The Space Congress® Proceedings

1968 (5th) The Challenge of the 1970's

Apr 1st, 8:00 AM

Saturn IB Stage Launch Operations

G. Salvador
Chrysler Corporation Space Division, Cape Canaveral, Florida

R. W. Eddy
Chrysler Corporation Space Division, Cape Canaveral, Florida

Scholarly Commons Citation

Salvador, G. and Eddy, R. W., "Saturn IB Stage Launch Operations" (1968). *The Space Congress® Proceedings*. 4.
https://commons.erau.edu/space-congress-proceedings/proceedings-1968-5th/session-14/4

SATURN IB STAGE LAUNCH OPERATIONS

G. Salvador and R. W. Eddy
Chrysler Corporation Space Division
Cape Canaveral, Florida

Abstract

The prelaunch and launch activities are described as they pertain to the S-IB (booster) stage of the 1.6 million-pound thrust Uprated Saturn Launch Vehicle. The typical over-all schedule for an Uprated Saturn Launch is presented, culminating in the launch, and concluding with analysis of the data returned. The launch vehicle is described, with a precis of the stages and the role each has in the performance of the mission. The paper is concerned with the testing performed to bring the composite parts of the launch vehicle to flight readiness status, with emphasis on the booster stage.

Vehicle Concept

The Saturn IB launch vehicle was conceived in 1962 at the NASA Marshall Space Flight Center as the quickest, most reliable, and most economical means of providing a booster with greater payload capability than the Saturn I. The new launch vehicle would be used for earth orbital missions with the Apollo spacecraft before the Saturn V lunar launch vehicle would be available.

Development of the Saturn IB was based on a blending of existing designs for the Saturn I and the Saturn V. It uses a redesigned Saturn I booster (designated the S-IB Stage), together with the S-IVB upper stage and the Instrument Unit from the Saturn V.

The concept permitted rapid development of a new vehicle. Maximum use of designs and facilities available from the earlier approved Saturn programs saved both time and costs.

Saturn IB thus becomes a second generation of the Saturn family -- the first U.S. rocket boosters developed from the start as large payload, manned space launch vehicles.

Vehicle Description

Saturn IB, including the spacecraft and tower, stands approximately 224 feet tall and is about 21.7 feet in diameter. Total weight empty is about 85 tons, and liftoff weight, fully fueled, will be approximately 650 tons.

First-stage flight is powered by eight H-1 Engines generating 200,000 pounds of thrust each, for a total of 1.6 million pounds. In approximately 2.5 minutes of operation, it will burn 41,000 gallons of RP-1 fuel and 66,000 gallons of liquid oxygen, to reach an altitude of approximately 42 miles at burnout. H-1 engines for later S-IB vehicles will be uprated to 205,000 pounds of thrust each.

The S-IVB stage, with a single 200,000 pound thrust J-2 engine, burns 64,000 gallons of liquid hydrogen and 20,000 gallons of liquid oxygen in about 7.5 minutes of operation to achieve orbital speed and altitude. Thrust of the J-2 will be uprated in later Saturn IB vehicles.

The Instrument Unit is the Saturn IB "brain" responsible for originating electronic commands for stage steering, engine ignition and cutoff, staging operations, and all primary timing signals.

Primary payload for the Saturn IB is the Apollo spacecraft which is being developed by NASA for manned flights to the moon. It will be carried atop the Instrument Unit to complete the vehicle's launch configuration.

Development Highlights

Because of NASA's original determination to make maximum use of technology and equipment already existing or under design, Saturn IB has been brought to full development in less than four years after the initial go-ahead decision.

In that time, Marshall Space Flight Center and Chrysler Corporation have completed necessary modifications and uprating on the S-IB stage; Douglas has developed the S-IVB stage for the Saturn IB and accelerated production and testing to meet the launch schedule; MSFC and IBM Federal Systems Division have done the same in adapting the Saturn V Instrument Unit for Saturn IB; and Rocketdyne has uprated the H-1 engines for the S-IB first stage and stepped up development and production of the J-2 engine for the S-IVB second stage.

The first S-IB booster was test fired at MSFC on 1 April 1965 and subsequently delivered to Kennedy Space Center, Florida, in mid-August.

