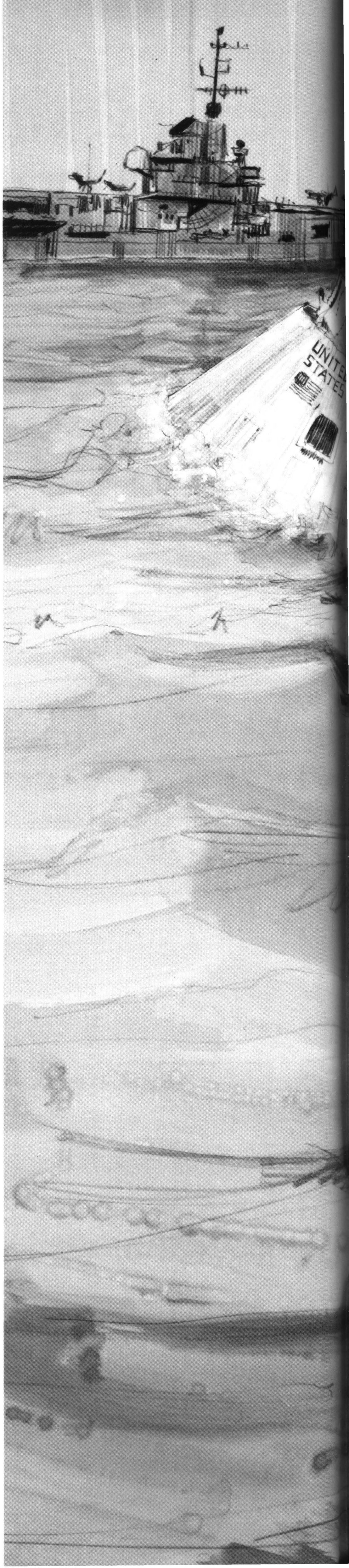
LIFT IT UP TENDERLY



Following splashdown, Apollo 4 is dissected by NASA and Space Division post flight evaluation teams.

By L. B. TAYLOR, JR.

Gunther Schurr leaned over the railing on the hangar deck of the carrier USS *Bennington* and squinted into the horizon at a faint object, bobbing above the sea swells several miles off. Schurr, a physicist-engineer with Space Division's Flight Technology group, was aboard ship to get an on-the-spot look at the Apollo 4 command module following its history-setting eight hour and 37 minute flight November 9, 1967, that exceeded even the most optimistic expectations for success. A specialist in thermal control, he wanted to see how well the spacecraft had withstood the roasting of entry through a narrow corridor into the Earth's atmosphere closely similar to the one American astronauts will take upon their return from the first manned lunar landing.

As the *Bennington* maneuvered in for the recovery, Schurr's first impression of what he saw caused gnawing apprehensions. "The side facing the ship" he recalls, "was not blackened, and I thought it must not have gone through the expected entry temperatures." But as the carrier's powerful crane began to hoist spacecraft 017, his fears quickly disappeared. The other half of the command module and the entire bottom of the aft heat shield were scorched black.

Foam Cushion Protection

After Apollo 4, dripping sea water, was cradled in its specially designed dolly on a protective cushion of eight foam rubber pads, Schurr and Larry Williams and Jim Pavlosky of NASA, got a first look at it on the ship's elevator.

"I estimated we had lost around two-tenths of an inch of ablative material at the hottest spot," Schurr says. "This is about what we had expected, what we had predicted. In fact, though I thought there might have been more surface recession."

Even from this cursory inspection, the men determined 017 appeared to have met its heat shield objectives under lunar reentry conditions. Thus began, for teams of NASA and North American Rockwell engineers and technicians—members of a post recovery evaluation task force—the delicate, critical job of inspecting, examining, testing, dissecting and analyzing 017's vital organs. For the next several weeks, long after the flight headlines had died, they performed, in essence, a complete autopsy on the command module.

There are three ways to ascertain perfection in space vehicle performance. One is visual, through a flawless liftoff and a pin-point splashdown into the ocean.

Another is through reading of the telemetered data gushing back from the module as it streams about in space.

The third is through a surgical operation, slicing up the returned module, putting the pieces under a microscope, and verifying the perfection.

Preliminary Data

Preliminary mission data strongly indicated there was nothing basically wrong with the spacecraft or its behavior. But this had to be verified through detailed post-flight analysis of all systems. Nothing could be left to chance. If some component doesn't measure up to standard, reasons have to be found and corrective action taken. Every minute deviation from normal has to be checked. If an instrument, no matter how inconsequential to the overall mission, gives an abnormal reading, it must be inspected to see if the information actually was abnormal, or if the instrument itself was faulty. Results of such investigations can be used to advantage on future spacecraft flights. It might necessitate a minor modification, or a major design change, depending upon the significance of what was found and how it might affect upcoming missions.

Aboard the *Bennington*, 017 was nestled in its dolly, and under a 15-man NASA team captained by recovery leader John Stonesifer, post-flight inspection procedures were begun. Working from a half-inch-thick, blue-covered post retrieval manual, in sort of a countdown in reverse, engineers removed the outer hatch. Before the inner hatch was opened, however, they sampled the cabin air through a fitting.

Next, in order, came: inner hatch removal; readings of panels and switch positions; shutdown of systems; command module interior inspection; and removal of vapor sensitive tapes, which record any hypergolic fuel or oxidizer fumes inside the cabin. The NASA team found a small amount of sea water, perhaps two quarts, inside the spacecraft. It entered through an Environmental Control System (ECS) cabin pressure relief valve. Actually there were also about 50 pounds of water in the cavities between the heat shields and the CM's shell, as was anticipated.

Engineers entered the module and took out data storage equipment, the flight qualification tape recorder and the camera. The tapes carried vital information of spacecraft performance, including the highly important entry phase of the mission. The recorder and camera were carefully packaged and flown from the carrier to Hawaii and then to Houston for analyses.

Post retrieval procedures carried on, methodically, into the night. Ticked off, item by item were: inspections of the command module exterior, the ECS, and the uprighting system; pyrotechnic inspection; apex cover inspection; inspection and stowage of two antennas and the flashing light; post landing vent system valve test. By 11 p.m., work aboard the *Bennington* was closed out.

Pearl Harbor Arrival

At 10 a.m. sharp, Nov. 11, the ship tied up in Pearl Harbor, and the spacecraft was offloaded. Standing by, with NASA representatives Roderick S. Bass and John K. Hirasaki, were two teams of Space Division personnel under the leadership of George Blanchette, test project engineer for post recovery operations. Each team included a Reaction Control System (RCS) engineer, an electrical engineer, and three technicians. Also at Pearl was SD's Howard Spencer, an RCS specialist and a key member of the landing/safing unit. Working 12-hour shifts for the next two and a half days, the men first inspected the entire CM, again, then disarmed and safed the onboard ordnance devices which were not expended during the mission.

Next, they systematically deactivated 017's RCS fuel and oxidizer lines, flushing out residual propellants left in lines and tanks. The hypergolics that hadn't been consumed in flight were burned on the chute descent. With the safing and cleansing operations completed, the spacecraft was loaded aboard an Air Force C-133B and flown to California. Blanchette and his teams followed.

On Nov. 16, a week after its flight, 017 was the subject of a press conference in Space Division's Bldg. 247, a scant quarter of a mile from where it had been finally assembled, tested and checked out, in Bldg. 290, in the nation's largest known clean room. Barely had the cameras stopped grinding and the reporters finished taking notes, when SD engineers and technicians approached the blackened module to begin preparations for removal of its major components for analysis and evaluation.

Nation-wide Inspection

Though the work was essentially done under the direction of Blanchette, project engineer Dick Brundin, flight evaluation engineer Paul McMillan, and Harry Peck, NASA's resident Apollo project officer, components of Apollo 4 were shipped to other laboratories and offices at Space Division, to Rocketdyne, Atomics International, Autonetics and the Los Angeles Division, to NASA's Manned Spacecraft Center, and to component manufacturers across the country.

Most of the dismantling and hard core inspections fell under what Brundin calls "baseline testing." Space Division had 35 days from delivery of the spacecraft at Downey to complete its input into the flight mission report.

"Basically, we divided the operations into phases I and II," Blanchette, an 11-year North American veteran, explained. "Phase I included all routine requirements given us by NASA. Phase II involved any additional test needs that developed from results of the flight itself."

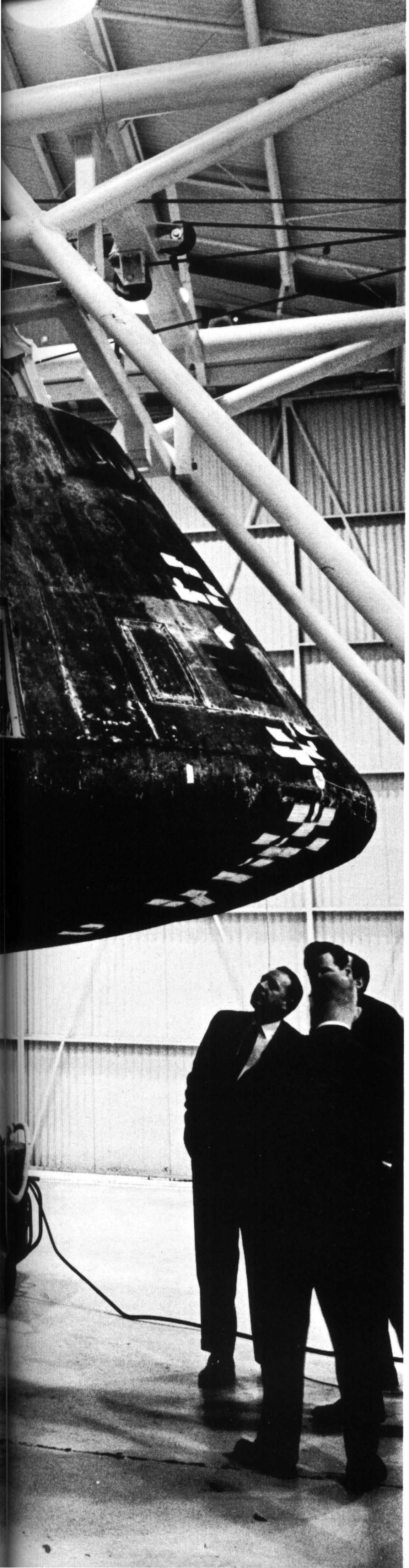
The work began, as it had on the *Bennington* and in Hawaii, with yet another inspection of 017. It was then photographed from all angles while its systems were still intact. A check was made of the RCS to insure there were no lingering hypergolic fumes. Then, ordnance items were removed.

