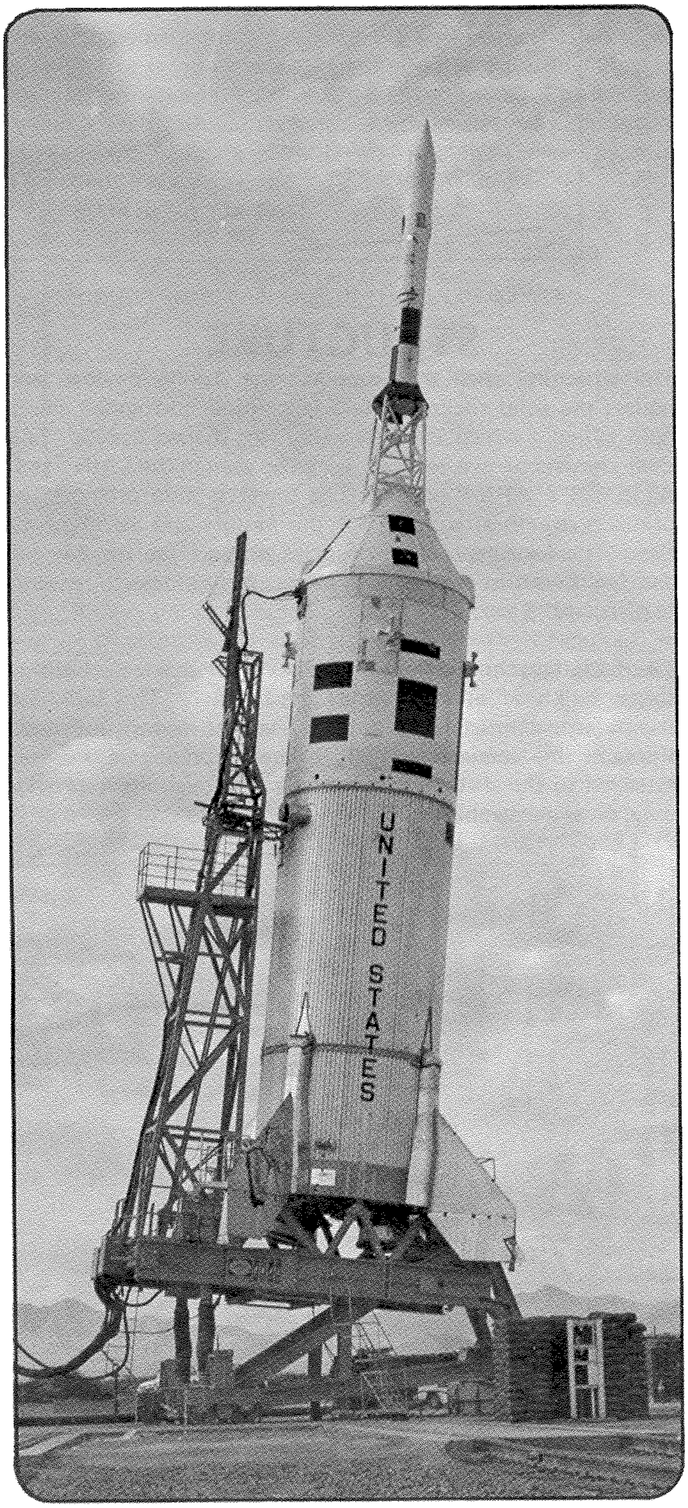
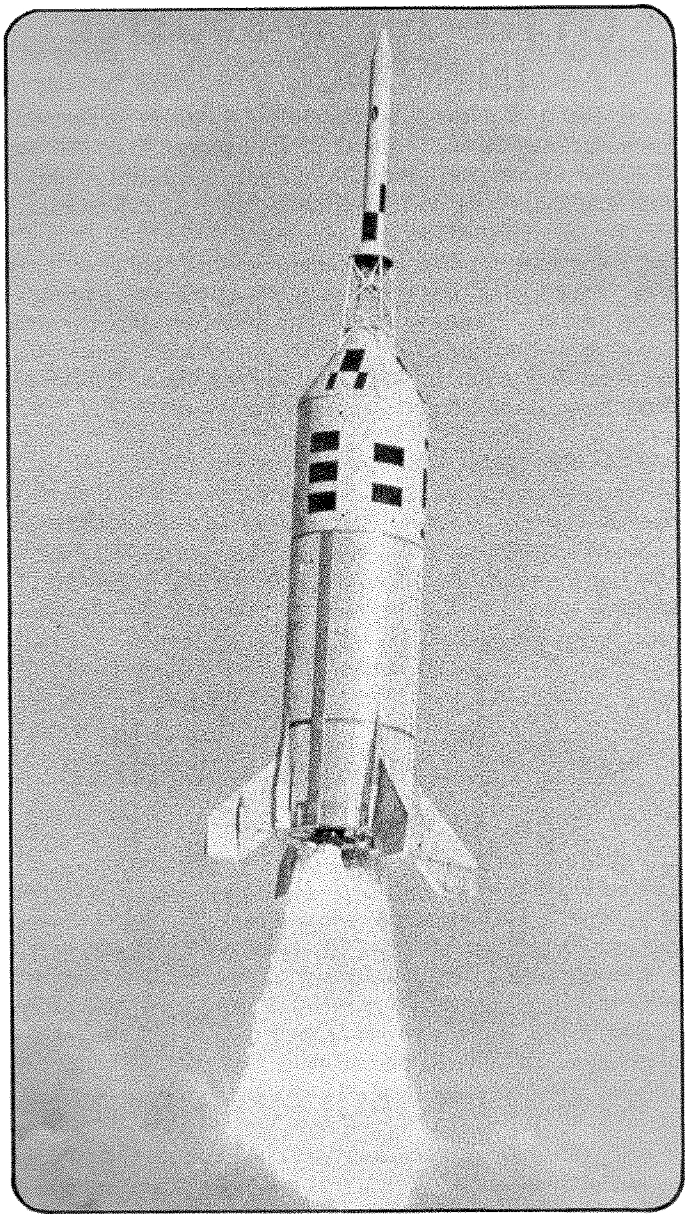
APOLLO
LITTLE JOE II


Apollo Spacecraft–002 on Launch Pad (NASA Photo S-65-19887)


Boilerplate-23 Liftoff (NASA Photo 64-H-2805)

The Little Joe II is a solid rocket booster designed and produced by the Convair Division. of General Dynamics for the NASA Apollo Program. Its specific purpose was the man-rating of the Apollo Launch Escape System which pulls the three moon-bound astronauts to safety in the event of a catastrophic Saturn V booster failure.

Little Joe II uses a cluster of up to seven ALGOL 1D solid propellant motors, which produce a combined total thrust of 860,000 pounds. It is the most powerful all solid propellant rocket ever flown in the United States. All of the unmanned Launch Escape qualification flight tests, using the Little Joe II booster, were conducted at the White Sands Missile Range in New Mexico between August 28, 1963 and January 20, 1966.

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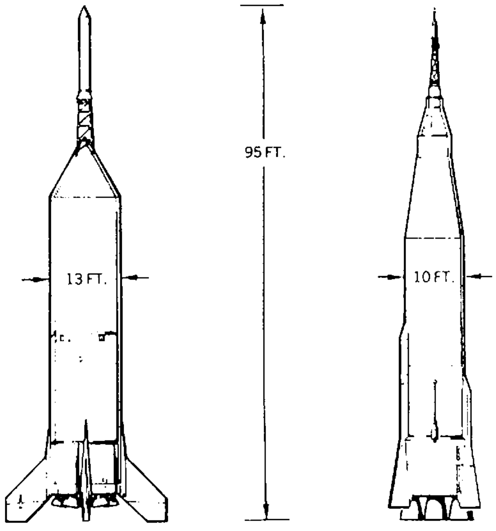
Centuri

LITTLE JOE II BOOSTER INTRODUCTION

Little Joe II is a solid rocket booster for flight testing the Apollo Launch Escape System. It was designed to be capable of lifting unmanned Apollo Service and Command Modules into suborbital trajectories up to 200,000 feet in altitude.

The name Apollo-Little Joe II is really quite deceiving. It is only "little" when compared to today's 396 foot Saturn V moon rocket. It is actually 3 feet larger in diameter and almost as high as our country's first manned space vehicle, the Mercury-Atlas used to put John Glenn, Scott Carpenter, Wally Schirra, and Gordon Cooper in Earth orbit.



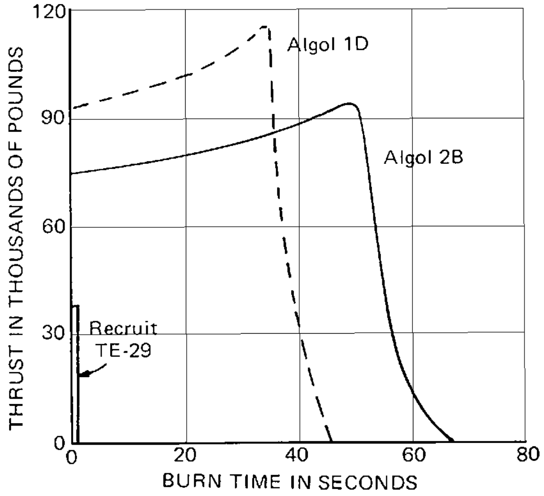
Little Joe II -Apollo

Mercury -Atlas

PROPULSION

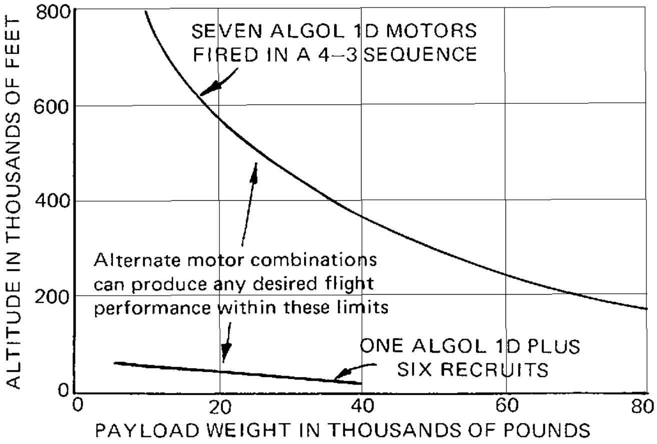
A peak thrust of approximately 860,000 pounds is produced by a cluster of seven Algol 1D motors fired in an overlapped four-three arrangement.

