SKYLINE

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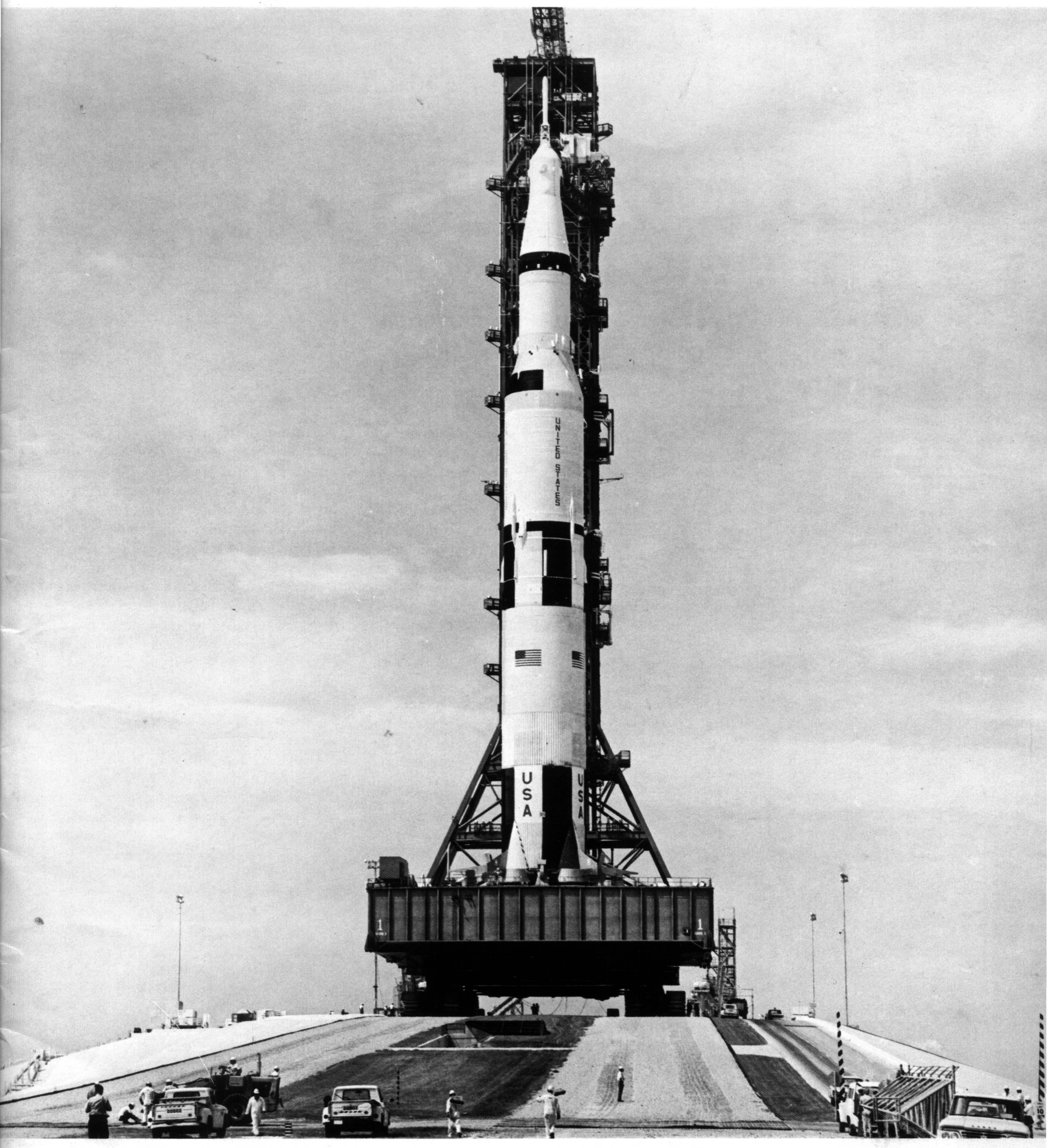
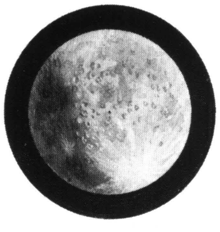
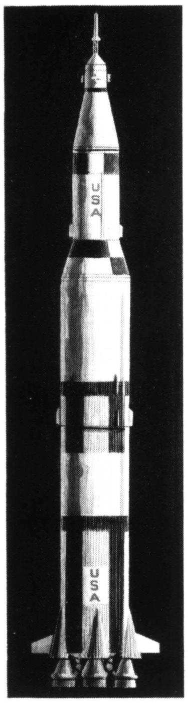


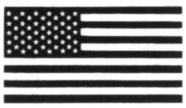




APOLLO 4:
THE BIG TEST

NASA's Moon Vehicle, on the pad at Florida, waits for start of momentous first flight.

BY EDWARD A. HERRON



Twice around the Earth, a push out to nearly 11,500 miles, then a screaming, full-powered dive back into the atmosphere, to splash-down in the Pacific. This is the mission of Apollo 4.

On Complex 39, in these quiet hours at Cape Kennedy, stands a towering space vehicle, Apollo 4, the almost-complete NASA Saturn-Apollo moon voyager, awaiting its first leap into space. Three-hundred and sixty-four feet tall, the biggest and heaviest vehicle ever lifted from the Earth, Apollo 4 is the culmination of six years of preparation, the stark, outward symbol of the greatest research and development project ever undertaken in the history of man.

Apollo 4 was moulded in a hundred thousand component and engine and stage tests; the flight itself will be still another in the series of tests, but a test on a grand scale, with all three stages mated, all the engines firing, all the systems, for the first time, interacting in the perfection demanded for the fulfillment of the voyage to the moon. Two million parts will be meshing, pulsing, interacting; the work of a score of major contractors will be interfacing, the success of one dependent on the smooth functioning of the other, and that one in turn relaying its contributions and its needs to still another. Only the astronauts will be missing.

The vehicle, as it stands, is physically capable of sending the sleek, rounded command module hurtling outward to moon orbit. But the demands of one major aspect of the test, the proof-positive that the heat shield will survive the scorching heat of lunar reentry, have bent the trajectory commands. The module will go out 11,400 miles, then bend and scream back to Earth.

Dr. George E. Mueller, associate administrator for Manned Space Flight, National Aeronautics and Space Administration, is slight, quick-moving. He is in finger-tip control of this greatest research and development project ever attempted.

"For six years," he said quietly, "we've been testing the sub-systems, the systems, and the stages. The major fraction of the funds allotted for the Apollo program have been for the test programs. More than 200,000 people have been working on the bird, with another 100,000 in support. We're looking to this mission and to a second Apollo unmanned mission to give us verification of all that has gone before. They're being flown to verify correctness of design. If they are correct, then we go ahead into the manned effort.

"It will be the first time we've flight-tested the entire vehicle." He started to enumerate. "It's the first flight of the booster stage with the F-1 engines; the first flight of the second stage with the J-2 liquid hydrogen engines." He shrugged his shoulders. "There are so many 'firsts' I can't mention them all. The heat shield alone. It's the first time we've been able to test it at lunar re-entry velocities. The heat shield is a crucial test — just as they all are. But we've got to get this data before we move on to manned flights."

Mueller was speaking in California. Three thousand miles away, Apollo 4 stood alone and impassive, waiting.

"This mission," Mueller continued, "is the culmination of effort by a lot of people. We've done everything humanly possible as far as ground testing goes." He paused reflectively. "We depend on people to do things properly. The integrity of their work is the basis of the integrity of the space vehicle.

"No one underestimates the enormity of the task that has been accomplished and that is still waiting for us. All the blood, sweat, and anguish that went into the building of the Pyramids, all the hurry-up scientific genius that went into the Man-

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Edward A. Herron, Editor. Front cover by Bill James, rollout of Apollo 4 at Kennedy Space Center. Back cover by Ted Faux.

Dr. George E. Mueller, associate administrator for Manned Space Flight, NASA, controls greatest research and development effort ever attempted. "We're looking to the Apollo 4 mission to give us verification of years of preparation and test that have gone before."

hattan atomic bomb development project, all the 60 years of preparatory aircraft work that went into the supersonic transport — those three combined just begin to equal what Americans have accomplished in the past six years leading to this launch.

"We've been fortunate in our flight efforts to date. We have a high degree of confidence that we will meet with the same success in this mission." He was silent for a moment, and then finished quietly, "If we don't meet with the entire success we had hoped for, we're ready with the next vehicle. The program will continue. And we will meet our goals."

Apollo 4 weighs 6,200,000 pounds, the heaviest space vehicle ever scheduled for launch. It is transported from the Vehicle Assembly Bldg. aboard this massive crawler along 3.5 miles of a custom-built road leading to the launch site at Pad A, Complex 39.

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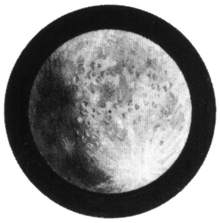
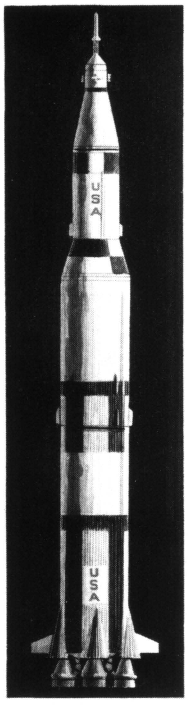
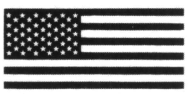




THE RAMRODS

Three booster stages will take on weight-lifting, speed accelerator chores in first flight of combined units.



It is referred to ingloriously as 'the stack'—the complete giant Apollo 4, the Boeing-built S-1C first stage, 138 feet tall; the Space Division-built S-II second stage, 81 feet, 7 inches tall; the Douglas-built S-IVB third stage, 58 feet, 7 inches tall. The two lower stages have fat 33-foot diameters; the third stage slims down to 21 feet, 8 inches in diameter.

Above the three stages, the ramrods that shove the payload into space, soar still another 82 feet of streamlined metal, covering the IBM instrument unit, the spacecraft adapter that hides the "dummy" lunar module, the Apollo command module itself, and finally, the ladder-thin launch escape tower.

The ramrods, the two bottom stages and the third stage, which partakes of both the elements of a rawhide booster and a sleek, hot-and-cold space vehicle, stand apart. On their shoulders is the first responsibility, to get the Apollo 4 airborne, to get it up to altitude, to ram the upper portion into an Earth orbit.

For two of the stages, this will be a virgin effort. The third stage has gone before, in several successful flights perched on the shoulders of the up-rated Saturn 1, but this, too, for the third stage, will be momentous, its first meeting, its first operation in concert with the two big ones, the first and the second stages.

In $2\frac{1}{2}$ furious minutes the first stage must lift the entire vehicle 38 miles into the sky and ram it forward at a speed of 5360 miles an hour.

Francis Coenen is first stage program executive for the Boeing Co.'s Launch Systems Branch at the NASA Michould plant, in New Orleans, La.