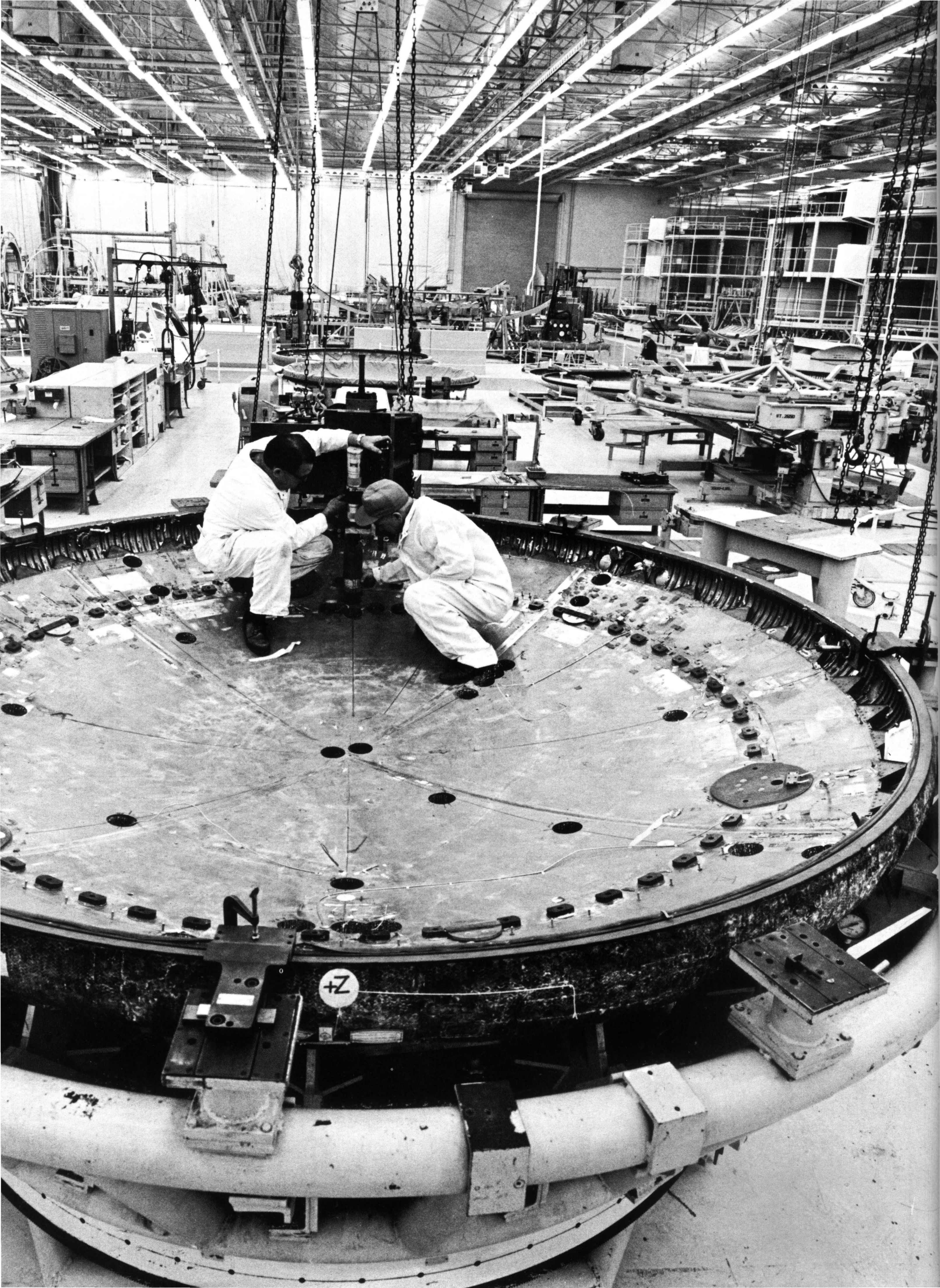
Meticulously running down a lengthy requirements list, Blanchette's crews began the testing activities. Items included battery and platform removal; wiring inspection; structural damage survey; simulated unified hatch assessment. The list covered several dozen separate functions.

Cradled securely in a special rig inside Building 247 at Downey, the Apollo 4 command module is thoroughly inspected before components are removed for analysis.

Far right, above, engineer Chuck Smith holds light stick as he examines network of wiring inside spacecraft, and cameraman shoots documentary photos of the interior.

Technician Ossie Reid, far right, makes line hookup for purging of Apollo 4's reaction control system (RCS) to flush any lingering traces of residual hypergolic propellants.

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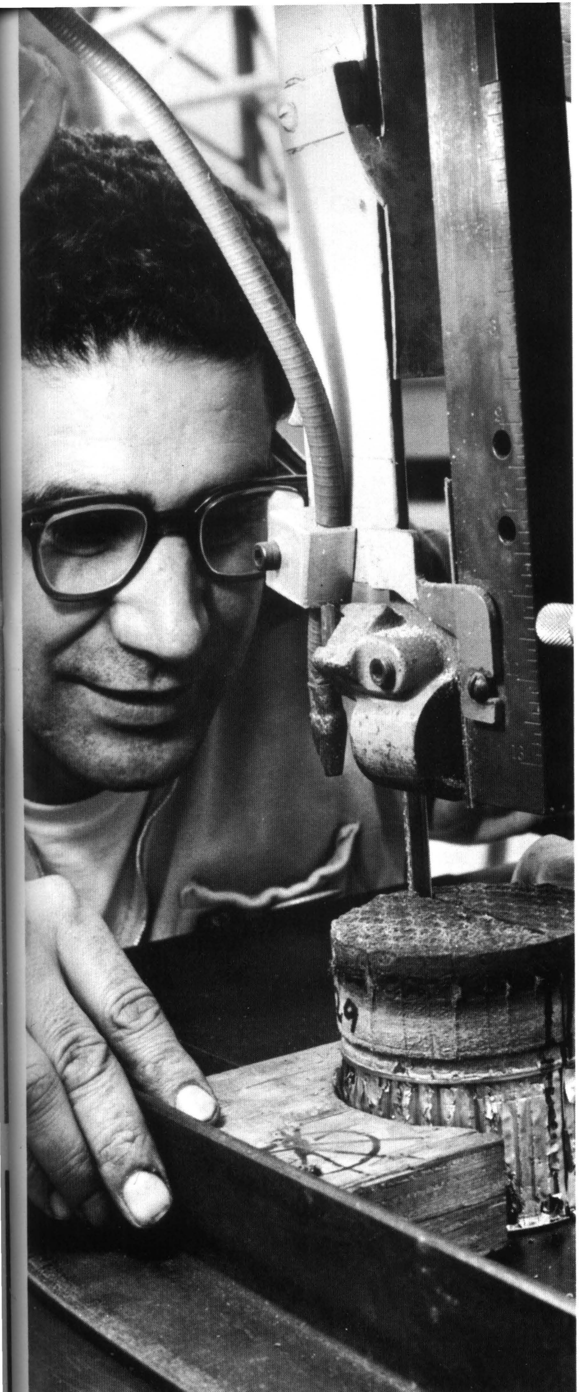


Apollo 4's outer coats—the aft and crew compartment heat shields—were carefully taken off, exposing a shiny, copper-colored shell, surrounded by miles of tightly wound wires and tubing. One of the primary mission purposes was to test resistance of these shields to the fiery Earth entry temperatures, which exceeded 5000 degrees F. They were transferred to Dept. 665, where Manufacturing personnel drilled 32 core samplings from the aft shield and five from the crew compartment, giving them the appearance, as one shop worker observed, of "great round hunks of Swiss cheese." Borings were made near instrument locations, where measurements were recorded, so more precise data could be gained through calibration and analysis.

Triple Surveillance

Each core, three and a half inches in diameter, and varying in length, depending upon the thickness of the char layer, was then sawed into two equal parts. Half of all the samples were sent to MSC, where NASA ran spot checks on some, sent others to the Avco Corp. in Wilmington, Mass., manufacturer of the ablative entry heat shield. The other half of the cores stayed in house. They are still undergoing chemical and mechanical analysis in Space Division laboratories, to determine, essentially, the density, depth and composition of char.

Four outside windows on the spacecraft were sent to Atomics International for extensive light transmission tests. The remaining four windows were sent to MSC for testing. Scanning the visible range from near infrared to near ultra violet with a spectrometer, engineers sought to find how much visibility was lost in flight. Through the process of spectroscopy, they also determined the mineral content of contamination that formed on the windows. They did this by placing a small sample of the contamination on a piece of mineral-free paper, then applying a hot spark to ignite it. From the burning, they learned the mineral content. Later, AI personnel tested contamination particles for their organic composition.

From AI, the windows went to the Los Angeles Division's Bldg. 261 where they were measured with spectrophotometers — to check the degree of degradation in light transmission encountered during flight; i.e. to see how much was reflected and how much was absorbed by the windows. It is believed most contamination, perhaps 90%, resulted during the re-entry portion of the mission.

Engineer Roger Otos said astronauts would have had only about 25% visibility out of the windows at splashdown.

Following the work at LAD, the windows were cleaned with choloroform, to cut the organic solubles, and with distilled water, to wash off the water solubles. They were then sent back to Downey for bonded storage.

The automatic controller that flew in the command module was sent to Autonetics. This actually is a Mission Control Programmer that, to an extent, performs functions normally carried out by an astronaut on a manned flight, such as turning on switches and starting sequencing systems. Says Space Division's Bill Paxton, "There are three main packages in the programmer and all worked beautifully in flight." These included the spacecraft command controller, the ground command controller and the attitude and deceleration sensor. All three packages were farmed out to Autonetics' Electro Sensor Systems division for functional redundancy testing, and passed, Paxton said, "with flying colors."

Other "black box" systems checked included the Mission Events Sequence Controller where some minor malfunctions were detected during flight. These also went to Autonetics where the boxes were torn down to find the cause of the failures. Additionally, tests were run on the Pyrotechnic Continuity Verification Box at Space Division, and on the Earth Landing Sequence Controllers at Northrup Ventura. These performed flawlessly in flight and in the post evaluation followups.

Back to Milwaukee

The 460-pound guidance and navigation system was removed from 017's lower equipment bay and flown back to its point of manufacture — the A. C. Electronics Division of General Motors in Milwaukee, Wis. Essentially, they wanted to examine the G & N's erasible memory content of its computer and compare its data with known flight trajectory measurements. The entire system did its job well in space, yet there were a couple of faulty measurements in the pulsed integrating pendulus accelerometers during Apollo 4's countdown. Though the read-

Atop pizza-shaped aft heat shield, far left, Manufacturing personnel drill 32 core samplings for detailed laboratory analysis.

Each core sampling, left above, is sawed in two. Half of all cores are sent to Houston, remaining halves stay inhouse.

Left, core's ablative material includes black char layer from fiery entry. Brazed steel honeycomb substructure is at left.

ings were not in themselves enough to halt the mission, part of the post-flight evaluation was to find the reasons why they were not within design specifications.

Several components of the spacecraft, including parts of the Mission Control Programmer, were refurbished following their tests and used as spares for command module 020, atop Apollo 6, the second Saturn V space vehicle.

Reaction Control System engines—two roll and two yaw engines—were taken to Rocketdyne. There, in the Small Engine division, they were sectioned and analyzed. Primary objective was to check effects of entry heat flux on the RCS engines. Also, the two yaw engines had leakage rates over that planned, and causes for this had to be found. Overall, however, the engines fared well despite their exposure to temperatures of extreme heat.

Parachute Inspection

Parachutes, including one main chute, the first recovered from space in the Apollo program, were forwarded to prime vendor Northrop Ventura. Later, they were sent to Houston. MSC also asked Downey to ship them some "cold plates" —machine parts with bond skin over the top, through which water glycol is piped to cool electronic components that heat up in flight. Though these had not malfunctioned, NASA engineers wanted to check them for corrosion and other effects.

The Environmental Control Unit (ECU) was not removed. The one in spacecraft 011 had been sent to Air Research, the prime ECU contractor, but the system's performance on 017 was so smooth there was no need to repeat a detailed evaluation. Some instrumentation was pulled, however, for Space Division lab testing and calibration, including a cabin pressure transducer and temperature sensors in the water glycol system. Houston also asked for some armored sleeves (joints) on ECS lines that had been installed at the Kennedy Space Center in Florida. These had also worked well, but NASA wanted to pressure test and analyze them.

