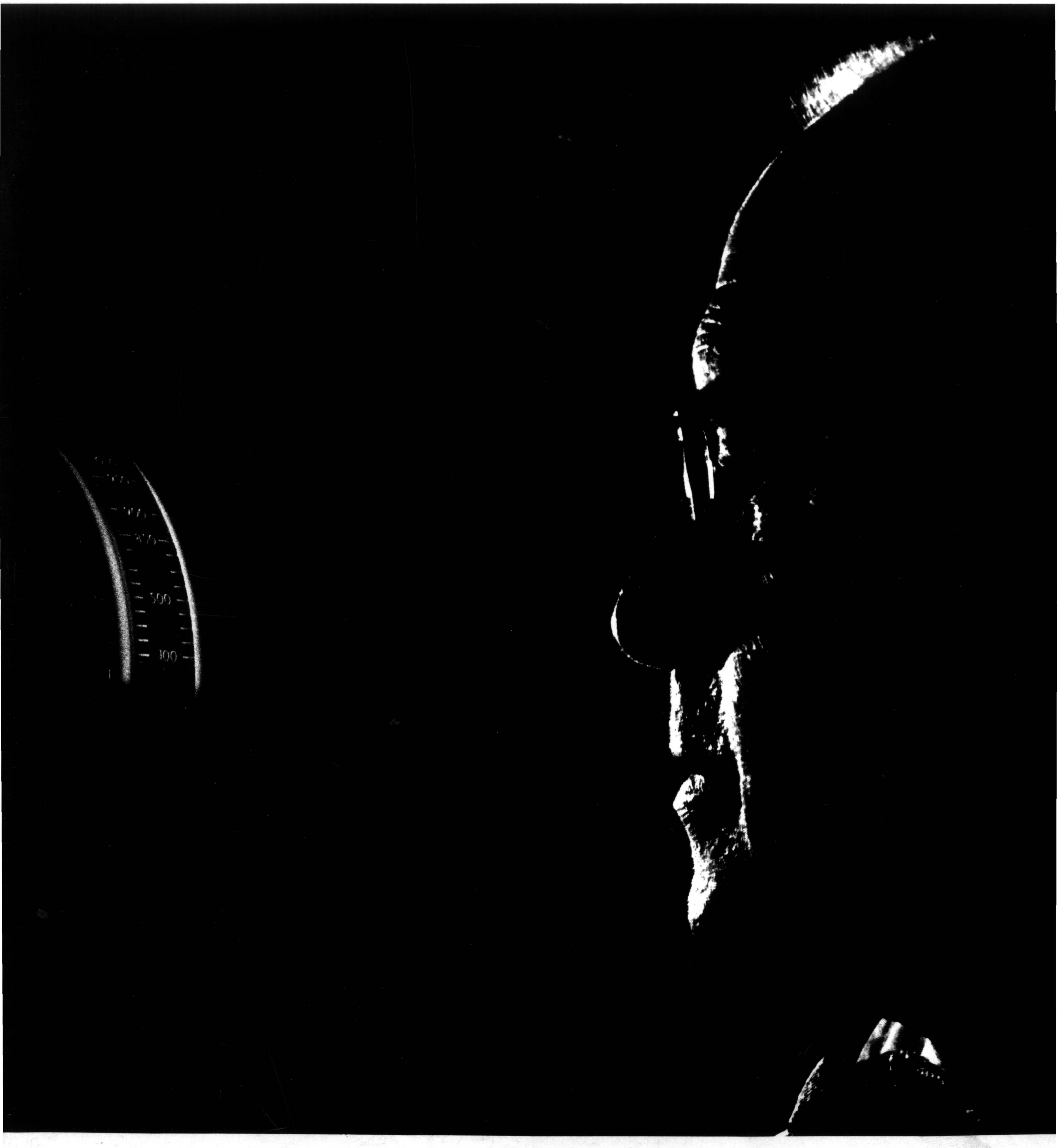
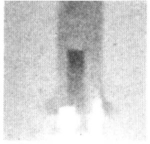
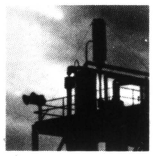
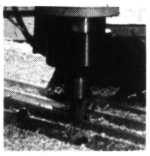
SKYLINE

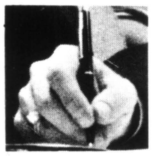
NORTH AMERICAN ROCKWELL CORPORATION • 1968 • VOLUME 26 • NUMBER ❶
(AEROSPACE AND SYSTEMS GROUP)

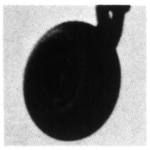












SKYLINE Vol. 26 No. 1

Published quarterly by the Aerospace and Systems Group of North American Rockwell Corporation for employees. Contents copyrighted 1968 but may be reprinted with credit.

Printed in the U.S.A.

John J. Oswald,
Group Director of Public Relations

A. R. Sorrells, Publications Manager

Edward A. Herron, Editor

Front and back covers by Ted Faux. Front cover, luminescent instrument dials are sample of many new changes in the Apollo command module. Page 27, NASA Ames Research Center photos, plant test fixture; collecting frog eggs for biosatellite experiment.

Art and Production, General Offices Services.

PERFECTION

A pin-point landing in the Pacific, a perfect series of maneuvers in Earth-orbital flight, and a flawless liftoff from the pad at Cape Kennedy — this was the record placed in the pages of space history by the flight of Apollo 4 on Nov. 9, 1967.

