum of 12 g's deceleration being

ATLAS 10D





Adapter and lower portion of Big Joe capsule (pressure compartment and below) were black. Upper portion of Big Joe capsule was medium metallic color (Inconel metal) with stiffeners as shown on cover photo. The identification UNITED STATES was painted in white across Big Joe pressure compartment.



NOTES

1. PAINTING AND PRIMING SHALL BE OMITTED ON THE FOLLOWING AREAS: EQUIPMENT PODS, ANTENNA AREAS, THRUST CYLINDERS AND ENGINE NACELLES.
2. ALL BOOSTER STRUCTURE OUTER SURFACES, AS INDICATED, TO BE POLISHED, CLEANED & PROTECTED. PROTECTIVE COATING TO BE REMOVED WITHIN 48 HOURS OF LAUNCH TIME.

LEGEND

INSIGNIA WHITE
INSIGNIA RED
BRIGHT BUFFED FINISH

experienced at T+560 seconds at an altitude of 240,000 feet. The drogue chute deployed at T+661 seconds. The main chute deployed at T+751 seconds when the capsule reached 10,000 feet. Big Joe fell into the Atlantic Ocean at T+1055 seconds (17.6 minutes) after launch.

Recovery

The capsule had been aimed at a point located at latitude 15° 26' North, longitude 51° 08' West. Actual landing coordinates were 19° 20' North latitude and 58° 25' West longitude. This worked out to be a shortfall of 575 miles in range with a landing point several hundred miles northeast of Antigua. Ships detected a SOFAR bomb explosion in the water. The explosive had been released at the time of main parachute deployment. At about 6:30 a.m. a P2V aircraft operating out of Antigua made the first contact with the capsule at a range of 50 miles when it picked up the capsule's radio beacon. Shortly thereafter a large fluorescent patch (described as being one block wide and three blocks long) was sighted, followed by a sighting of the capsule itself by aircraft personnel. By this time the smoke generating system had been expended, but the flashing light was functioning. The destroyer USS Strong raced to the position as NASA representatives stressed the boilerplate nature of the spacecraft to the press least they envision a similar short fall occurring on a production Mercury capsule.

At 10:38 a.m. EST, eight hours and nineteen minutes after liftoff, Big Joe was safely pulled aboard the destroyer USS Strong. The capsule was returned to Cape Canaveral late that same night. It was delivered to Hangar S where Bob Gilruth stood with Maxime Faget waiting to inspect the condition of the capsule. It had come through with flying colors with even the paint being hardly singed. Space Task Group personnel quickly disassembled the capsule to get into the instrumentation section. A note was pulled from the capsule's interior and handed to Bob Gilruth. The note read: "This note comes to you after being transported into space during the successful flight of the 'Big Joe' capsule, the first full-scale flight operation associated with Project Mercury. The people who have worked on this project hereby send you greetings and congratulations." It was signed by 53 members of the Space Task Group.

Flight Test Results

Although the Big Joe capsule did not reenter the atmosphere at the hoped for velocity, Project Mercury officials were elated at the amount of data returned and the agility of the recovery forces in locating and picking up the capsule. During reentry the g levels reached nearly 12 -- more than the 8 g's expected. Visual inspection of the recovered capsule aftbody showed very little thermal damage had taken place, Even the painted letters UNITED STATES were still clearly visible on the conical portion. The only significant localized heating damage occurred on the cylindrical section of the capsule. Two of the recovery hooks were highly eroded and small skin areas near the hooks destroyed. The third recovery hook was undamaged.

The heat shield showed discoloration due to the dye marker and scuff marks caused by handling during the recovery operations. The shield appeared speckled with many hairline cracks and a 3-inch delamination, but these were only surface features which had no bearing on the soundness of the heat shield. The heating rate experienced by Big Joe was about 80 % of the desired value, while the total heat load was less than half of that predicted. Maximum recorded temperatures ranged from nearly 1800° F along the cylinder portion of the capsule to under 400° F along the conical portion. Temperatures inside the pressurized instrument compartment measured less than 100° F, much less than the 150° F expected. Temperatures of at least 1600° F charred the heat shield, but the char depth averaged only about 0.2 inches over the shield. Less than 6 pounds of the shield ablated during the reentry.

Significance

The majority of the test objectives were accomplished by the Big Joe flight. The ability of the test capsule to survive the severe test of reentry from near orbital velocities in spite of its unusual release conditions was noteworthy. The heat shield performance was excellent. The capsule demonstrated it ability to reenter the atmosphere and maintain its position with the heat shield forward without the aid of a control system.

