TESTING

INTRODUCTION

The expense of the Saturn V makes it imperative that no effort be spared to assure that it will perform as expected in flight. The magnitude of the Saturn V ground test program, therefore, is unprecedented. To qualify for flight, all components and systems must meet standards deliberately set much higher than actually required. This margin of safety is built into all manrated space hardware.

Compared with earlier rocket programs the ground testing on Saturn V is more extensive and the flight testing is shorter. The ground test programs conducted on the F-1 and J-2 engines, which power the three stages, offer an example of the thoroughness of this testing effort. The J-2 has been fired some 2,500 times on the ground, for a total running time of more than 63 hours. The F-1 has been fired more than 3,000 times for a running time of more than 43 hours.

Further, in earlier rocket programs such as Redstone, Thor, and Jupiter, 30 to 40 R&D flight tests were standard. In the Saturn I program,where more emphasis was placed on ground testing prior to the flight phase, 10 R&D flight tests were planned. The vehicle was declared operational after the first six firings met with success.

The Uprated Saturn I (Saturn IB)—an improvement on the basic Saturn I—was manrated after three flights. On the Saturn V, only two flights are planned prior to the attainment of a "manned configuration."

The inspection to which flight hardware is subjected is thorough. Following are examples of many steps which are taken to inspect the Saturn V vehicle:

1. X-rays are used to scan fusion welds, 100 castings, and 5,000 transistors and diodes.
2. A quarter mile of welding and 5 miles of tubing are inspected with the use of a sound technique (ultrasonics). The same type of inspection is given to adhesive bonds, which are equivalent in area to an acre.
3. An electrical current inspection method is used on 6 miles of tubing, and dye penetrant tests are run on 2.5 miles of welding.

Each contractor has his own test program that is patterned to a rather basic conservative approach. It begins with research to verify specific principles to be applied and materials to be used. After production starts each contractor puts flight hardware through qualification testing, reliability testing, development testing, acceptance testing, and flight testing.

QUALIFICATION TESTING

Qualification testing of parts, subassemblies, and assemblies is performed to assure that they are capable of meeting flight requirements. Tests under the conditions of vibration, high-intensity sound, heat, and cold are included.

RELIABILITY TESTING

Reliability analysis is conducted on rocket parts and assemblies to determine the range of failures or margins of error in each component. Reliability information is gathered and shared by the rocket industry.

DEVELOPMENT TESTING

A battleship test stage constructed more solidly than a flight stage is often used to prove major design parameters within a stage. Such a vehicle verifies propellant loading, tank and feed operation, and engine firing techniques.

Battleship testing is followed by all-systems testing. For example, one of four ground test stages of the first stage completed 15 firings at Marshall Space Flight Center in Huntsville. The firings proved that the design and fabrication of the complete booster and of its subsystems were adequate.

The entire Apollo/Saturn V vehicle, consisting of the three Saturn V propulsive stages, the instrument unit, and an Apollo spacecraft, was assembled in the Dynamic Test Stand at the Marshall Center. This is the only place, aside from the launch site, where the entire Saturn V vehicle has been assembled. The purpose of dynamic testing was to determine the bending and vibration characteristics of the vehicle to verify the control system design. The 364-foot assembly was placed on a hydraulic bearing or "floating platform". Electromechanical shakers caused the vehicle to vibrate, simulating the response expected from flight forces.

ACCEPTANCE TESTING

Finished work undergoes functional checkout to insure it meets operational requirements. Tests range from continuity and compatibility of wiring to all-systems ground testing. Fluid-carrying components are subjected to pressures beyond normal operating requirements, and structural components receive visual and X-ray inspections. Instruments simulate flight conditions to evaluate total performance of electrical and mechanical equipment.

Rocket engines are static-fired before delivery to the stage contractor. Such tests demonstrate performance under conditions simulating flight temperatures, pressures, vibrations, etc.

Each flight stage completes a series of systems tests which lead to a full-power, captive acceptance firing. Afterwards it is refurbished and given a postfiring checkout before going to Kennedy Space Center.

AUTOMATIC CHECKOUT

A fully automated, computer-controlled vehicle checkout has been designed into all major segments of the Saturn V for extensive stage test operations.

Automatic checkout is used first in the final factory checkout and then throughout prefiring preparations for static tests and during the actual countdown for these firings. It is employed again throughout the postfiring checkout and finally for prelaunch checkout and launch operations at Kennedy Space Center.