Little Joe II is highly versatile in that various combinations of Algol and Recruit TE-29 solid rocket motors can be used in different firing sequences to provide an optimum thrust combination for a wide variety of missions. The thrust-time curves for the various Little Joe II motors are presented below.



FLIGHT PERFORMANCE

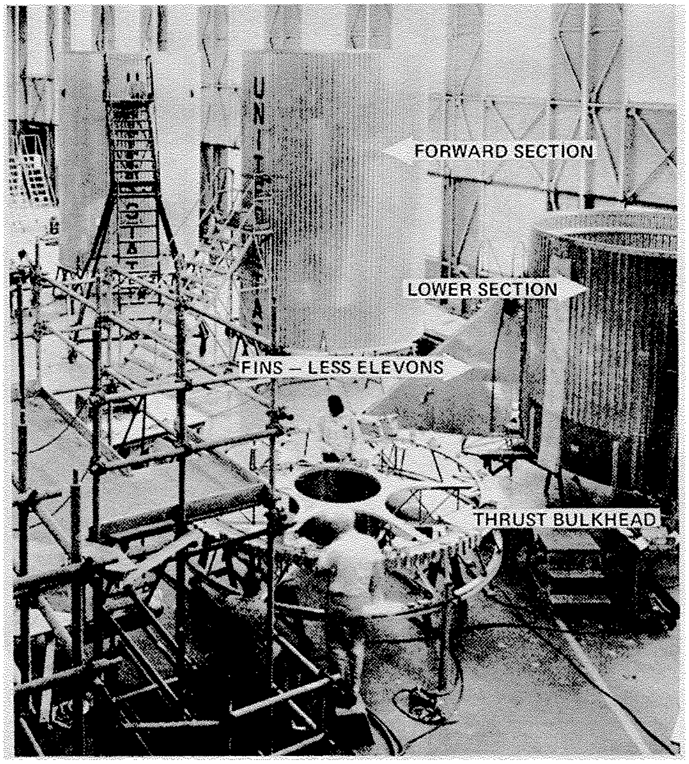
By selecting the proper combination of Algol and Recruit rocket motors, the flight performance can be varied as shown.



STRUCTURE

The structural shell that supports the Apollo payload and houses the solid rocket motors is a simple corrugated aluminum cylinder which is stiffened by ring-shaped frames. This shell consists of two sections as can be seen in the Little Joe II ASSEMBLY AREA photo. The lower section provides the primary structural support for the motors and aerodynamic fins. The forward section provides support for the payload and flight control electronic systems. It also locks the motors in place at the top.

The basic structural element of the vehicle is a large built-up thrust bulkhead at the base of the booster. This bulkhead transmits the thrust forces from the rocket motors uniformly through the corrugated shell. The aerodynamic fins are attached to the aft-section bulkheads by three bolts to provide easy, on-site assembly.

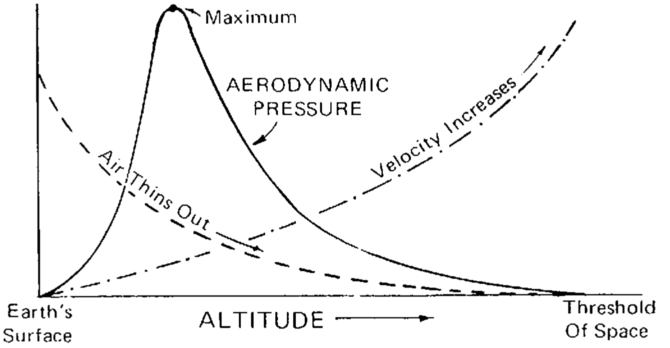


Little Joe II Assembly Area at General Dynamics/Convair, San Diego, California (NASA Photo 64 APOLLO 107).

FLIGHT CONTROL

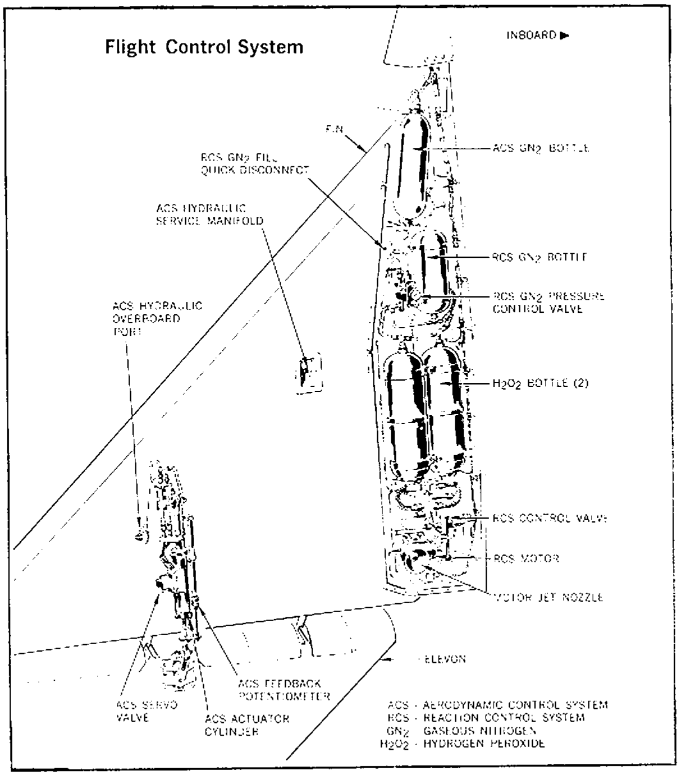
The first two Little Joe II test flights did not require precise attitude control and so were conducted with simple fixed fins. All other tests used fins with controllable elevons.

The aerodynamic control that could be generated by deflecting the elevons is directly related to available aerodynamic pressure. At any given altitude, the faster the rocket moves, the higher the aerodynamic pressure. However, as a rocket ascends the air gradually thins out until the rocket reaches altitudes where there is no air and, therefore, no aerodynamic control force – no matter how fast the rocket is traveling. Consequently, on a high altitude rocket flight the aerodynamic pressure increases from zero, reaches a peak, and then decreases to zero. This condition is represented by the following graph.



As you can see from the graph, there is very little aerodynamic pressure when the velocity is very low (the first few seconds after liftoff) and again when the air is very thin (high altitude). For this reason, a Reaction Control System is required for initial guidance during liftoff and again at high altitudes.

It should also be pointed out that the maximum aerodynamic pressure condition is one of the most important factors in determining the structural strength requirements of a rocket. One of the jobs of the Apollo-Little Joe II test was to simulate a Saturn V flight, which might fail at just this critical condition.


Flight Control System

GUIDANCE

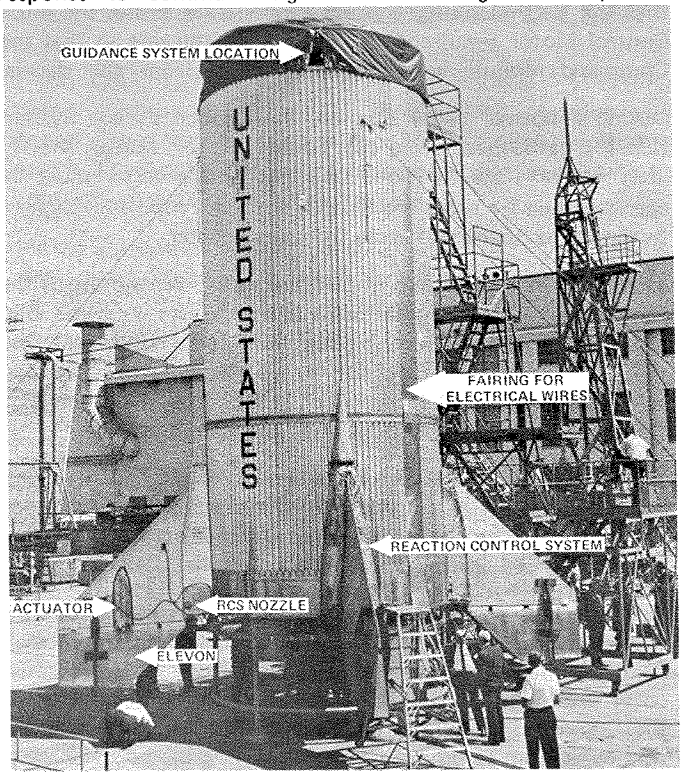
The guidance system controls the flight attitude of the Apollo-Little Joe II according to a pre-programed schedule or as commanded by radio from a ground station. This equipment is located in the forward section of the structural shell. Electrical command signals pass from the guidance system to the Fin Control Surface actuators and Reaction Control Systems via wires on the outside of the shell which are covered by a fairing as shown in the photograph below.

AERODYNAMIC CONTROL SYSTEM

Each fin includes a pneumatic-hydraulic system that actuates a corresponding aerodynamic control surface in response to guidance system command signals. A gaseous nitrogen system pressurizes the hydraulic fluid to 3,000 psi. A servo valve on the hydraulic actuator controls surface position by regulating hydraulic pressure and flow to each side of the actuator piston; a feedback potentiometer on the actuator relays position data back to the guidance system.