The second stage for the first Saturn IB flight vehicle was acceptance fired at the Douglas Sacramento Test Center on 8 August 1965 and delivered to KSC on 19 September.

The Instrument Unit for the Saturn IB was delivered to KSC on 20 October and mating of the IU and the rocket stages was completed at Launch Complex 34 on 25 October. The first Saturn IB flight vehicle was thus completed just 39 months after the initial NASA decision to proceed with its development.

Technical Advances

Automatic Checkout

Saturn IB is the first major space launch vehicle to employ completely automated, computer-controlled checkout systems for each of its stages during the manufacturing phase.

Both Uprated Saturn and Saturn V launch complexes now employ a computerized form of checkout, utilizing RCA 110A computers. While the RCA 110A is not the versatile analog model frequently found in business applications, it offers man-machine integration, of a sort, which lends itself to operations of this nature. The machine is, of course, programmed in many languages depending upon the assembler language. However, the more common language is known as ATOLL.

With electronic signals, the computer tests each item on the extensive checklist programmed into its memory. It compares the response with the result it is programmed to expect.

On receiving a proper response, the computer automatically moves ahead to the next test. But if any tested component fails to respond correctly, the computer automatically indicates the failure at the control console. The machine can pin-point the malfunction for the test conductor. It can also automatically indicate ways to double-check a questionable response in order to further define any difficulty.

The automatic control technology developed for the Saturn program shows promise of significant technical "fall-out" for application in many commercial and industrial applications where rapid, accurate testing of complex equipment is necessary.

Testing Requirements

The philosophy of "all-up" flight tests on Saturn IB launch vehicles requires that all stages and spacecraft modules be complete and fully functional so that a maximum of data and experience can be obtained from every launch.

Inherent in this approach is the requirement for absolute maximum reliability in the launch vehicle. When engines ignite and holddown mechanisms let go, the vehicle is committed to its mission.

Economics of present large rocket programs require that all possible steps be taken to insure the success of each mission before the countdown begins. This is the reasoning behind the immense ground testing effort in the Saturn program -- an effort in which every element, from the smallest component to the complete launch vehicle, is tested repeatedly in comparative safety on earth to prove that it will later work properly in space.

For Saturn IB, each contractor has established a test program that provides a firm foundation for confidence in the launch vehicle. It starts with applied research testing to verify specific principles considered in the basic design of the stage and its components. Every design element, every small part, and every major component goes through a similar process: design evaluation testing; qualification testing; production acceptance tests; subsystem testing; system testing; stage and vehicle testing; and finally, flight, which is the ultimate test.

Design Evaluation

Design evaluation testing establishes component configurations which will comply with actual operating requirements, and demonstrates that each part will function under all foreseeable operating conditions.

Qualification Testing

Qualification tests are similar in nature to design evaluation tests, but provide conclusive evidence that the test item will perform as required in environments to which it may be exposed. The program qualifies an article for use on a flight vehicle, and provides test data for documentary proof.

In both design evaluation and qualification testing, each item is actually subjected to a series of several tests in several different environments; namely, the conditions of vibration, high-intensity sound, electromagnetic interference, heat, or cold.

For each test, the proper equipment must be provided, a test setup devised that will yield the necessary information, and permanent records provided.

Design evaluation and qualification testing on each Saturn component actually involves dozens of separate test operations in several different environmental laboratories, and may require a period of several months.

Production Acceptance Tests

Production acceptance testing consists of a functional checkout of end-item hardware carried out in a regular program to insure that every article delivered meets operational requirements.

Each rocket engine undergoes three static test firings before delivery to the stage contractor.

All electrical and electronic components undergo a visual inspection and a 100 per cent functional testing. Fluid-carrying mechanical components are subjected to proof pressure and leak tests which exceed normal operating requirements. Structural components are given visual, and often, X-ray inspections and dimensional checks. Explosive components undergo visual and X-ray inspections, and destruction tests on a lot-size basis.

Subsystem Testing

After qualified and accepted parts and component assemblies are brought together in an operating subsystem, further qualification and acceptance-type tests are run on the complete package to demonstrate workability, reliability, and compatibility of the various components.

System Testing

All major systems on Saturn IB stages, and all individual subsystems which can function only after installation on the vehicle, are given final tests in a thorough factory checkout before delivery as a prelude to the final acceptance test procedures.