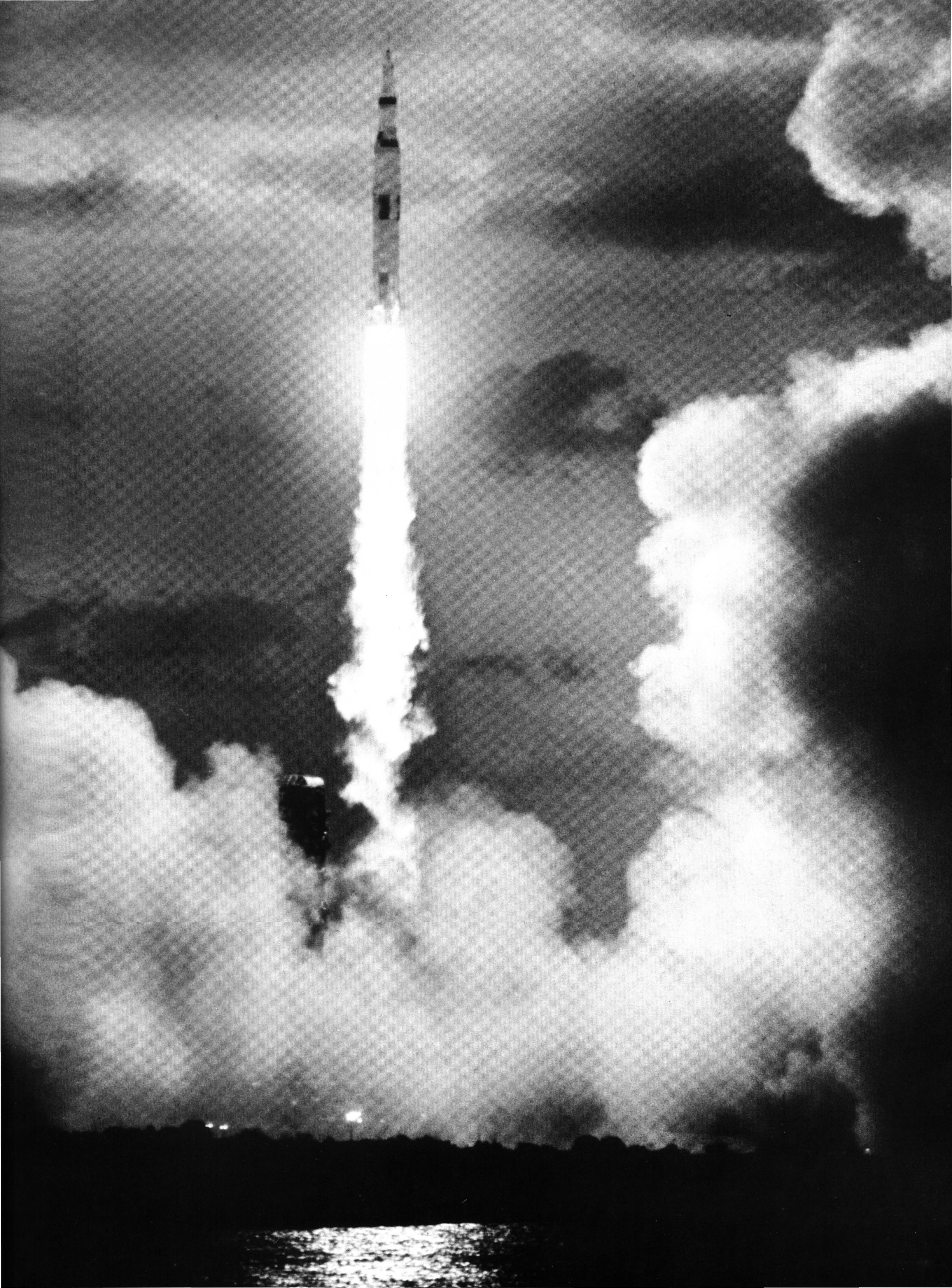
Dr. George Mueller, NASA associate administrator for Manned Space Flight, said the epic flight was a major milestone, perhaps the most significant in the entire Apollo program other than the lunar landing itself.

It was an "instant success" for every system and sub-system aboard, a smooth meshing of nearly 2,000,000 parts that brought man a giant step closer to the moon.

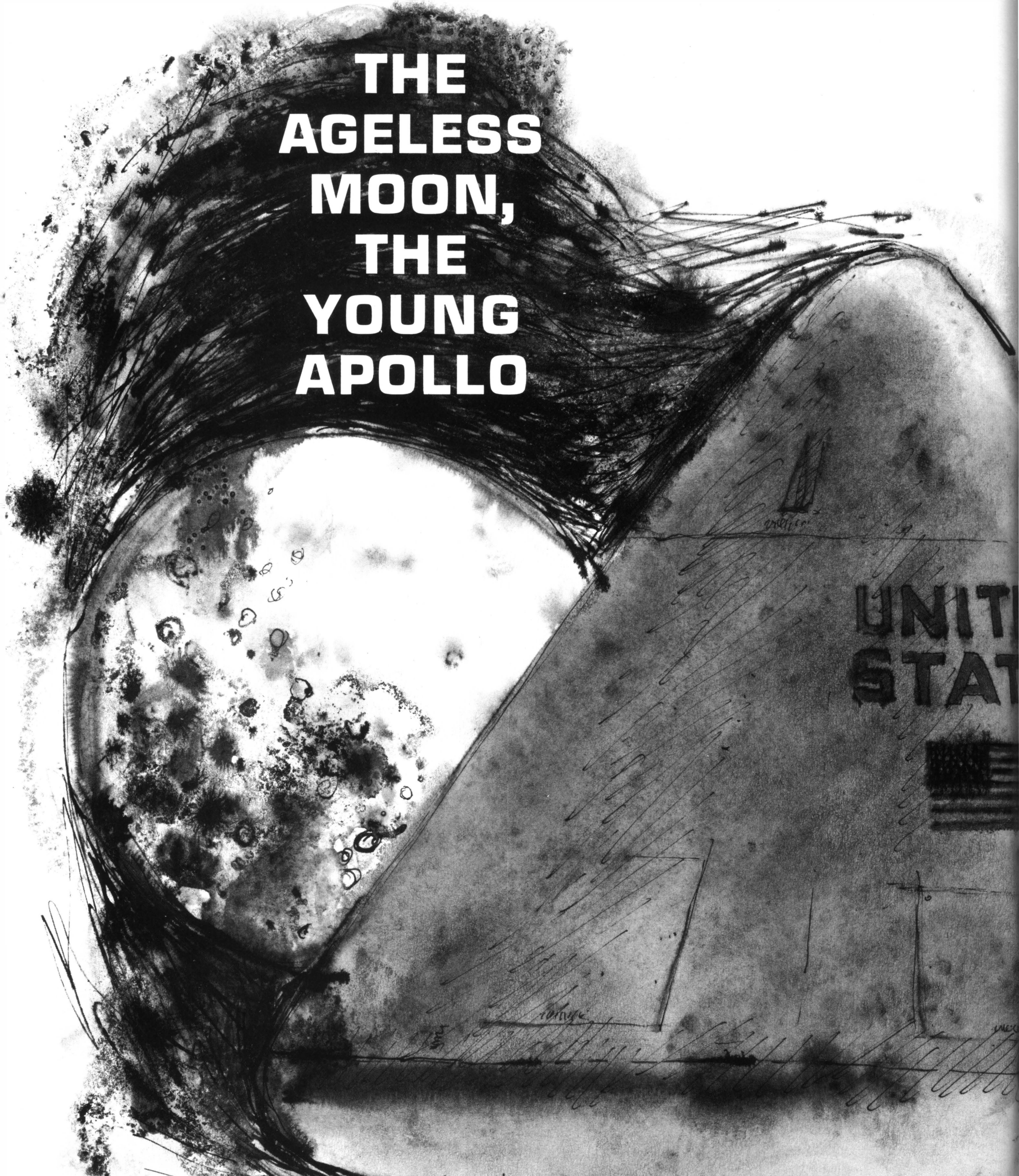
First-time endeavors for the Rocketdyne F-1 booster engine and planned outer space re-starts of the J-2 liquid hydrogen engine were flawless. The three massive stages of the moon vehicle, the first built by the Boeing Co., the second by North American Rockwell Space Division, the third by McDonnell Douglas, operated as though they had been over the space course many times although it was a virgin effort for the first and second stages.