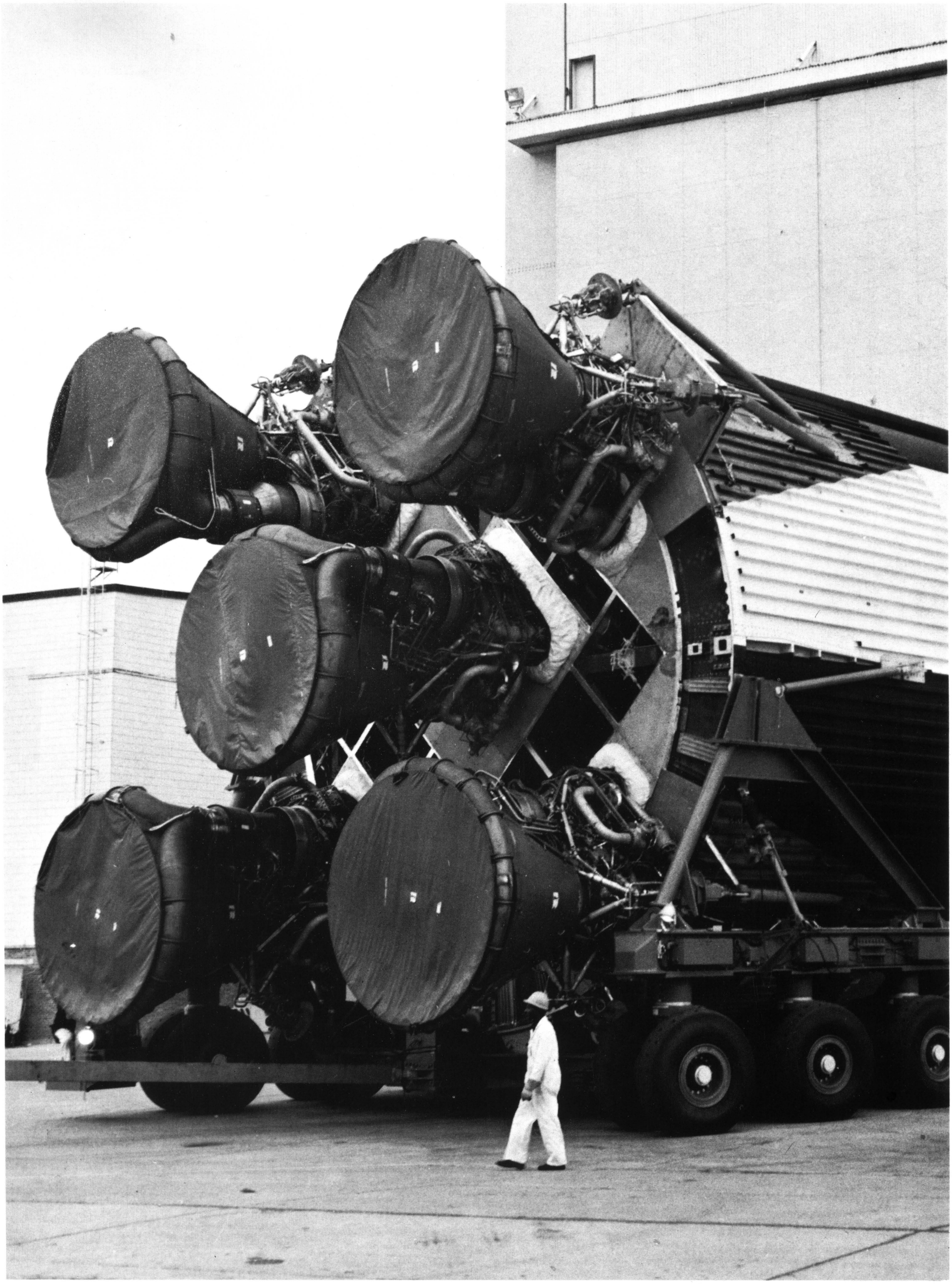
Mammoth Piece of Machinery

"Without question" he said candidly, "the launch of Apollo 4 is going to be the biggest day in my life, I've worked with this first stage from the very beginning. It's a mammoth piece of machinery, sitting there as the bottom of 6,200,000 pounds of weight. We're going to be watching for good ignition, good thrust build up from the five F-1 engines. We'll worry about clearing all the umbilicals, getting clear from the tower." He leaned back in his chair, closing his eyes as though visualizing the first moments of liftoff when the vehicle begins the incredibly slow upward climb past the steel lacework of the service tower.

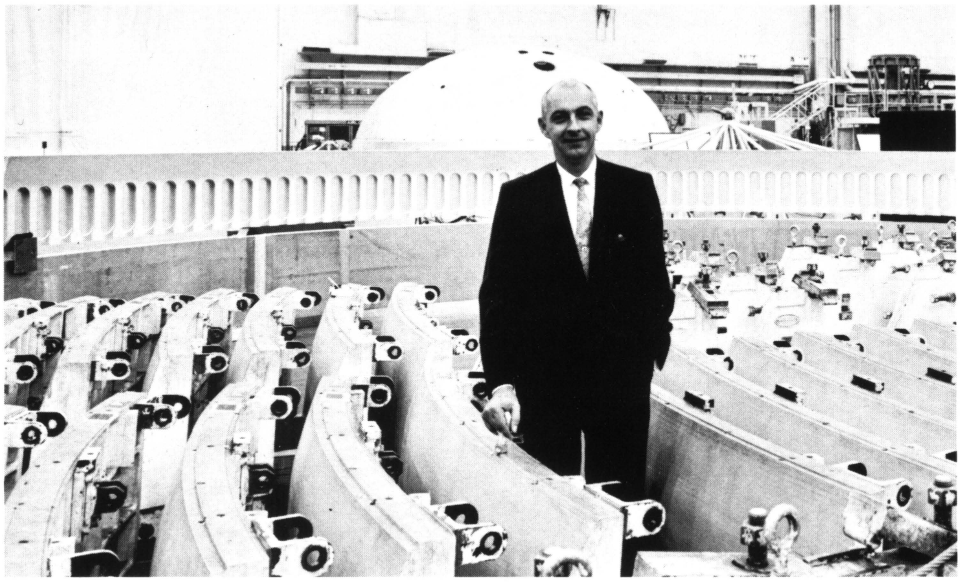
"We've got no sweat on structural integrity," he said. "All the structural tests have confirmed not only specification safety level, but much higher. We've simulated every condition that is possible on the ground. We've qualified individual components. We don't know of any further testing we can do short of flying."

Coenen walked from his office to the cavernous fabrication lines at the Michoud plant, one of the largest structures of its kind in the world. First-stage boosters, their tough corrugated skins painted green and white, in various stages of construction, were almost engulfed in the expanse of space.

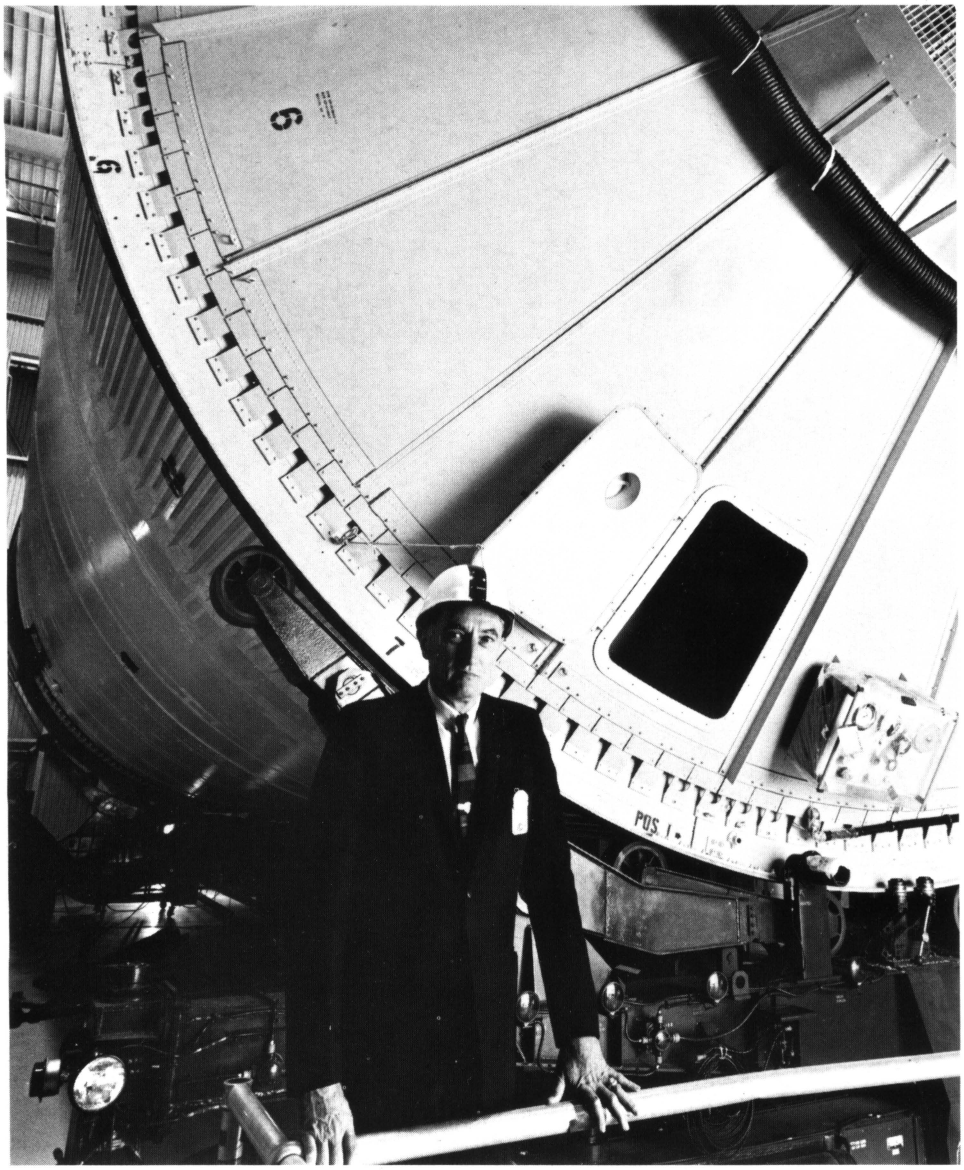
"Six years ago," Coenen said, "we didn't know how to put a 33-foot stage together. We didn't know where we'd get the machinery, or how to go about it. Now our viewpoint has changed with success." Then his thoughts came back to the Apollo 4 mission. "Every engineer, during the launch and the mission, is going to be worried about his equipment. How did the structure perform? Did the valves open and shut correctly? Did the regulators perform as desired? There is so much required—the interaction during the liquid oxygen loading, the kerosene fuel loading, everything blending properly, the computers working together, the millions of parts designed by hundreds of contrac-



In 2½ furious minutes the Boeing first-stage booster must lift the Apollo 38 miles and ram it forward at 5360 miles an hour. Apollo 4 effort will be first flight of the booster.



Francis Coenen is first-stage program executive for the Boeing Co. at NASA Michoud plant in New Orleans. "We don't know any further testing we can do on the stage short of flying."



Bob Greer, Space Division vice-president and program manager for second stage. "We'll get a final answer on structural integrity, confirmation or denial on design correctness."

tors, all working together. It's simply fantastic. This Apollo 4 is like an iceberg—the public only sees a fraction of the effort of the equipment that goes into it.

"We want the entire mission to succeed; we have confidence it will succeed; but believe me, if we can get this vehicle launched, if we can clear the tower, get our full-duration fire from the F-1 engines in the first stage; shut down, retro-fire, and then get second-stage ignition, with that alone we'll have advanced the state of the art immensely."

Perched on the shoulders of the Boeing first stage is the second stage built by Space Division in the Seal Beach, Calif., facility.

In 6½ minutes, with liquid hydrogen and liquid oxygen meeting and searing into flame within the five J-2 engine thrust chambers, the second stage rams the remaining segments of the Apollo 4 vehicle upward to an altitude of 114.5 miles, and has it pushing to near-orbit velocity of 15,400 miles per hour.

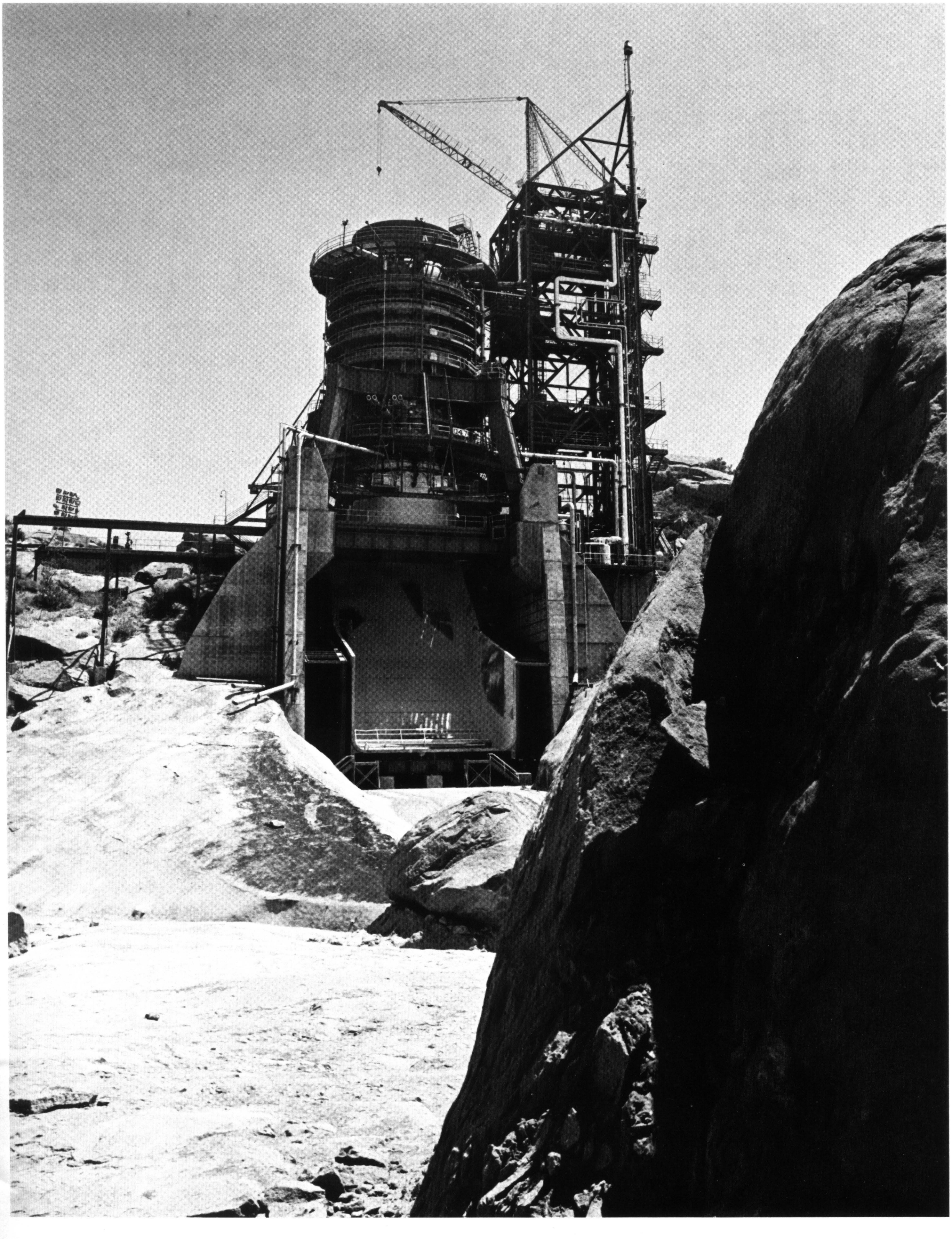
The second stage is the most powerful hydrogen-fueled launch vehicle under production. The entire stage is essentially two thin-walled propellant tanks, self-supporting with no braces, in one of which is stored liquid hydrogen and in the other liquid oxygen. The business end of the stage encloses five Rocketdyne J-2 engines, each developing 200,000 pounds thrust.