Final Acceptance Tests

Each completed Saturn IB flight stage is subjected to a series of systems tests which lead to a complete, full-power, full duration static firing which is the final trial before formal acceptance by NASA. On the S-IB, static tests are conducted at the Marshall Space Flight Center, Huntsville, Alabama. S-IVB stage static firings are carried out at Douglas Sacramento Test Center. Following static firing, each stage is put through a detailed post-firing inspection and checkout to determine how it weathered the stresses of simulated flight and to establish readiness for delivery to the launch site.

Flight Test

Every flight program is designed to provide a mass of information on vehicle performance which is vital to planning future launches. Each stage carries a complete network of instrumentation to measure and record the performance of every system, subsystem, and vital component. Data collected and telemetered back to earth during the few minutes of flight becomes a wealth of information for engineers and scientists which cannot be obtained on earth.

Test Documentation

In all Saturn test operations, from design evaluation to flight, documentation of results is important as the acquisition of data. In order to assure reliability and provide maximum confidence in every vehicle, the performance history of every part, component assembly, subsystem, and system must be accurately detailed and permanently recorded. This formidable task of record-keeping provides a test data bank for Saturn program engineers and can be an invaluable source of reference in the event of minor or major malfunctions in a test or flight.

Vehicle Assembly at Kennedy Space Center

Stages and modules that comprise the Saturn IB launch vehicle are brought together for the first time at Kennedy Space Center. There are over 90 operations performed for preflight testing and checkout. The S-IB stage, S-IVB stage, and Instrument Unit (IU) of the launch vehicle as well as major Apollo spacecraft modules undergo numerous, complex testing operations to insure flight-ready space vehicles.

S-IB Stage Operations

The S-IB stage is transported by barge from Marshall Space Flight Center's Michoud plant to the Hangar AF at Kennedy Space Center. After a receiving inspection and pre-erection preparation, the stage is transported to the launch complex and erected on the launch pedestal where the following operations are performed:

1. Installation of Fins
2. Power-on Checks
3. Digital Data Acquisition Checks
4. Radio Frequency and Telemetry Checks
5. Electrical Networks Checks
6. Mechanical Systems Checks
7. RP-1 and Liquid Oxygen Loading Tests

S-IVB Stage Operations

The S-IVB stage is delivered from the Douglas Sacramento Test Center to Kennedy Space Center and transported to the low bay area of the Vehicle Assembly Building for receiving inspection and pre-erection preparation. The following operations are performed:

1. Power-on Checks
2. Digital Data Acquisition Checks
3. Radio Frequency and Telemetry Checks
4. Electrical Networks Checks
5. Mechanical Systems Checks

The S-IVB stage is transported to the launch complex and erected and mated to the S-IB stage on the launch pedestal.

Instrument Unit Operations

The IU is delivered from Huntsville to Kennedy Space Center and transported to a hangar for receiving inspection and alignment of the inertial guidance platform. The IU is transported to the launch pad where it is mated to the S-IVB stage, and the following operations are performed:

1. Cold Plate Checks
2. Power-on Checks
3. Digital Data Acquisition Checks
4. Radio Frequency and Telemetry Checks

Integrated Launch Vehicle Operations

After the S-IB stage, S-IVB stage, and IU have been mated to form an integrated Saturn IB launch vehicle, the following operations are performed:

1. Electrical Mating Checks
2. Switch Selector Function Test
3. Power Transfer Test
4. Propellant Dispersion Functional Test
5. Guidance and Control Test
6. Exploding Bridge Wire Functional Tests
7. Sequence Malfunction Tests
8. Emergency Detection Tests

Following these tests, the integrated Apollo spacecraft is mated to the Saturn IB Instrument Unit to form the Apollo/Saturn IB space vehicle. The following prelaunch operations are conducted:

1. Integrated Test with Launch Vehicle Simulator
2. Spacecraft/Launch Vehicle Electrical Mating and Interface Tests
3. Spacecraft/Launch Vehicle Malfunction Detection Test
4. Space Vehicle Integrated Test with Umbilicals Connected
5. LES Mate and Thrust Vector Alignment Verification
6. Space Vehicle Radio Frequency Compatibility and Swing Arm Test
7. Space Vehicle Integrated Test with Umbilicals Disconnected
8. Countdown Demonstration Test
   a. Spacecraft Ordnance Installation and Removal
   b. Spacecraft Water System and Oxygen System Servicing
9. Space Vehicle Flight Readiness Test
10. Launch Vehicle Umbilical Connection Verification
11. First Stage (S-IB) RP-1 Loading
12. Second Stage (S-IVB) APS Loading
13. Space Vehicle Launch Countdown

Launch Countdown

During the launch countdown, which is currently approximately 75 hours in duration, many functions are carried out which are generally serial and time oriented with respect to launch. Final ordnance items are installed and connected. Verification tests are performed of the various propulsion RF and TM system. Power Transfer test is performed and Houston and Range command checks are made. Once these tests are complete (at approximately T-4 hours) the service structure is removed and cryogenic propellant loaded aboard the vehicle (remotely). LOX is loaded aboard the S-IB and S-IVB stages simultaneously, the operation taking about one hour. Liquid Hydrogen is then loaded aboard the S-IVB, an operation generally complete at T-1 hour. The final 60 minutes prior to launch is absorbed by the terminal count which is comprised of final reverification of command, RF&TM checks, a power transfer test, and various calibrations of measuring equipment. At T-2 minutes 43 seconds, the launch sequencer, a one PPS timer, is started, the output of which is used to sequence the final event required for S-IB stage ignition. At T-28 seconds, the vehicle goes to internal power. At T-3 seconds, ignition of the H-1 engines takes place in pairs, 100 milliseconds apart. Holddown Arm release occurs at T-0 followed by actuation of the liftoff switches.

Telemetering Calibrator

A telemetering calibrator installed in Instrument Compartment No. 1 improves the accuracy of the telemetry systems. The calibrator supplies known voltages to the telemeters periodically during the S-IB stage operation. Their reception at tracking stations provides a valid reference for data reduction.

Tape Recorder

The effects of retrorocket firing attenuation can seriously degrade the telemetry transmission during stage separation; therefore, a tape recorder installed in an instrument compartment records data for delayed transmission. The commands for tape recorder operation originate in the Instrument Unit.

Tracking System

The S-IB stage carries a transponder to facilitate ground tracking. The transponder, installed in Instrument Compartment No. 1, is part of the ODOP Tracking System. The ODOP is an elliptical tracking system that measures the sum of the ranges between the stage and three ground stations. The range sum is determined by measuring the total Doppler shift in frequency of a continuous wave radio frequency. Since the transponder is phase-coherent, the Doppler shift is determined primarily by the range and velocity of the stage.

Flight Measurement Program

The requirements for preflight and inflight performance measurements of the Saturn vehicles differ substantially from those of conventionally guided missile systems. A large number of measurements must be obtained to meet the stringent demands of the Saturn research and development program. The various physical events and environmental condition which prevail throughout the vehicle before and during flight must be made available to ground stations in a precise, real-time format.

About 440 measurements are made and telemetered during the S-IB stage flight. Before launch, approximately 110 measurements will be transmitted to the blockhouse by hardwire connections.

Many of the source signals are not suitable for direct transmission by the telemetry system; therefor, signal conditioning devices are required to modify the signals. The conditioning devices are replaceable modules installed in eight measuring racks in the tail unit area and in three measuring racks in Instrument Compartment No. 2.

Measuring distributors are junction boxes which connect the measurement signals to the telemetry systems and provide points for checkout, maintenance, and modification of the systems. Three distributors are located in the tail unit area and one is located in Instrument Compartment No. 2.

Telemetry Systems

Stage performance measuring signals when grouped according to frequency and accuracy requirements, can be most effectively transmitted by using several types of telemeters. Four telemeter systems are required to transmit the S-IB stage measuring signals. Most of the components of the telemetry systems are located in Instrument Compartment No. 1; however, a telemetry system multiplexer is installed in the aft skirt of fuel containers F-1 and F-2. The telemeters transmit data through a common antenna system.

Telemeters F1 and F2:

Telemeters F1 and F2 are identical systems which transmit narrow band, frequency-type data such as that generated by strain gages, temperature gages, and pressure gages. The system can handle 234 measurements on a time-sharing basis and 14 measurements transmitted continuously. Data may be sampled 120 times per second or 12 times per second.