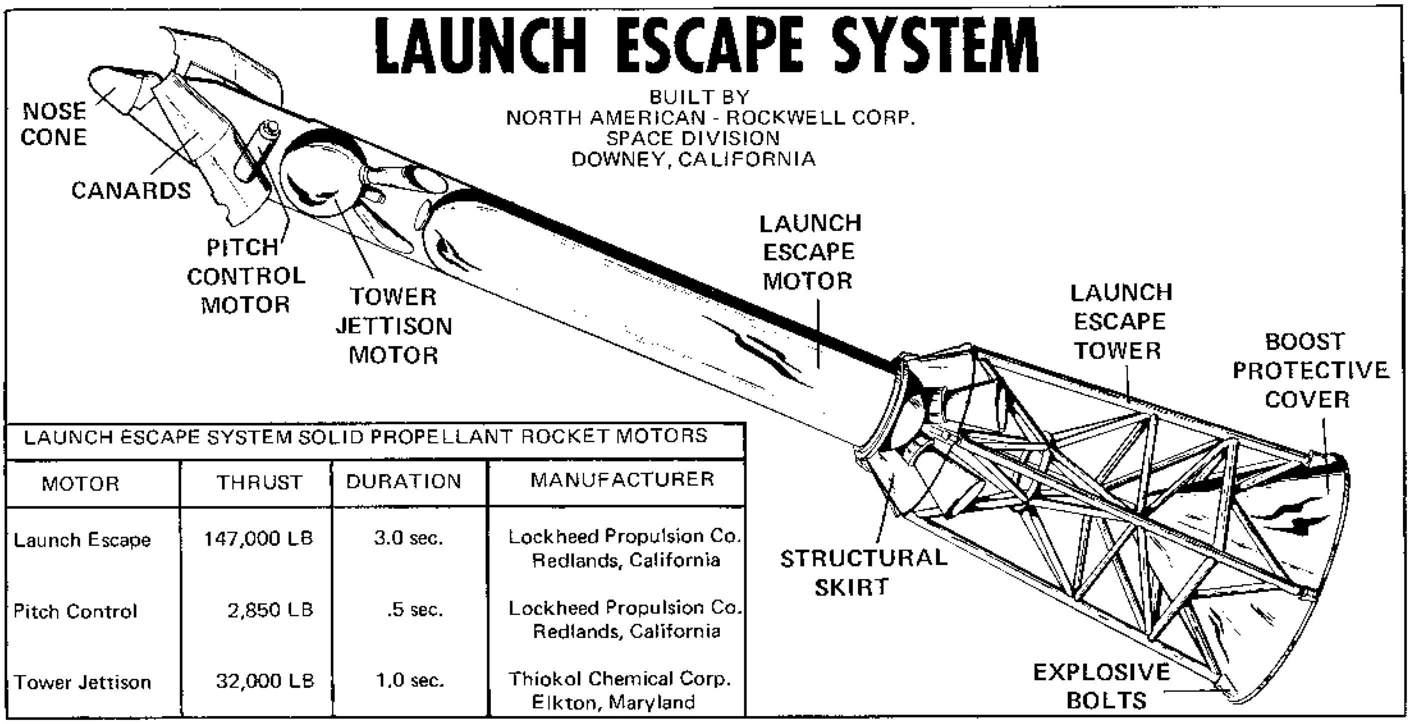
REACTION CONTROL SYSTEM

The monopropellant systems (one for each fin) uses hydrogen peroxide (H_2O_2) for fuel. Gaseous nitrogen provides fuel pressurization and operates the motor valves. A catalyst in the decomposition chamber of each reaction motor converts the hydrogen peroxide to oxygen and superheated steam, providing 600 pounds of thrust from the motor jet nozzle. The motors are mounted in back-to-back pairs that thrust perpendicular to the fin plane. The system provides thrust pulses in response to command signals from the guidance system.



LAUNCH ESCAPE SYSTEM

BUILT BY
NORTH AMERICAN - ROCKWELL CORP.
SPACE DIVISION
DOWNEY, CALIFORNIA



LAUNCH ESCAPE SYSTEM SOLID PROPELLANT ROCKET MOTORS

MOTOR	THRUST	DURATION	MANUFACTURER
Launch Escape	147,000 LB	3.0 sec.	Lockheed Propulsion Co. Redlands, California
Pitch Control	2,850 LB	.5 sec.	Lockheed Propulsion Co. Redlands, California
Tower Jettison	32,000 LB	1.0 sec.	Thiokol Chemical Corp. Elkton, Maryland

The Launch Escape System (LES) will take the Command Module (CM) containing the astronauts away from a Saturn launch vehicle in the case of an emergency on the pad or until 173 seconds after liftoff (approximate altitude 265,000 feet). The launch vehicle Emergency Detection System is designed to warn the astronauts, and automatically initiate the abort signal. Also, a manual abort can be initiated before or during launch by the command pilot.

After receiving an abort signal, the Command Module-Service Module separation device is detonated and the Launch Escape and Pitch Control Motors are ignited. The Launch Escape Motor carries the Command Module to a sufficient height so that the Earth Landing System can operate, while the Pitch Control Motor simultaneously pushes to the side so that the Command Module will be carried away from any debris.

During a normal (safe) mission, the Launch Escape System (LES) is jettisoned, using the Tower Jettison Motor, shortly after second-stage ignition. Any abort thereafter must be accomplished by using the Service Module Propulsion System to thrust the Spacecraft away from the booster.

The LES consists of two major structures. At the top is the forward cylindrical compartment which houses the three solid propellant rocket motors, ballast, the Canard subsystem, and the Q-ball (which senses and sends dynamic pressure and vehicle angle-of-attack information to the automatic Emergency Detection System and also inside to the astronauts).

The Launch Escape Tower is made of welded Titanium tubes. The Tower serves as a method for transmitting the thrust load and positions the CM a suitable distance away from the hot exhaust of the Launch Escape Motor.

The Tower is attached to the structural skirt that covers the Escape rocket exhaust nozzles and to the Command Module (CM) by means of four explosive bolts. A hard, protective cover is attached to the Tower and a soft cover is attached to the Command Module to help protect the CM (especially the windows) from aerodynamic heating during the boost phase of a normal mission and also from rocket exhaust soot.

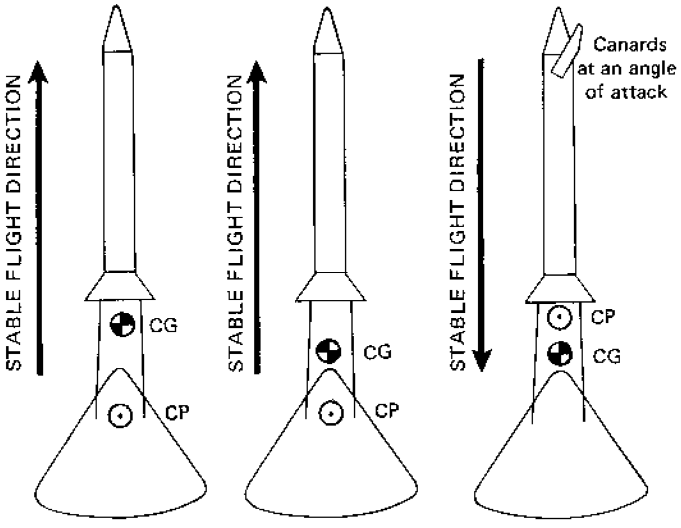
CANARDS

This system, first flown on the Boilerplate-23, consists of two wing-like surfaces and a deploying mechanism which are all part of the Launch Escape System nose cone. The Canard surfaces are deployed 11 seconds after an abort is initiated by a piston device which is powered by the high-pressure gases generated when two pyrotechnic charges are fired electrically.

The Canards change the stability of the Launch Escape System-Command Module configuration as shown below. Once deployed, the lift on the Canard surfaces cause the configuration to flip end-over-end so that the Command Module is stabilized on a blunt-end (or heat shield) forward trajectory. Stabilizing the 5 ton Command Module in its normal landing direction eliminates the possibility of parachute shroud lines twisting around and being severed by any exposed structure.

STABILITY

Launch Escape System center-of-gravity and center-of-pressure.