Throughout the inspecting, checking, testing and removal of equipment in Bldg. 247 and at other sites, a running log was kept. Daily activity reports were made on work progress, and an engineering summary report was filed for each test conducted.

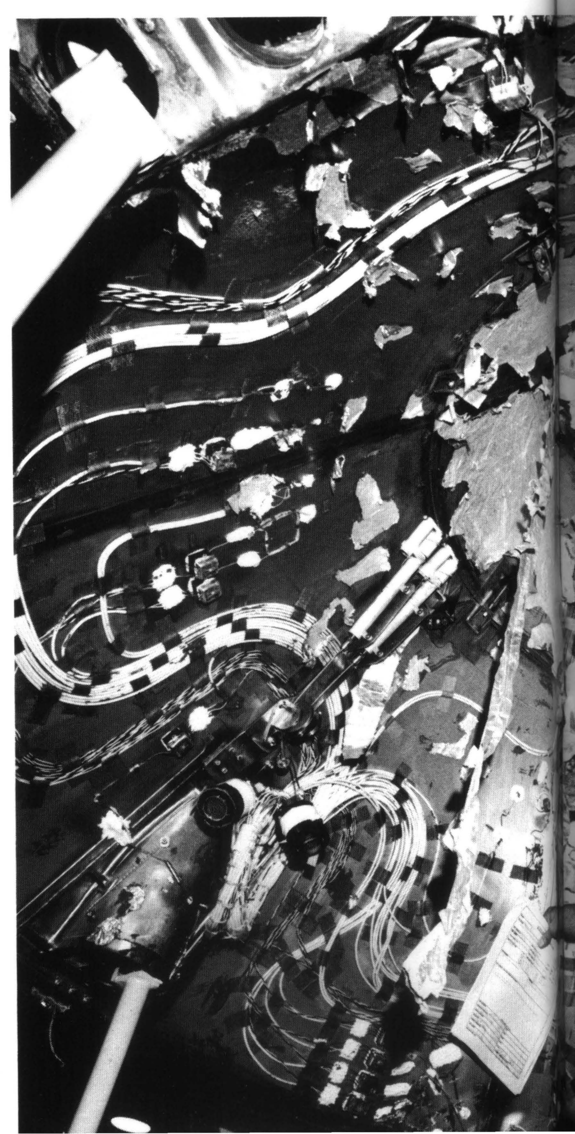
Brundin said that preliminary results from the weeks of intensive testing have produced no major problem areas. "I guess you'd have to say our research hasn't turned up anything dramatic, and we almost completely disassembled 017. But this just further proves the overall integrity of the basic design."

Though the spacecraft was turned over to Ben Bolger, Logistics representative, Jan. 12, for storage, after testing had been completed, work continues at various laboratories throughout the nation. Detailed chemical analysis of the aft heat shield core samplings at Space Division, for instance, will take several months, as scientists probe ever deeper into the mysteries of space and and its effects on man-made machines.

But from documentation already tabulated, officials can proceed to the next steps in the manned space flight program confident that 017 performed well and produced no major "anomalies," as engineers term them, during the exhaustive post evaluation tests. Apollo 4 was under the microscope for weeks. Now, with the autopsy virtually complete, final verification of its near-perfect performance has been duly recorded, establishing a historical milestone of unprecedented achievement.

World-Wide Display?

What will be its final fate? If its two predecessors set any precedents, 017 will come to a glorious end. Spacecraft 009 was cleaned up and sent to the Paris Air Show. Number 011 was a star performer at the World's Fair in Montreal. Perhaps 017 will make it to the Smithsonian Institute, or even more fitting, it may go on a triumphant world tour—this time at ground level. That is, all except the Mission Control Programmer's spacecraft command controller. When a problem occurred in this system on 020 at the Kennedy Space Center in late December, a replacement had to be found—quick. The controller in 017 had performed so well and was in such good condition, it was flown to Florida, after thorough refurbishing and retesting, installed in Apollo 6, and was scheduled to fly again!

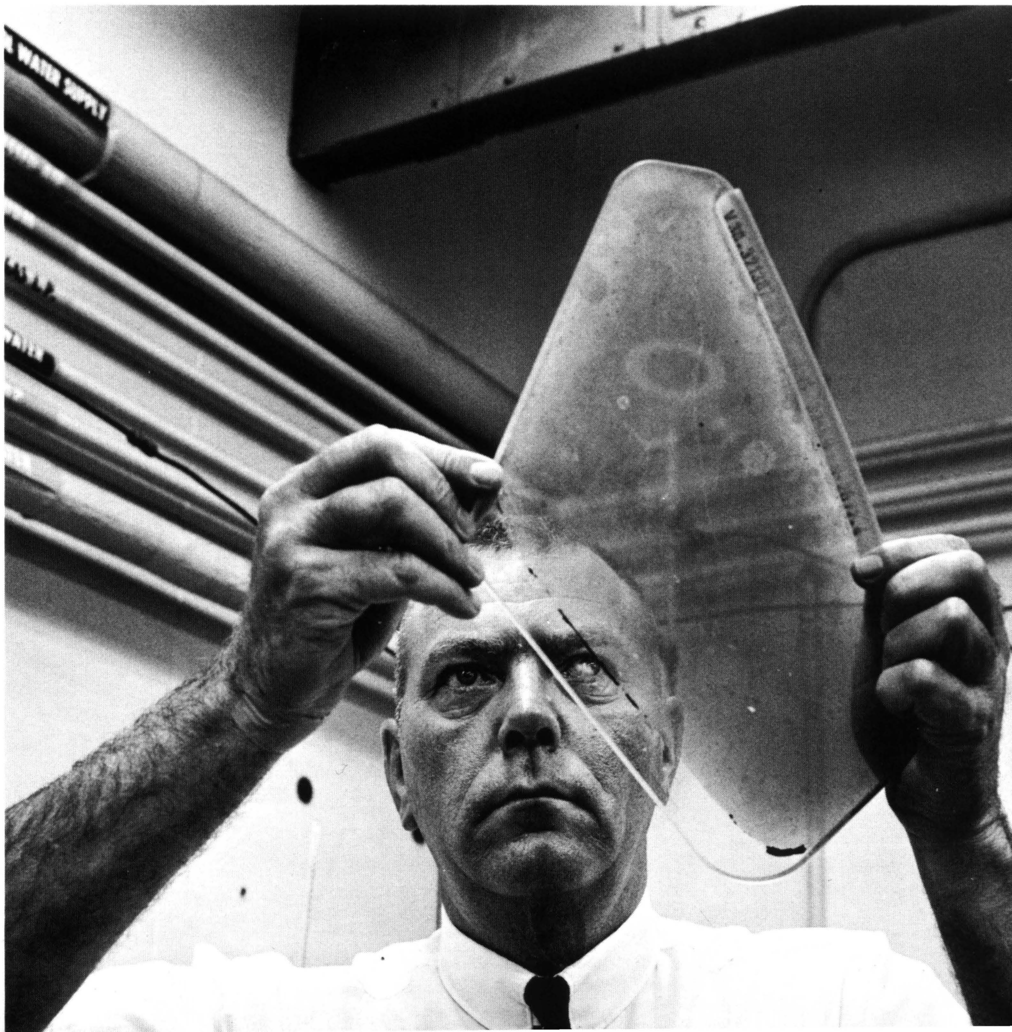


Daily status meetings, right above, on post-evaluation progress were held in a room next to the spacecraft. Left to right are B. B. Bolger, R. M. Dela, project engineer Dick Brundin, test project engineer for post recovery operations George Blanchette, and test conductors J. P. Michaels and H. R. Voleker. Missing regulars are flight evaluation engineer Paul McMillan and NASA's Harry Peck, resident Apollo project officer.

Inside cluster of instrumentation, wires and foil on the spacecraft's inner shell, left, an engineer methodically runs down check list.

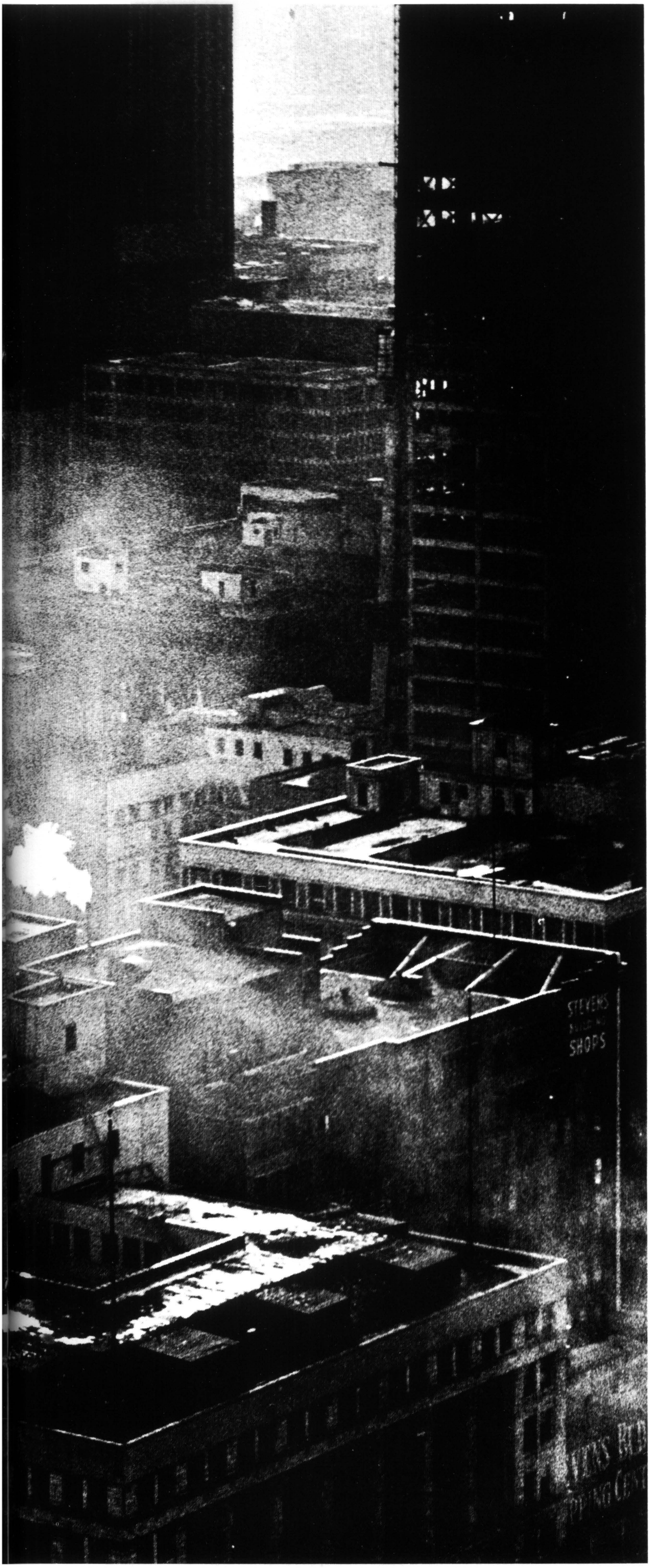
Eyeing clouded haze of contamination, right, on one of command module windows removed for analysis is engineer Roger Otos.


GRID LOC. S97-E171
Schedule for Mon 27Nov.
Window Removal


WATER SUPPLY

APOLLO: the strength of a nation

By EDWARD A. HERRON



The nation's major industries have been strengthened by participation in the National Aeronautics and Space Administration's man-to-the-moon project.