Telemeter S1

Telemeter S1 transmits wide band frequency-type data generated by vibration sensors. The S-IB stage measuring program requires 39 data sources transmitted on a 25 per cent duty cycle, 8 data sources transmitted on a 50 per cent duty cycle, and 4 data sources transmitted continuously.

Telemeter P1

Telemeter P1 transmits pulse code modulated, or "bang-bang" type data. This type of data is generated by limit switches, pressure-actuated switches, valves, and relays. Five multiplexers supply data to the telemeter; three handle 234.

Launch Vehicle Flight Events

The following typical launch vehicle operations are listed for reference to post-liftoff events. The times specified are subject to change and should not be considered final.

Nominal Flight Time (Seconds)	Flight Time Base (Seconds)	Event
0.0	T_1 + 0.0	Liftoff; range safety receivers on.
10.0	T_1 + 10.0	Change from S-IB stage single engine out to multiple engine out capability.
39.0	T_1 + 39.0	Command S-IB stage tape recorder RECORD.
77.6	T_1 + 77.6	Time of maximum Q.
133.3	T_1 + 133.3	Arm S-IB stage fuel and LOX engine cutoff sensors.
138.3 (Approx.)	T_1 + 138.3 T_2 + 0.0	S-IB stage fuel or LOX cutoff sensors actuate.
140.3	T_2 + 2.0	Command S-IB stage inboard engines shutdown.
144.1	T_2 + 3.8	Command recoverable cameras ON.
146.6	T_2 + 6.3	S-IVB stage ullage EBW system primed to fire ullage rockets.
147.3	T_2 + 7.0	Arm S-IB stage fuel depletion sensors; electrically interconnect outboard engines thrust OK switches.
148.3	T_2 + 8.0	S-IB stage fuel depletion actuates, or outboard-engine thrust OK switches deactuate and outboard engines shutdown.
149.0	T_2 + 8.7	Fire S-IVB stage ullage rockets to settle propellants in tanks.
149.1	T_2 + 8.8	Command S-IB/S-IVB stage separation; fire S-IB retrorocket to brake spent S-IB stage and S-IVB aft interstage start S-IB stage tape recorder playback and recoverable camera ejection delay timers.
150.7	T_3 + 1.6	Start S-IVB, J-2 engine after sufficient clearance between stages.
155.1	T_3 + 6.0	Activate S-IVB stage propellant utilization system.
161.4	T_3 + 12.3	S-IVB stage ullage rocket jettison EBW system primed to blow off ullage rockets.
163.9	T_3 + 14.8	Jettison spent ullage rockets to decrease S-IVB stage weight.
630.0	T_3 + 500.0	J-2 engine cutoff; propellant nearly depleted; engine is stopped on fuel depletion or IU command.
	T_4 + 0.5 to + 2.1	Auxiliary pump, range safety receiver, and PU system are turned off; all systems, having completed their functions, are turned off to conserve remaining battery power.
660.0	T_4 + 29.1	Telemetry turned off.

Flight History

Although general aspects of the flight are known even as the flight progress, complete reduction of the data usually takes two weeks. The complete reduction is published in report form and the data stored on microfilm.

Saturn IB AS-201:

The first Apollo/Saturn IB (AS-201) flight followed in the tradition of the completely successful ten vehicle Saturn I series.

The unmanned vehicle was launched at 11:12 a.m. (EST) on 26 February 1966 from the NASA-Kennedy Space Center's Launch Complex 34.

This launch marked the first flight tests of a powered Apollo spacecraft, a S-IVB stage, and a J-2 engine. The two-stage vehicle achieved all test objectives in its 32 minute suborbital flight down the Atlantic Missile Range.

The mission of the AS-201 flight was to test the launch vehicle and Apollo spacecraft systems.

The AS-201 launch was delayed three days because of unacceptable weather in the launch area. On launch date, a series of technical problems delayed the firing about three hours. The major trouble was a lack of required pressure in the control pressure system gaseous nitrogen sphere in the booster stage. Nitrogen from this container is used to operate valves, purge certain components, and provide pressurization for engine turbine gearboxes.