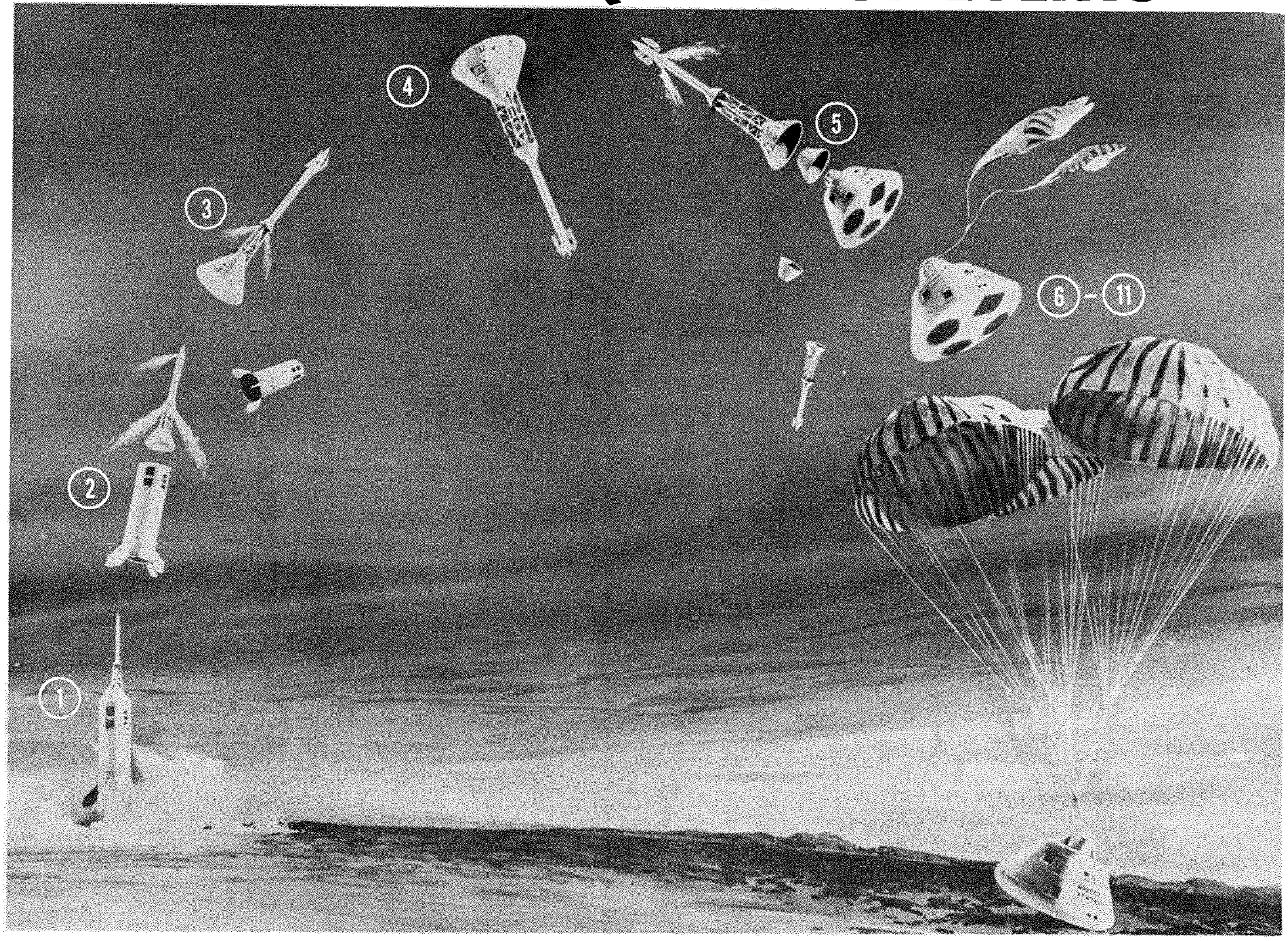


At Launch Escape Motor Ignition

At Burnout

After Canards Pop-Out

ABORT TEST SEQUENCE OF EVENTS



The sequence of events above is representative of a typical Little Joe flight. (NASA Photo #65-H-716).

①Apollo-Little Joe II Lifts Off at White Sands Missile Range.

②After reaching the desired test altitude, the abort sequence is initiated by igniting the Launch Escape and Pitch Control Motors.

③The Launch Escape Motor pulls the Apollo Command Module to safety; eleven seconds later, the wing-like Canards are deployed.

④The aerodynamic forces on the Canards change the stability of the configuration from nose-forward to blunt-end forward. This causes the vehicle to flip end-over-end and become stabilized blunt-end forward.

⑤After stabilizing in the proper heat shield forward direction, the four explosive bolts connecting the Tower to the Command Module are activated and the Tower Jettison Motor is ignited. The Tower then pulls clear of the Command Module.

Due to the high weight of the Command Module and its high velocity, the main chutes are not deployed immediately as the high aerodynamic pressures would just rip them apart in an instant. Instead, a series of chutes are required to provide gradual deceleration.

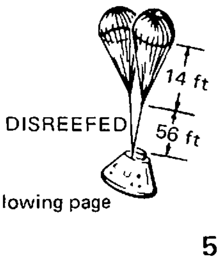
EARTH LANDING SYSTEM

The total weight of all the parachutes used in landing the 5 ton Command Module is only 540 pounds. The three main parachutes each have 68 shroud lines, meaning each shroud line supports about 50 pounds of Command Module weight. The Apollo Recovery System is produced by Northrup Ventura in Newbury Park, California.

⑥At an altitude of approximately 24,000 feet, the Command Module is traveling at about 290 MPH. The recovery sequence begins here with the jettison of the APEX COVER which houses the parachute compartment.

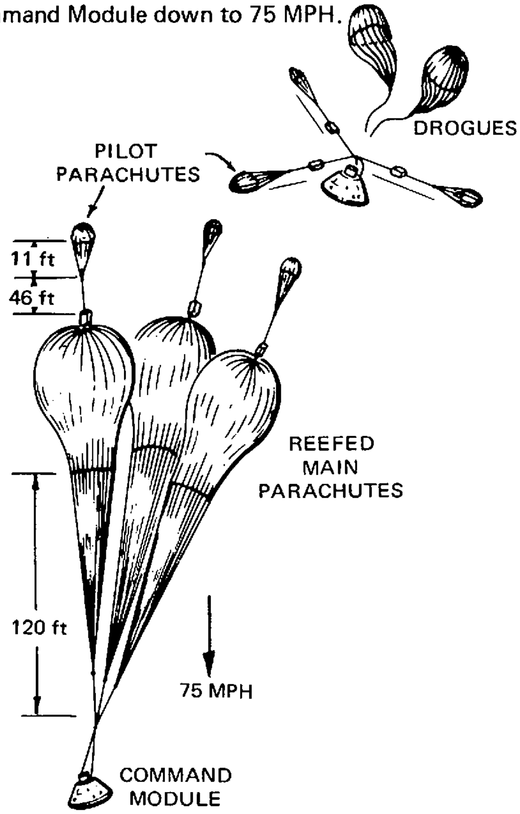
⑦1.6 seconds later the Drogue Mortar Cartridges are fired to deploy two 13.7 feet diameter DROGUE PARACHUTES in a reefed (partly open) condition.

⑧After 8 seconds, the reefing lines are severed by pyrotechnic cutters and the Drogue Chutes fully open. They decelerate the Command Module down to a speed of 160 MPH.

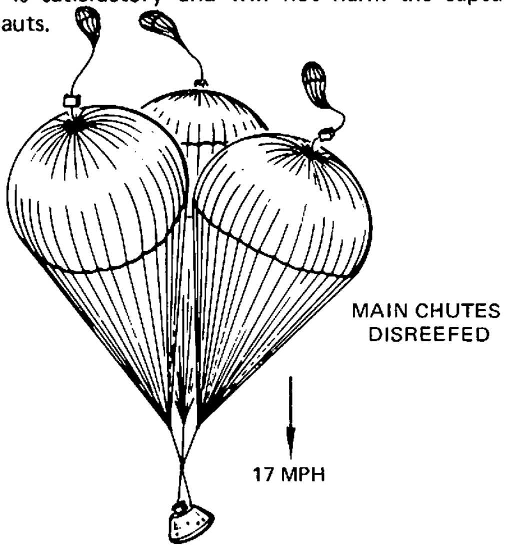


Sequence of Events continued on following page

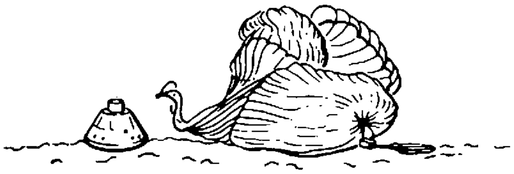
⑨ At approximately 10,000 feet, the Drogue Chutes are released and simultaneously the three Pilot Chute Mortars are fired. The mortars eject the 7.2 foot diameter PILOT PARACHUTES horizontally in order to extract and deploy the 83½ foot diameter MAIN PARACHUTES with minimum interference. To avoid damaging the main parachutes because of excess velocity, they first open to a reefed condition which further slows the Command Module down to 75 MPH.



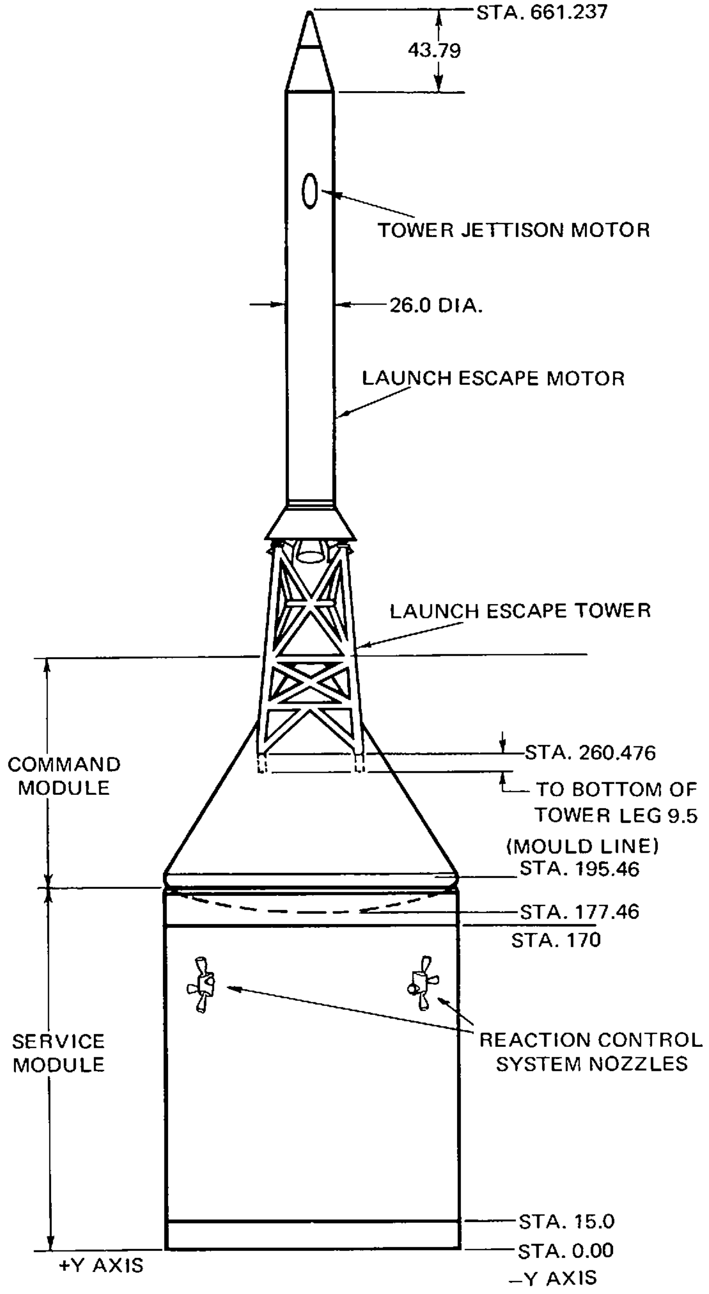
⑩ After 8 seconds, the main chutes are disreefed and allowed to fully open. The Command Module then reduces to 17 MPH for a safe, gentle landing. If only two of the main parachutes fully open, the touchdown velocity will be 22½ MPH which is satisfactory and will not harm the capsule or the astronauts.