The sytem uses a carefully detailed computer program and associated electronic equipment to perform the complete countdown of each Saturn stage.

With electronic speed, the automatic checkout moves through a precisely controlled and repeatable checkout test program. The system performs a point-by-point test of each function, indicates responses to tests, and pin-points any malfunction that occurs. The automatic checkout can also indicate ways to double check a questionable response in order to define any difficulty. It virtually eliminates the possibility of human error during a countdown.

FLIGHT TESTING

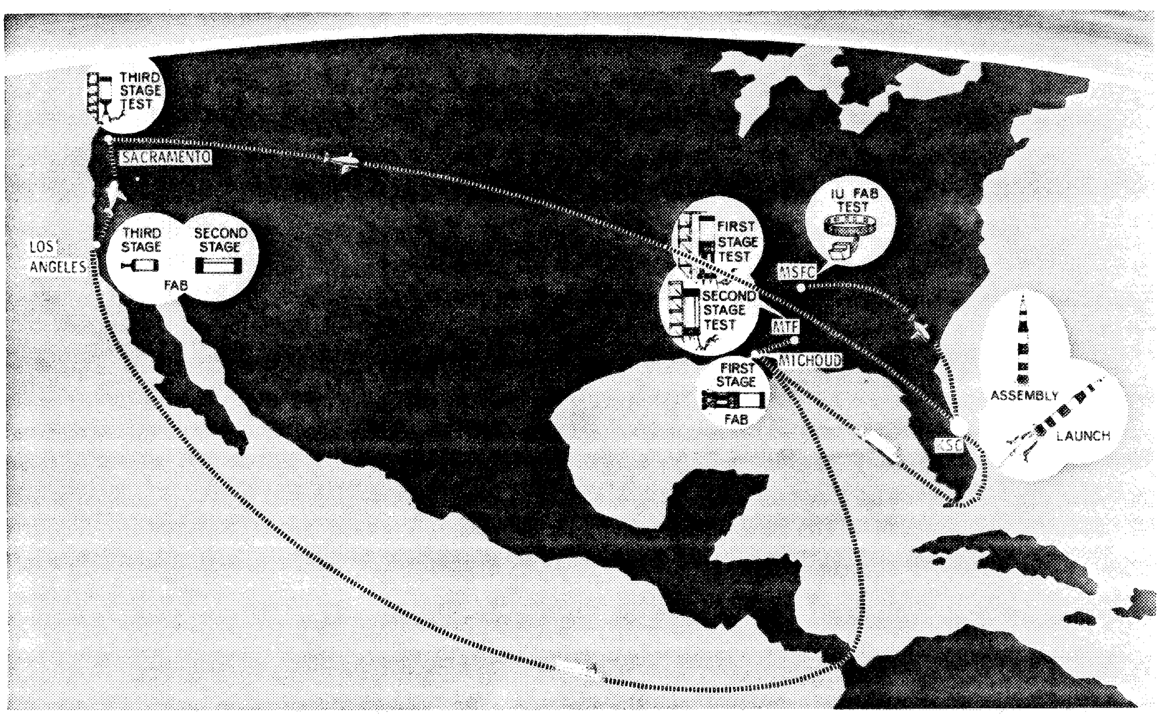
Every flight program is designed to provide a mass of vehicle performance information which is needed in planning future launches. Each stage carries a complete network of instrumentation to measure and record the performance of every system, subsystem, and vital component.

TEST DOCUMENTATION

In all Saturn V test operations, from ground development through flight, documentation of results is as important as the acquisition of data. The performance history of every part, component assembly, subsystem, and system must be accurately detailed and permanently recorded.

These records give engineers a basis for making evaluations of the performance of parts and subsystems. These evaluations provide maximum confidence in every vehicle.

The formidable task of record-keeping has necessitated the establishment of a test data bank for Saturn V program engineers. It can be an invaluable source of reference in the event of minor or major malfunctions in a test or flight.



Traveling Saturn– This depicts the Saturn V assembly and test sequence and the transportation routes of rocket-carrying craft.

VEHICLE ASSEMBLY AND LAUNCH

ASSEMBLY AND CHECKOUT

Saturn V stages are shipped to the Kennedy Space Center by ocean-going vessels or by specially designed aircraft. Apollo spacecraft modules are transported by air and delivered to the Manned Spacecraft Operations Building at Kennedy Space Center for servicing and checkout before mating with the Saturn V.