Technicians corrected the low-pressure problem (a pressure of 3,000 pounds at ignition is required) by increasing the supply pressure in the ground system. A test was run which demonstrated that the problem would not affect the flight. A decision then was made in the blockhouse to launch the vehicle. The decision was sound, for the proper pressure was maintained throughout the flight.

The Apollo spacecraft, which reached a peak altitude of 306 miles, splashed down about 200 miles southeast of Ascension Island in the South Atlantic.

Performance of the first stage was normal. The four inboard engines cutoff at 141.4 seconds after liftoff, about 0.4 second later than expected.

The second (S-IVB) stage ignited on command at 149.3 seconds, 0.4 second later than predicted, and was cut off at the desired velocity at 602.9 seconds, burning 10 seconds longer than programmed. The longer burn time was the result of action by the stage propellant utilization system at 240.5 seconds to insure the simultaneous depletion of both propellants by adjusting the consumption rate of liquid oxygen. Sensors in the vehicle tanks monitor propellant mass throughout the flight and direct an engine-mounted propellant utilization valve to vary the flow of LOX so that it will be depleted simultaneously with the depletion of LH_2. Varying the LOX consumption rate, which also controls engine thrust, caused the vehicle guidance system to compensate by extending the burn time. The variation in LOX comsumption rate and burn time both were well within the planned tolerances, and the predicted burnout velocity was achieved. The guidance and control system performed well; both S-IB and S-IVB trajectories and end velocities were normal. No structural problems were found in either of the stages or the instrument unit. The quality of data received at ground stations was good and very few losses occurred in the approximately 1,200 measurements telemetered. One of the two cameras carried aboard the first stage and ejected following burn was recovered by Air Force crews. The camera had excellent coverage of stage separation and S-IVB ignition.

The test marked the introduction of a new launch vehicle for the U.S. space program with an unmatched payload capability and with all stages and systems fully functional on the first flight.

Saturn IB AS-203

The second Apollo/Saturn IB (AS-203) added to the impressive record of Saturn vehicles by making the 12th consecutive successful flight in as many launch attempts.

The unmanned vehicle lifted off the pad at Launch Complex 37, NASA-Kennedy Space Center, at 9:53 a.m. (EST) on 5 July 1966.

The AS-203 was topped by a simple aerodynamic shroud (nose cone) instead of an Apollo spacecraft as was carried on the previous Saturn AS-201. The second stage (S-IVB) containing about ten tons of liquid hydrogen was the "payload". The vehicle instrument unit and nose cone weighed a total of about 38,500 pounds, the heaviest object launched into orbit by the United States.

The primary purpose of the flight was to verify the orbital conditioning characteristics of the second stage propulsion system which uses liquid hydrogen as its fuel. This information was needed for future Saturn V applications in which the S-IVB stage must restart in earth orbit.

Engineers at the NASA-Marshall Space Flight Center the agency responsible for Saturn development, and Douglas the second stage contractor, planned the experiment to determine the behavior of liquid hydrogen under weightless conditions. The hydrogen continuous vent system was arranged to provide a very slight amount of thrust as the gaseous hydrogen produced by boiloff escaped. Additional thrust was provided periodically by opening a liquid oxygen tank propulsive vent valve. The information obtained was needed to determine if the thrust and resulting slight acceleration would keep the fuel settled in the bottom of the tank where it would be available for use in restarting the J-2 engine.

Television pictures of the tank interior showed that the fuel settled properly in the bottom of the tank and remained stable during venting, thus verifying the theory. Simulated engine restart conditions were also accomplished successfully.

Launch of AS-203 was delayed one hour and fifty-three minutes due to trouble in the television system. One of two camera systems was inoperative. Rather than postpone the flight, officials decided to proceed with the remaining camera in operation.

Performance of the first stage was normal. Engine cutoff occurred 141.8 seconds after liftoff; 0.8 second sooner than predicted. Stage separation took place at 142.6 seconds. The J-2 engine of the second stage ignited at 144 seconds and cutoff occurred at 432.5 seconds. Cutoff was predicted at 435.3 seconds.

The guidance and control system performed well. The vehicle reached the proper altitude and velocity for insertion into orbit ten seconds after second stage cutoff.

The orbit planned for AS-203 was circular at an altitude of about 115 statute miles. The first orbit of the vehicle was almost exactly as planned, having a perigee of 115 miles and apogee of 117.6 miles. Orbital period was 88.24 minutes.