Tough Development Problem

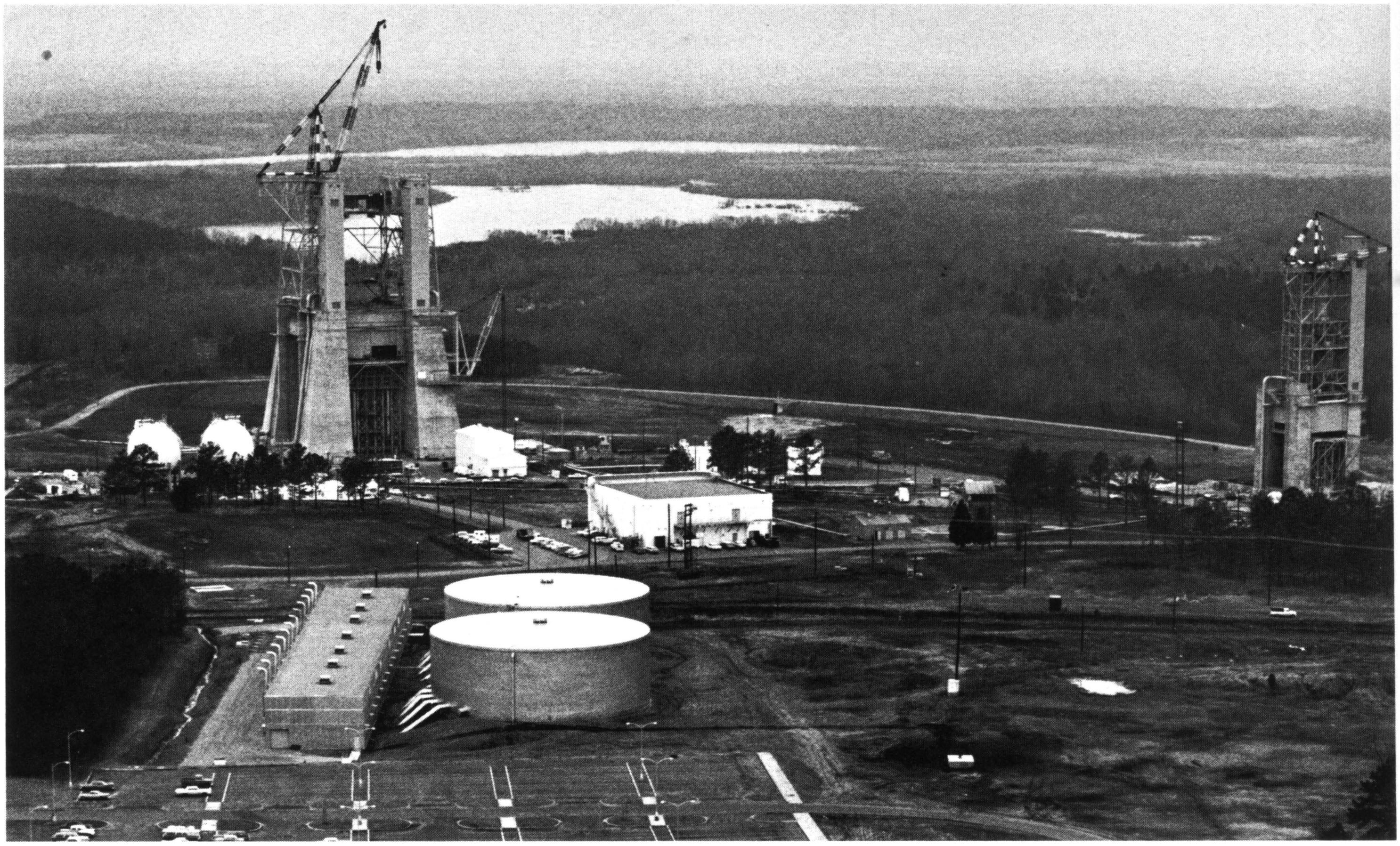
Stated that way, the stage seems the acme of simplicity. Actually, its construction, the unswerving demand for weight savings, the intricate, ingenious design that permitted that weight savings, the impossible-made-possible requirement to house liquid hydrogen cheek-to-cheek with liquid oxygen, without freezing the latter, and without losing an unacceptable amount of both through boil-off, presented one of the toughest development projects in aerospace history.

Bob Greer, tall and spare, is Space Division vice-president and program manager for the second stage. He clasped his hands and placed his two index fingers to his lips, projecting his thoughts to the morning of the launch.

"What we're going to get for the second stage basically is verification. We're going to get the final answer on the structural integrity, a confirmation or denial that we're right on design. We're going to be watching the electrical features, the sequencing of valves. The liquid hydrogen engines, the five clustered J-2s, will hold our closest attention. Have they been integrated correctly? Will they gimbal



At Rocketdyne's Santa Susana facility, extensive testing with heavyweight 'battleship' configuration of second stage was part of unending preparation for stage flight in Apollo 4.



NASA's Marshall Space Center, Ala., supervised development of large portion of Apollo 4. Engine tests and construction of first stage from Boeing components were major efforts.

smoothly, without fluttering? We'll have our eyes turned up to the IBM Instrument Unit, the basic brain of the vehicle. Will our stage respond to the requests from the Instrument Unit?

"Then we'll be concerned with the separation planes. We have two separation moments, first the primary explosion with linear charges that cut us clean from the booster stage. We get a four-second burn from the small Rocketdyne ullage engines that give a little shove to the stage before the J-2 engines cut in. We get a 30-second burn of the big engines before another linear charge blows off the entire lower skirt surrounding the engines. The skirt is 18-feet high, and it must slip by the engines with only a 3-foot clearance. We'll be watching closely.

"Understand we've checked and rechecked, tested hundreds, even thousands of times, but this will be the first time in space. We've double checked on structural integrity with a full-scale model. We've done a considerable amount of testing up at Rocketdyne's Santa Susana Field Laboratory with the common bulkhead test tank—cycled it at least 100 times to nominal design operating loads."

The Rocketdyne-built J-2 engines, five of which power the second stage for a total of 1,000,000 pounds, use super-cold liquid hydrogen as a fuel. Combined with the oxidizer, liquid oxygen, the two imposed extraordinary demands on the designers. "It was a tough problem," Greer said, "Everything had to be exact. Minimum weight was an absolute necessity. Utilization of the common bulkhead between the two propellant tanks permitted a 2300-pound payload increase alone.

"We've done all the testing on the ground that we could—now we look forward to the flight."

The third stage, on the invisible track above the Earth, hurtles the Apollo 4 into Earth velocity at 17,500 miles per hour. Then the stage coasts, baking on one side, freezing on the other, until called upon for a second effort, the crucial restart of the J-2 engine, a burst of power that will hurl the Apollo outward to the 11,400 mile mark at a velocity of 23,368 miles per hour.

Ted Smith, lean, sandy-haired, is senior director for the third stage at the Douglas Aircraft Co. Division of McDonnell Douglas, Huntington Beach, Calif. Unlike his counterparts on the first and second stages, Smith has had the comparative luxury of seeing his stage perform almost flawlessly on three previous missions. "We know that the systems, the attitude controls, and the other elements will work. We've got the basic vehicle under our belt. But we still have this worry that's going to keep us on the edge of our chairs during the Apollo 4 mission—never before in the history of this nation's space effort have we had a successful re-start of a new engine the first time out for the vehicle."

The third stage is *different* from the two lower stages. It not only operates as booster, making the last two-and-a-half minute push up to Earth orbit velocity, but it must also function as a space vehicle for 4½ hours, providing attitude control for itself and the Apollo spacecraft, going through an in-orbit checkout. After hours in the alternately baking heat and freezing cold of outer space it must give the crucial command, the restart of the J-2 engine.

"Failures? We have to be prepared for failure anywhere at all throughout the mission from the very moment of takeoff. All of us in the industry have been in this business a long time. We've never had a program of the magnitude of Saturn Apollo without an accident. But we're getting further and further away from the old philosophy of accepting 50% failures in missile development. And we're getting closer and closer to aircraft development where you do all your work on the ground and don't have any failures. All of us, all the contractors, are solving our problems on the ground, but there's still that last 5% you can't simulate. We've got to be prepared."

One of the most realistic ground tests for Apollo hardware took place at the NASA Marshall Space Center in Alabama. Brig. Gen. E. F. O'Connor, on assignment from the USAF to serve as Director of Industrial Operations, said, "We stacked a complete Saturn, from the ground up, and ran it through the bending and torsion modes to simulate flight modes. We did it in three steps, backwards. First we took the entire 364-foot stack, started off with a little shake, then built up to the full G load of flight maneuvers. Then we took the stack less the first stage to simulate the modes after first stage cutoff and duplicated the shakes through the full swing of G loads. Finally we dropped off the second stage also and repeated the tests.

"There were a few failures during dynamic testing, but none of them were serious. And none of them reflected on the structural design. For example, we relocated some brackets and improved the shock mounting.

Wind Tunnel Precaution

"Even before we took the actual vehicle, stacked it, and shook it, we had taken the precautions to do scale model wind tunnels tests. We had reasonable confidence that the results of the wind tunnel tests could be extrapolated. But we took that extra step for safety in structural design and did the full-scale shake testing of the vehicle itself. It's a one-time endeavor. We proved our point, and that will be it."

Dynamic testing of the static was only a fraction of the Marshall activity that has been carried on leading to this momentous flight of Apollo 4.

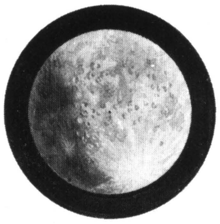
Marshall monitors about 90% of the Apollo 4 vehicle from the ground up to the Instrument Unit. The center did the preliminary work on the first stage, then assembled and checked out the stage from components and assemblies supplied by Boeing. The same was true of the next vehicle. From that vehicle on, the booster assembly has been by Boeing at Michoud.

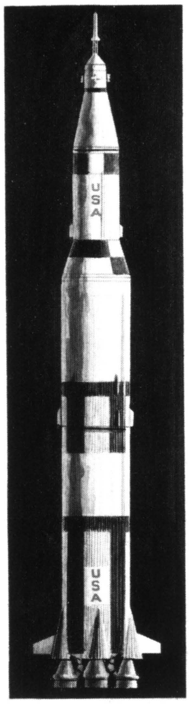
Marshall has surveillance over the fabrication of the second stage being built by Space Division at Seal Beach, Calif., and over the third stage built by Douglas at Huntington Beach.

The stages in the stack are marvels of engineering skill—but they can't move without the engines.

Inside liquid hydrogen tank, Ted Smith, senior director third stage, McDonnell Douglas Co. "We know the system and elements will work. We've got the basic vehicle under our belt."

Brig. Gen. O'Connor, USAF, NASA's director of Industrial Operations at Marshall Space Center where in realistic test entire stack of Apollo 4 was vibrated in flight test simulation.





THE STRENGTH OF GIANTS

F-1, world's largest liquid rocket engine, shares spotlight with crucial mission task assigned J-2 liquid hydrogen engine.

A rocket engine, in the quiet hours before its use, is an inconspicuous piece of hardware. In the Apollo 4, waiting on the launch pad at Florida, the metal skirts of the five F-1 engines drop modestly into view at the very bottom of the vehicle. Everything else is hidden. The five J-2 engines in the second stages, the one J-2 in the third stage, and the Aerojet engine that propels the command module into the backdive for the re-entry test, are all completely hidden within the streamlined metal that soars upward in the night shadows.

Stepladder From Earth

Yet those engines, brought to life, during the precise programming of the mission, become the sun and the moon, and the stars, and the entire firmament of the space endeavor. They are the stepladder from the Earth's reluctant surface, they are the superhuman shove to Earth-orbit velocity; they are the final massive kick that sets up the crux of the Apollo 4 experiment, the screaming downward descent of the command module at lunar re-entry velocity.

In California the Rocketdyne Division has designed and developed for NASA the F-1 rocket engine which has a champion 1,500,000 pounds thrust. Used in a cluster of five, with a total thrust of 7,500,000 pounds, the engines gulp liquid oxygen and kerosene-type fuel at 900 tons per minute.