Saturn V stages go into the Vehicle Assembly Building low bay area where preparation and checkout begins. Receiving inspection and the low bay checkout operations are first performed before stages are erected within a high bay.

After being towed into the high bay area and positioned under the 250-ton overhead bridge crane, slings are attached to the first stage and hooked to the crane. The stage is positioned above the launch platform of the mobile launcher and lowered into place. Then it is secured to four holddown/support arms. These support the entire space vehicle during launch preparation and provide holddown during thrust buildup prior to launch.

Next, engine fairings are installed on the stage and fins are moved into position and installed in line with the four outboard engines.

Mobile launcher electrical ground support equipment is connected to the launch control center (LCC) via the high speed data link, and the test program is started with the actual launch control equipment.

Prior to and during this time, all low bay testing is completed and the upper stages are prepared for mating. The mating operation consists of stacking the stages. Umbilical connection begins immediately and continues during the mating operation on a noninterference basis. The vertical alignment of the vehicle is performed after each stage is mated.

When the launch vehicle is ready, the Apollo spacecraft is brought to the VAB and mated.

Checkout of all systems is performed concurrently in the high bay. The first tests provide power and cooling capability to the vehicle, validate the connections, and establish instrumentation. When this is completed, systems testing begins. The systems tests are controlled and monitored from the LCC wherever practical and "break-in" tests are held to a minimum. Following the validation of each stage, a data review is held and the vehicle is prepared for combined systems tests.

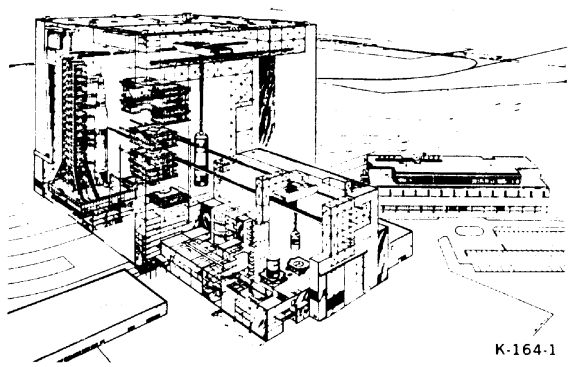


Illustration of Vehicle Assembly Building Interior at Kennedy Space Center

The combined systems tests verify the flight-readiness of the overall vehicle. These tests include a malfunction sequence test, an overall test of the launch vehicle, an overall test of the spacecraft, and a simulated flight test. Prior to the simulated flight test, final ordnance installation is completed. After the test, vertical alignment is checked, a data review is held, and the vehicle is prepared for transfer to the pad. These preparations include disconnecting pneumatic, hydraulic, and electrical lines from the mobile launcher to the VAB.

After the lines are disconnected, the transporter is moved into position beneath the mobile launcher. Hydraulic jacks engage the fittings on the mobile launcher and raise it approximately 3 feet so that it clears its mount mechanisms. Then the transporter moves out of the VAB, over the crawlerway, to the launch pad.

TESTING AT LAUNCH SITE

At the launch pad, the transporter moves the mobile launcher into position, lowers and locks it onto another set of mount mechanisms. The transporter then moves to the mobile service structure parking area, picks up the service tower, and positions it beside the Saturn V to provide vehicle access for pad operations.

The digital data link, communications circuitry, pneumatic supply lines, propellant lines, environmental controls, and electrical power supply lines are connected.

Power again is applied to the vehicle and the control and monitor links are verified. Pad testing is held to a minimum. The high bay from which the vehicle was moved remains empty during pad operations.

A spacecraft systems verification test is performed, followed by a space vehicle cutoff and malfunction test. Radio frequency compatibility is established and preparations are made for a final flight readiness test, which involves sequence tests paralleling the actual countdown and inflight operations. Compatibility with the stations of the Eastern Test Range and the Integrated Mission Control Center in Houston, Tex., are verified at this time.

Following an evaluation of the flight readiness test, all systems are reconfigured for launch, and all plugs reverified. A countdown-demonstration test is then performed as the final test prior to launch. The countdown-demonstration test consists of an actual launch countdown, complete with propellant loading, astronaut embarkation, etc., with the exception of actual ignition. This test exercises all systems, the launch crew, and the astronauts, and prepares the "team" for the actual operation to follow. This "dress rehearsal" is used to divulge any last minute problems and affords the mission a better chance of success.