Today, visitors to NASA's Langley Research Center can see the Big Joe capsule on display at the Visitor's Center. It sits off to one side, and its excellent condition belies the fact that it had flown a severe reentry test. It is significant to realize that had a man been on board Big Joe, he would have survived the flight. Thus, as the first major test of the United States man in space program, Big Joe had earned its niche in the history of spaceflight

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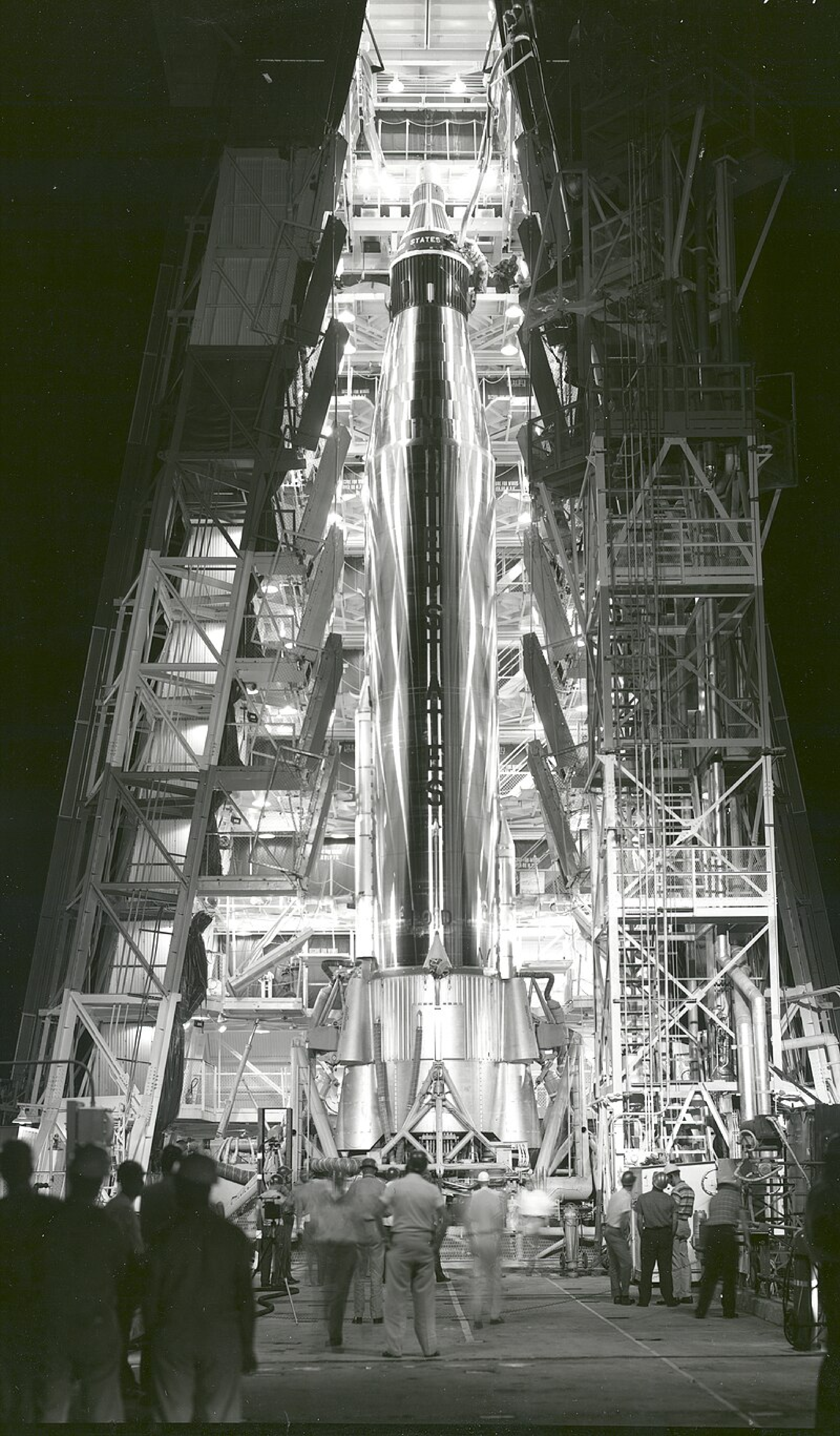
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