It's a nice, tidy statement, and very true, but how do you prove it?

The measure of strength in the nation's industry, unless one is content with statistics on car loadings and steel tonnage, is elusive. The steady rise of the gross national product looms like a Rock of Gibraltar, but for most people it is incomprehensible.

Industrial strength can be gauged by the men who help guide the destinies of major companies involved in the space effort.

Richard T. Baseler, vice-president, Engineering, Pratt & Whitney Aircraft division of United Aircraft Corp., said flatly, "There's no question but that our participation in the NASA space program has been invaluable to P&WA. The knowledge we've gained, specifically from the Apollo fuel cell contract, has enabled us to move into other new and advanced areas, including some commercial possibilities."

P&WA has developed the fuel cells under subcontract to North American Rockwell's Space Division. There are three of the cells located in the service module. In simplest terms, the fuel cells, something fairly new on the American industrial scene, convert oxygen and hydrogen into usable electrical current with an added bonus of pure drinking water. To replace the fuel cells with conventional lead-cell batteries would add an unacceptable weight to the 14-day Apollo moon mission.

Baseler sketched with his fingers on the green pad of his desk as he recounted the P&WA experience.

"That seven years of concentrated effort for NASA has encouraged us to explore the fuel cell principle even further. We're spending several million dollars each year to investigate possible applications for industrial and commercial usage. For example, there is a possible place for fuel cells in some of the oceanographic applications. In the long-time undersea living quarters now being studied there is need to convert fuel into energy with as little machinery and space as possible.

"We're actively linked by contract to a group of 28 natural gas companies throughout the country investigating the possibility of developing "on-the-spot" gas-fueled sources of electrical energy for homes, apartments, and businesses. The fuel cell would be the basis for a powerplant that would be economically competitive, silent, and smokeless.

"We're out of the laboratory with the concept. We've got hardware, and we have demonstrated technical feasibility.

Major Evolution

"That one line of endeavor alone would be a major evolution from our NASA work, but there are many other avenues we're actively investigating—oceanography applications that I mentioned before, small units for the Army and for industrial use, any place where we can offer a source of electricity, independently operated, supplanting the need for heavy, cumbersome batteries."

Baseler leaned back in his chair and said with a quiet finality, "If it hadn't been for our space effort P&WA wouldn't be grappling with this exciting fuel cell development today.

"It's opening up avenues that had not been envisioned by P&WA ten years ago. It holds promise for a significantly different line of business in the future."

The opening up of new avenues for company exploration isn't the only type of strengthening that has been achieved. Maj. Gen. Don R. Ostrander, vice-president, Planning, for Textron's Bell Aerosystems at Niagara Falls, N.Y., said, "It's almost like a process of osmosis, things you sometimes can't see in black and white. Maybe a new material, some new trick in fabrication,

"The knowledge we've gained has permitted us to move into other new and advanced areas, including some commercial possibilities."

Richard T. Baseler, vice-president, Engineering, P&WA, Hartford, Conn.

"If we focused on increased reliability alone as it may apply to commercial products, the potential savings to consumers are staggering."

Irving Kessler, vice-president, RCA Defense Electronics Products, Moorestown, N. J.

some new approach in production that consciously or unconsciously the company applies to other products.

"A great deal that we have learned through our NASA space efforts, not only the ascent engine we're developing for the lunar module and the score or more titanium tanks we're providing to North American Rockwell's Space Division for use in the Apollo command and service modules, has filtered through the company in this osmosis-type transfer.

"We might be hard put to point a finger at it, but it is there. We've had problems with our space projects, and we've solved them, and I'm sure Bell Aerosystems has emerged a lot stronger because of our participation. And not only we here at Bell. I'm equally convinced that American industry is doing a better job in their other products because of space effort activity—and perhaps without even being aware of it. The end result, and I'm firm on this—has been better products from many companies, and for lower prices.

"It might be difficult to prove, but that's my observation. It's based on the knowledge that every participating company in the space effort has been forced through a new and a very fine sieve of quality control and reliability. It's inevitable that product betterment would be the result."

RCA has devised for the Apollo module a four and one-half pound television camera that contrasts strongly with the conventional 200-pound camera used in commercial studios. In addition, it has devised a 56-pound portable color camera, a complete broadcasting system in itself. Both units are remarkable achievements that will have a profound influence on the miniaturization of future television equipment.

RCA Experience

But it was not that technical feat that occupied the thoughts of Irving Kessler, division vice-president of RCA's Defense Electronics Products.

Kessler is vigorous, outspoken, typical "young-man-in-charge." The question was put to him, "NASA has spent nearly 30 billion dollars on the space effort—what has that meant to American industry aside from 'making things'?"

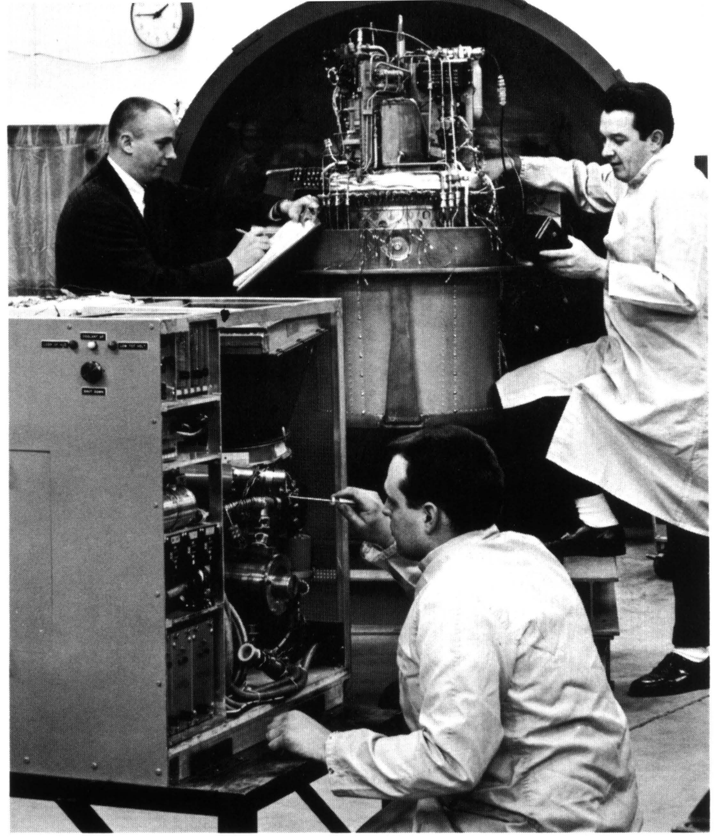
His answer was direct and forceful. "It's meant a major advance in the state of the electronics art that will be felt in all sectors of the American economy. Specifically, the space program has built an entire industry complete with all its supporting functions. Today we in the industry can produce small, lightweight, equipment to a degree that would be unthinkable without the assist we gained from the space program."

Kessler was asked, "All these things you've mentioned—smaller, lightweight units, higher reliability—wouldn't they have been developed as a natural industrial evolution even without the space effort?"

"In time, perhaps," he agreed, "but at an equal or greater national investment. What people do not realize," he continued, "is that any technology must have a supporting service. Our auto industry couldn't exist without good roads, service stations, traffic lights, and so on. The same holds true for the technology developed through the space effort—no one company, nor group of companies, could possibly have evolved the tremendous supporting services that have paved the way for the push into space.

"We've developed entirely new items and management techniques that have crept over from the space side of the house here at RCA to the commercial side. Maybe it's a kind of serendipity that was never intended, but it has happened.

"We've made tremendous strides in reliability, at least in an order of magnitude. If we focus on increased reliability alone as it may apply to commercial products, the potential savings are staggering.



At P&WA, a compact, self-contained power plant, foreground, suitable for all energy needs of individual homes, apartments, stems directly from company's development of Apollo fuel cells, rear.

At RCA, development of a 56-pound portable color camera, suitable for use on moon surface, is an achievement expected to have profound influence on miniaturization of future television equipment.

"Every participating company in the space effort has been forced through a new and very fine sieve of quality control and reliability. It's inevitable that product betterment would be the result."

Maj. Gen. Don R. Ostrander, vice-president, Planning. Textron Bell Aerosystems, Niagara Falls, New York.

"Unquestionably the entire data processing area has benefited from the space program." He paused and leaned forward to emphasize his words. "It's impossible to give full value to our increased computer technologies alone. Computers are our 'think machines' . . . The nation that can be trained to think for itself, using computer technologies, will acquire an unbeatable edge in world competition."

Smooth, round, delectable, photographical hardware, the much discussed visible "spin-off" from the space effort, is always an item of intense interest. Industry leaders would much rather discuss evolution of new techniques from the space effort into present-day commercial activities. However it is apparent there have been remarkable applications.

AC Electronics, division of General Motors, Milwaukee, Wis., provides the guidance and navigation systems for both the Apollo command module and the lunar module under prime contract to Manned Spacecraft Center at Houston, Texas.

Dr. James Bell, director of Reliability at AC Electronics, stressed a point. "We can't say that we've gone from a hardware concept of our Apollo effort to the hardware of our Carousel IV, our commercial inertial navigation system." (Carousel IV is AC's automatic inertial navigation system which was selected by the Boeing Co. for use in the gigantic 747, and which has potential for retrofit into all current long-range jets. Some type of autonavigator, whether it be AC Electronic's or another company's is almost a necessity for the new high-speed commercial jets now taking form throughout the world.)

"No," he repeated, "we can't draw a clear black-and-white line from Apollo to Carousel. But the many, many things we learned on Apollo have gone directly into Carousel. The problems we licked on the space project have spared us considerable development time on Carousel. We learned a lot about materials under temperatures and stress that opened the way for this commercial application. We know more about stability, about performance, than we possibly could have acquired without the Apollo effort. Now, when we are asked to look at airline requirements for safety and reliable performance, we have a better background to take care of their stringent demands. We've got a better understanding of quality control; we've learned how to screen out defects.

"Apollo shoved us forward, made us aware of the need for new technologies; it accelerated all our thinking, our research and development techniques. As a result of that concentrated space effort, when the Boeing 747 autonavigator needs appeared, we were ready.

"It's foolish to underestimate the push industry receives from urgent national needs and goals. We saw what World War I did for airplanes. It lifted the airplane from a country-fair attraction to an entirely new concept of warfare and transportation. Look at radar. Before World War II radar was on a slow burner. Then the war rammed the needs for radar up forward and the result has been an entirely new industry, television.

"American industry has always been stimulated by national goals, just as we've been pushed forward by the needs of the moon program. We needed that goal, that timetable, that concerted national effort. No single company, General Electric, General Motors, North American Rockwell, RCA, could possibly have accomplished these tremendous advances working alone."

Invisible Subject

The transfer or the evolution of hardware like autonavigators is sharp and visible; but International Business Machines has made an equally remarkable and still-visible transfer of an invisible subject — technology. An entire IBM scientific team has made the transition from the manufacture and test of the big instrument stage on the Saturn 5 moon vehicle to water pollution monitoring system management.

IBM, under contract to NASA's George C. Marshall Space Flight Center, Huntsville, Ala., is building the instrument unit that clings tightly to the walls of the 22-foot diameter section immediately above the third stage of the mammoth Saturn 5. The tightly packaged section, encompassing 57 different components, is just a portion of IBM's space effort. The busy unit checks all the stages prior to liftoff, provides the final signal to ignite the engines of all stages, and provides the precise timing for all the instrumentation.