Dave Aldrich is program manager for the F-1 engine development at Rocketdyne. Aldrich has been with the gargantuan F-1 ever since the first "big engine" concept by the Air Force. Nearly nine years ago in January, 1959, Rocketdyne engineers turned tough sheets of steel plate to form a skirt, and above the skirt put the first of giant high-speed turbopumps to form a belching monster appropriately called King Kong. The first belch of million-pound power was measured in microseconds.

With the formation of the National Aeronautics and Space Administration and a clear need for a moon booster, the development was rapid. The sheet steel disappeared, replaced by thin-walled tubes that cooled the nearly 6000 degree F temperatures inside the thrust chamber. The turbopumps that shoved the propellant through the chamber at three tons per second vaulted the state of the art into entirely new design regions.

This will be the first flight of the F-1.

Aldrich is quietly confident of success for the engines in the flight of Apollo 4. "We've had an amazing test stand record," he said. "At Edwards Rocket Center, where we do our testing, we've had a total of 780 full-duration firings on 128 different engines. Full-duration for the F-1 is 160 seconds. From the very first day we started the program we've had 2057 tests. Since October 1963, in 1640 starts, we have not had an engine-hardware failure.

"Down at Marshall, and at NASA's Mississippi Test Facility, they've had 22 full-cluster firings of the engines. In these last days before the launch we're going through all the countdown procedures to assure ourselves that all will be well, that the engines will be operating as we think they should be. We're just as determined that the engines will work as well in Apollo 4 as they will next year when we have the manned flights.

Several Unknowns

"We're sure of ourselves—but there are still several unknowns that we're going to be watching like hawks during the liftoff and the initial boost. We've never been able to duplicate the acceleration modes that the engine will encounter during those 160 seconds when it's picking up speed from zero to 5360 miles an hour. We're not positive about the heating effects that will occur in the engine area during the flight. The heating effects are due to the radiation from the adjacent engines and from the gas re-circulating around the cluster. Just to be safe, we've put 1200 pounds of thermal insulation around each engine, a total of three tons weight. It may be that the flight data from Apollo 4 will permit us to drop off some of

Five of these Rocketdyne F-1 engines, with total of 7,500,000 pounds thrust, lift entire weight of Apollo 4. In 1640 engine test starts, there has not been a failure due to engine hardware.

that weight for future flights. Every 13 pounds of weight we can save down at the bottom of the stack means the possibility of adding an extra pound to the payload."

Len Bostwick, F-1 project manager at NASA's Marshall Space Flight Center, repeated Aldrich's observation about the prior testing that had gone into the F-1. "The depth of the test program was extraordinary when viewed against the size of the engine. It was far more than we had thought possible when we got underway.

"We'll be watching, among a great number of other activities, the propellant flows," he continued. "Mathematically and from our tests we know about the propellant flows, but now, with this first flight for the engines, we face the truth, we meet up with the unknowns."

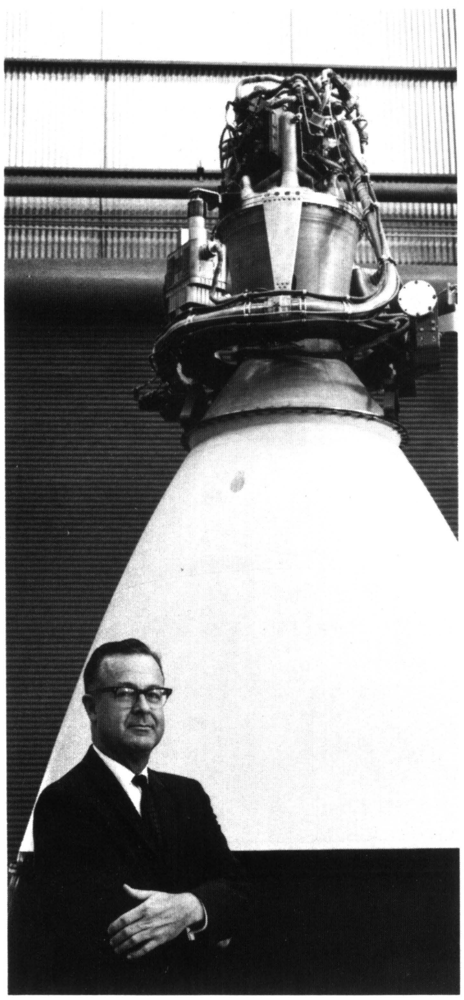
Cold Soaks for Hours

Among the many vital questions that will be answered in the test flight of Apollo 4 will be, "Can the J-2 liquid hydrogen engine be successfully re-started after the engine has remained cold and dormant for $4\frac{1}{2}$ hours, coasting in the freezing temperatures of high space?"

The J-2, developed in California by Rocketdyne Division for NASA, has a dual role in the big Apollo 4. The highly efficient engine, burning liquid hydrogen and liquid oxygen, develops a thrust of 200,000 pounds. The engines is not asked to come to life until it is 38 miles above the Earth, in a rarefied atmosphere that holds little kin with rocket engine events that take place on test stands anchored to Earth.

Re-start? That's the focal point. The J-2 engines used in a cluster of five for the second stage, and singly for the third stage, are set up on the ground while the Apollo 4 is awaiting launch. All the tanks are pressurized, all the valves sequenced for the first burn, a normal preparation cycle that permits close human supervision. In that respect the pre-launch preparations with the J-2 are similar to those with the F-1 engines. It is on the third stage the re-start requirement crops up.

After the first burn of the third stage the engine shuts down, then must re-set itself, re-pressurize its re-start hydrogen bottle, and re-set the control system. By that time, the engine men are 115 miles below and perhaps a half world away. The engine is on its own, asking itself, "Am I ready?"



Herman L. Coplen is manager of service propulsion system development at Aerojet-General. "We'll be getting a lot of additional data on the performance of the engine in space." The 20,000 pound thrust engine gives big push to command module to gain lunar reentry velocity in critical test of heat shield.

Paul Castenholz, serious, intent, is program manager for the J-2 engine development at Rocketdyne. "We've run scores of re-starts on the engine on the stands at the Santa Susana Field Laboratory. We've done similar work under high vacuum conditions at the Arnold Engineering Development Center in Tullahoma, Tenn. But none of these duplicate exactly what will be required at altitude. We've done everything possible in our ground tests. We don't think there are unknowns, but it is never possible to simulate all conditions exactly. This is a big engine. It has more controls than other types that have restarted successfully in space.

"We're not concerned on this flight with performance parameters. The engine has pretty well proved itself in the three prior successful flights of the S-IVB. Our concern is engine operation and uncovering unknowns if there are any. We profited by previous flights of the engine. We made several small modifications. And we're going to profit by this flight in the Apollo 4."

Jerry Siniard, who matches Castenholz in youth and intentness, is J-2 project engineer at NASA's Marshall Space Flight Center. "The test firing at simulated altitude in the Arnold Engineering Development cells has given us added confidence. Ideally we would have liked to have fired the entire cluster of five engines in that vacuum cell at Arnold but it's physically impossible.

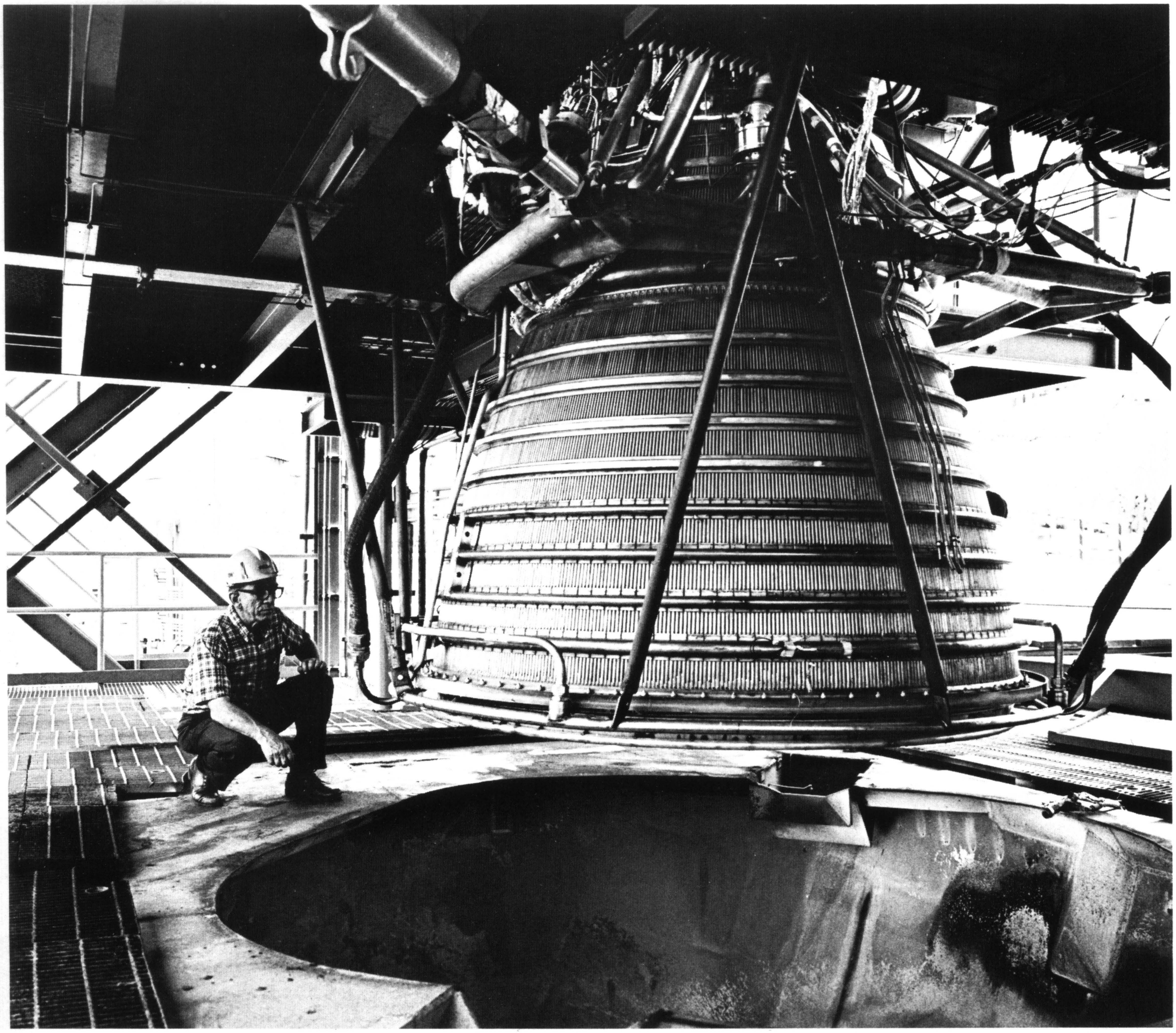
Pleasant Surprises

"Despite the assurance of Tullahoma, we still want to know about the fire effects, the gimballing effects of the five engines at altitude. Maybe we'll have some pleasant surprises. For example, we don't expect as much vibration at altitude as we get at sea level because there are no flame buckets, no canyons to bounce the sound waves as up at Santa Susana. We expect that the operation of the engines at altitude will be less drastic than it is at sea level.

"I'd say the J-2 was more mature at this stage of flight testing than any other big engine at this point of development. Since the start of the program at the Santa Susana Field Laboratory, we have had 3605 tests on the J-2 for a total of 314,959 seconds!

"It is this depth of experience, coupled with the altitude simulation work at Arnold, and the three previous successful flights with the single engine, that give us a high degree of confidence."

The Service Propulsion System (SPS), developed for NASA by Aerojet-General Corp. at Sacramento, Calif., is deceptive



Rocketdyne J-2 engine has dual role in Apollo 4 — second-stage boost in a cluster of five, and third-stage power used singly. Re-start of J-2 at altitude is critical mission test.

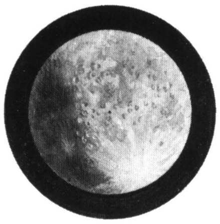
in appearance. The engine develops 20,000 pounds thrust, and it is small, only 3-feet, 5-inches tall. But it sits atop a wide, flaring skirt, 9-feet, 4-inches high, that lifts it in one wave of thin-walled titanium and columbium into the big league size.

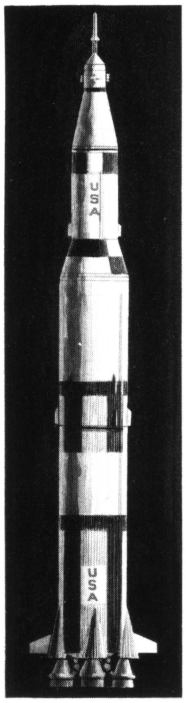
Herman L. Coplen, a veteran in rocket engine development, is manager at Aerojet-General for the SPS. He too speaks from the confidence born of almost six hours of engine firings at simulated altitude and two highly successful previous firings of the engine during the earlier Apollo 1 and 2 flights on a ballistic lob down the Atlantic and on the longer flight that splashed down in the mid-Pacific. But he, too, called out the difference in the Apollo 4 experiment. "This is the first time out for the service propulsion engine at extremely high altitude. In the Apollo 1 flight we were suborbital. In Apollo 2 we reached a 620-mile altitude. Now we're asked to operate with very long burns when we're nearly 10,000 miles out in space.