The unmanned Space Division command module was flung outward for 11,234 miles, then harried back to Earth at scorching speed. It emerged from the ordeal charred and blackened on the exterior, but its temperature-rebuffing heat shield performed exactly as predicted.

Everyone had been confident of success. No one was prepared for perfection.



THE AGELESS MOON, THE YOUNG APOLLO



MULTIPLE CHANGES HAVE BEEN MADE IN COMMAND MODULE AT SPACE DIVISION SINCE START OF CONTRACT IN 1961

The oceans of space reaching from Earth to eternity may be ageless and changeless, but the tools men are using for conquering those oceans are both young and in a constant state of change.

An example is the Apollo spacecraft command and service modules being developed for the NASA moon project by North American Rockwell's Space Division.

In outward appearance the sleek, streamlined, conical module, 12 feet tall, 13 feet across at the boat-shaped base, is almost exactly like the scale model tested in the wind tunnels of NASA's Langley, Va., facility in 1961, shortly before the awarding of contract to North American.

But inside the module there are many changes. Some have been brought about because units were so improved during the development period that they gradually outstripped the original equipment in everything but size and weight. Some took place because of new concepts, for example when Mercury flight experience dictated the change from in-flight repairs by the astronauts to the present redundant switching. Many are a result of the flammability program inaugurated after the fire at Cape Kennedy early in 1967.

Changes in any research and development program are inevitable. John Moore, president of the Aerospace and Systems Group of North American Rockwell, recently cited a Department of Defense study which showed that 37% of the technical innovations required for a program's ultimate success occur after the start of the program. In Apollo, the greatest research and development program ever attempted, the basic design concepts recognize the capability of making changes.

No matter how seemingly insignificant, each change is important. To those involved, perhaps in the second and third tier of contracting, they become highly significant, requiring engineering, quality control, and production effort.

Take for example the instrument indicators inside the command module. There are 72 of them, mostly of the on-and-off variety. Originally the cockpit in the module was illuminated by flood lights which permitted the astronauts to read the dials of the indicators.