Upon completion of the countdown demonstration test, the space vehicle is recycled to pre-count status, and preparations are made for the final countdown phase of launch operations. Normal recycle time between completion of the countdown demonstration test and beginning of launch countdown is 48 to 72 hours.

Propellant loading of the Apollo spacecraft is performed prior to launch day. Aerozine 50 is the fuel and nitrogen tetroxide, the oxidizer. Also prior to launch day, hypergolics for the third stage reaction control system are loaded and ordnance connected. Loading of the cryogenic propellants for the launch vehicle begins on launch day at approximately T-7 hours. (The kerosene is loaded one day before launch.)

Liquid oxygen loading is begun first. The tanks are precooled before filling. Precool of one tank can be accomplished concurrently with the fill of another. Loading is started with the second stage to 40 per cent, followed by the third stage to 100 per cent. The second stage is then brought to a full 100 per cent followed by loading the first stage to 100 per cent. This procedure allows time for the liquid oxygen leak checks to be performed prior to full loading of the second stage. Liquid oxygen is pumped at a flowrate of 1,000 gallons per minute for the third stage. For the second stage, the tank rate is 5,000 gallons per minute, and the first stage tank flowrate is 10,000 gallons per minute.

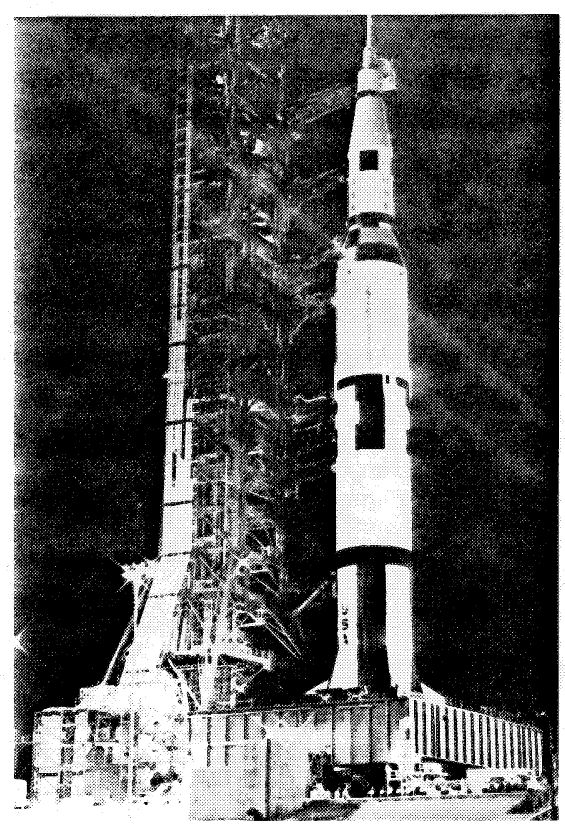
Liquid hydrogen loading is initiated next, beginning with the second stage to 100 per cent. Loading of the third stage liquid hydrogen is last. Liquid hydrogen is pumped to the second stage at a rate of 10,000 gallons per minute, and to the third stage at a rate of 3,000 gallons per minute. Topping of cryogenic tanks of the launch vehicle continues until launch. Total cryogenic loading time from start to finish is 4 hours and 30 minutes.

At approximately T-90 minutes, after propellants are loaded, the astronauts enter the spacecraft from the mobile launcher over the swing arm walkway.

LAUNCH

During the remainder of the countdown, the final systems checks are conducted.

Launch vehicle propellant tanks are then pressurized, and the first stage engines ignited. During the thrust buildup of the F-1 engines, the operation of each of these engines will be automatically checked. Upon confirmation of thrust OK condition, the launch commit signal is given to the holddown arms and liftoff occurs.



P39963

Assembled Vehicle—The Saturn V facilities vehicle, the 500F, arrives at Launch Complex 39A.

PROGRAM MANAGEMENT

NASA ORGANIZATION

The Saturn V development program comes under the direction of the NASA Office of Manned Space Flight, Washington, D.C. That office assigned development responsibility to the Marshall Space Flight Center, one of the three Manned Space Flight field centers. Another of those field centers, the Kennedy Space Center, has been delegated the responsibility of launching the Saturn V. (Development of the Apollo spacecraft, the first "payload" for the Saturn V, was assigned to the Manned Spacecraft Center, the other MSF field organization.)