⑪ After touchdown, the MAIN PARACHUTES are automatically released.



APOLLO



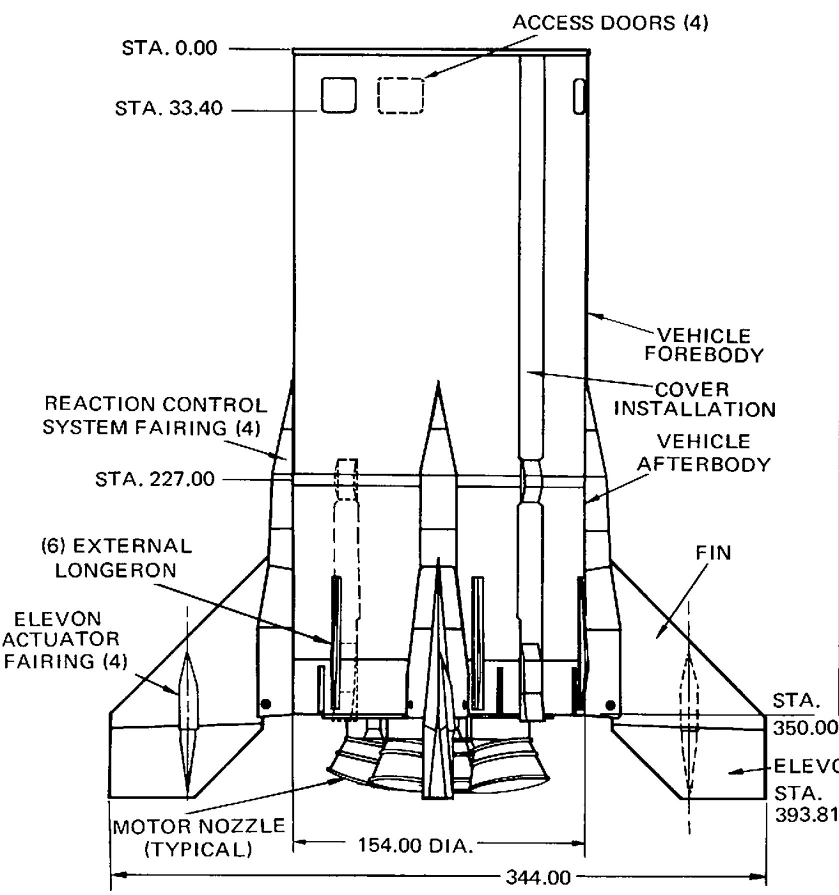
APOLLO PAYLOAD

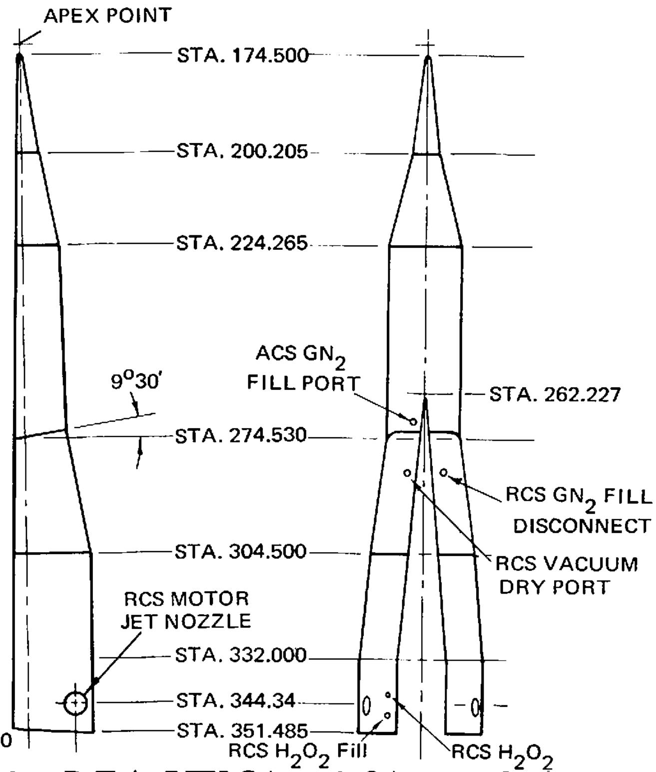
SCALE 1″ = 100″

Built By
North American Rockwell Corp.
Space Division
Downey, California

LITTLE JOE II SCALE DETAILS
SPACECRAFT –002 CONFIGURATION

From Convair Drawing 12-1.045

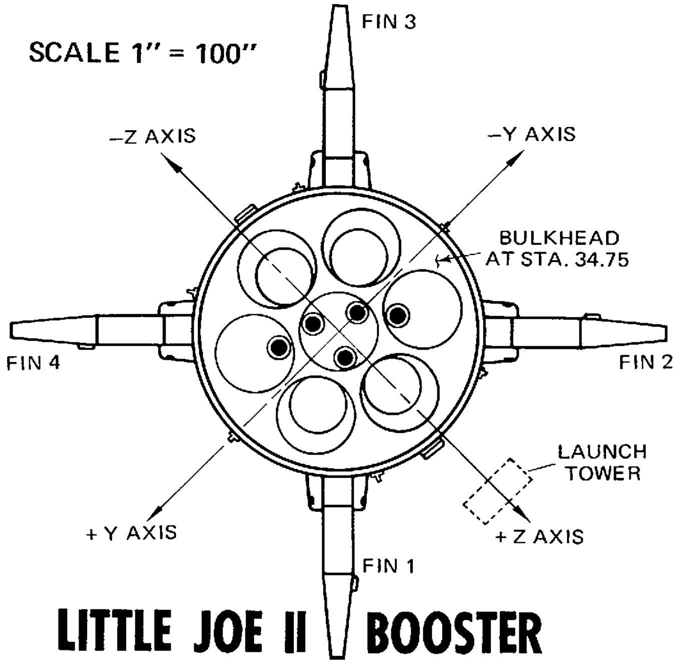




REACTION CONTROL SYSTEM FAIRINGS

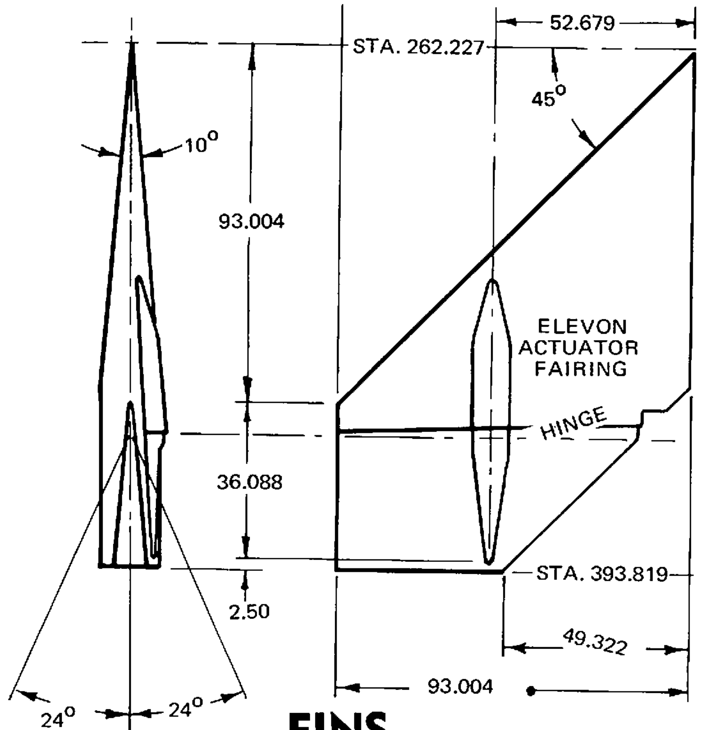
SCALE 1" = 50"

SCALE 1" = 100"



LITTLE JOE II BOOSTER

Built By
General Dynamics Corp.
Convair Division
San Diego, California



FINS

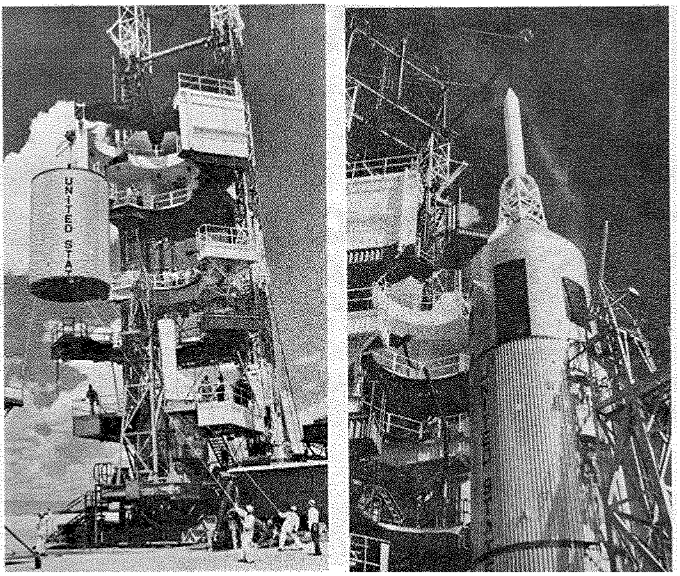
SCALE 1" = 50"

1 QTV - TEST VEHICLE AUGUST 28, 1963

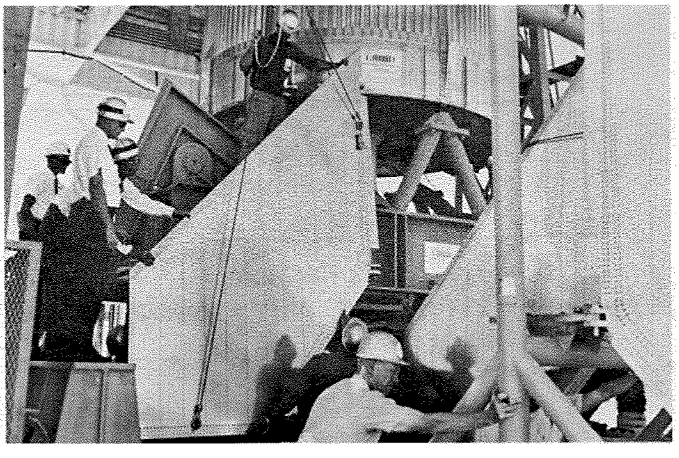
This was the first flight in the Little Joe II series. It carried a dummy Launch Escape System, Command Module, and Service Module and was propelled by a cluster of seven motors (a center mounted Algol surrounded by six Recruits).