"So we'll be getting a lot of additional data on the performance of the engine in space. We hope to get some new insights on actual specific impulse at space vacuum conditions. There's still some question as to what the exact flight specific impulse may be—Tullahoma tests were a great help, but they didn't simulate entirely what we're going to encounter at 10,000 miles.

"We've got a re-start requirement—in fact, we're asked to re-start 36 times during the mission, varying all the way from ½ second for trimming to 265 seconds. But this is a pressure-fed system and we use storable hypergolic fuels that ignite on contact, so that our achievable reliability in re-start is quite high."

The big moment in the life of the SPS engine will come 8 hours into the programmed mission when a final 4½ minutes burn of the 20,000 pound thrust engine will hurl the command module on its redhot re-entry into the atmosphere. From that moment on, all attention will be riveted on the sleek module as it drives back through the resisting air and reaches for an ocean landing and a safe return home.





AND A SAFE RETURN HOME

New strength of Apollo 4 to permit vital test on heat shield impossible to perform on earth.

Despite the intensity and depth of ground testing afforded the sub-systems, the systems, the stages, and the rocket engines of Apollo 4, there are some full-scale tests that necessarily have had to wait for the coming of the biggest of all space vehicles. No vehicle that has flown before has been powerful enough to set up the precise test conditions required.

An example is the full-scale testing of the heat shield that surrounds the command module, the pressurized metal world of the three astronauts.

The heat shield, developed by Avco Corp. of Wilmington, Mass., under subcontract to Space Division, developers for NASA of the command, service modules, is a charring ablative material composed of a filled epoxy resin, bonded in fiberglass honeycomb to the outer shell of the double-wall command module. The function of the heat shield during the 16 minutes of scorching re-entry to the Earth's atmosphere can be expressed in this manner: 4500 degrees F; 600 degrees F; 80 degrees F.

The ablative material will have to endure the 4500 degree metal-melting temperatures on re-entry, consuming itself, charring, but allowing no more than 600 degrees to penetrate to the secondary heat shield around the inner shell. That secondary shield, in turn, tames the temperature down to the 70-80 degrees F the astronauts will experience inside the command module.

The full-scale heat shield has never been exposed to the precise conditions it will meet on lunar re-entry. On the ground 10,000 tests have been conducted with the ablative material—but only on small sections about three inches in diameter.

Avco Responsibility

Ed Offenhartz is program director for the heat shield development at Avco.

Offenhartz knows exactly where he stands with his development effort. The 10,000 ground tests on the ablative material brought about a revolutionary change in lightweight heat shielding concepts. Avco, long a veteran in re-entry heat problems with ICBM nose cones, started off its Apollo work in 1962 with a high-density material that had to be pressed like tiles and cemented after a fashion to the outer skin. The concept wasn't adequate for the total mission. They kept testing, testing, testing, and gradually drove the density of the ablative material down to where it looked like fluffy, reddish-tinged mohair. They evaluated, repeated the tests, used scores of materials, and finally evolved the material in use today

"This flight of Apollo 4," Offenhartz said, "will be crucial. It will be the first time the heat shield will re-enter at velocities similar to lunar return. For manned missions, we're assuming that the astronauts will be in control so that they will be bringing in the vehicle at the correct attitude. In the case of the unmanned mission, like this Apollo 4, we're assuming the vehicle will have been placed in the correct attitude by remote control. It hits the Earth's atmosphere at 36,000 feet per second, in some hot spots generating up to 4500 degrees Farenheit.

"Because of the size of the heat shield, we couldn't test the entire unit on the ground simulating the same temperatures, the same pressures, the same aerodynamic shear forces. It would require another TVA just for the power consumption alone if we were to conduct such a test.

"What we have done is to expose representative pieces of the material and get the information we need to verify our concepts. We've found out that the combination of theory, ground test, and a cross check with performance data in flight has worked adequately."

Offenhartz has had backup verification of flight test on the heat shield. It rode the ballistic flight of Apollo 1 where thermocouples embedded in the ablative material sent back signals detailing the ablation process during re-entry flight. Aboard Apollo 2, the flight of the Apollo that went half-way around the world to a Pacific splash down, the ablative material came through splendidly. But in neither of these flights did the re-entry speed begin to approximate the 36,000 feet-per-second to be encountered on a lunar return. That type of speed can only be achieved now that the brute boost strength of Apollo 4 is available, "With the boost we're able to lift the third-stage with a full fuel load for the J-2 engine, permitting the outward drive to more than 11,000 mile apogee. And now, we're able to carry along the service module engine with a full fuel load that makes possible the last powered dive back to Earth at the required velocity.

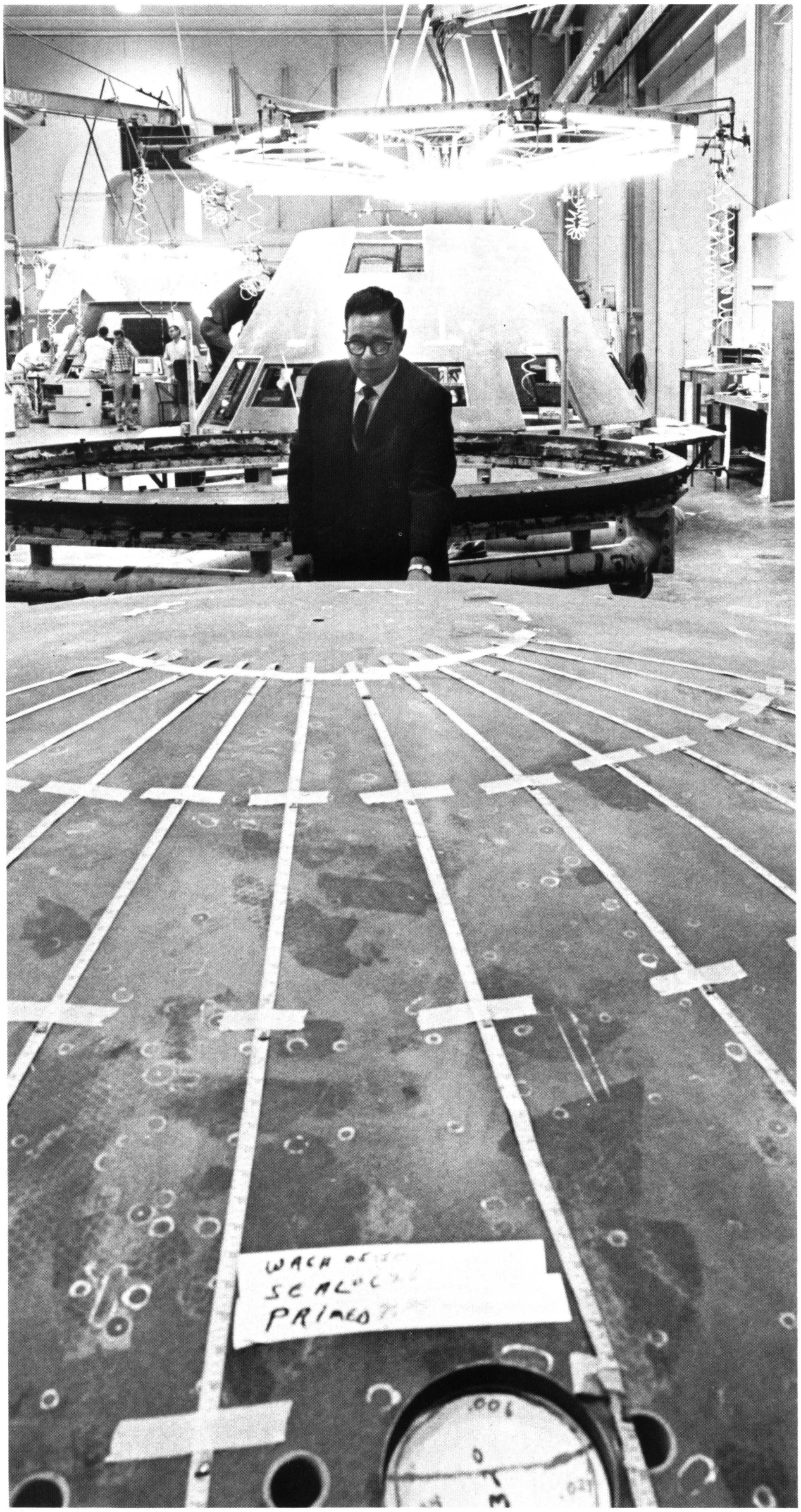
"Based on all the information we have been able to get on all our ground tests, and from the flights of Apollo 1 and 2, we have every reason to believe that the heat shield on Apollo 4 will perform as expected."

Data Will Tell Story

A man who will be watching intently as the readings are telemetered back from the thermocouples buried deep within the heat shield is Dale Myers, vice-president of Space Division and program manager for the Apollo command and service modules.

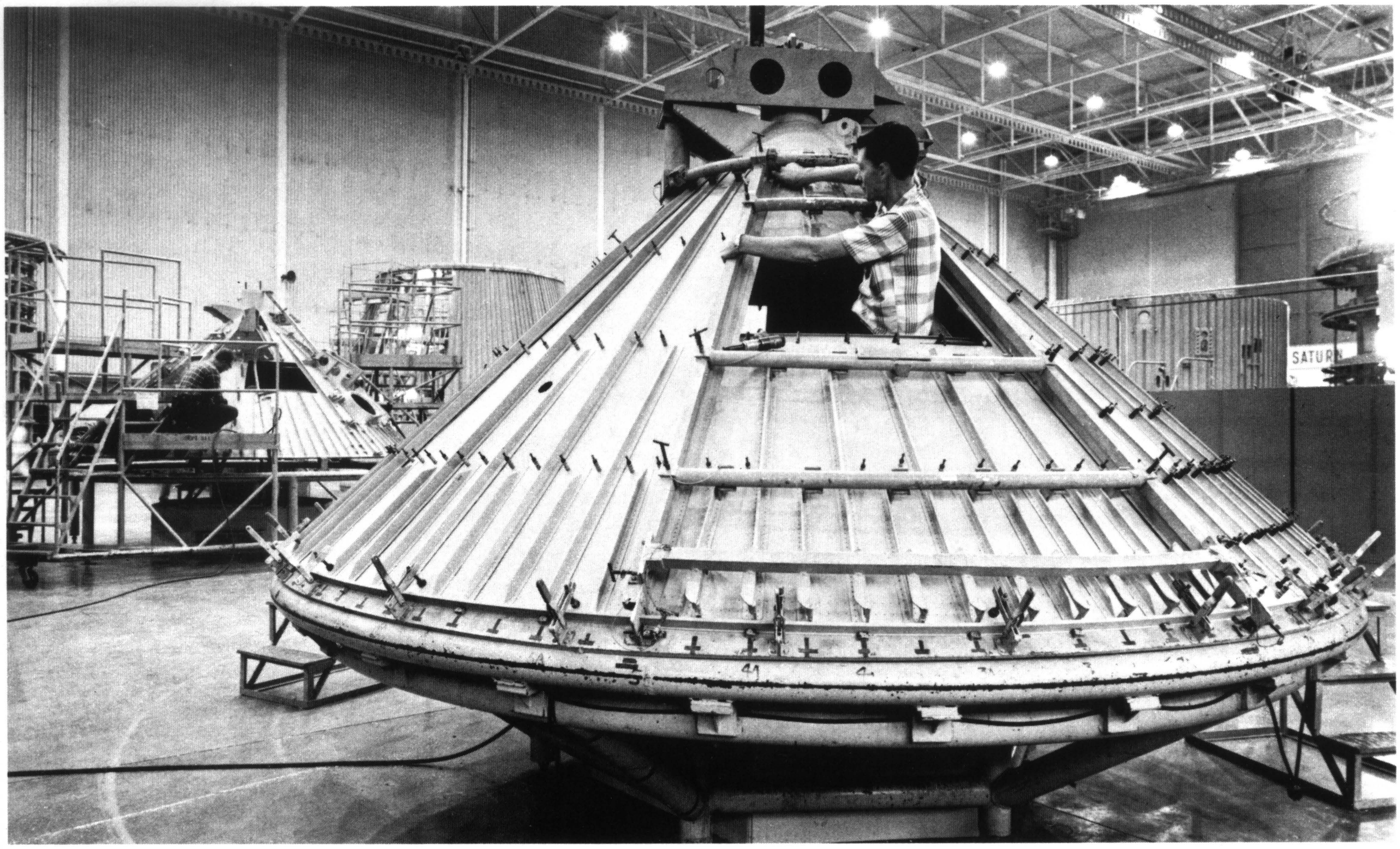
"The continuous flow of data we'll be getting as the module returns will permit a necessary step forward in the program. The shield will be subjected to three times as much heat rate and twice the heat load it experienced in the flights of Apollo 1 and 2. We're going to be testing for both heat rate and rise at the most severe conditions, greater than those that will be encountered in the manned moon mission. There will be new knowledge from the flight; for example, the influence of the overall heat shield on the gaps along the parting lines of the ablative material.