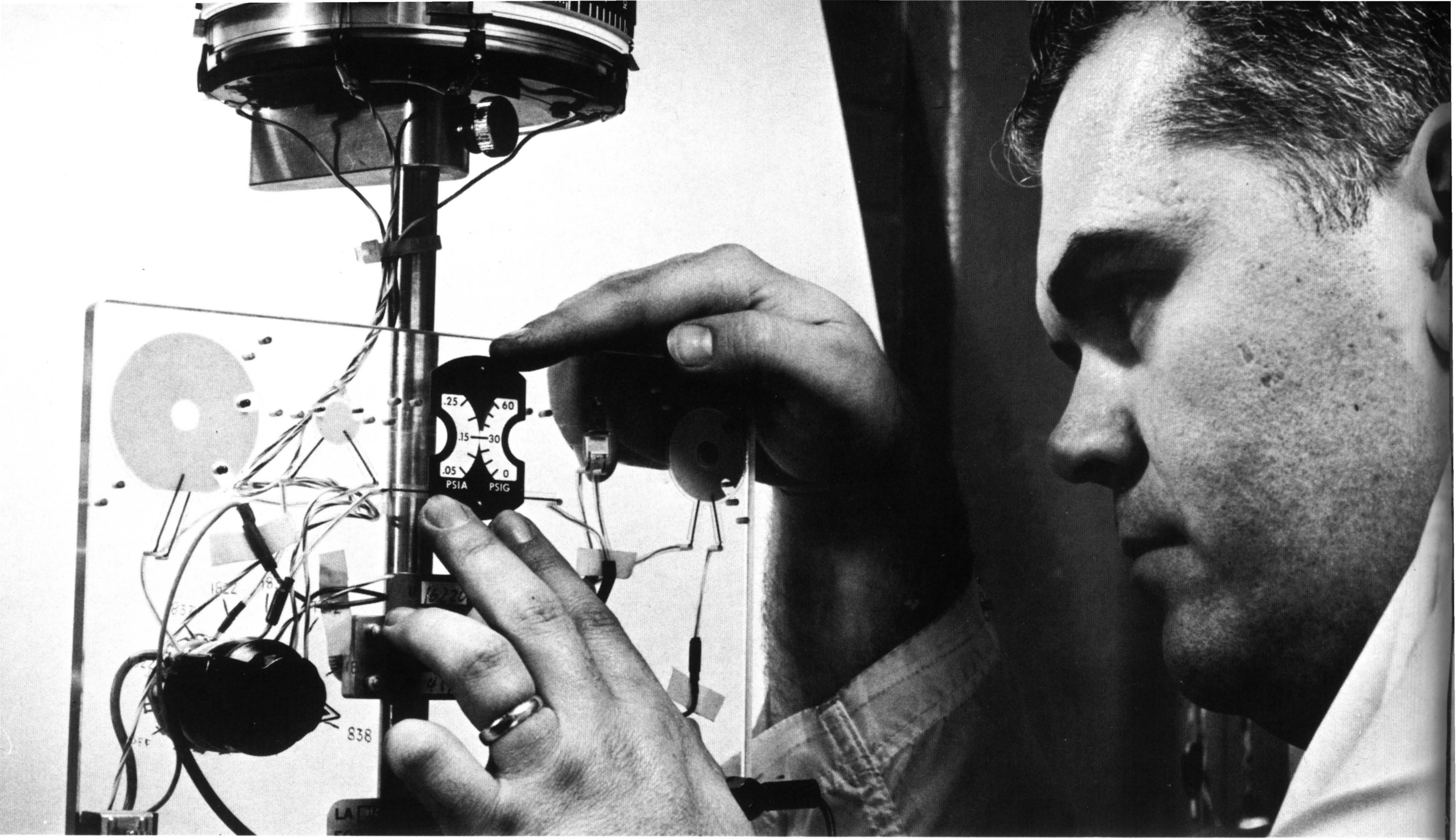
In order to get better readability under any circumstances, it was decided to switch over to electro-luminescence in which the white dials would be silhouetted against a black background. Electro-luminescence wasn't new — but it was startling new for instrument makers when combined with the pressurized oxygen environment of the command module. Bob Lender, chief engineer at Weston Instruments in Newark, New Jersey, said, "The changeover to electro-luminescence sounds simple, but for us instrument makers it was a real problem and required a big advance in the state of the art. It was necessary to change the design, get new drawings, set up new test procedures. It took three months of concentrated effort, weeks of vibration and environmental testing."

The end result is a panel of instruments that glows softly in the completely dark cockpit, one that is of great help to the astronauts in adjusting easily to the abrupt changes from daylight to darkness on the journey to and from the moon. As a backup feature, neon floodlighting is still available.

Some changes occur in the command module because the engineering specification is such a great step forward in the state of the art that it becomes impossible for the original contractor to meet the demand and he must step aside to let another take up the challenge.

It was just this kind of challenge which brought United

By EDWARD A. HERRON



Every change in the Apollo command module is significant and requires careful engineering, quality control. At Weston Instruments, Newark, N. J., the change to electro-luminescent instrument dials, above, entailed months of effort, new design, drawings, and tests.

Entirely new principle in radiator heat dissipation was evolved at LTV Aerospace, Dallas, Tex., designers of thermal radiator, below, that leads unwanted heat away from the Apollo command module. Joe Angelone, LTV project manager, points to radiator area.

Size of component involved in change did not always relate to its importance. This small pendulum, heart of accelerometers built by United Control, Redmond, Washington, was responsible for a significant change, big step forward in ultra-sensitivity.

Control, a subsidiary of Sundstrand Corp., located in Redmond, Washington, into the Apollo program. The problem was accelerometers. There are three of them in the command module that sense pitch, yaw, roll, acceleration and deceleration of the module at liftoff, during flight, and on re-entry.

Resistance to high g forces is a way of life for accelerometers. Thumb-nail size pendulums, swinging on jeweled movements, are expected to survive shocks of 30 g, which is roughly equivalent to taking a wrist watch, slamming it against a brick wall at 70 miles an hour 18 times — and still obtain perfect time keeping. The United Control accelerometers had to take that punishment and at the same time retain a sensitivity that was unparalleled.

The accelerometers could sense if the vehicle was off course less than an inch shortly after takeoff. If the vehicle was travelling 5000 miles per hour and slowed down to 4995 miles per hour, the United Control units would sense the change and cause the message to be relayed to the control center in Houston.

It was a challenge, a change, and United Control met the requirement.

"Storage House"

The tentacles of interdependence reach from the command module down into the accompanying service module, the "storage" house crammed with supporting equipment that journeys out to the moon with the module and then returns almost to the point of re-entry. On the exterior surface of the service module are two radiator panels thermally designed by Ling-Temco-Vought's LTV Aerospace Division at Dallas, Texas.

The job of the panels is to dump excess heat overboard. Electronic gear such as that in the command module churns up heat like a furnace. The astronauts themselves, moving about, contribute to the heat load. It's the job of the environmental control system to channel away that heat, lead it down to the radiator panels, and dump it almost like a liquid.

It's not easy, and a lot of changes took place before the problem was licked. To some engineers, the radiator problem was one of the most difficult of its kind on the Apollo, and its solution one of the most gratifying. If the radiator concept didn't work, it would be necessary to carry a huge additional load of water embodied in the original cooling concept, the use of boiling water.