Marshall Center Project Management Organization

More than 125,000 prime and subcontractor employees and 7,500 civil service employees are working on the Saturn program. Saturn industrial activities are scattered nationwide but there are three major areas of concentration:

1. the Northeast, with its grouping of electronic industries.
2. the Southeast, for production, test, and launch operations.
3. the West Coast, with its concentration of aerospace industries for design, production, and test work.

In addition, various research projects by scientific institutions and subcontractor production efforts contributing to the Saturn program are spread throughout the nation.

The wide dispersion makes necessary very comprehensive and reliable management systems and control techniques to manage the program effectively. The geographic dispersion of the Saturn effort requires excellent communications. The Marshall Center must be aware of related programs carried out by other NASA centers—especially the Manned Spacecraft Center, managing the Apollo spacecraft program, and Kennedy Space Center, responsible for Saturn/Apollo launches.

The Marshall Center has found that one of the more effective tools for total program visibility is especially constructed and outfitted rooms called Program Control Centers. The Saturn V launch vehicle program office and other major groups have such centers.

The budget for the current fiscal year at the MSFC is about $1.7 billion. The center must have a well staffed organization responsive to the many changes which can take place in a program of this magnitude.

One of the Marshall Center's two major divisions—Industrial Operations—is responsible for the management of the Saturn launch vehicle development programs for NASA manned space flight. Dr. Arthur Rudolph, the Saturn V program manager in Industrial Operations, controls the project effort, plans, and budgets. For technical solutions to vehicle problems, the manager gets assistance from the laboratories of the Research and Development Operations—the second major and largest MSFC division reporting directly to the center director. Because of the many interfaces between the stages and with ground support equipment, program management responsibility in Industrial Operations includes establishing specifications and procedures which assure physical and functional compatibility. Formerly, the Marshall Center did the overall design of stages and major systems inhouse, but more recently, particularly with subsystems and components, the program managers have concentrated on performance specifications and left the details to the contractors. This management function keeps the program engineers very much in the mainstream of technical design activity. Thus, Industrial Operations program managers are quite active in the areas of: test requirements, qualification testing, product control, systems engineering, program control, and flight operations.

Marshall Center's Research and Development Operations laboratories are oriented functionally in such primary disciplines as mechanical engineering, electronics, and flight mechanics. Collectively, the laboratories provide the deep-rooted technological foundation on which the success of all Marshall projects depends. In the project offices, technical decisions are made which affect many areas. These decisions are formulated by drawing upon the full technical resources of the laboratories, which maintain a high level or professional competence.

Laboratory personnel work on selected projects to keep their technical knowledge updated and their technical competence at a high pitch. This is the Marshall work bench philosophy—the "dirty hands" approach.

The Saturn V program office is headed by a program manager. There is a stage manager or project director for each of five major vehicle systems. A stage manager primarily deals with only one major contractor. In the case of the instrument unit and the ground support equipment project, there are several major contractors. The principle of a single project management focal point is the objective of each project team.

Program management is vested in the program manager. Technical project management, so far as NASA is concerned, occurs at the stage or project level. The program and stage managers are fully responsible for technical adequacy, reliable performance, and for management of all related contractor activity.

These program and project managers must be backed up and supported by technical competence in depth. This in-depth support is provided, to a degree, by a staff of competent technical and business management people in the program manager and stage manager office, and to a much larger degree, by Research and Development Operations.

There is a resident manager at each of the contractor plants to act as the "official" voice for the Marshall Center. All MSFC instructions to the contractor are transmitted through the resident manager. Through the resident manager, MSFC maintains a direct contact with contractor operations and is kept informed of the status of all significant program events.

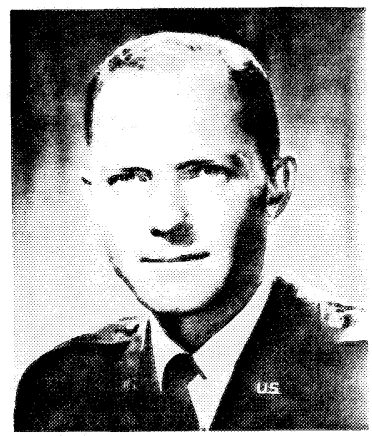
Marshall Center laboratory technical personnel are assigned to the resident managers' staffs. These technical people are assigned to each resident manager's office to provide him with assistance in resolving technical problems, and to keep the MSFC technical laboratories directly informed of field technical effort. Laboratory participation is dictated by need as determined by project management.