"Our assurance comes from the conservative approach we at Space Division, working with NASA and Avco, have taken on the heat shield requirements. If the shield comes through the flight showing we've got a real safe margin, I'm satisfied." When Apollo 1 and 2 returned to Earth and were plucked from the ocean, the surfaces in some spots were blistered



Ed Offenhartz is program director for command module heat shield development at Avco. Ablative shield absorbs 4500 degree Fahrenheit re-entry heat. Apollo 4 is first vehicle powerful enough to set up precise conditions for realistic test of full-scale heat shield.

Dale Myers is vice-president of Space Division and program manager for Apollo command and service modules. "We're not working in the dark. We have an enormous amount of ground data. We have all kinds of assurance but we still want verification from Apollo 4."



Outer heat shield will tame 4500 degree F re-entry heat to 600 degrees felt by this Apollo command module inner shell. Maximum temperatures for astronauts will be 80 degrees.

and turned black. Myers pointed to the photo. "Apollo 4 will be the hottest object ever recovered from space. When it comes back it will look a heck of a lot worse than Apollo 1 and 2—but it will be on the money in the safety region, I'm sure.

"We're not concerned about the boost integrity of the module itself. After all, this is the fourteenth flight and we've had plenty of time to satisfy ourselves that we have a sound structure. We will be learning more and more about the interaction of the systems inside the module. In the previous Earth orbit flights the environmental control system has been helped by heat emanating from the Earth. But that was at a comparatively low altitude, and now we're in a new ball game—we're really pushing out, more than 11,000 miles, where we have a different set of conditions. Operating in deep space without help from that warm body Earth is a factor in the environmental control system operation.

"We're not working in the dark. We have an enormous amount of data from ground tests that have been going on for years. We know just what G loads the command module can absorb from those flights on the Little Joe at White Sands; we've slammed the module into water from a drop tower in two hundred tests that give us assurance; we've seen it fall dozens of times in parachute drop tests out in the desert. We have a good safety factor in the construction.

"Down at Houston, NASA built that enormous environment chamber and we placed the entire command and service modules inside for very realistic testing, simulating high altitude. It gave us a good feel of what we're going to encounter on this Apollo 4 mission. At the Arnold Engineering Development Center in Tullahoma, Tenn., we've had excellent high-speed wind tunnel tests to confirm our projections on the lift-over-drag ratio of the module as it comes skipping back to Earth. Here at Downey we've had numerous realistic tests on the module systems —for example, the 14-day test where we had three men living inside a pressurized module, entirely dependent on the environmental system, living and working as though they were on a mission.

"We have all kinds of assurance—but we still want to verify everything we learned here on the ground with an actual flight into deep space before we send men out in the vehicle.

"It's a complex mission, this flight of Apollo 4. And you want to keep in mind that an unmanned mission, like this one, is much tougher to execute than a manned mission. We designed this command module from the word 'go' for manned participation. We need man in there. We rely on his judgment. On Apollo 4, we're going to miss him."

The substitute for man on Apollo 4 is a Mission Control Programmer, MCP, developed by engineers of the Autonetics Division. The MCP is a carefully engineered unit, crammed with relays. On orders from the spacecraft computer, the programmer opens and closes switches. The computer tells the MCP "Open this valve. Shut the other valve. I want to go faster. I want to go slower." And the MCP reacts, without question, reaches behind the switch, and activates the necessary component.

It is a startling demonstration of remote control, proved in two flights, but, in the words of Myers, "We're going to miss man."

Ken Kleinknecht is manager of the

Ken Kleinknecht is manager of Command, Service modules, NASA Manned Spacecraft Center, Houston, Tex. "Unlike Mercury and Gemini missions, Apollo may be several days away from Earth. There is no margin for error, no forgiveness for omissions in preparation."

Command and Service Modules at NASA's Manned Spacecraft Center in Houston. Kleinknecht has been watching the interaction of men and hardware in high-speed Earth and space vehicles ever since the Bell X-1. He worked with all the high-speed experimental aircraft, including more than five years on the rocket-powered X-15, before moving on to the Mercury and Gemini programs.

"We've always had a weight problem," he said, looking back over the years of high-speed manned efforts. "Whether it was in the X-1, the X-15, the Mercury, Gemini, or Apollo, we somehow or other seem to bring the weight right up to the capability of the vehicle."

He pointed to a diagramatic sketch of the Apollo module, the conical shape measuring 12 feet at the apex of the cone, and 12 feet, 10 inches across at the base, a small, metal, pressurized world, crammed with essentials and a few modest comforts to keep men functioning, alert and ready during the 14-day moon mission. "The cabin has always been the critical part. We've always been crowded. It hasn't changed since the X-1. The leak problems and cleanliness problems in the X-15 and Apollo have a great deal in common.

Time Difference in Apollo

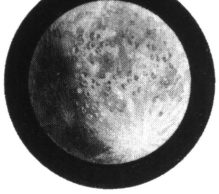
"But with Apollo there is a difference. About 9 minutes elapses from the B-52 drop until the X-15 is on the ground. In Mercury and Gemini, the astronauts were always only 30 minutes away from splashdown. In contrast, Apollo may be several days away from Earth. There is no margin for error, no forgiveness for omissions. That's why we're so stringent in all these preliminary ground and flight test programs.

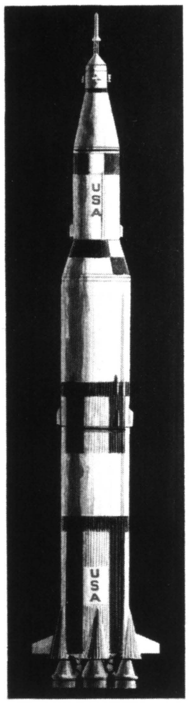
"The astronauts will need every bit of preparatory help we can give them."

Kleinknecht folded his arms and leaned back in his chair. "We're planning for a full success with Apollo 4. All our thoughts and efforts are directed to full success. But the most convincing flight won't satisfy us. One good mission doesn't necessarily mean, 'You can repeat this time-after-time.' Regardless of the outcome of Apollo 4, we're still planning to launch the next unmanned vehicle to get the only kind of data that convinces an engineer—solid repeatability. We want to be sure that the initial effort wasn't just a ramdom success."

Kleinknecht looked out the window to a Texas thunderstorm pounding sheets of rain on the sweeping lawns of the Manned Spacecraft Center. "Successes are made by people working hard," he concluded. "They just don't happen by accident."

At NASA's Manned Spacecraft Center, Houston, Tex., stacked modules are swallowed within a ponderous metal bottle for realistic hot-and-cold tests simulating 80-mile altitude. Data obtained gives preview of spacecraft reactions expected during flight of Apollo 4.





LAUNCH WINDOW OPENING

Kennedy Space Center prepares the site, ignites the engines, then Manned Spacecraft Center guides Apollo 4 through mission.

NASA has spent five years preparing the Kennedy Space Center for the launch of Apollo 4 and its follow-on space vehicles.

Before the present area on Merritt Island in Florida was selected, a committee investigated sites in the Pacific, California, New Mexico, Texas, Georgia, Florida, and the Caribbean. Each was assessed for logistics, cost, community services, and water availability. The committee was concerned with the problems of flight safety, the determination of where the boosters would fall back to Earth, and the need to make maximum use of existing facilities.

The recommendation was unanimous for Merritt Island. The transformation from muck to moon vehicle launching site began late in 1962.

An entirely new concept in space vehicle preparation was evolved for the Apollo.

"In former programs," Kurt Debus, director of Kennedy Space Center, said, "a contractor prepared his missile or space vehicle in a particular environment; he hooked on his test instrumentation; tested; disconnected; sent the vehicle out to the launch pad, and went all through the tests once more.

"With this Apollo series of launches," he continued, "we agreed not to follow that procedure. We said we wouldn't disconnect the vehicle after the checkout in the environmental building. That decision forced us to adopt a launch pad that could be moved." He gestured out the window to the outlines of a massive crawler and a 400-foot service tower sitting in the hot sun just beyond the world's largest structure, the Vehicle Assembly Building, VAB. "We didn't go to the crawlers right away. The logical thing was to use barges, but studies at Taylor Model Basin showed we would have tremendous problems with water dynamics. So we looked at railroads, rubber tires—the whole spectrum of transportation. Finally we turned to the crawler, a technique developed by Bucyrus-Erie for strip mining operations."

The entire stack of Apollo 4 moves from the assembly building, after checkout test, along a custom-built road 3.5 miles to Complex 39, the launch site.

"The mobility means a great deal," Debus said. "If we have an engine shutdown on a launch attempt, we can move the vehicle back to the VAB. If we have a hurricane warning, we can come back. We don't need expensive permanent structures out on the pad to shield the people from the rain.

"If we had gone the regular route and used three, four pads, we would have had our people scattered for miles, instead of being concentrated as they are now in the Vehicle Assembly Building. It's not necessary, anymore, to have the control center right up close to the vehicle. The old analog techniques of recording data necessarily kept us close in to the pads in control centers with 12 feet of concrete over our heads. Now with digital recording, we're back a safe distance, right next to the Vehicle Assembly Building."

Debus will be in the control center during the $5\frac{1}{2}$ hour launch window opening the day of the launch. When the engines ignite, the vehicle lifts and clears the tower, control passes over to the Manned Spacecraft Center in Houston.

Flight Director for Apollo 4

Flight Director for NASA on Apollo 4 at Houston will be Glenn Lunney. He's 30 years old. This will be his sixth mission as a flight director, the final authority between the decision makers on Earth, and the Apollo 4 vehicle spinning around the globe. Grouped around him during the flight will be about 11 men, specialists in electrical environment, computer tactics, propulsion systems, attitude control, launch vehicles, and flight dynamics. Fanning out from them, in rooms immediately adjacent to the Houston Control Center, reading the identical data pouring down from the spacecraft, are another 400 support people, including contractor experts

Complex 39, Kennedy Space Center, Fla., is jump-off for first flight of Apollo 4 and for future moon missions. Fully assembled, checked-out space vehicle moves on crawler from Vehicle Assembly Bldg., background, along custom-built road 3.5 miles to launch site.

Dr. Kurt Debus is director of NASA's Kennedy Space Center. "An entirely new concept in vehicle preparation was evolved for Apollo."

Glenn Lunney, NASA's Manned Spacecraft Center, Houston, Tex., is flight director for Apollo 4, the sixth mission in which he has directed world-wide team which monitors, controls vehicles in deep space penetration.

familiar with every phase of the vehicle, ready to come up with answers should they be needed in a hurry.

"Once that thing lifts off," Lunney said informally, "the big question in our mind is, 'what can we do to get the best out of the black boxes?' Actually, if everything goes well, there will be only one necessary ground command during the mission. We're going to update the guidance and navigation information just before the module turns around on the apogee and starts the drive back. You see, we release the guidance and navigation, the G&N autopilot, at liftoff, and it navigates the mission for about 8½ hours. Without an update, it tends to drift, and if we left it alone it might send the module back about 200 miles off target. A couple of undesirable things might happen—for example, the mission profile might get outside the conditions we want to verify.

"But aside from that planned activity from the ground, our whole function in the Control Center will be oriented to taking action if a failure occurs. In an unmanned mission we've got to be prepared to do with ground commands many things that an astronaut ordinarily could do for us."

He paused, thinking back over past missions. "The kind of problem that clutches you is not 'This is broken,' but, 'This is almost broken, what shall we do?' That's when you earn your money.

"There are a whole raft of airborne malfunctions where we on the ground can take action. For example, suppose the computer on board the spacecraft told the automatic Mission Control Programmer to order the full burn for the re-start of the third stage. The MCP triggers the engine, and we only get a partial burn, or no burn at all. When we detect that, we here in the Control Center can step in and send a command that will tell the spacecraft to go out to the 11,400-mile ellipse. There is a considerable fuel surplus in the service module engine to help do this. We might not get the 36,000 feet-per-second on reentry drive that we want, but we could get a satisfactory 30,000 fps.

"If the spacecraft wants to come apart, there's nothing we on the ground can do about it. But if the systems don't want to do something, there are many things we can do about it. Luckily, the stage won't fight us. If the spacecraft computer fails, the vehicle just holds itself—that's when we step in and try to take charge.

"We've spent a long time getting ready for this mission. In fact, one of the reasons for the Gemini program was to establish the ability of this Control Center team to perform accurately and on schedule.

"There's a great similarity in our planning and preparation for the Apollo 4 mission and the rendezvous missions we had with the Gemini. For months we've had 25 men performing analytical studies on the trajectory and guidance problems. We pre-plan all the obvious things that we can do in certain problems. Then for hard-rock training, we present realistic missions to the crew in the Control Center and have them work on them.

"The men who give the commands for the spacecraft to perform some maneuvers are highly trained, highly skilled. It takes a definite touch, a feel of things, to execute a radio command to a space vehicle, a skill almost akin to what the astronauts have when they're standing at the switch.

"This is a lunar rehearsal," the flight Director said. "In many ways it is very close to the real thing. When we burn the Saturn third stage we'll have to do it out-of-plane, at high pitch angles, otherwise that spacecraft could take off for the moon."