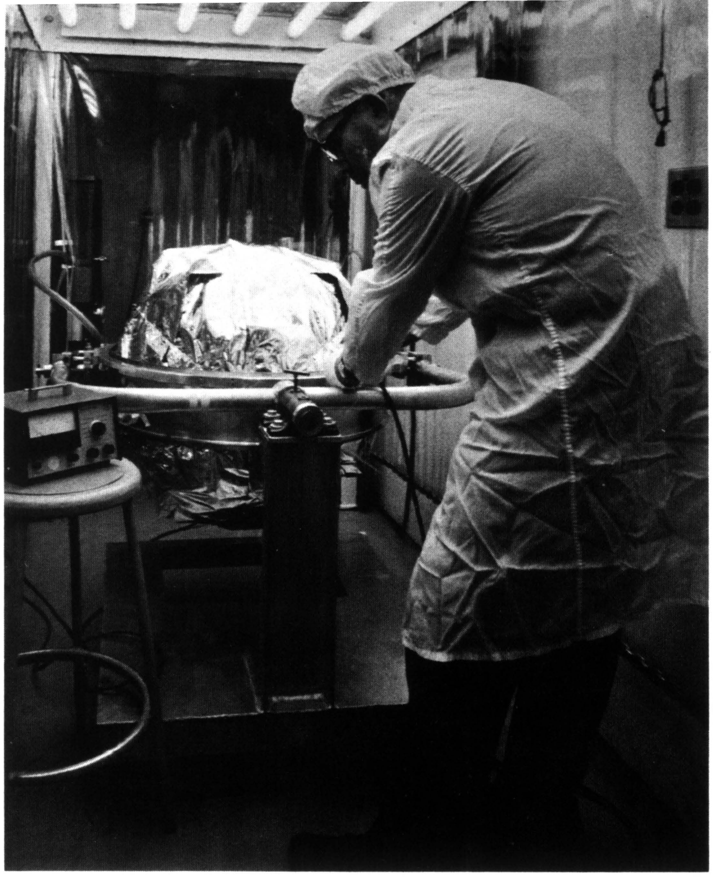
Joe Angelone, program manager for the Apollo environmental control system radiator project at LTV Aerospace, said, "It's hard to reject heat when the module's in lunar orbit. You've got the sun on one side, and you've got the heat of the moon's surface on the other. But bigger problems come much sooner.

"It's difficult to reject the large heat loads imposed on the radiator at lift-off and during the initial push out toward the moon due to the tremendous workout of the electronic equipment and the astronaut activities. Again, we hit a peak demand during mid-course correction when the service module propulsion system cranks up. At some periods during the lunar flight we skid into a valley when not much of the electronic equipment is called to function. Astronaut activity is at a minimum, and the heat from the Earth is absent.

"If we sat then with a great big radiator, with very little heat to dissipate from it, the system would be inefficient."

It required a change, an important change, and LTV Aerospace, working with NASA engineers, came up with a new idea, selective stagnation of the radiator panels. When heat dumping needs were minimal, the new technique let part of the radiator tubes freeze, in effect, reducing the size of the radiating surface. When the demand rose, the tubes unfroze and sent the whole rig back into high gear. Simple—but glycol fluids passing through small diameter tubing are not easily shoved around. Glycol refuses to march like a soldier in a nice orderly path. It begins to fight, seeking some tubes, ignoring others. LTV overcame the eccentricity, and the end result of the radiator change was an almost automatic switch from a big panel to a little panel, and a big step forward in reliability.

Some changes are so small they scarcely see the light of day,



Achievement of near-perfect vacuum in spheres containing liquid hydrogen, oxygen used in Apollo fuel cells was major feat for Beech Aircraft, but it was a comparatively small supply tube that gave Beech engineers trouble, caused a series of changes.

Most visible change on the Apollo command module exterior is a new quick-opening hatch, opposite page, that provides rapid egress in emergency on launch pad. New door will be flight-tested soon.

but to those involved, they are as important as the module itself. Beech Aircraft, at its Boulder, Colorado, plant, developed the double-jacketed pressurized titanium and inconel spheres that contain the liquid hydrogen and liquid oxygen supplied to the power-producing fuel cells and to the environmental control system. Some of the engineering tasks that Beech has accomplished are almost staggering, incomprehensible, for example, providing a near-perfect vacuum in the hollow space between the sphere which contains the liquid hydrogen or oxygen, and the outer sphere which encompasses it. According to Seymour Colman, Apollo program manager at Beech, "There is nothing that has ever been built that is free of leaks. Our pressure vessels come close. If the allowable leak rate were experiencd in an automobile tire, it would take 32,400,000 years to go flat."

Beech took that one in its stride. The change that they collided with was in a small pure titanium tube, linking the plumbing in the interior of the hydrogen tank with the spacecraft plumbing. Beech found out that pure titanium, under certain conditions, is incompatible with liquid hydrogen. It leaks. Colman said, "We switched to stainless steel tubes, but the move is not as simple as it sounds. It created a whole series of transition joints that had to be solved in turn."

Quick-Opening Hatch

The most visible change on the Apollo's exterior is a new quick-opening hatch. The original opening through which the crewmen moved in and out of the module was, in fact, two hatches. The outer section was tethered to the module and swung outward away from the unit. Inside, matching the other in size, was an inner hatch which lifted off entirely, then was slipped down for storage between the crew couches.

The new hatch is a one-piece unit, built almost like the door on a kitchen refrigerator. It opens outward with a quick-release mechanism, providing rapid egress or rescue in the event of an emergency on the ground. The hatch can be manually operated even with large internal pressures such as are imposed on the module during short periods before liftoff. It can be operated both by the crew inside and the ground crew on the outside.

There have been 79 changes inside the module since last January, most of them adding safety-on-safety to fire precautions already existing. Examples would be moves to reduce or eliminate possible spillage or leakage of the water glycol in the coolant system, or the changeover from aluminum tubing with solder joints to stainless steel tubing with brazed joints in certain portions of the environmental control system's oxygen lines. Protective covering of 20-odd miles of wiring, previously left exposed for easier maintenance, and improved cable routings are other examples.

Each change, no matter how small, has been arrived at after careful engineering consideration first for the safety of the astronauts and again for the overall efficiency of the moon mission.