The purpose of this qualification test was to check out the basic systems of the Little Joe II booster – not the Launch Escape System. There was no abort capability with this vehicle and the flight merely attempted to carry the dummy payload through a desired "test window" where, if everything met approval, the next vehicle would carry a LIVE Launch Escape System and Boilerplate Command Module.

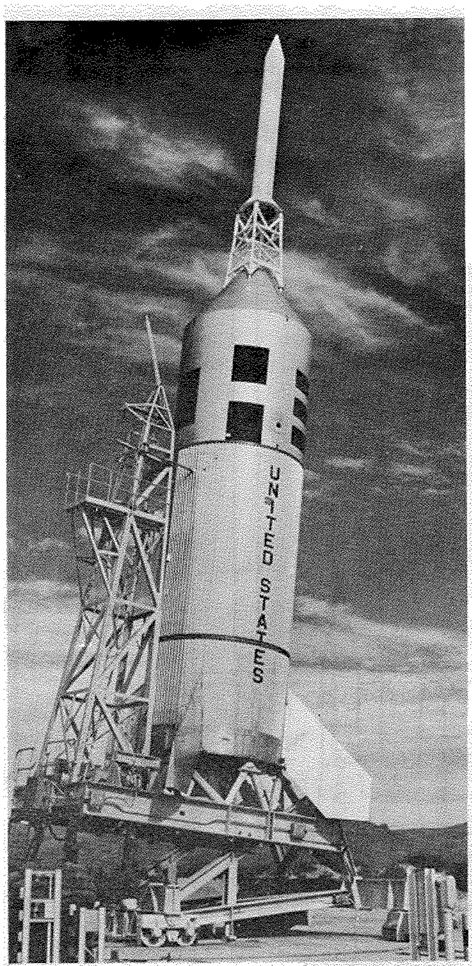
The Little Joe II Qualification Test Vehicle successfully reached the desired transonic abort condition – 24,000 foot altitude, at the proper speed (Mach 1.1), flight path angle, and aerodynamic pressure. Within 3 seconds of successfully passing through the test window, a Destruct Command was given and nothing happened. The vehicle remained intact and impacted 47,000 feet down range.



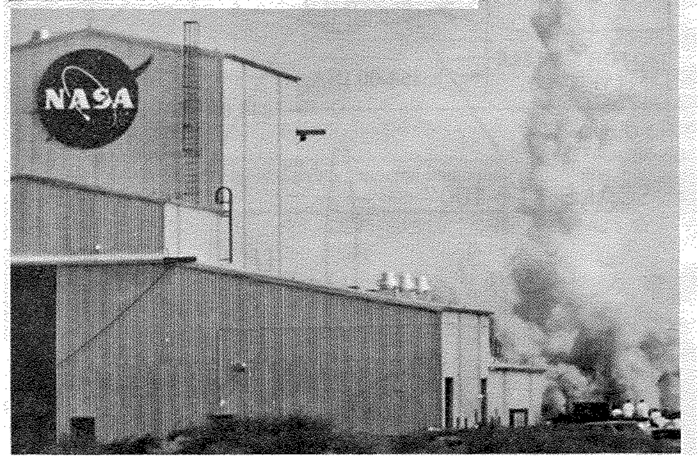
ASSEMBLY
Overall view of launch tower and assembly tower. (NASA Photo S-63-13539)



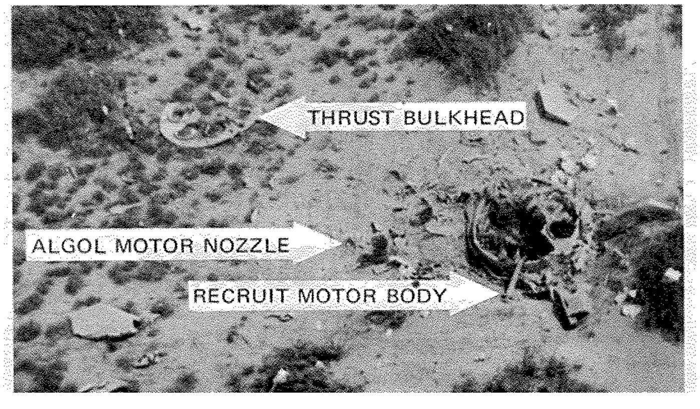
BOLTING FINS TO AFT BODY (NASA Photo S-63-13546)



QUALIFICATION TEST VEHICLE POISED FOR LIFTOFF (NASA Photo 63-LJII-5)



LIFTOFF (NASA Photo 63-LJII-12)



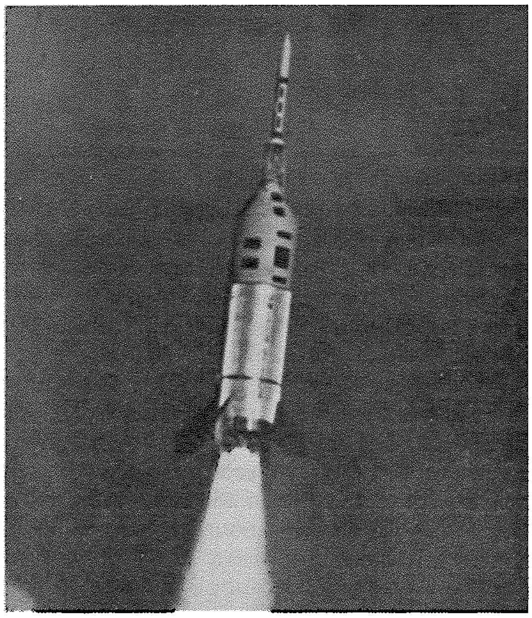
BOOSTER IMPACT (NASA Photo 63-LJII-16)

2 BOILERPLATE - 12
MAY 13, 1964

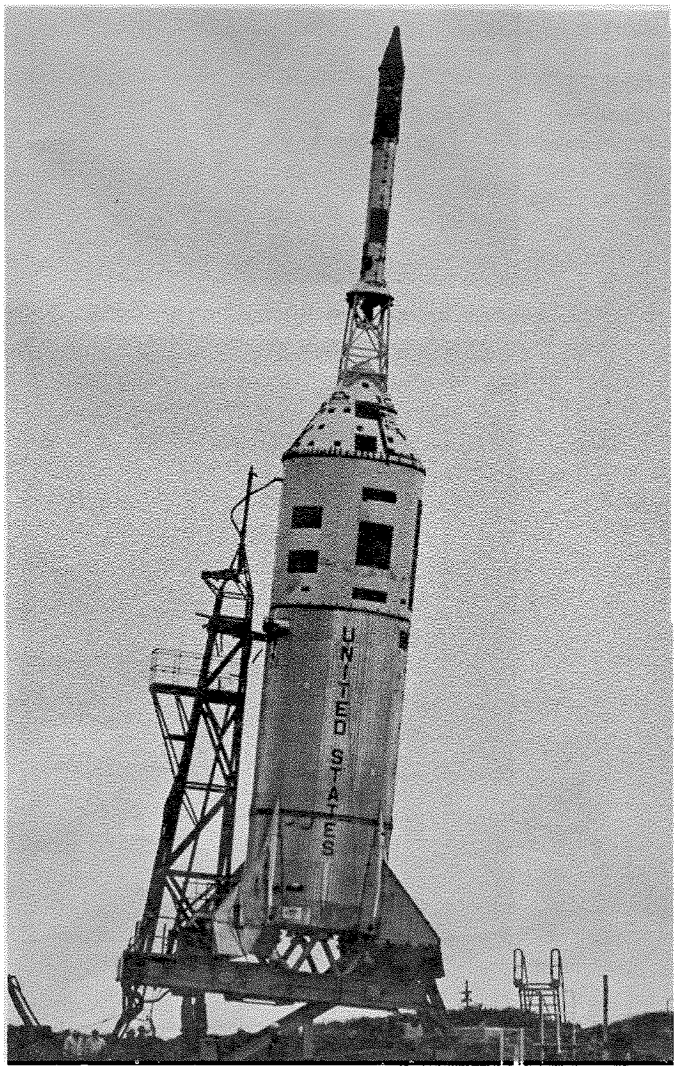
This flight carried a Boilerplate Command Module and Live Launch Escape System to a simulated Saturn V transonic abort.

Boilerplates are research and development vehicles that simulate production Spacecraft Modules in size, shape, weight and center of gravity. Each Boilerplate also has special instrumentation to record flight data for engineering review and evaluation. Spacecraft, on the other hand, are production modules that use actual life-support systems, construction materials, and electronic hardware.