New Aids for Recovery

Many new forces have been added to the round-the-world tracking devices and to the recovery forces for this flight of Apollo 4. Because the boost engines burn so long and so powerfully in contrast to previous boosters, the vehicle is far out of range of the Bermuda Eastern Tracking Range facility when it comes time for insertion in orbit. To overcome the deficiency, a new vessel, an insertion ship, the *Vanguard*, will give that coverage from the ocean waters deep in the Atlantic.

New Apollo Range Instrumentation aircraft, C-135s equipped with S-band radio communication, will fly along the ground track and record the burn of the third stage, not for immediate use, but for post-mission analysis when the question will be asked, "How did the third stage perform?"

The "footprint" for recovery may be large, possibly entailing a 1000-mile search area. Six C-130 aircraft, complete with swimmers and safety flotation collars, will be fanning out to provide high-speed search. The six can cover 1500 miles in a few hours. These, of course, are in addition to the regular scanners aboard the aircraft carriers, the human eyeballs and the helicopters.

Lunney and the men surrounding him in the Houston Control Center are the "tail-end Charlies" of a vast effort that has been going on for six years, preparation for the test flight of Apollo 4.

"Let's get that bird clear of the tower," Lunney said, "then all the way!"

At Kennedy Space Center, Fla., months of final preparation precede the moon vehicle launch. Here the second stage of the Apollo 4 is lifted to join the 'stack'; while command module, service module, and adapter shielding lunar module await their turn on the hoist.


NO STEP
REUSEABLE DO NOT DESTROY

WHO BUILDS FOR APOLLO?

300,000 American Workmen Pool Their Skills for the Moon Effort

AT THE FINAL second in the launch of a space vehicle, the umbilical cord encasing electrical and communication lines snaps back, away from the path of the upward climbing vehicle. By contrast, in a simulated test launch, a technician stands by the command module, listening to the countdown and physically jerking away the umbilical cord, preventing unnecessary damage.

At 1 p.m on Friday, January 27, Jim Gleaves, for two years a Space Division Mechanical leadman, picked up his lunch bucket, said goodbye to his wife and two small daughters, and drove 43 miles from Orlando, Fla., to Kennedy Space Center, to Pad 34 where command module 012 was under final test before the planned flight of the first manned Apollo.

Sequence of Tragedy

Gleaves did not return home for 26 hours. Three hours after the start of his swing shift atop the gantry, 200 feet in the air, his hand resting on the umbilical cord, ready to jerk it away, he was caught up in tragedy. That night Gleaves was hospitalized for burns and smoke inhalation. In company with 13 other Space Division employees he later was cited for bravery in a vain effort to save the three astronauts inside the module.

No man is more fiercely determined of success than Gleaves and those who work with him. "Those astronauts," he said, "are going to fly. I've asked for the duty when the hatch is closed for the next launch." He looked across the flat Florida mangrove swamp to the distant Pad 34. "We built a damned good module in 012."

When Gleaves spoke of a "good" module, he was speaking, not from affection alone, but from proof. For 012 is not a solitary item, like an ornament atop a tall tree, but it is one of a procession of modules, boilerplates and flight configurations, proved in 13 successful prior flights. Some of the flights have been in the heat of the White Sands Missile Range in New Mexico, where modules were wrenched and careened in purposeful, high-g maneuvers during proof of the launch escape system. Others have been successful unmanned flights in roaring launches from Cape Kennedy, proving the white-hot integrity of the heat shield before the modules splashed down on target in the Atlantic and around the corner of the world in mid-Pacific.

There are other spacecraft in production and test at Space Division's Downey, Calif. plant. And at Cape Kennedy in Florida, the latest completed spacecraft, 017, perches atop the towering bulk of the Apollo 4 vehicle ready for the start of an entirely new chapter in space endeavor.

Strength and Integrity

The strength and integrity of Apollo, its ability to withstand the rigors of launch, the planned 14-day flight around Earth, and the ultimate trip to the moon, before plummeting back to the waiting ocean pickup vessels, have been proved by hundreds of test drops, slamming, crashing returns into the water lagoon beneath tall swinging drop towers. And in other tests, parachutes have billowed a score of times in flawless module drops by the Salton Sea. The intimate integration of the systems is not conjecture, but proved. The environmental control system has kept

The liquid hydrogen that fuels these five Rocketdyne J-2 engines, powerplant for Apollo 4 second stage, exacted great care and attention from engineers and technicians who shepherded the stage from California to Mississippi, to Florida launch site.

three test crewmen alive and alert for 14 days of utterly realistic testing under pressure in a small metal module linked only by a television camera and sucking pumps to the outer world.

Gleaves continued, "We'll give this program every last bit of energy and skill we have."

The "we" that Gleaves referred to is not just the 50 Space Division technicians, the 20 Quality Control men, the 25 engineers who are on the job in the final weeks and days and hours of launch preparation on the Florida pad, but the 300,000 American workmen in nearly every state of the Union who, directly and indirectly, for years have given every last bit of energy and skill to fashioning the metal that carries men to the moon.

There is no subtle magic that brings about the transformation from a blueprint to a piece of moon bound hardware. It is brought about by workmen, whether they be in a small ball-bearing plant in New Hampshire, a giant research laboratory in Michigan, or a parachute plant in El Paso. It is brought about by people who drive the Los Angeles freeways, the flat roads of Oklahoma, the new Interstate 59 in Mississippi, and over the causeway leading to Merritt Island and Cape Kennedy in Florida.

Complex Research Effort

It is those people, in California, Oklahoma, Texas, Florida, Massachusetts, Rhode Island, Minnesota—the callout of States is long — who are absorbed in what has been termed the "most complex research and development effort ever undertaken." It is those people who recognize that in space work the standards are and must be extremely high, who know that perfection is the goal, who not only work within the demands of perfection but broaden and deepen those demands.

NASA's Saturn/Apollo effort is a gigantic one. The interlocking complexity of the task is awesome, a mix of liquid and solid rocket engines, of new and old propellants, of guidance systems, lightweight fuel and oxidizer tanks, boosters, second stages, third stages, lunar modules, command modules, service modules, pipes, wires, probes, sensors, radios, panels, insulation, aluminum and steel. Few other projects in the history of the United States have been so thoroughly integrated into the national economy. In few other proj-

For 12 years Tom Peters, left photo, has watched procession of Rocketdyne high thrust engines lift 799 space vehicles, missles from Cape Kennedy. At Mississippi Test Facility, Gerry Wilson, right photo, heads Space Division group, part of those cited for tireless efforts in preparing S-II booster for test firing, shipment to Florida.

ects have American workmen, collectively, been able to say with equal emphasis, "We built this."

In just one portion of the effort alone, the command and service modules being researched and developed by Space Division, there are 16 subsystems, each one of them a scientific and engineering feat, all of them the product of more than 3000 subcontractors located in every section of the nation. The sleek, conical-shaped command module, with its supporting stack of fuel cells, propellant tanks and rocket engines in the service module, is not Space Division in California alone, but Motorola in Arizona, Honeywell in Minnesota, McGraw Edison in New Jersey, Bell Aerospace in New York, Avco in Massachusetts—just a few of 34 companies throughout the country whose workers have built major systems of the command and service modules. Each one of those companies in turn is backed up by a myriad of third-tier subcontractors and suppliers, some of them renowned throughout the industrial world, others small shops in small towns in remote areas.

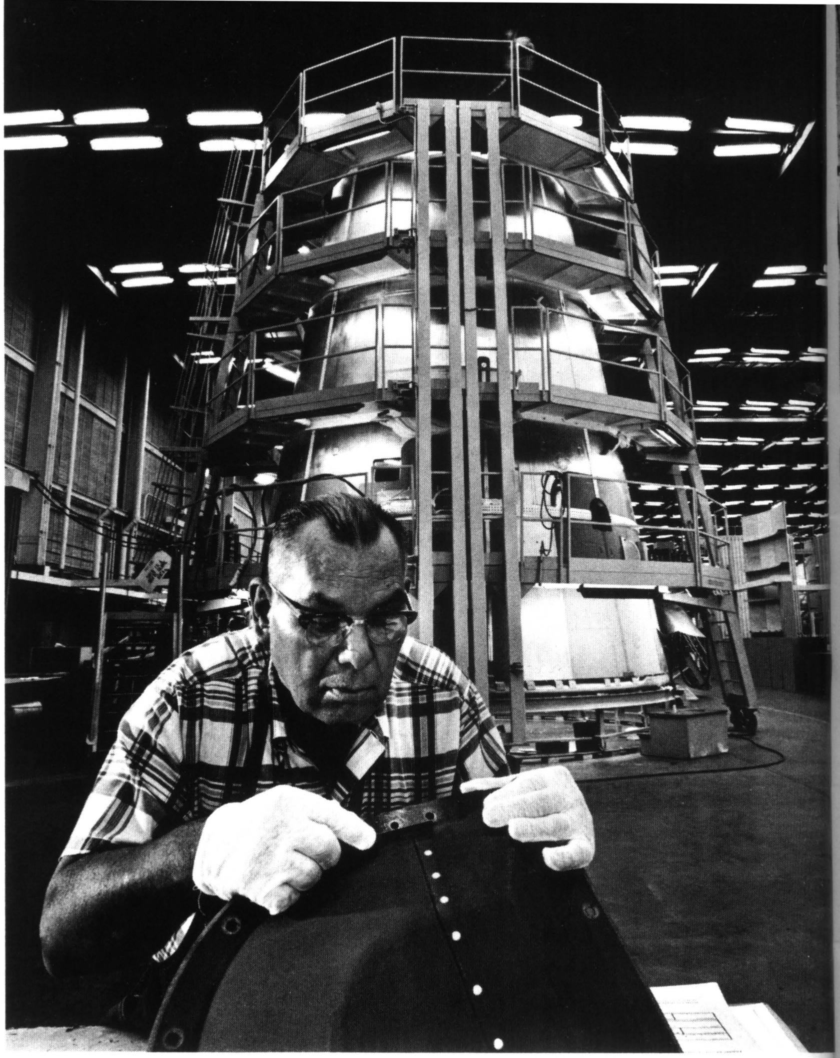
Quality Control Demands

One factor binds them all together. The quality control demanded of the workers in the smallest shop is as stringent as that on the workers in the largest industrial giant. Near-perfection is demanded of the product shipped upward in the supply line.

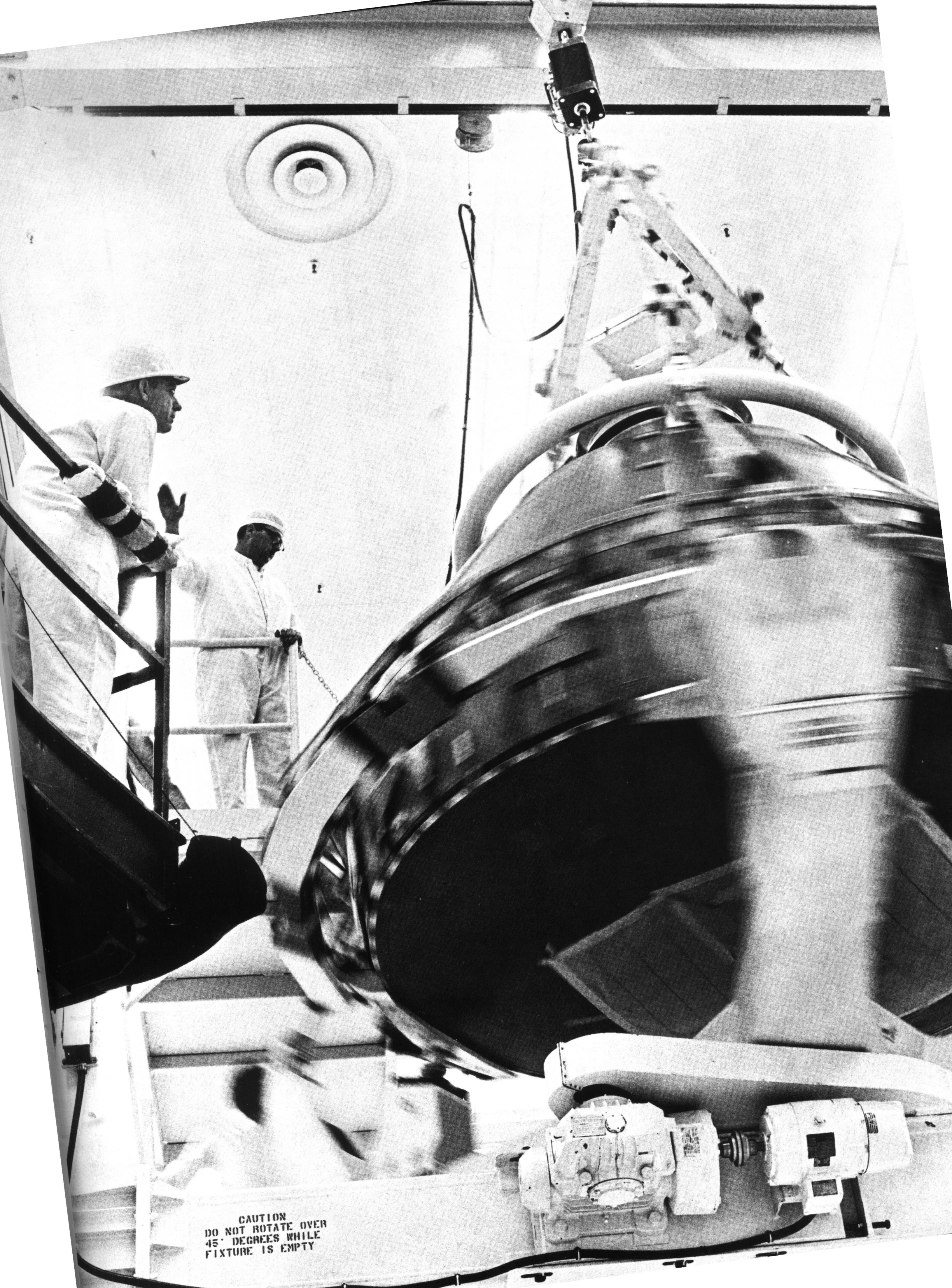
The very metal in the moon vehicle is traced and tagged from the raw ore coming in from all corners of the world and from many of the States through the steel and aluminum mills, to the fabrication plants, into the completed panels and components. At every stage, no matter how remote, material for Apollo is given special care. The part makes its presence felt. The men who handle it, know its destiny.