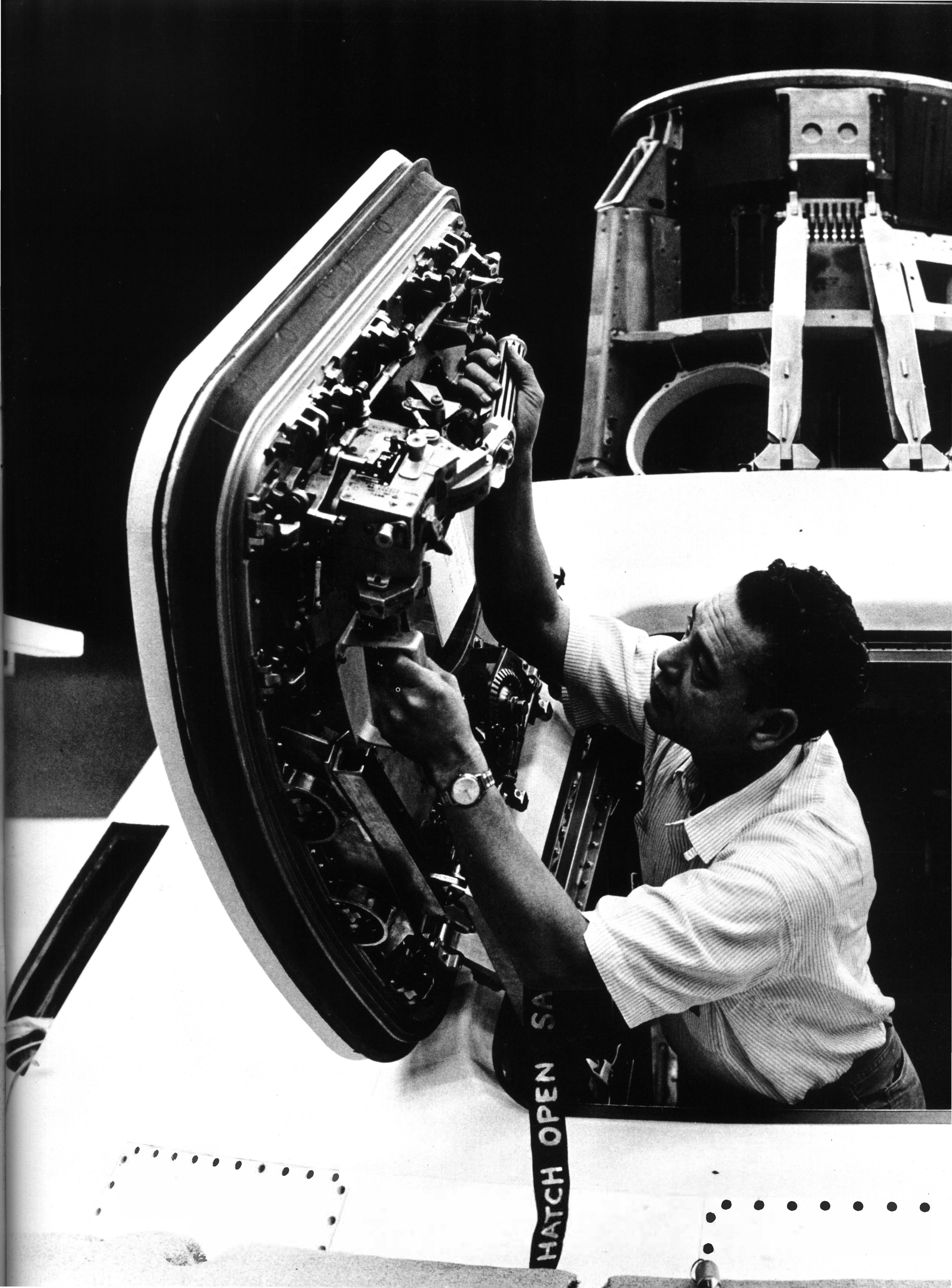
New Research Area

An entirely new research area, the flammability of materials, has been opened up by the need for change in Apollo. This is directly related to pressure and oxygen content.

When the astronauts crawl into the command module approximately three hours before launch, the hatch door is closed, and the pressure is built up to 16.5 pounds per square inch (psi) in order to leak-check the seals around the door. Oxygen is then force-fed into the module until a 100% oxygen content is achieved. This precaution eliminates any possibility that the astronauts might suffer from the 'bends' during decompression, exactly as a deep sea diver might. (Oxygen is used because it is the least complex of the atmosphere systems considered for the module.)

The pressure at liftoff is 14.7 psi; this gradually declines to 6 psi three and a half-minutes after launch, then, at a later time, reaches 5 psi, a figure that is held by the environmental control system until the module completes re-entry into Earth's atmosphere.

Any pressure with 100% oxygen is a potential hazard, but the major concern comes at 16.5 psi, perhaps the most stringent


HATCH OPEN SA

Most striking newcomer to the command module is Beta fabric, above, shown being seared by gas torch in flammability demonstration. Pure glass cloth, soft, resilient, is made by Owens-Corning Fiberglas Corp. Fabric resists temperatures as high as 1500 degrees.

At Cape Kennedy new fire prevention and rescue techniques have been inaugurated under direction of John R. Atkins, NASA Safety chief. Demonstrating self-contained air breathing rescue equipment are Space Division's Fred Foote, left, and Elton M. Whaley.

Dick Bricker, chief of the Structures Test section of the Manned Spacecraft Center, Houston, is conducting final flammability tests on Apollo command module. Scores of fires will be deliberately induced in electrical components in proof of fire-resistant changes.

requirement ever faced by engineers whether in space or on Earth. At 16.5 psi and 100% oxygen, one engineer said shortly, "Given the right conditions we can burn anything—even water."

Every non-metallic material inside the command module has been scrutinized, and replaced where necessary, in the light of the new safety precautions. The object has been to obtain a condition such that if a fire occurs in the crew area it cannot propagate or result in critical structural or functional damage to the spacecraft.

The research in the area of material selection for use in high pressure and 100% oxygen has been tremendous.

Tom Markley, deputy Apollo program manager for Manned Spacecraft Center at Houston, said, "We at NASA Houston and North American Rockwell Space Division have probably encompassed all the best knowledge in the industry in the area of flammability of materials at 16.5 psi and 100% oxygen. We have conducted three years of research in six months. We are perhaps the only groups that have collected all this information at one time in one place."