This flight basically was a repeat of the QTV flight, but this time an actual abort was initiated as Little Joe passed through the transonic buffeting. It was a successful abort. During the recovery phase, one of the three main chutes ripped away at the time of deployment due to excessive swinging of the 5 ton Command Module. The landing was a success, however, as you'll remember that the Apollo Capsule was designed for safe recovery with two chutes. The third chute, of course, is a welcome additional safety factor.



BP-12 LIFTOFF (NASA Photo 66-40001)



BOILERPLATE-23 ON LAUNCH PAD (NASA Photo S-64-35835)
(Note addition of moveable control surfaces and Reaction Control System)

BP-23 LIFTOFF shown on front cover.

3 BOILERPLATE - 23
DECEMBER 8, 1964

In this test Little Joe II used two of the large Algol motors and four of the Recruit motors to propel the Boilerplate Apollo to an even higher velocity and altitude in order to reproduce the maximum aerodynamic pressure condition of a Saturn V flight. At this point, a PITCH-UP maneuver to increase angle-of-attack was started. The abort was then initiated under this greatly increased sideways aerodynamic pressure. It was successful — and the dynamic pressure was a full 25% higher than could be expected on a Saturn V flight.

Parachute recovery was perfect thanks, in part, to the help of the new Canard system which aerodynamically flipped the Boilerplate Apollo completely around to its proper heat shield forward attitude. The Canards also damped out the swaying motion before the tower was jettisoned and the drogue chutes were deployed.

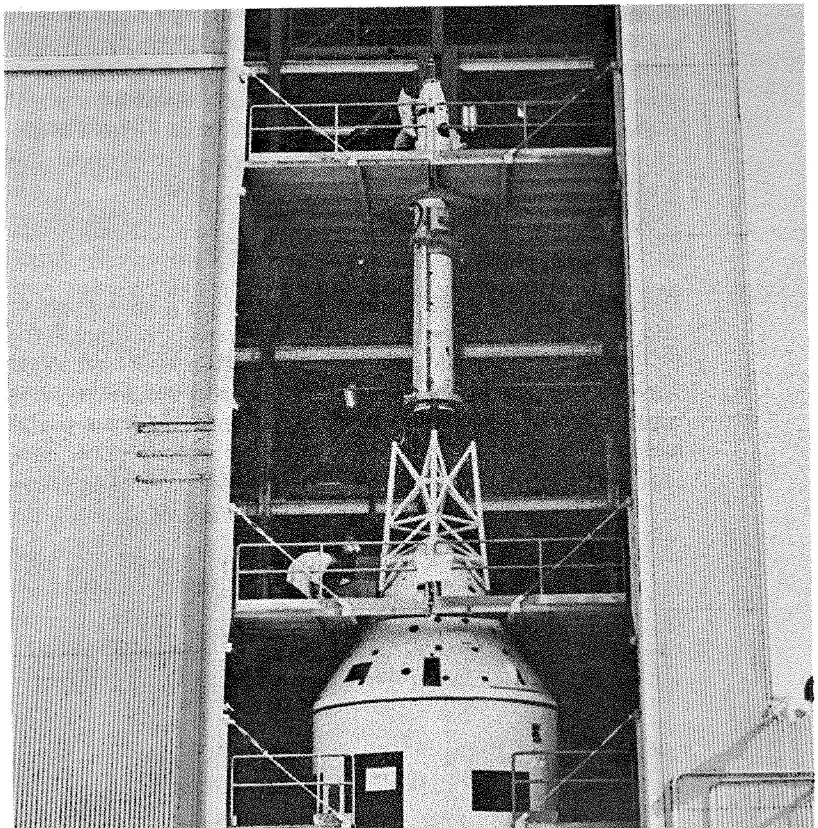
ENGINEERING INSPECTION AFTER DOWN-RANGE RECOVERY (NASA Photo S-64-35843)
(Note Slight Ablation from Aerodynamic Heating)

4 BOILERPLATE - 22
MAY 19, 1965

This time a total of six Algol motors were inside the Little Joe II shell. The Boilerplate Apollo was to be lifted to a very high altitude (over 110,000 feet or about 20 miles) for a simulated vacuum abort. Besides verifying the abort capability and canard performance, this flight would also provide the scientists and engineers with their first real chance to prove that the heat shield was adequate in an actual, though not severe, re-entry heating condition.

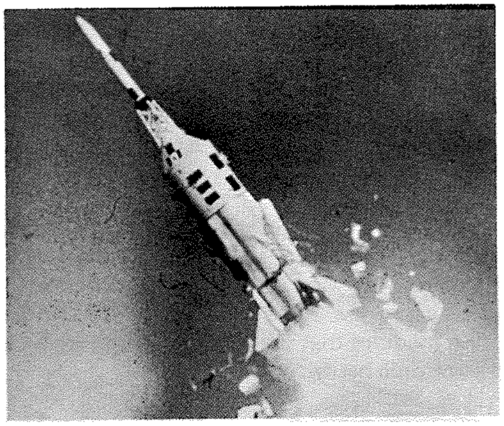
As you can see from the sequence of photos to the right, the test actually turned into a real abort condition when the booster disintegrated at an altitude of 12,400 feet. The reason for this was that a control system failure locked the fins in the fully deflected position. The vehicle then began spinning so fast about its vertical axis that the centrifugal forces caused it to break up.

The Boilerplate Command Module was successfully pulled away from the debris by the Launch Escape Motor and all of the Apollo recovery parachute systems functioned perfectly. The engineers were obviously elated to see the Launch Escape System function so perfectly in a true abort condition, but they had to patiently wait until February 26, 1966 for the first orbital flight of the Uprated Saturn (which carried Spacecraft-009) in order to qualify the heat shield which was built by AVCO Corporation of Wilmington, Massachusetts.

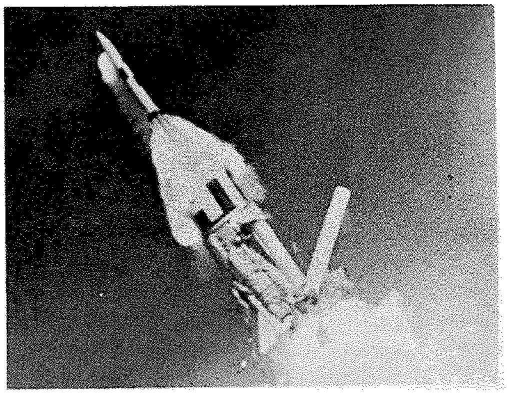


Boilerplate Apollo-22 being checked out before mating to Booster. (NASA Photo 65-H-677)

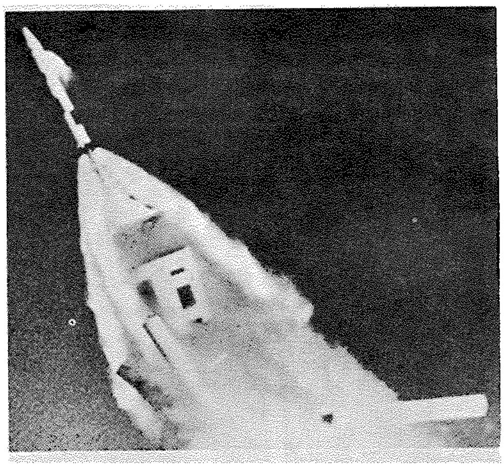
BREAK-UP SEQUENCE (NASA Photo 65-H-823)



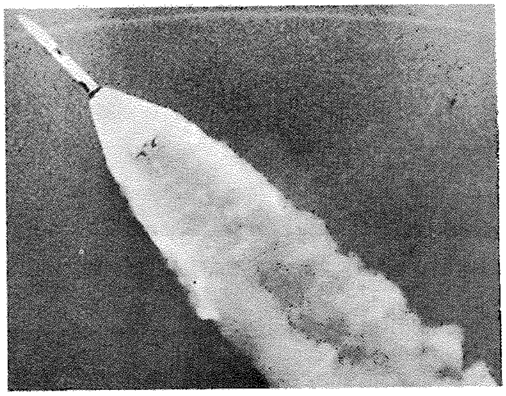
Booster begins to break up at 12,400 ft. Note fully deflected fin control surface, Algol motor breaking away, and roll pattern location in each photo.



Launch Escape and Pitch Control Motors ignite.



Command Module pulls away from debris.

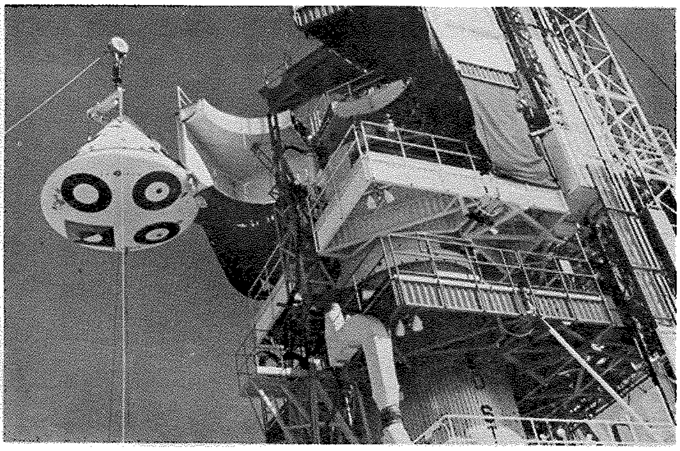


5 SPACECRAFT - 002
JANUARY 20, 1966

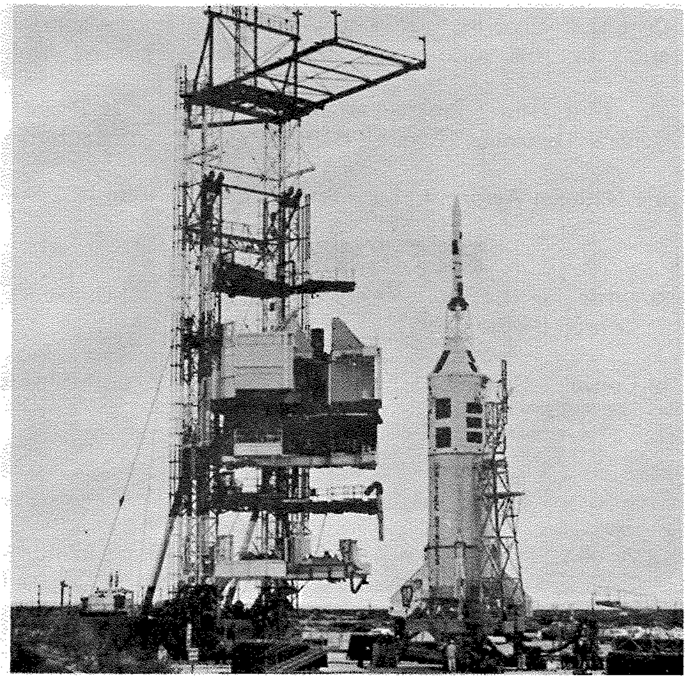
Although this was the final test in the series, this was the first time Little Joe II was to carry an actual production Apollo Spacecraft, Command Module and Service Module. In this flight Little Joe II played the roll of a Saturn that had a control system failure which would cause end-over-end tumbling under full power.