Arthur E. Cooper, vice president of IBM's Federal Systems Division and general manager of the division's Space Systems Center, said, "We were pushed to the limit to invent new ideas, new management methods, new techniques, new quality control. We had a running start from our autonavigator work on the XB-70 research aircraft, but normal quality control wasn't enough. We were sampling 100%, checking and rechecking two and three times."

He leaned back in his chair and looked at the ceiling. "If we were to pick out the one item of hardware that has had, or is going to have the most significant impact on IBM activities, I'd say the development for the multi-layer (12 layers) circuit board we developed for both the Gemini and the Saturn effort. The refined, multi-layer board is directly responsible for a great forward step in microminiaturization." He straightened in his chair and leaned forward. "That one item alone has eliminated a rat's nest in electronic packaging. It's increased reliability and ruggedness. It's used heavily in military applications. Right now it's an expensive item, but I'm convinced it's going to become commercially feasible.

"It may happen within five years when we can start coupling this advanced multi-layer circuit board concept with multiple circuits and apply them commercially." He paused. "In fact, in one case, we've already reached the point where the economic hurdle has been overcome, and the system has become feasible. We've applied it in a water pollution monitoring system we're providing for the State of Pennsylvania. Air traffic control is another example where urgent need is bringing these concepts onboard quicker than we had hoped.

"It's fascinating to contemplate the possibilities that are awaiting the circuit application when initial cost and customer needs begin to meet on the graph.

"It's easy for a computer-oriented man to get lost in his own jargon," Cooper said candidly, "but I can state this plainly: out of the space effort, not only here at IBM, but out of all participating industry, have come a lot of new innovations such as teleprocessing, real-time control, sensors, actuators, and many others. They can be used to make our world a happier place in which to live. I know that here at IBM we've begun to put them to work."

Maurice Sciaky, gray-haired, intent, possessed of a colorful accent despite his 30 years residence in the United States, is vice-president of Sciaky Bros., one of the nation's leaders in the building of advanced resistance, electron beam and fusion welding equipment. "We in the welding business," he said, "we do not create the problem. YOU (meaning North American Rockwell's Los Angeles, Rocketdyne and Space Divisions) you present the problems! They stimulate us and make us fanatics to arrive at the solution.

"It was North American that presented us with the extremely tough problem on the Apollo modules, and the F-1 and J-2 engines, and the S-II second stage, and we solved them, and today the entire industry is profiting. It was you who compelled us to design and build very high-precision and miniaturized welding equipment; it was you who compelled us to devise adaptive controls to fusion weld the S-II stage on a tower 300 feet in the air.

"But it's been a very valuable activity for the aerospace industry in general. If we in the welding equipment business have no problems, we have no solutions. We're not going to create a piece of machinery if there is no need for it.

"Out of the space effort, not only here at IBM but out of all participating industry, have come a lot of innovations that can be used to make our world a happier place in which to live."

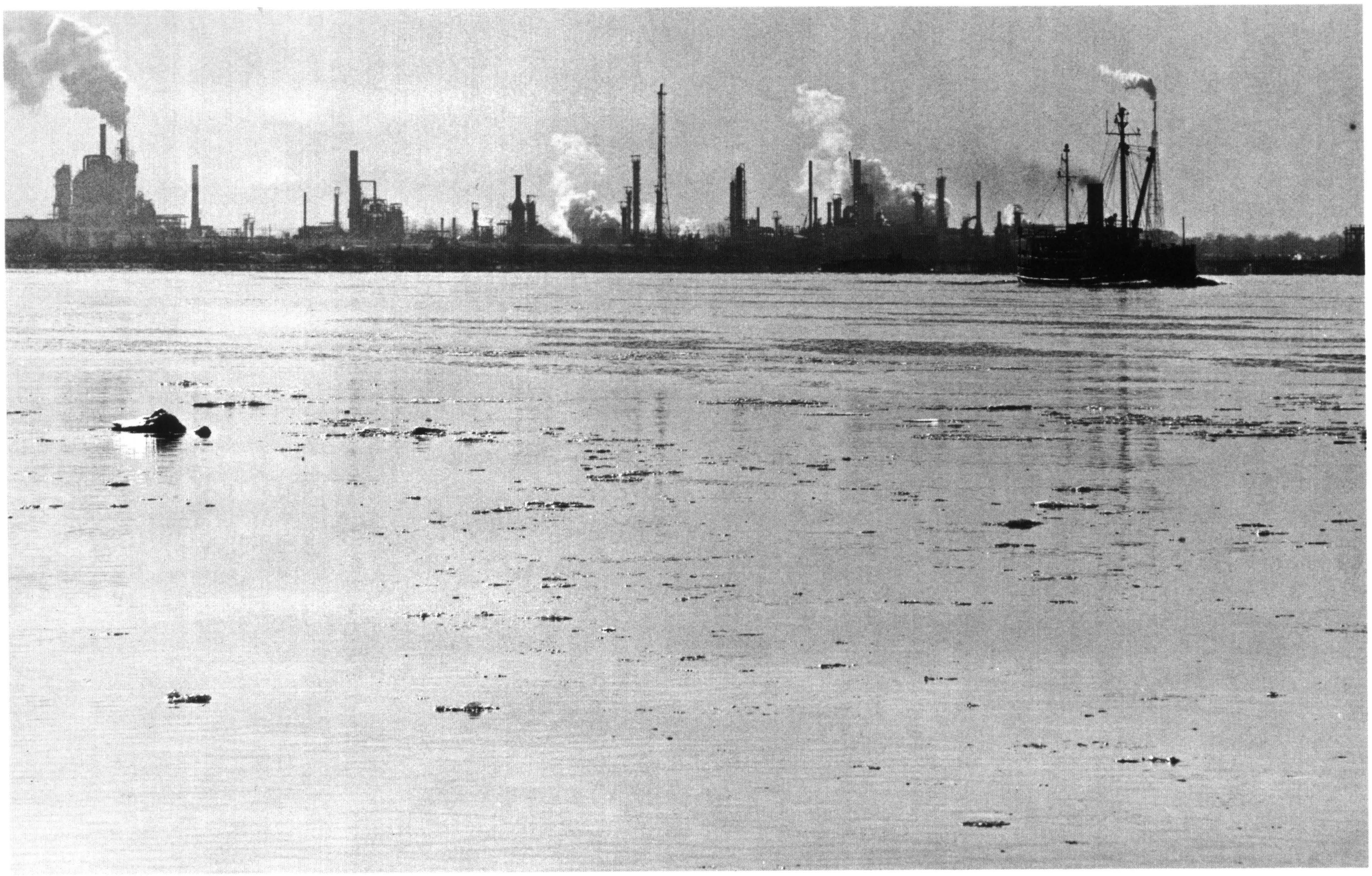
Arthur E. Cooper, vice-president, IBM Federal Systems Division, Gaithersburg, Maryland.

"Apollo shoved us forward, made us aware of the need for new technologies; it accelerated all our thinking, our research and development techniques. It's foolish to underestimate the push industry receives from urgent national needs and goals."

Dr. James Bell, director of Reliability, AC Electronics, Milwaukee, Wisconsin.

"It was North American that presented us with the extremely tough welding problems on the Apollo modules, and the F-1 and J-2 rocket engines, and the S-II Saturn second stage, and we solved them, and today the entire industry is profiting from the solutions."

Maurice Sciacky, vice-president, Sciacky Bros., Chicago, Illinois.



At IBM, an entire scientific team has made the transition from the manufacture and test of the big instrument stage on Saturn 5 vehicle to a State of Pennsylvania water pollution monitoring program.

At AC Electronics, experience gained on Apollo guidance and navigation system, right, prepared the company for development of automatic inertial nav system, left foreground, for gigantic Boeing 747.

"True, the dollar value from the space effort has been small, but it's influence has been far greater than the dollar amount.

"We've upgraded the quality of the entire welding effort. As an example, one avenue is leading us into the beverage industry where we're doing production welding that satisfies the strict requirements in the fabricating of aluminum beer kegs.

"Over in the automotive industry where they've long been acquainted with the usefulness of resistance spot welding, we've developed a profitable fusion substitute, Tungsten Inert Gas spot welding, as a result of space demands. In fact, we've just completed a $600,000 order from an automotive body builder for this welding equipment—T.I.G. spot welders for doors and deck lids, that will finally provide the quality of finished work needed.

"Regularly, we negotiate with leading automotive, appliance, electrical, and other commercial manufacturers on jobs which would have been very difficult for us to do without experience we piled up on the North American space work requirements.

"We expect many more commercial businesses to take advantage of this new equipment that has directly come about because of the space effort. As with any new development, expense and time are important initial considerations, but once produced, the entire metal-working industry can immediately benefit, again and again—and it is."

Dr. Van Bearinger is vice-president of Honeywell, Inc., and general manager of the company's Systems and Research Division. The Minneapolis firm furnishes, under subcontract to North American Rockwell's Space Division, the stabilization and control system which maintains the Apollo spacecraft in all the necessary positions or attitudes during the mission and the

"We were forced into evolving a new philosophy, a new approach, systems management, getting the big picture, solving the big problems, learning how to look at the next level above in order to do a complex job well."

**Dr. Van Bearinger, vice-president, Honeywell, Inc.
Minneapolis, Minnesota**

critical period of re-entry. It was a $125,000,000 venture that employed 1200 people during production.

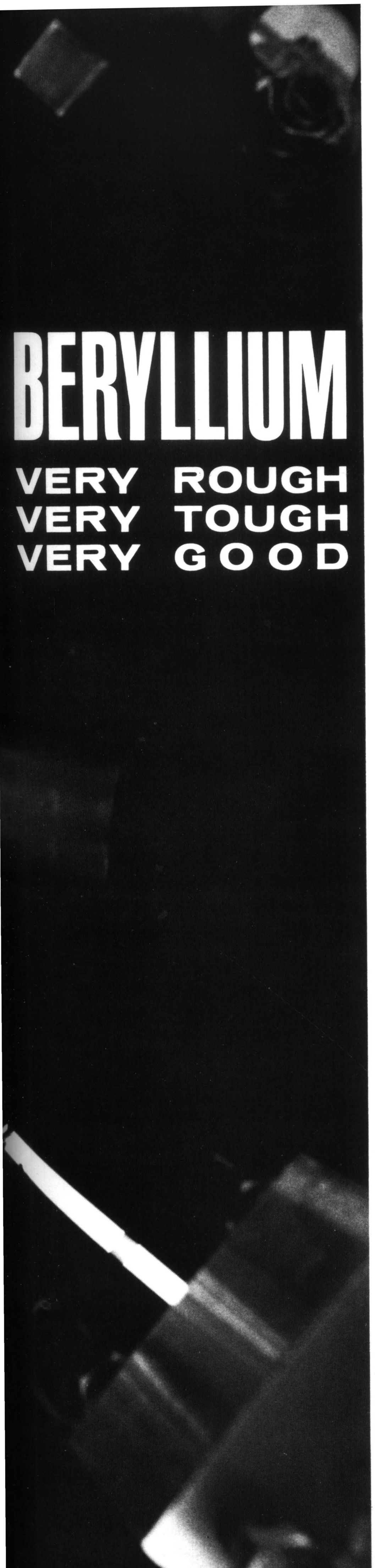
"Quite frankly," Bearinger said, "before we got into the space effort we were a hardware house. But we found it more and more difficult just to sell hardware. We found out, when you go to a customer, that you've got to understand his system in order to show him how your hardware will perform a function in that system. So we were forced into evolving a new philosophy, a new approach, systems management, getting the big picture, solving the big problems, learning how to look at the next level above in order to do a complex job well.