The most striking newcomer in the module as a result of material scouting is Beta fabric, developed by Owens-Corning Fiberglas Corp. at its red-brick plant in Ashton, R.I. Beta fabric is pure glass, and it resists temperatures as high as 1500 degrees F. Despite the 'glass' connotation, the cloth is as soft and resilient, as conventional woven materials. It now is used throughout the module, in everything from waste containers to sleeping covers, to the thick mattress-like batting used in the crew couches, to flame protection around rubber parts. Wherever flammable cloth was used previously, Beta fabric has, in most instances, been substituted.

The soft, resilient weave of Beta fabric is something new. Ed Cobb, Jr., program manager for Apollo at Owens-Corning, said, "In Apollo we're not only getting a dramatic demonstration of glass cloth in its customary fire-retardant application, but for the first time we're using it in a close-to-the-skin situation. It opens up a lot of possibilities beyond space flight use."

Formerly, nylon webbing was used to fill the gaps between electrical components, preventing small objects from falling into the crevices. Now aluminum panels perform the same function. Velcro strips, of great use in stabilizing body movement or for holding tools in a zero environment, have been reduced to small squares at strategic points, or replaced by metal snap fixtures.

The electrical system has been placed under a microscope.

As long as electric current is flowing through two wires, there is the possibility of a short. The object of the changes within the module has been first to isolate the wire from the crew so no inadvertent wear can take place, and then to assure, should a fire start in an electrical connection, it will confine itself to a tight area and will not propagate to an adjoining area.

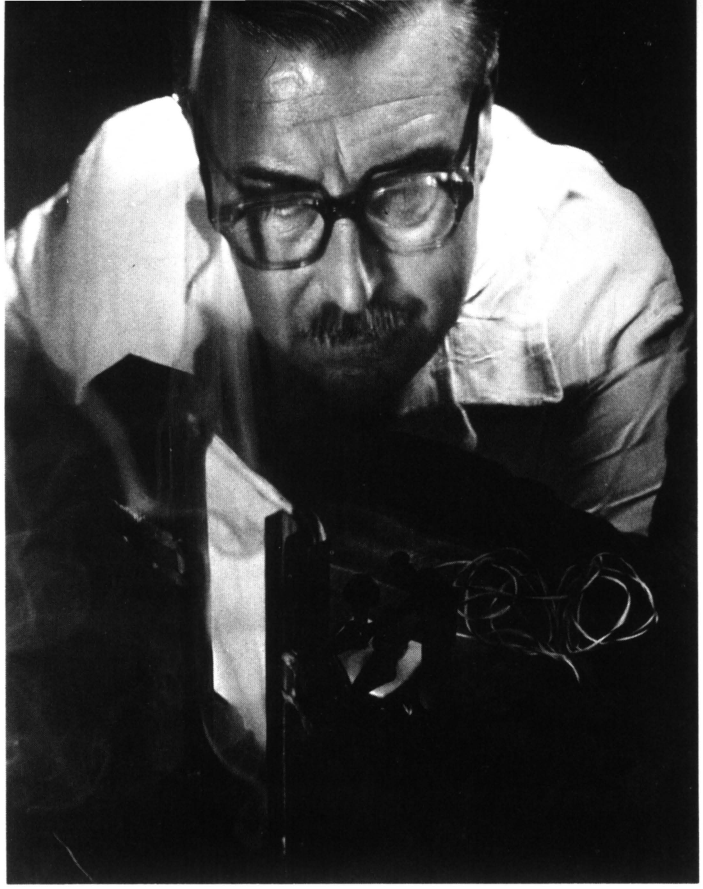
At Space Division a series of tests have been conducted on electrical connections in the module.

Worst Possible Conditions

Every electrical component which could possibly catch on fire or which could possibly ignite from a fire in an adjacent unit was investigated. John Tropilla, of Apollo Engineering, directed the effort. "We tested circuit breakers, terminal boards, black boxes, and wire harnesses for the worst possible conditions in 16.5 psi with 100% oxygen," he said.

Individual components, wired for the test, were thrust into a tough steel chamber looking like a rugged trash can, a vacuum was pulled, oxygen pumped in, and then shorts were deliberately induced. "During this test effort phase we were more interested in propagation than what starts the fire," Tropilla said.

That interest in control of propagation led to a search for some practical wire terminal coating that would function as a fire retardant. Ken MacDowall, a specialist in coating materials in the Los Angeles Division Non-Metallics and Optics Laboratory, had previously developed various high temperature coatings, including the Larodyne ablative coating used on the Rocketdyne J-2 engines. Working under a company-funded



Electrical components in the Apollo command module are covered with Ladicote, a fire retardant, insulative material that looks like plastic paint. Ladicote was developed by Ken MacDowall, at left, Los Angeles Division, under a company-funded program.

program, he had earlier conceived and developed a new series of fire retardant insulative coatings that he termed Ladicote. Spurred on by the Apollo command module requirements, MacDowall adapted his Ladicote material to coating the electrical components in the spacecraft. It looks and acts almost like a thick plastic paint, light blue in color. It has both insulating and fire-resistant qualities. It can be brushed or sprayed on electrical connections. As many as 12 quick-drying coats are applied.

Ladicote is used liberally on wire terminations in the command module. In test after test it proved capable of preventing the electrical component from catching fire from an adjacent blaze. If the electrical connection itself shorted and blazed beneath the Ladicote, the fire was snuffed out.

The experience gained in all the individual test efforts, in all the new material selections, in all the varied fire-induced changes in the module, will be demonstrated in an entirely new technique in materials testing.

It's the "high-fidelity" mockup, a command boilerplate spacecraft in which the final, conclusive tests will be conducted at the Manned Spacecraft Center in Houston, Texas.

At Western Way, Inc., in Chatsworth, California, the Apollo module was reconstructed, incorporating every non-metallic material that exists in a flightweight Apollo such as the one which recently completed the two trips around the Earth then splashed down successfully into the Pacific.

Everything non-metallic was included, sleeping bags, blankets, all the crew stowage items, food, and crew couches. Three complete crew suits will be inflated and in position. The interior spacecraft wire harness is in the module. Every electric item that could possibly contribute to a short circuit and a resulting fire is included.