Many people are involved in attaining the final goal. Project management, technical, and contractor personnel are tied in a close knit group capable of managing this country's large launch vehicle program.

MANAGEMENT PERSONNEL

NASA

Dr. George E. Mueller, Associate Administrator for Manned Space Flight, NASA Headquarters.



Major Gen. Samuel C. Phillips, Director, Apollo Program, NASA Headquarters.

Dr. Wernher von Braun, Director, Marshall Space Flight Center.

Dr. Kurt H. Debus, Director of John F. Kennedy Space Center.

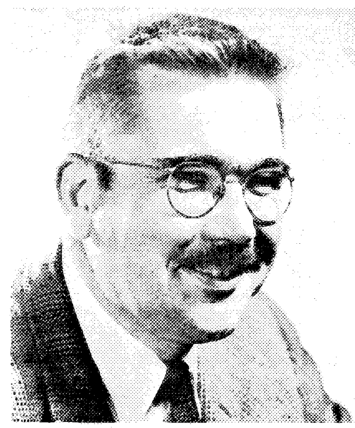
Dr. Arthur Rudolph, Manager, Saturn V Program Office, Marshall Space Flight Center.

Rocco A. Petrone, Director of Launch Operations, Kennedy Space Center.

MANAGEMENT PERSONNEL

BOEING

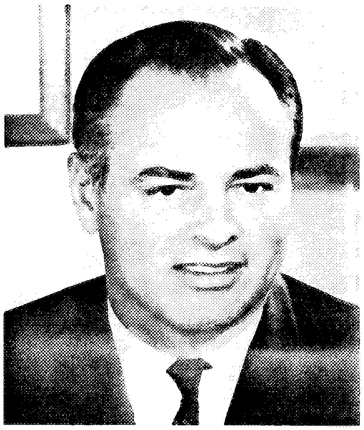
L. A. Wood, Group Vice President, Aerospace.



G. H. Stoner, Vice President and General Manager, Space Division.

R. H. Nelson, General Manager, Launch Systems Branch.

A. M. 'Tex' Johnston, Director, Boeing Atlantic Test Center.



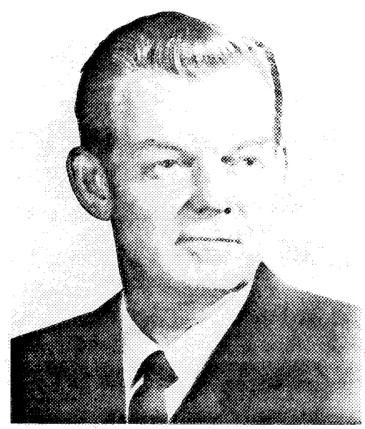
MANAGEMENT PERSONNEL

DOUGLAS

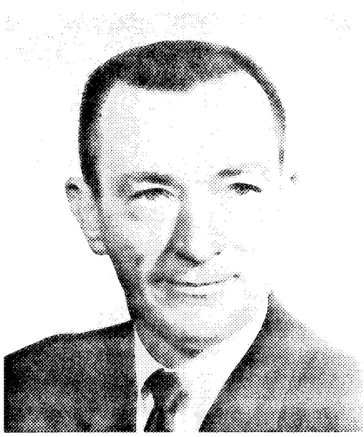
Charles R. Able, Group Vice President, Missile and Space Systems.

Jack L. Bromberg, Vice President and Deputy General Manager, Missile and Space Systems Division.

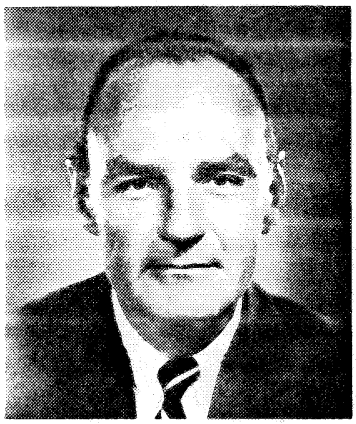
Theodore D. Smith, Senior Director, Saturn Apollo Programs, Assistant General Manager, Missile and Space Systems Division.