"It was our Apollo effort that brought about the change. We had to interface with many other systems in the spacecraft, all of which had the same problems that we did. We were cheek-to-cheek with navigation systems, scores of sensors, environmental control — myriads of other systems, and all of us meeting on a common parade ground, the on-board computer. None of us could act independently of the other. It was Honeywell's first big excursion into complex interface, and it forced us to develop a system approach, and not just build to specifications.

"It was during that period Honeywell made the transition into a systems management house. We've developed a capability to manage complex systems. That capability led directly to our prime study contract with NASA for the management of the orbital scanner satellite program."

Systems management, perhaps one of the most significant payoffs from the space program, is a word that is going to loom larger and larger in the American economy. It requires a new breed of engineer, one who can think in terms of diversity of technologies and comprehend obscure and often perplexing interrelationships.

Systems management capability, part of the nationtal resource, has been developed through space program efforts at great expense to the American public. Arthur Cooper of IBM acknowledged this when he said, "What greater contribution can we in industry possibly make to the nation than to find ways and means of effectively applying the systems technology and the systems management techniques to help provide solutions to our immediate social needs and to the needs of our future society?"



BERYLLIUM

VERY ROUGH VERY TOUGH VERY GOOD

Metal's Unique Characteristics Have Multiple Applications In Aerospace Industry

Skyrocketing interest in tough, tricky, lightweight beryllium hasn't revolutionized the metal working industry, but it is providing a series of lively skirmishes that are influencing the future course of metal-in-space.

Despite a price tag of roughly $5 an ounce, beryllium is fast becoming one of the aerospace industry's hottest items. Its recent burst of popularity is directly attributed to a unique combination of characteristics: it is only two-thirds the weight of aluminum, yet more rigid than steel, has excellent thermal qualities, and unsurpassed dimensional stability in the metals family. Such qualifications are directly applicable to the future needs of man in his exploitation of space.

Recognizing this vast potential early in the game, North American Rockwell's Aerospace and Systems Group is today one of the largest single users of the metal in the world. Autonetics Division alone has accounted for up to 20% of the annual market to produce more than 5000 precision parts a month. The Los Angeles Division machines some of the largest and most unusual beryllium components ever designed; Rocketdyne is pioneering technology in its use on rocket engines; Space Division is a prime buyer of beryllium sheet metal for spacecraft antenna; and Atomics International has long employed it in the SNAP 8 nuclear reactor.

Advantages Recognized

Though major beryllium producers began operations in the 1930's and the metal was widely used in the 1950's on atomic reactors, it has only been in the past decade that its multiple aerospace advantages have been fully recognized.

Autonetics was one of the nation's first major organizations to explore these new applications. Research studies began there in 1960, and the first actual machining with the difficult-to-handle metal started two years later at the facility in Compton, where the Navigation Systems Products division began producing beryllium gyroscope, accelerometer and structural detail parts for the Minuteman II ICBM guidance system. Before this, Autonetics had been buying semi-finished beryllium products from outside companies.

White-hatted Tommy Thompson works on SNAP 8 nuclear reactor at Atomics International. Pivoting beryllium control elements are mounted around reactor core.

There were some formidable initial problems to overcome. At the head of the list, remembers machine shop General Supervisor Fury Corazza, were people. "There was an early fear of working with the metal because of its toxicity," he says. "There had been quite a bit written about the dangers of beryllium, and a lot was misunderstood." To counter this, a series of safety lectures was held, and strict industrial hygiene and medical controls were instituted in beryllium areas. Also, ample dust control measures were invoked.

Specifically, two processes were initiated—wet and dry machining. On the wet operation a red-colored coolant, combined with de-ionized water, washes the fine dust from a machined piece of metal into a sump. Under the dry method, a high-velocity exhaust system with a suction hose is placed over equipment while beryllium is being drilled, turned or milled. With an air intake velocity of 10,000 feet per minute through this nozzle, tiny chips and dust are vacuumed and carried to a depository outside the building. This waste is later disposed of in sealed containers.

Humidity Control

Further, the precision parts area at Autonetics was enclosed, with temperature maintained at 68 degrees and humidity controlled at 45%. Total volume of shop air within the enclosure is changed once every six minutes. Employees also wear white smocks and clean their shoes on special brush machines before leaving their work area. Equally intensive safety programs have been enacted at other divisions working with beryllium.

With this problem whipped, the next step was actual machining of the metal. This caused more headaches, as both Autonetics and the Los Angeles Division soon found out. "You have to say it's a difficult material to work with," says Stan Seefried, general supervisor of LAD's Beryllium Dept., which was organized in June 1963. "It's relatively brittle, and if it starts to crack you can't salvage it." Actually, beryllium machines much like cast iron. It is very abrasive and quickly dulls cutting edges. "It's just plain hell on tools," Corazza says bluntly. "The secret is to keep sharp cutters on the job."

Steel gray in color, beryllium is a light metal that resembles magnesium in appearance and chemical properties. It is mined principally in Brazil, South Africa and India, but is only one seventh as abundant as tin.

Though beryllium had been machined

for years at various companies across the United States, it is a strange phenomenon that technology gained is not easily passed on to a new user. Representatives of LAD and Autonetics inspected existing machining processes at dozens of locations, but finally scrapped all data and started their own operations fresh.

"You just couldn't apply it to the specific work we were contracted for," Corazza explains. For a while it was trial and error as different cutting geometries and other techniques were tried. To reduce expenses, aluminum mockups of complex parts were test machined first.

As the tradesmen began to feel at ease with the metal, mistakes were decreased and production went up. Says Autonetics engine lathe machinist Joe Fischer, 21 years in the business, "I don't care to work with any other metal. Why? Because beryllium holds size so much better. It's easier to cut. Granted, it is rough on tools, but you never have to fight any chips. Its cleaner."

Today, the Aerospace and Systems Group has one of the world's leading beryllium machining operations, and, as Seefried points out, "We're still learning about it. We have several years experience, and have been instrumental in extending the state-of-the-art."

Refined Techniques

"You can't rightfully say we pioneered in this field," says Autonetics group scientist Al Gross, an acknowledged expert on beryllium. "But we have learned a lot and refined techniques. I doubt that anyone is further along than us today on the machining of the metal."

Autonetics currently has 125 people producing precision parts to exacting tolerances down to 10 millionths of an inch; as close as any in the industry. Final products range from needle size up to basketball dimensions. Conventional workshop machines—lathes, mills, grinders, drills, hones, jig borers — are used along with such special equipment as an electrical discharge machine, for processing very thin, unsupported sections. More than 95% of beryllium bought by the division is used in the machining of precision instruments—mostly for missile and nuclear submarine guidance and control systems and inertial navigation equipment.

The Los Angeles Division has one of the largest beryllium machine centers anywhere, employing 198 specialists on three shifts. Giant tools cover a wide range in capacity, and flexibility has been designed into the operation so both high volume production and prototype runs can be accommodated.

For instance, LAD machines gyro platform components used in the Minuteman guidance system—more than 750 have been finished to date—for Autonetics. Each platform consists of roll and yaw axis gimbals and a stable element. Sets are machined from solid material and assembled to exacting requirements on a production line basis. At the peak of work activity on these units, LAD was the largest single user by weight of beryllium pressing in the nation.

"We also do many one-of-a-kind pieces," says Program Manager Ron Olsen. "A big part of this work comes under sub-contracts. Raw material producers frequently contract with LAD to fill their machining and fabrication requirements because our facility is equipped in depth to accomplish all phases of fabrication."

An outstanding example was the manufacture last year of a large space mirror for the Beryllium Corp. It was 36 inches in diameter and had an unusual design, calling for dozens of intricate triangular and circular patterns to be machined at varying depths. The solid disc of beryllium used was valued at approximately $25,000, so there was no cushion for error. An aluminum mockup was made first, with engineers and metallurgists working in close collaboration.

LAD pioneered in the little-known art of beryllium brazing on this project. Sheer size of the unit caused problems in handling and in tooling to maintain stability and flatness required for a good bond. Tests were run during the machining period on small blocks and a scale model of the mirror, and several precious alloys were tested to determine their integrity. After the mirror base was fully machined internally a beryllium backplate was furnace brazed with silver alloy in a hydrogen atmosphere. The brazed assembly was then remachined externally to an exacting spherical contour on the mirror. The resulting 96% braze joint far exceeded specifications. The mirror was one of the largest beryllium components of this type configuration ever brazed in the United States.

Other prime jobs in recent months have included fabrication of Apollo boom antennae, 36 inches long and six inches in diameter, and, currently, huge ring assemblies for a large optical instrument.

In Los Angeles Division's Crenshaw facility, machinist measures diameter of large beryllium piece to be used in nose cone.

"We're not just involved in the machining of these rings," says Keith Wallace, manager of Structural and Precision Machining and Assembly. "We're designing, forming, machining and assembling them."

The rings, 82½ inches in diameter, consist of form skins and are adhesively bonded. Machine caps for these assemblies are made from one of the largest beryllium pressings ever attempted.

In Bldg. 164 at the Crenshaw facility craftsmen are now fabricating huge beryllium nose cones, four of them. Despite the size—each one is several feet long—specifications demand fine tolerances to one thousandth of an inch in areas where the sections are joined.

The Los Angeles Division is also spearheading one phase of beryllium research. "We've been leaders in solid state diffusion bonding of advanced metals for more than nine years," says Norm Klimmek, manager of Materials and Producibility.

In diffusion bonding, pressure and heat are applied simultaneously to produce a metallurgical bond between two segments. Two basic techniques have been developed for work with beryllium. In one, sheets of the metal are joined by overlapping strips, using a resistance welding machine to achieve proper conditions of pressure and heat without melting. The resultant joints have proven superior to brazed, riveted or adhesive bonded joints.

Rocket Engine Use

At Rocketdyne the company has scored a clean beat in the advancement of beryllium technology, and it has been done in a field the division has led for years—rocket engines. From the beginnings of NASA's Gemini program, Rocketdyne's Small Engine division has been producing attitude control engines of 100 pounds thrust and less; the ones astronauts fire to maneuver their spacecraft during such delicate operations as rendezvous and docking. The thrust chambers of these engines are made from a plastic-like ablative substance.

Late in 1964, engineers began serious efforts for a replacement material that

Engine lathe machinist Joe Fischer, left photo, Autonetics Division, performs closeup work on precision Minuteman gyro rotor.

Submerged in long vat of oil, right, extruded beryllium tubing for communication satellite is machined by electrical discharge.


AIRETEST

would combine economy with high performance, multiple, extended firing durations. The new chamber would have to be everlastingly durable, for future requirements might demand 100,000 firings or more on a single mission.

Refractory metals such as molybdenum were given a hard look. But they require protective coatings. If the coating flakes, erodes, or deteriorates in any way, the engine fails almost instantly. Rocketdyne felt this was too great a weakness, and discarded this concept.

Stainless steel and L605, a cobalt-steel super alloy, were examined, but failed to meet all stringent specifications, which included light weight, high heat capacity and thermal conductivity, and a relatively high melting point.

Beryllium Investigations

Intensive research with beryllium began late in 1964 under the leadership of Small Engine division Program Manager Frank Campagna. Preliminary results were promising. The metal proved to have a natural resistance to rocket exhaust flames and a capacity for internal solid-state cooling. Moreover, this concept had the decided advantage of simplicity. It could be machined readily, thus despite its high initial cost, it could drop production costs drastically to a fraction of those experienced with the ablative engines.