Four Algol and five Recruit motors powered Little Joe II and Spacecraft-002 up to 57,000 feet. A pitch-up maneuver was then begun and Launch Escape Motor ignition was delayed for 3 seconds to allow enough time for the vehicle to tumble. Then at 61,000 feet, the abort was initiated. All systems functioned perfectly and the Spacecraft gently landed several minutes later.

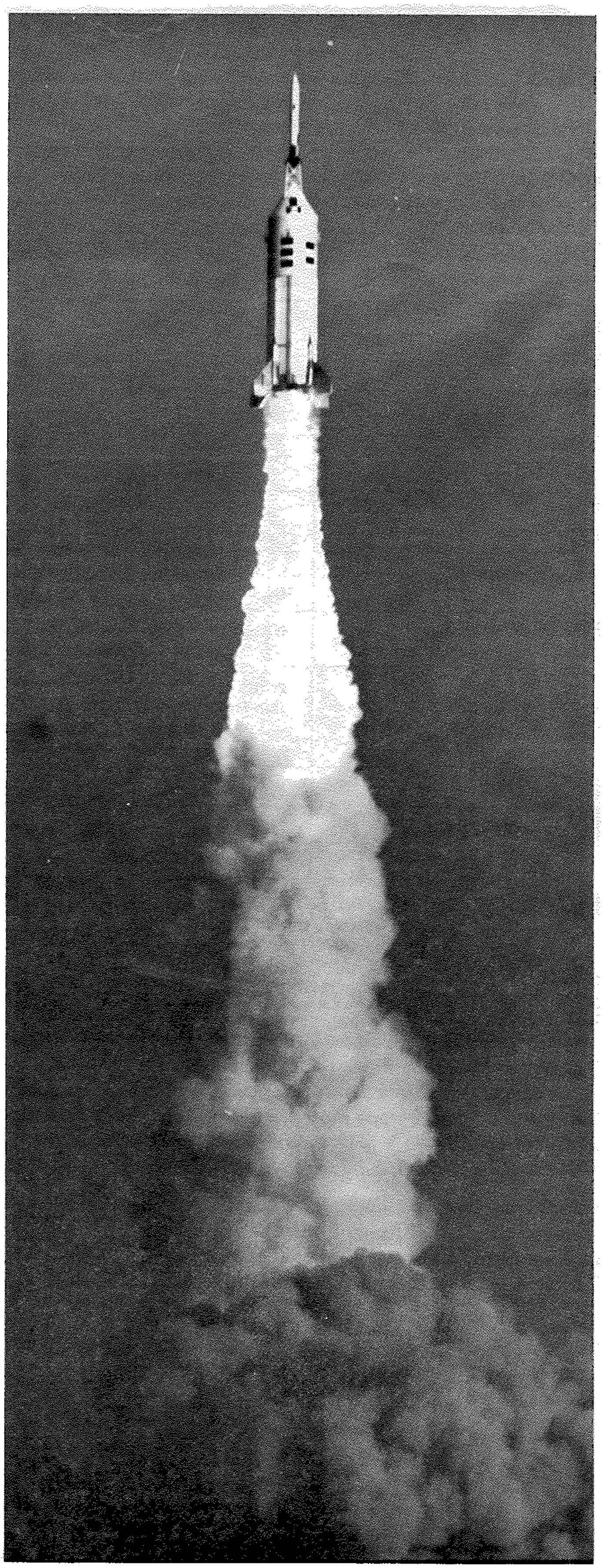
With the successful completion of the SC-002 abort and recovery mission, NASA announced that the astronaut escape system was now officially qualified for use on manned flights.



Apollo Spacecraft-002 is placed on Little Joe II booster (NASA Photo 65-H-2010)



Assembly tower at White Sands, New Mexico (NASA Photo 65-19888) (Spacecraft-002 Mission)



SC-002 LIFTOFF (NASA Photo S-66-18203)

Spacecraft-002 is also shown on the cover.

APOLLO-LITTLE JOE II SCALE DATA AND FLIGHT INFORMATION SUMMARY

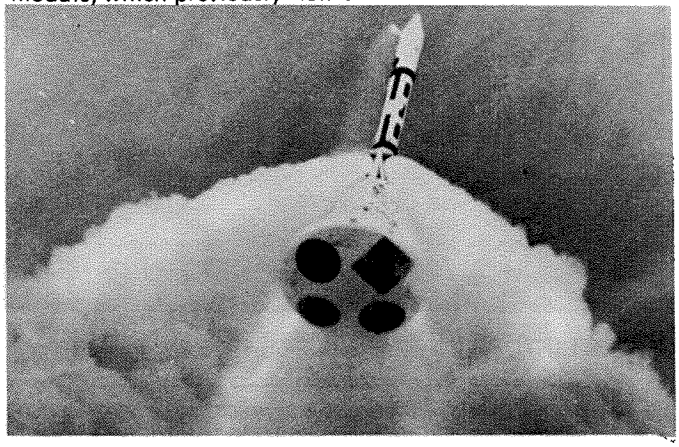
Apollo Mission	QTV	BP-12	BP-23	BP-22	SC-002
Date Flown	August 28, 1963	May 13, 1964	December 8, 1964	May 19, 1965	January 20, 1966
Test Objective	Booster Qualification	Transonic Buffeting Abort	Maximum Aerodynamic Pressure Abort	High Altitude Abort	Power-On Tumbling Abort
Liftoff Weight	57,165 lbs.	57,930 lbs.	94,331 lbs.	177,189 lbs.	139,731 lbs.
Abort Altitude	No abort capability	19,400 ft.	32,000 ft.	12,400 ft. (111,200 planned)	61,000 ft.
Propulsion – 1st Stage Recruit	6	6	4	–	5
– 1st Stage Algol	1	1	2	3	2
– 2nd Stage Algol	–	–	–	3	2
Booster Aerodynamic Control	Fixed Fins	Fixed Fins	Fins Had Hinged Control Surfaces	Fins Had Hinged Control Surfaces	Fins Had Hinged Control Surfaces
Booster Jet Reaction Control	None	None	Housed in Small Fin Fairing	Housed in Larger Fin Fairing	Housed in Larger Fin Fairing
Command Module	Silver (No Roll Pattern)	White With Black Roll Pattern	White With Black Roll Pattern	White With Black Roll Pattern	White With Black Roll Pattern
Service Module	Silver With Black Roll Pattern	White With Black Roll Pattern	White With Black Roll Pattern	White With Black Roll Pattern	White With Black Roll Pattern
Service Module Reaction Control Nozzles	No	No	No	Yes	Yes
Launch Escape Motor	White (No Roll Pattern)	White With Two Vertical Black Stripes, Rings, and 6 Rectangles	White With Black Roll Pattern Consisting of 4 Rectangles	White With Black Roll Pattern Consisting of 4 Rectangles	White With Black Roll Pattern Consisting of 4 Rectangles
Tower Skirt	White	White	White	Black	Black
Launch Escape Motor Nozzles	No Nozzles	Black	Black	Black	Black
Canards	No	No	Yes	Yes	Yes

NOTES: (1) QTV Tower had no ring in the structure and also used some rectangular plates rather than round tubes.
(2) Booster upper and middle connection rings were painted flat black on QTV flight only.
(3) For exact details on BP-22 and SC-002 roll patterns and paint scheme, see Centuri's Little Joe II kit instruction booklet.
(4) Refer to photos for additional information.

PAD ABORT TESTS

Part of the Launch Escape System qualification approval tests consisted of simulating an emergency before launch and while still on the pad atop a Saturn. Basically the tests were to prove that the Launch Escape Motor could pull the Command Module to an altitude which would allow enough time for the three main chutes to fully deploy.

The first of two successful pad aborts was conducted on November 7, 1963 using Boilerplate-6. The second was flown on June 29, 1965 and it re-used the Boilerplate-23 Command Module, which previously flew on the Little Joe II.



ACKNOWLEDGMENTS

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Mr. J. B. Hurt, Program Manager, Little Joe II Project, General Dynamics, Convair Division, San Diego, California
and
the National Aeronautics and Space Administration (NASA).

REFERENCES

a) Little Joe II Performance Capabilities, General Dynamics, Convair Division, San Diego, California.

b) Convair, General Dynamics, Flight Test Report Sheets C-6062-52, C-6062-10, and C-6062-11.

c) Apollo Spacecraft News Reference Book, North American Rockwell Corp., Downey, California, 1966.

d) Apollo Training Manual, Spacecraft and Systems Familiarization, Course No. APC-118, North American Rockwell Corp., Downey, California, February 24, 1967.

e) Apollo Training Manual, Sequential Systems, Course No. A-324, North American Rockwell Corp., Downey, Calif., July 1, 1967.