Later orbits varied slightly, as expected, because the slight thrust provided by the continuous venting of hydrogen continued to increase the vehicle's velocity, causing the stage to drift slowly into higher orbital paths.

The second stage was broken up near the beginning of the fifth orbit during a hydrogen tank pressure rise rate and bulkhead test. The last telemetry received from the vehicle at the beginning of the fifth orbit indicated the pressure inside the fuel tank was 39.4 psi and the oxygen tank 5 psi. This created a pressure differential across the common bulkhead of 34.4 psi. Shortly after this point, a structural failure occurred at the bulkhead disintegrating the stage. The structural failure of the bulkhead was anticipated, but the time when failure might occur was uncertain.

The failure verified results of a similar test performed on a test model some months earlier at Douglas in which the common bulkhead failed at very near the same pressure differential. Payload breakup had no effect on the AS-203 mission because all other planned experiments had been completed.

Pressure readings proved that the stage structure would withstand pressure differentials between the two tanks more than three times greater than those experienced under normal operating conditions, further verifying stage design.

The quality of data received at the ground stations was good and the television pictures were excellent. About 1,500 measurements were telemetered back to earth from the complete vehicle. One of two ejectable motion picture cameras carried in the interstage section was recovered. The color pictures taken by the recovered camera were excellent.

All aspects of the flight including general tests of the vehicle's propulsion and guidance systems and observation of the instrument unit's operation in orbit were carried out satisfactorily.

Saturn IB AS-202

The third unmanned Apollo/Uprated Saturn I (AS-202) the 13th vehicle of the Saturn Program was launched successfully into space at 12:15:32 p.m. (EST) on 25 August 1966. Liftoff of the vehicle was from launch complex 34 at the NASA-Kennedy Space Center.

Primary purpose of the suborbital flight was to test the Apollo spacecraft's heat shield. Also, the flight provided another check of the launch vehicle.

About 93 minutes after launch, the uprated Saturn had hurled its payload three-fourths of the way around the earth.

The uprated Saturn pushed the spacecraft into space with its 1.6 million-pound thrust first stage, and 200,000-pound thrust second stage before spacecraft separation. Then the Apollo's 21,500-pound thrust service engine carried the spacecraft to an altitude of more than 700 miles.

The Apollo command module made a "skipping" reentry into the atmosphere, somewhat like a roller coaster ride, subjecting the heat shield to extended high heat loads. The previous re-entry test had been at a sharper angle reducing the time of reentry.

Splashdown of the command module occurred in the Pacific Ocean near the vicinity of Wake Island. The recovery point was about 17,800 miles from the launch site at Kennedy Space Center. The successful flight followed a three-day delay which allowed engineers to complete minor reworking and additional testing of components in the spacecraft stabilization, guidance, and control systems.

The first stage S-IB performed satisfactorily. Shutdown of the first stage engines occurred at 143.5 seconds, or 1.1 seconds earlier than nominal.

First stage S-IB and second stage S-IVB separation occurred at 144.2 seconds followed by ignition of the S-IVB stage 1.4 seconds later. Active guidance was initiated successfully 28.2 seconds after separation. All ullage rockets functioned as expected and were jettisoned successfully.

Second stage cutoff occurred at 588.5 seconds, or 13.7 seconds earlier than predicted. Separation of the spacecraft occurred 10.2 seconds after second stage cutoff, or 13 seconds earlier than predicted.

Overall performance of the second stage propulsion system was satisfactory. The J-2 engine was flown at a mixture ratio of approximately 5.5:1 for the first 350 seconds of burn, after which the mixture ratio was changed to approximately 4.7:1. Late mixture ratio cutback contributed to the higher average stage performance. The vehicle liquid hydrogen recirculation valve failed to close as scheduled just prior to J-2 engine start, but the valve failure had no effect on the mission.

The guidance system performed adequately, and the control system deviations were about as expected. Acoustic levels and vibration levels were within expected tolerances and no structural problems appeared in the first stage, the second stage, or the instrument unit. The launch vehicle's electrical systems performed as expected and within appropriate limits.