But how would it stand up under firing? Here, the findings were astounding. The normal life span of an ablative engine is generally several hundred seconds. Firings cause an irreversible chemical and physical change to the material, thus limiting its use.

"In a beryllium engine, we found there is absolutely no change in its characteristics as it is fired," Campagna said. "We have accumulated on one such engine several hours of hot firing." One 100-pound thrust engine, which incidentally weighs but five and a half pounds, has been fired over 2.8 hours in the longest known single test run with any rocket engine anywhere. Campagna believes the beryllium thrust chambers can be used again and again, almost indefinitely.

Potential of such a design is equally limitless. Further testing has shown beryllium engines from one to 1000 pounds thrust out-perform any predecessors regardless of the criteria measured, and at a substantial dollar savings. They are, clearly, *the* small rocket engines of the future, and through the early research and development of them, Rocketdyne has taken a significant lead in a new field of rocket engine technology.

Space Division's Central Manufacturing Facility is one of the prime users of beryllium sheet metal—to fabricate a hi-gain Apollo structural antenna, which is deployed in space. Again, the metal's light weight, stiffness, and high strength-to-weight-ratio are near-ideal characteristics for the job. The antenna consists of a beryllium housing, machined at LAD, and three beryllium sheet metal sectors bonded to the interior of the housing.

"We started working with the metal about three years ago, and we now have a detailed operation," says project engineer Del Kern, "including material preparation, machining, sawing, forming, chemical milling and assembly."

Innovations Tried

As at other divisions, there were initial ills to cure, particularly in the process of developing sheet metal forming techniques. For example, it was necessary to use temperatures above 1300 degrees F. Anything over 800 degrees causes a beryllium emission of toxic fumes. To compensate, a coating was designed at Space Division which not only curbed the potential health hazard, but doubled as a die lubricant. The coating was such an innovation, in fact, that a patent application on it has been filed.

Also, joining techniques using adhesives had to be devised for the high-performance space hardware. These included new polyaromatic adhesives which have good strength retention at elevated temperatures between 500 and 1000 degrees F. And, to CHEM-MILL the material properly, different solutions had to be researched.

In addition to the Apollo antenna, Space Division sculptures beryllium tubes for an unmanned communications satellite. This work calls for approximately 100 holes to be drilled into the tubing walls, which are but twenty-three thousandths of an inch thick. Here, conventional machining methods proved impractical. Mechanical drilling of beryllium, especially wafer-thin stock, chips as the drill breaks through the material. Thus, electrical discharge machining has been used.

Of all Aerospace & Systems Group divisions, Atomics International has used beryllium longest. In the SNAP 8 design,

At Rocketdyne, beryllium research began in 1964 under leadership of Small Engine Division Program Manager Frank Campagna.

Far right, Robert Valdez chrome plates beryllium gyro balls for finer finish in environmentally controlled Autonetics area.

pivoting beryllium control elements are mounted around the reactor core. They reflect escaping neutrons back into the core, thus contributing additional neutrons toward the maintaining of a chain reaction.

Though Atomics International does not process the metal, an anodized film on the outside of the elements is applied before they are assembled into the completed reactor. This film prevents oxidation of beryllium, which occurs at the high temperatures of the reactor operation, and it increases the ability of the control elements to emit waste heat.

Beryllium is also used in the basic frame of the SNAP 8 reactor, and, similarly, was used for the control elements of AI's SNAP 10A, the first reactor to operate in space.

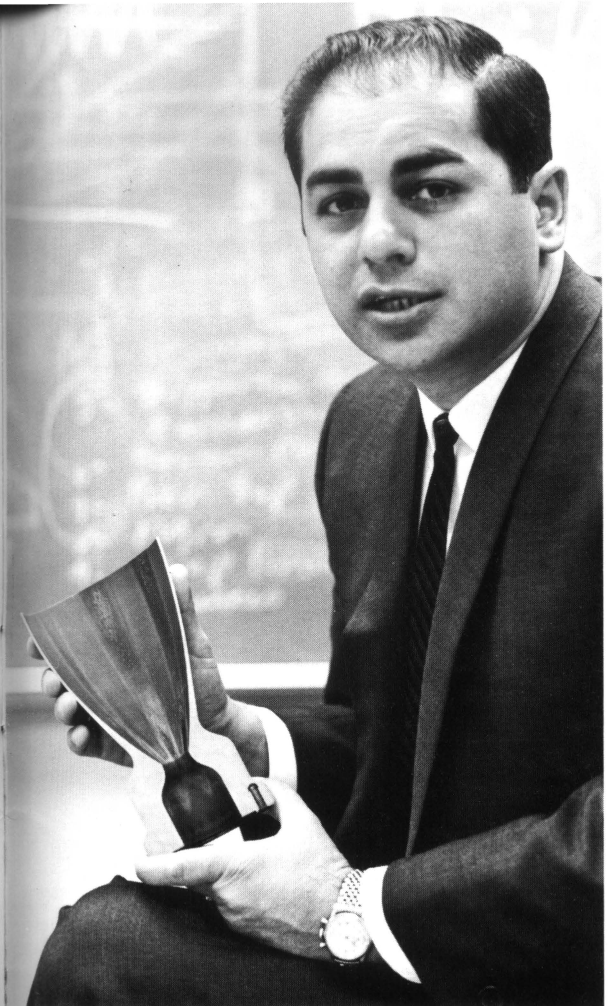
Despite the wide use of the metal throughout the divisions, many feel its potential has barely been tapped. Possible applications might include: beryllium aircraft brakes; rocket fuselages and skirts; re-entry payload housings; large booster engine actuator tubes and struts; V/STOL engine components and airframe structures; inertial navigation instruments; space radiators and condensers; micro-meteoroid bumpers; gamma ray detectors; x-ray telescopes; and large solar cell array structures, among others. The lengthy list is added to with each new advance in technology.

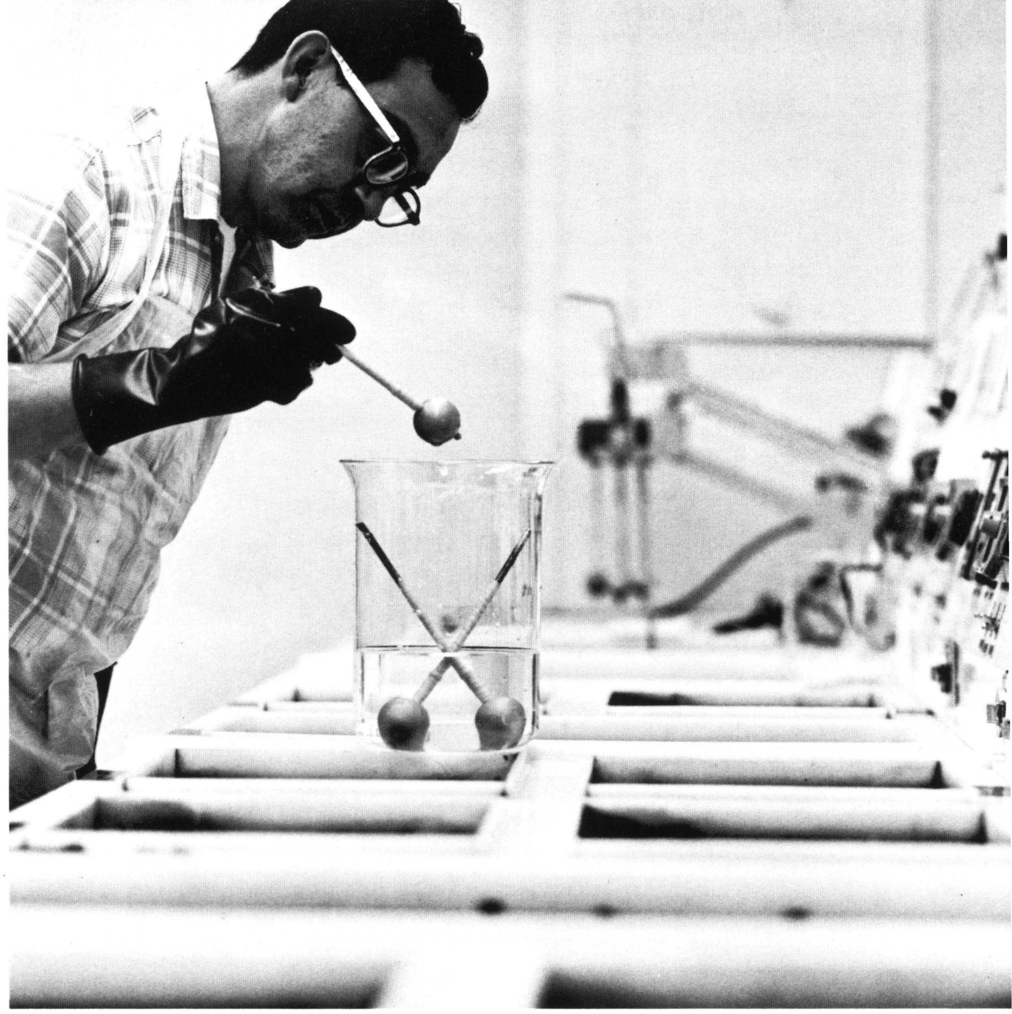
Development Barriers

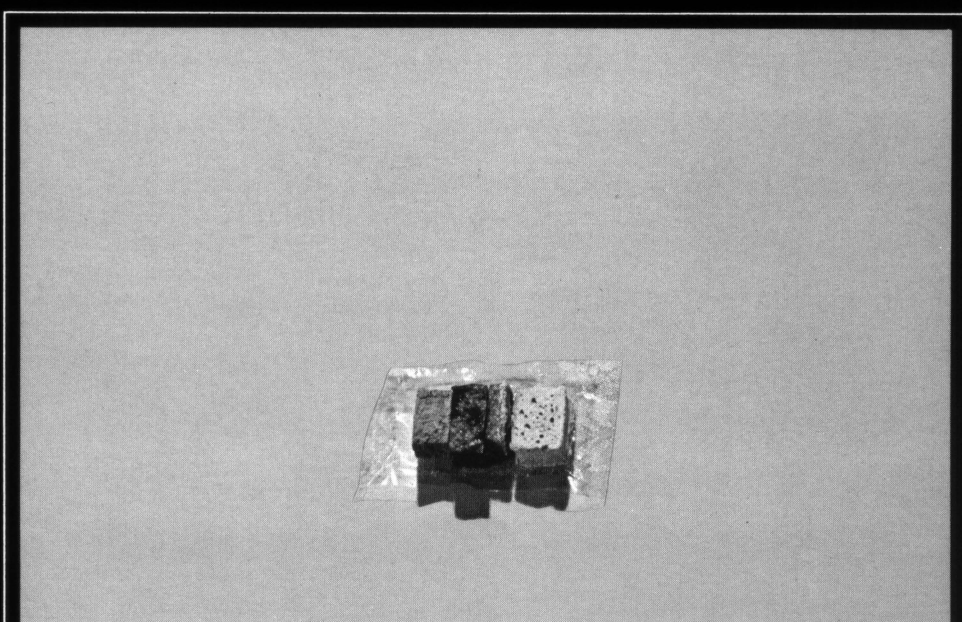
There will be developmental barriers, monumental ones. For instance, beryllium has a brittle behavior characteristic when subjected to high complex stresses. This must be solved before progress continues. And price is still a consideration which must be balanced against cost effectivity. Still, the metal's future, particularly in space adaptations, is assured.