More than 2500 miles from the modules taking shape in California, an engineer in Carpenter Steel, Reading, Penna., speaking of metal destined for module components, said, "Never before has the need for predictable results in the making of specialty steel been so great . . . we know exactly where we stand in quality at every minute of production."

And in the plains of mid-America



Thousands of individual efforts, woven into bigger efforts, are responsible for Apollo. Top photo, Perry Mosely, technician at the Tulsa, Okla., facility, fashions cover for use on big Apollo adapter, background. Opposite page, technicians at Space Division, Downey, prepare moon module for first component installation. Lower photo, Eleanor Coronado, foreground, assembles with microscopic precision sensor for use in Apollo.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DO NOT ROTATE OVER
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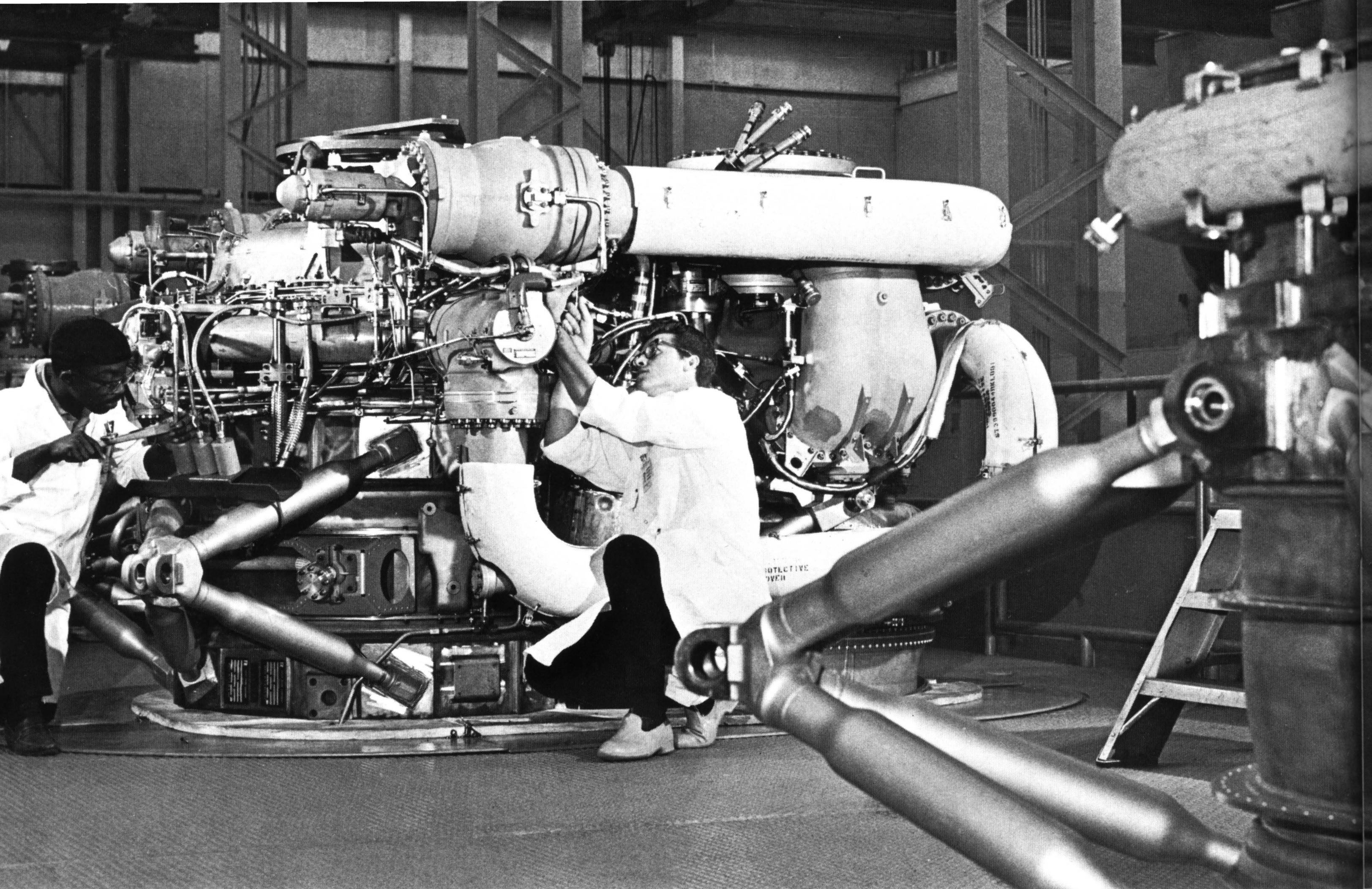

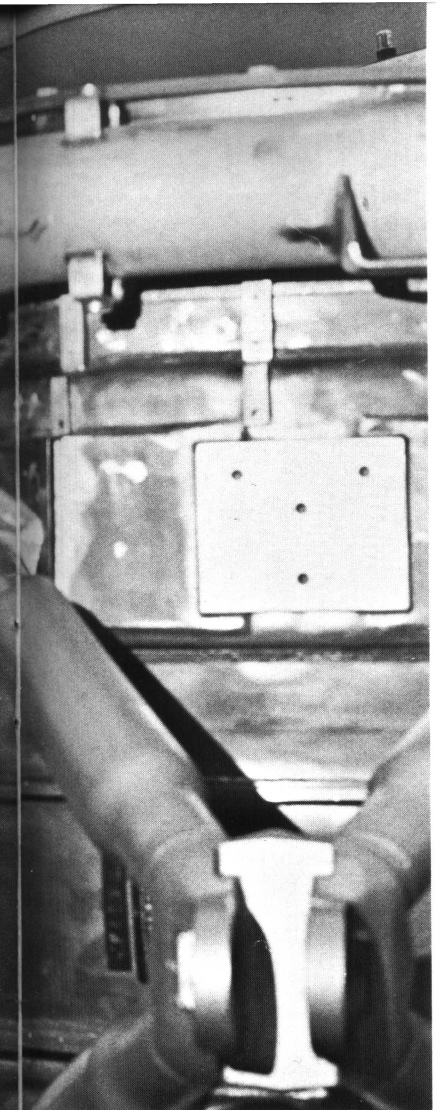

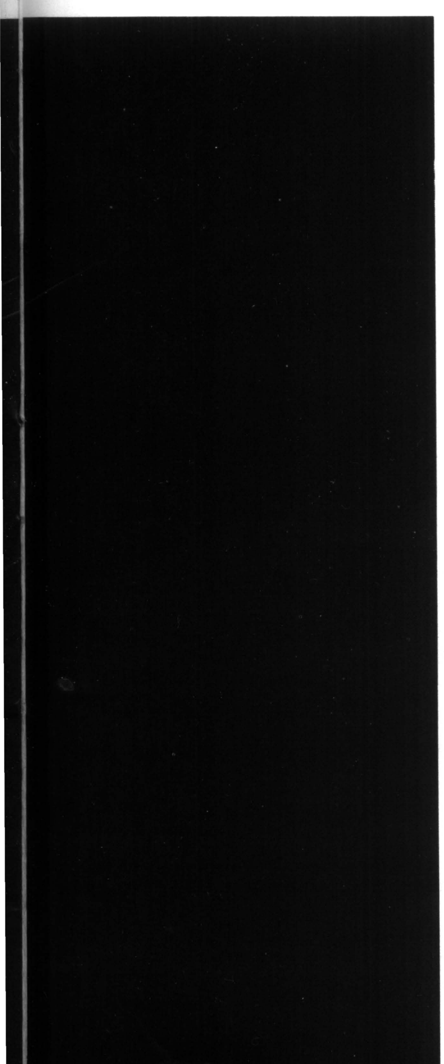

in the Tulsa facility where panels for the Apollo-supporting service module are formed, a supervisor pointed to a sheet of metal proudly. "We processed that panel with no defects. It was an extremely complex component to bond because of its conical shape and the many metal-to-metal bonds required." Then he lapsed for a moment from his careful engineering phrasing. "The shape of it, the different areas of bonding, made it rougher than hell." In a final burst of realism he said candidly, "Bonding that panel required a great deal of care, patience, and skill. If the men didn't have all three of them, they wouldn't get it together."

One of the technicians spoke up, "Sure, it's the service module we're working on, but any part of the Apollo 4 means a chunk of the manned space program. Even if it is only a service module panel. One can't work without the other."

Trying to call out every person who helped shape the metal of moon hardware is an impossibility, just as it is impossible to single out the individuals responsible for the victorious armies of World War II.

Only the large outlines of big organizations are apparent. The vast majority of tireless individual contributions are engulfed in the gigantic span of endeavors. At Mississippi Test Facility, where the S-II second-stage booster is readied for its Apollo-lifting chore, it is not unusual for an engineer whose system is being checked to stand by 22, even 24 hours. One of them said, "When we got that stage on the barge heading for Florida, I went home and died. I slept 12 hours straight through." In a driving routine to keep his part of the Saturn S-II vehicle on schedule, the engineer rose every morning at 5 a.m. at his home in Picayune, left home at 6 a.m. and stayed with "the bird" until 8 and 9 o'clock each night.

It was of him, and others like him that Chuck Allen, Space Division's director of Mississippi Test Facility activities, said, "The exacting and demanding requirements of a Saturn S-II test have meant many personal sacrifices by members of our team. We particularly thank the families behind our personnel who have tolerated their absence from home in order to get this job done."

The individuals come to the fore only by chance, or by the slenderizing, upward thrust of passing milestones and accumulated events. In the shifting spotlight is a thin line of soldiers on the front line of battle—a handful of workers who make the final adjustments in the moments before launch.

The slenderizing, upward thrust. In the Space Division's facilities in Downey, California, about 4000 employees are involved in the Apollo command and service modules during the 70 weeks of effort as a module takes its shape from raw metal to conical form. When the stripped, unadorned module moves over from preliminary manufacturing to the final 48 weeks of assembly and checkout of systems in the aseptic atmosphere of Building 290, one of the nation's largest clean rooms, only 800 test people, Quality Control inspectors, and engineers, on three shifts, have direct access to the modules under assembly.

Necessary Changes, Modifications

Apollo is a research and development effort. Changes, modifications are a necessary routine. Even after shipment of the spacecraft to Kennedy Space Center in Florida, Space Division employees still shepherd the moon-bound vehicle. About 800 are involved in the spacecraft and Saturn second-stage effort in Florida, backed up by 580 supporting personnel. Yet of these, those who work directly within the module during the three-month launch preparation number just 50 technicians, 20 Quality Control inspectors, and 25 engineers. When the module moves from the Operations Bldg. to the launch pad, the same teams follow it.

It is in the brief period before launch that the final slenderizing effect takes place. Working with NASA engineers, only a score of Space Division technicians are in direct touch with the spacecraft on the launch pad. They are the final representatives, the final symbol of hundreds of thousands of American workmen, the thin forward line at the battlefront.

Who builds for Apollo? The names of those on the front lines, those who were cited for bravery during the fire in Florida come readily:

Al Journey, Bill Schneider, John McConnell, Will Medcalf, Scotty Scott, W. D. Brown, Dave Howard, Higgie Hickenbottem, L. D. Reece, Jerry Hawkins, Steve Clemmons, Jim Gleaves, Don Babbitt, Bill Wingfield, George Rackleff, Dick Bachand, Burt Belt, Bob Foster, Jesse Owens, Bob Hedlund and Bruce Davis.

But behind them stretching north to New Hampshire and westward to the Pacific are 300,000 others.

Top photo, exacting demands of designers are woven into final product, F-1 booster engine, by Rocketdyne assemblers Art Bogan, left, Ross Clyborne. Lower photo, end point of all the care and preparation comes with launch preparation by Space Division employees at Kennedy Space Center, Fla.

Cluster of five J-2 liquid hydrogen engines, power plant for the Apollo 4 second stage, prior to test at Rocketdyne's Santa Susana facility.