Ron Bergeron is project engineer for Space Division on this high-fidelity mockup that was prepared for demonstration of the new flammability measures. Bergeron said, "No one will be inside the module during the proof tests. All our tests are being conducted on the theory that there will be no help from the astronauts in fighting any fire that may result. This is an added safety precaution, even though we know the crew will be provided a new-type fire extinguisher to be used inside the module for emergency.

"All the components have been tested individually at the 6.5 psi and the 16.5 psi level. Now we're getting the entire works together inside this module. Our primary objective is to demonstrate that if a fire starts anywhere inside, it will be completely localized in its immediate area; it should burn itself out without damaging any adjacent equipment."

The complete module, almost an exact replica of the actual moon craft except for weight, has been shipped to NASA Houston for a series of tests that will extend over a two-month period.

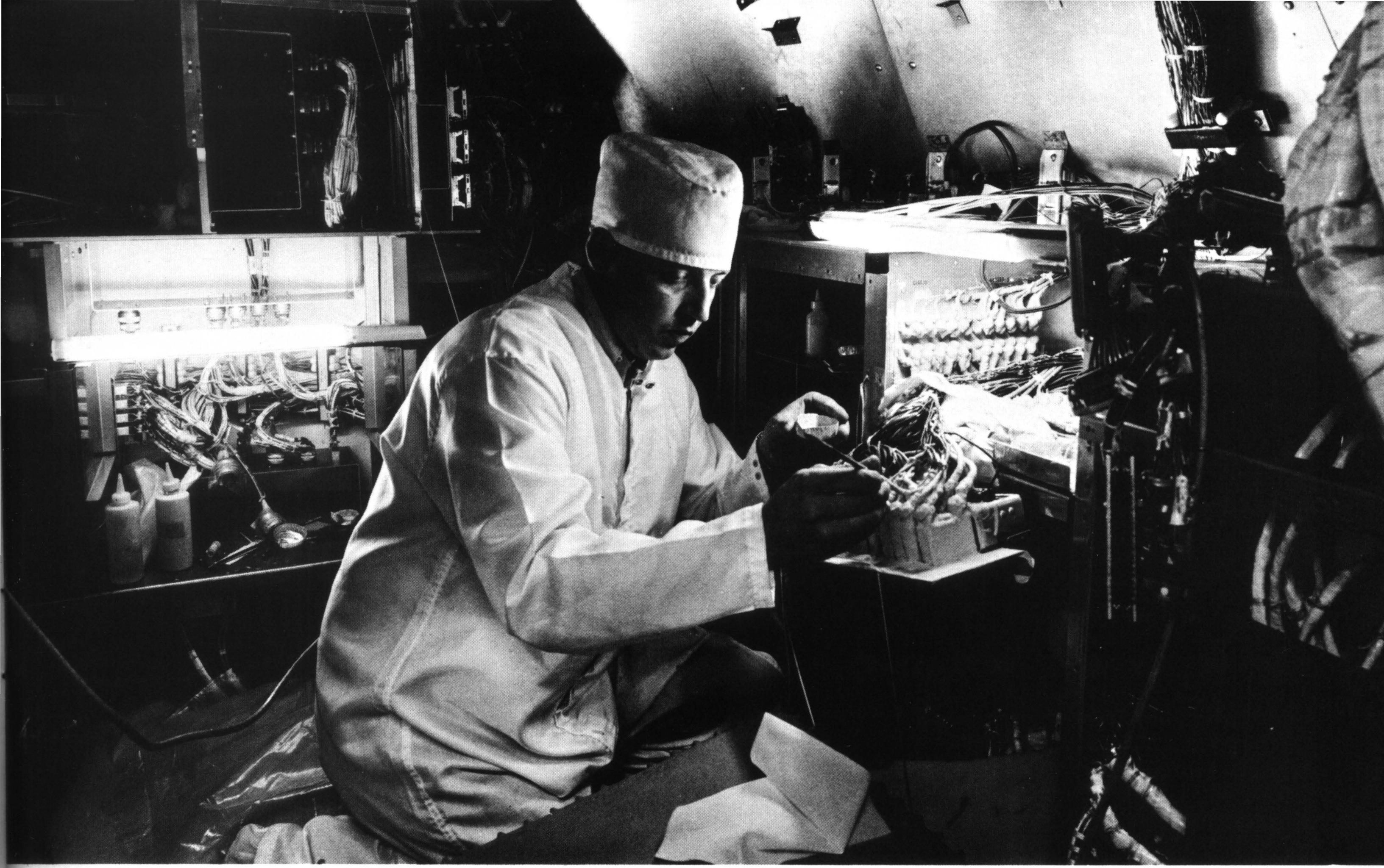
The nub of the tests at Houston will be this: NASA, as a final proof of the new flammability changes, will deliberately induce 20 to 30 fires within the module.

Dick Bricker, chief of Manned Spacecraft Center's Structures Test section who is conducting the final proof tests, said, "If we have a problem at 16.5 psi, we want to know it now."

In the mechanics of the test now underway at Houston, a nichrome wire, similar to those in household toasters, will be led from an outside panel, inside the module, and buried, for example, alongside an electrical circuit breaker. A 40-amp. current will be sent through the wire and held until there is visual evidence of a fire. The demonstration is expected to show that the fire may originate but will not propagate.

Other test steps will send showers of sparks into wire bundles wrapped in Teflon. Deliberate simulation of broken arcing electrical lines will be made.

When the tests are finished, and the proof is certain, men will again go into the command module, batten down the hatch, and resume the conquest of space, the flight to the ageless moon.



This "boilerplate" Apollo has been equipped with every electrical component, all wire harnesses, all non-metallic materials such as sleeping bags. Module has been shipped to NASA Houston for stringent series of tests, proving fire-preventive techniques, materials.

In tests at NASA Houston, shown below, nichrome wire, similar to those in toasters, will be led into module and buried alongside electrical component. Current will then induce fire. The demonstration will show fire may originate, but won't propagate.