In research departments, laboratories and production shops throughout the Aerospace & Systems Group, North American Rockwell is edging that future into the present.

Tensile test on strength of a diffusion bonded beryllium strip is Quality Control check. LA Division is advancing art of joining metal pieces by application of pressure and heat.







Underneath the title is a man. An astronaut needs clothing to keep warm. He has the same personal hygiene needs he has on Earth. He needs medicine to counteract pain and illness.

And he needs

Breakfast at Zero G

The astronauts are allotted 2500 calories of food per day per man. Inside the module there are about 5000 cu. in. of food storage space available, equivalent to a small living room bookcase.

There are about 50 different items from which daily menus are made up. The items fall into two major groups, freeze-dried re-hydratables and bite-sized cubes. Examples of freeze-dried items are salmon salad and beef-and-gravy. Examples of bite-sized items are miniature sandwiches and fruit cakes. The freeze-dry process squeezes out all but to 4% of the food moisture and offers about 70% weight savings and 50% in bulk. The bite-size sandwiches, cakes, fruit cubes, can be popped right into the mouth — they don't need reconstituting .

Space Kitchen Hints

The dehydrated bars need reconstituting to "bring them back alive." The men add hot or cold water through a one-way valve in the clear plastic food bag, then let the contents soak for about three minutes. When it's ready, the neck of the bag is cut off, and placed to the lips. A squeeze forces the food into the mouth. It's a primitive closed system, a necessity brought on by the zero g conditions in the module. Special utility tools which can be inserted into the food packages will be used in case of a pressurization failure in the module when the men would don their pressure suits and take food and water through ports in their helmets during the emergency return.

The water comes from a device that squirts a half-ounce with a squeeze of the trigger. The big advance in Apollo has been that now hot water is available. Hot spaghetti in the Apollo is better than cold spaghetti in Gemini.

When staid Earthmen are sitting down to breakfast, above, astronauts may be starting 2500-calorie per day intake with crumb-free, bite-sized sandwiches, fruit cakes, below.

An entire meal is contained in one vacuum-packed foil overwrap bag of clear Kel-F, a non-inflammable plastic. The bags are tough, reliable packages that won't leak in flight. In 1000 Gemini uses, there were only four broken packages.

The food packages are numbered in sequence for breakfast, lunch and dinner, and each group is color-coated. A red patch, for example, is assigned to the command pilot's food packages, a white for the pilot and blue for the lunar module pilot. On return from the moon voyage biomedical personnel on the ground can determine who ate what by counting and weighing the packages.

The food doesn't look especially appetizing in dehydrated form, but it tastes very good. Some of the astronauts develop special likes and dislikes and call out what they want emphasized in their particular menus. But there is no denying that eating from a plastic bag or sucking through a tube isn't very attractive. NASA is evaluating different eating concepts trying to reach a more normal situation, for example, eating with a spoon. About the closest to normal eating the astronauts attain is in the use of these bite-size particles. However, crumbling of the particles has been a problem. The U.S. Army Natik Laboratories and the Whirlpool Corp. have developed a coating to eliminate food particles from floating around the spacecraft.

Great care goes into the preparation of the food. The entire operation is microbiologically controlled and results in what may be the lowest count of viable organisms of food products available today. A man in space can't afford to have food poisoning hinder his activities or endanger the mission.

The NASA medical people set the requirements in the bio-medical area. The tendency has been to simplify procedures

Preparation of food for space use is microbiologically controlled, additional safeguard for astronauts on the 14-day moon voyage.

and requirements because of the confidence gained on Mercury and Gemini.

The overall garb for the astronauts on the Block II, the moon journey phase of Apollo, is a complete system in itself.

International Latex of Dover, Del., is the prime for the pressure garment assembly. Hamilton Standard is a prime for the back pack containing an environmental control system. The entire garment and life support system worn by the astronaut on the lunar surface weighs 183 pounds of which 123 pounds is the pack pack.

Stepping from his shower on the morning of launch, prior to liftoff for the moon journey, an astronaut will don a constant-wear garment that looks remarkably like long underwear. But the lightweight garment is much more than simple "long johns." It is engineered to be compatible with the entire suit system, and has three pockets for holding instrumentation.

Over the constant-wear garment goes the thermal meteoroid garment, the bulky, helmeted array, complete with bellows constant-volume convoluted joints, that imparts the "man-from-Mars" appearance. Leonard Shepard, Apollo program manager at International Latex, said frankly, "The suit is intended to be worn pressurized with maximum mobility; as such it is susceptible to compromises in its unpressurized comfort. These compromises are kept to a minimum. It takes only a small effort to bend one's arms or legs."

Pressure-Suits

Within the module, the men will be wearing the pressure suits at takeoff, accelerated flight, re-entry to Earth's atmosphere, and in the event of emergency during the journey.

It is during extra-vehicular activity that the thermal meteoroid garment will provide maximum protection against heat, cold and meteorites on the lunar surface.

In the lunar module, prior to stepping out on the surface, the astronaut will again strip and don an entirely new entry, the liquid-cooled undergarment. An electric blanket has coils of heating wire embedded in it; a liquid-cooled undergarment has, in contrast, 500 feet of plastic tubing stitched to the inner surface through which circulates one pint of distilled water. The tubing has 3/32 inside diameter, and placement is dictated by the body needs for cooling.

Special design of the cloth keeps the tubing close to the skin.

The liquid-cooled undergarent, designed to keep the astronaut from sweating, or to keep the sweating as low as possible, is not as radical a departure as it seems. The idea originated in England for use by coal miners who were plagued by overheating, and was later developed for high-speed flight use by the British Air Force.

The liquid-cooled garment is only worn during extra-vehicular activity, at times of high metabolic movement when it will be necessary to keep the astronaut's skin temperature to a maximum of 88 degrees to minimize perspiration. The astronauts has control over the liquid flow through the tubes, a heat transfer function, and can dial a high, low, or medium temperature condition.

Enthusiastic Response

On the Gemini 7 flight, the men responded enthusiastically to the relatively short periods when they were able to wriggle out of their pressure suits. In Apollo they will be out of the suits most of the time, walking or floating about within the module, clad only in their flight coveralls.

Sleep cycles are scheduled for the journey. To keep the men from floating about the module during sleep, thin sleeping bags are provided, their principal function being to keep the inert body in one place until the astronaut awakens and returns to work.

A medical kit will be aboard, as it was on the Gemini and Mercury flights. Supplied by the Rodana Research Corporation of Bethesda, Maryland, the kit measures 4 by 4 by 5½ inches and weighs only 1.3 pounds, but contains an array of remedies. Besides the home variety such as aspirin, band-aids, and sunburn lotion, there are tablet-type pain reducers, stimulants, antibiotics, and decongestants.

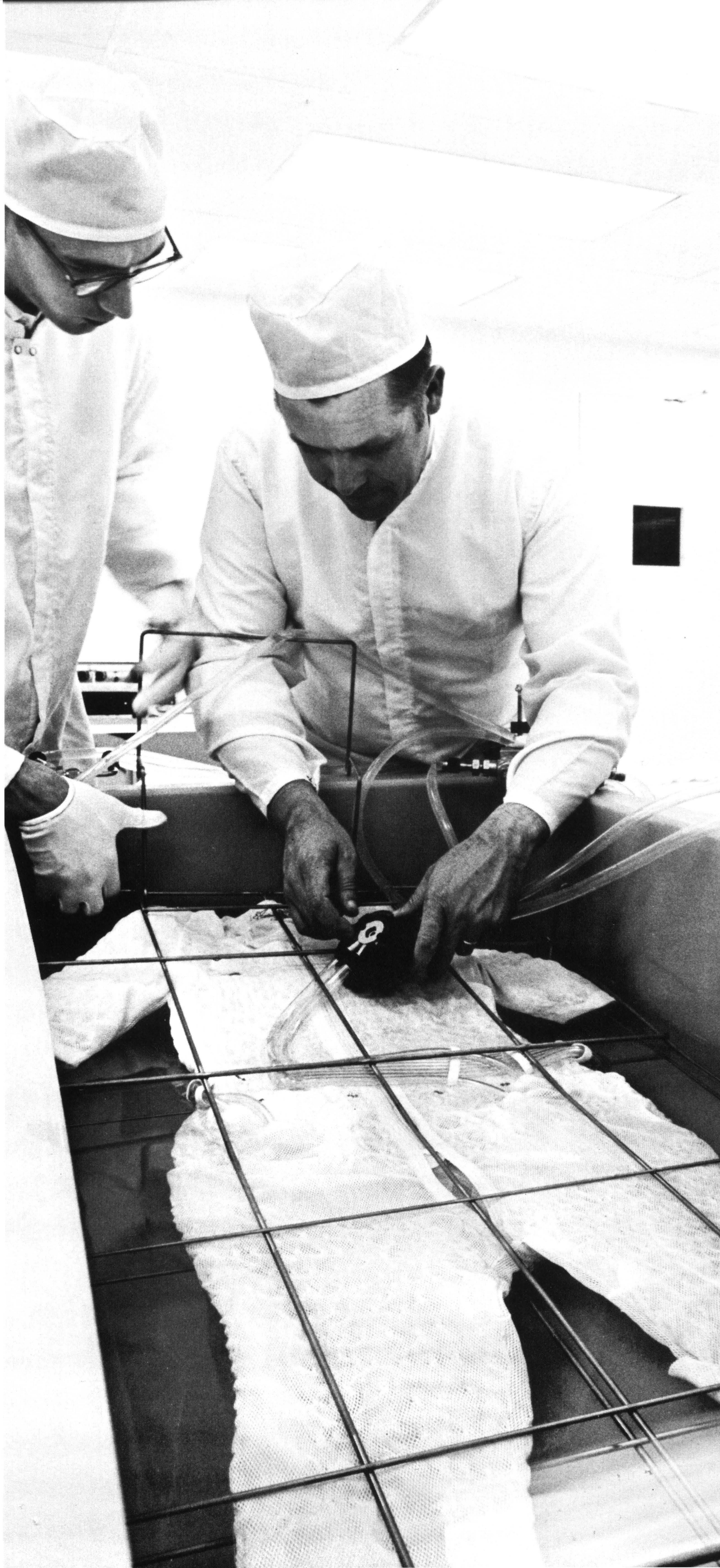
Two cubic feet of space and 60 pounds are allotted to the survival gear aboard the Apollo. Included are a 3-man raft, signal devices, radio beacons, and a small kit, 4 by 4 by 1½ inches which contains a flashing strobe light, signal mirror, fish hooks, knife, whistle, sewing kit, and cotton balls with a striker for lighting a fire.

In the midst of the greatest scientific adventure ever undertaken, it is warming to know that the participants are still men, that thousands of miles out in space, one man will turn to another and say, matter-of-factly, "Let's eat. I'm hungry."

Selection of food extends to source at very moment of harvest or of catch, such as this Alaska salmon which will be scrutinized carefully before final end in space salad.

Medical supplies, above, are packed in small kit carried in Apollo command module. Dr. Stanley J. Sarnoff, seated, is president of Rodana Research Corp. which provides the kit.

Left photo, some dehydrated foods need reconstituting to 'bring them back alive.' Small device injects half ounce of water with each squeeze, assuring tasty end product.



Liquid cooled undergarment, used by astronauts, has 500 feet of plastic tubing stitched to inner surface in which circulates one pint of water. Suit shown is under pressure test.

Detailed inspection of charred core sample from Apollo 4's command module heat shield is one of many Space Division flight evaluation procedures.