Marcus F. Cooper, Senior Director, Florida Test Center, Missile and Space Systems Division.



A. P. O'Neal, Director, Saturn Development Engineering.

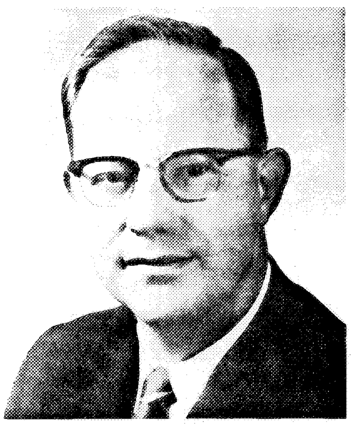


MANAGEMENT PERSONNEL

IBM

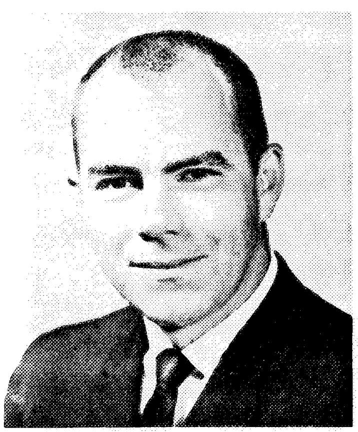
McLain B. Smith, Vice President and Group Executive.

Bob O. Evans, President of the Federal Systems Division.

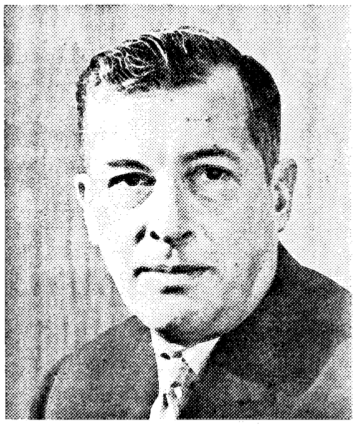


Arthur E. Cooper, Federal Systems Division Vice President and General Manager, Space Systems Center, Bethesda, Md.

Clinton H. Grace, Facility Manager, Space Systems Center, Huntsville, Ala.



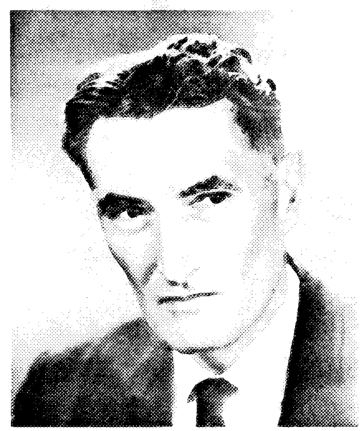
Ammon G. Belleman, Facility Manager, Space Systems Center, Kennedy Space Center.



MANAGEMENT PERSONNEL

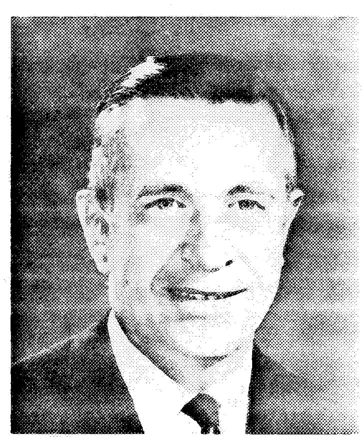
SPACE DIVISION —NORTH AMERICAN

William B. Bergen, Vice President, North American Aviation, Inc.; President, Space Division. Downey, Calif.

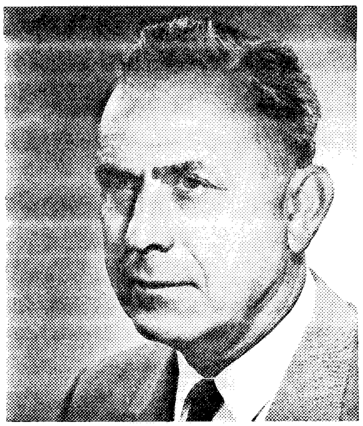


Robert E. Greer, Vice President, Space Division; Program Manager, Saturn Second Stage.

William F. Parker, Deputy Program Manager, Saturn Second Stage.



Bastian 'Buz' Hello, Vice President and General Manager, Launch Operations, Space Division, Florida.