The emergency detection system (EDS) was flown "closed loop" on this flight. The overall operation of the EDS was successful. However, an intermittent electrical short circuit beginning at 93.6 seconds occurred in the "Q-ball", which is an EDS sensor. Finally, a hard short occurred at 114.9 seconds in a regulator circuit. Other portions of the launch vehicle's EDS performed properly. Mission evaluation proved flight AS-202 was successful, and met all expected requirements.

SUMMARY OF SATURN FLIGHT PROGRAM

SUBORBITAL FLIGHTS

	Date	Duration	Altitude	Distance	Burn Duration	Remarks
				SATURN I		
SA-1	10/27/61	408 sec.	85 mi.	207 mi.	116 sec.	Successful ballistic flight.
SA-2	4/26/62	102 sec.	65 mi.	50 mi.	117 sec.	Project High Water I. 96 tons of water exploded.
SA-3	11/16/62	292 sec.	104 mi.	131 mi.	149 sec.	Project High Water II. 95 tons of water exploded.
SA-4	3/28/63	398 sec.	81 mi.	219 mi.	121 sec.	One inboard engine shut down intentionally after 100 sec. and flight continued successfully.

SATURN IB

	Date	Duration	Altitude	Distance	Burn Duration	Remarks
AS-201	2/26/66	1,917 sec.	306 mi.	5,400 mi.	602.9 sec.	Successful suborbital lob shot to position Spacecraft for earth reentry heat shield test.
AS-202	8/25/66	5,582.2 sec.	617 mi.	17,800 mi.	588.5 sec.	Successful suborbital flight to test spacecraft's heat shield and check launch vehicle.

ORBITAL FLIGHTS

	Date	Perigee	Apogee	Orbital Period	Burn Duration			Remarks
					1st Stg.	2nd Stg.	3rd Stg.	
				SATURN I				
SA-5	1/29/64	163 mi.	479 mi.	95 min.	146 sec.	481 sec.	0	First flight with live second stage. 37,900 lbs. into orbit.
SA-6	5/28/64	114 mi.	149 mi.	88 min.	149 sec.	473 sec.	0	Boilerplate Apollo Spacecraft. One inboard engine unexpectedly shut down 26 sec. early but did not impair flight.
SA-7	9/18/64	112 mi.	145 mi.	88 min.	147 sec.	471 sec.	0	Boilerplate Apollo Spacecraft. 39,000 lbs. into orbit. Declared operational three flights early.
SA-9	2/16/65	309 mi.	463 mi.	97 min.	145 sec.	473 sec.	0	First operational flight. Pegasus I placed into orbit.
SA-8	5/25/65	315 mi.	465 mi.	97 min.	148 sec.	473 sec.	0	Pegasus II. First night launch.
SA-10	7/30/65	328 mi.	330 mi.	95 min.	148 sec.	479 sec.	0	Pegasus III.
				SATURN IB				
AS-203	7/5/66	*115 mi.	*117 mi.	*88 min.	142 sec.	288 sec.	0	Test liquid hydrogen behavior. Simulation of Saturn V restart conditions.
AS-204	1/22/68							First Lunar Module flight.

*Orbital parameters given are for initial orbit only; propulsive experiments caused small variations.

REFERENCES

(1) Saturn IB Vehicle Handbook, Volumes I - IV, 25 July 1966, Chrysler Corporation Space Division, George C. Marshall Space Flight Center.

(2) Saturn IB News Reference, December 1965

(3) Saturn IB Orientation Course Handout, Chrysler Corporation Space Division, Huntsville, Alabama.

(4) S-IB Flight Measurements Manual, Volume I, 29 December 1966, National Aeronautics and Space Administration, Huntsville, Alabama.

(5) S-IB Stage Flight Evaluation Report, SDES-66-509, 24 October 1966, Chrysler Corporation Space Division, New Orleans, Louisiana.

(6) AS-202 Technical Information Summary, R-ASTR-S-140-66, 5 August 1966, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama.

(7) AS-203 Technical Information Summary, R-ASTR-S-85-66, 14 June 1966, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama.

(8) Technical Information Summary, Apollo 5 (AS-204/LM-1) Apollo Saturn IB Flight Vehicle, R-ASTR-S-67-63, 15 December 1967, Marshall Space Flight Center, NASA, Huntsville, Alabama.