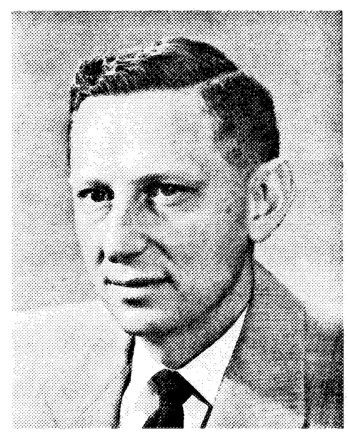
MANAGEMENT PERSONNEL

ROCKETDYNE—NORTH AMERICAN

Samuel K. Hoffman, President of Rocketdyne and Vice President of North American Aviation, Inc.

Joseph P. McNamara, Vice President and General Manager, Liquid Rocket Division.

Paul D. Castenholz, Program Manager, J-2 Engine.



Norman C. Reuel, Assistant General Manager, Liquid Rocket Division.

David E. Aldrich, Program Manager, F-1 Engine.

APPENDIX—GLOSSARY

The following list defines acronyms, abbreviations, nomenclature, and other terminology used in the Saturn V News Reference.

TERM	DESCRIPTION
APS	Auxiliary propulsion system
Bulkhead	A dome-shaped segment which encloses the end of a propellant tank.
Burnout	Point at which engines shut down due to lack of fuel or oxidant.
Burst Diaphragm	A disc designed to rupture at a predetermined pressure differential.
Bus	A main circuit for transfer of electrical current.
Cavitation	The formation of bubbles in a liquid, occurring whenever the static pressure at any point in the fluid flow becomes less than the fluid vapor pressure.
Convection	Mass motions within a fluid
Cryogenic	Ultra-low temperature
DDAS	Digital data acquisition system
Exhaust Nozzle	The lower section of the thrust chamber of a liquid rocket engine.
Expansion Area Ratio	The ratio of the measurements of an engine nozzle exit section to that of the nozzle throat area.
Exploding Bridgewire	Wire which explodes when subjected to a high voltage, high energy pulse.
Fusion Weld	To join two pieces of metal together by bringing the surfaces to a molten state by electric arc or gas flame controlled to produce a localized union through fusion or recrystallization across the interface.
Gimbal	A device on which a reaction engine may be mounted and which allows for angular movement in two directions.
GOX	Gaseous oxygen
GSE	Ground support equipment
Hydrostatic Test	Use of water for pressure test of propellant containers.
Hypergolic Liquids	Liquids that ignite spontaneously when mixed with each other.
Impeller	A device that imparts motion to a fluid or air.
Inducer	A pump which increases the pressure and motion of a fluid.
KSC	Kennedy Space Center
LH_2	Liquid hydrogen
LOX	Liquid oxygen
LVDA	Launch vehicle data adapter
LVDC	Launch vehicle digital computer
Monocoque	A structure in which all or most of the stresses are carried by the skin.
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
Multiplexer	A mechanical or electrical device for time sharing of a circuit.
NASA	National Aeronautics and Space Administration
ODOP	Offset Doppler System
Pitch	Movement of the vehicle from its lateral axis.
PSI	Pounds per square inch
PSIA	Pounds per square inch absolute
PSIG	Pounds per square inch gage
Purge	To remove residual fluid or gas.

SATURN V NEWS REFERENCE

TERM	DESCRIPTION
Retrorocket	A rocket fitted to a stage to produce thrust opposed to the stages forward motion.
RF	Radio frequency
RJ-I	A grade of kerosene which is used in the hydraulic system prior to lift-off.
Roll	The rotation of a vehicle about its axis.
RP-I	A rocket fuel consisting essentially of kerosene.
Squib	An explosive device used in the ignition of a rocket engine. Usually called an igniter.
Stator	A mechanical part that remains stationary with respect to a rotating or moving part or assembly.
Thermocouple	A device which converts thermal energy directly into electrical energy.
Thrust	The force developed by a rocket engine.
Thrust Vectoring	An attitude control for rockets wherein one or more engines are gimbal-mounted so that the direction of the thrust force may be changed in relation to the center of gravity of the vehicle to produce a turning movement.
Torus	A circular duct (manifold) used to collect fluid or gases.
Ullage	The amount that a container, such as a fuel tank, lacks of being full.
Umbilical	Any of the servicing lines between the ground or tower and a launch vehicle.
Volute	A flow passage that collects and redirects fluids.
Yaw	Movement of a vehicle from its longitudinal axis.