July 22, 1963

75 cents

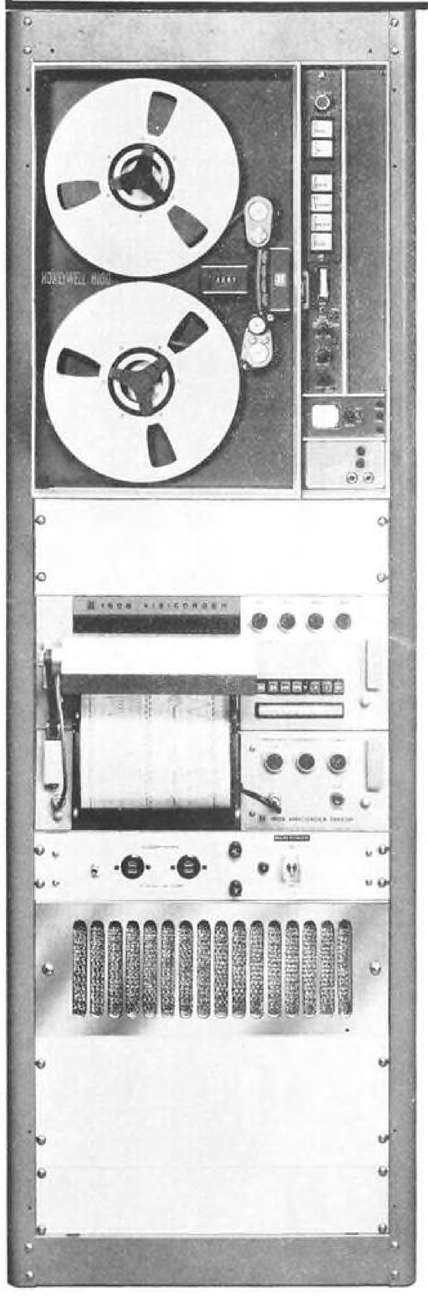
Aviation Week & Space Technology

A McGraw-Hill Publication



Manned Space Flight

You can take your work to the HONEYWELL 8100 TAPE RECORDER



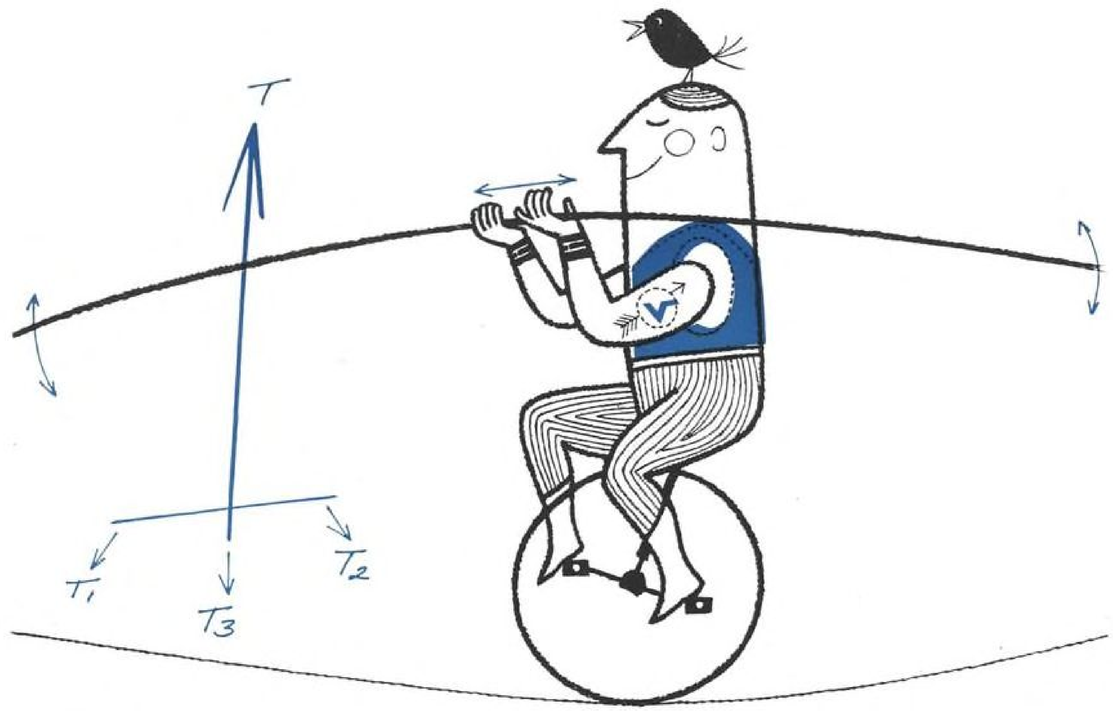


or you can take the 8100 to your work!

Completely portable, completely self-contained, the new Honeywell 8100 recorder/reproducer offers instrumentation quality in a package you can carry from test to test with one hand. Or you can rack-mount the 8100, as shown at left with a Honeywell Model 1508 Visicorder Oscillograph. The 8100 contains all its own electronics, plus such convenience features as a built-in calibration panel and automatic switching of center frequencies. You can record analog data from DC to 10,000 cps on up to 8 data channels. And there's an optional built-in scope for monitoring data while you record. Available with either ¼ or ½ inch tape. Weight only 85 pounds. Price from $5900 to $11,300. Write for brochure #2038 to Honeywell, Denver Division, Denver 10, Colorado.

Honeywell

Circle Number 2 on Reader-Service Card



WHAT DOES A PUMP MAKER KNOW ABOUT ATTITUDE CONTROL?

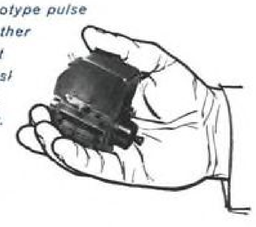
The answer is—lots! Both attitude and thrust vector controls stem from the science of fluid dynamics . . . a science that has formed the basis of Vickers business for more than 40 years. And, our specialization in the airborne phase of fluid dynamics covers nearly a quarter of a century.

Backup for this unmatched experience comes from two related areas: (1) unique research and development facilities devoted to the extension of knowledge in fluid dynamics, and (2) proved ability to manufacture highly reliable sub-systems and components to meet or exceed the most stringent aerospace requirements.

Performance proof is available both on programs initiated by Vickers and those undertaken for the various government agencies. In the specific areas of attitude controls, Vickers experience dates to 1955 when hot gas servo studies were initiated. Today's experience includes solid propellant and hypergolic bipropellant reaction controls, and secondary injection systems using either liquid (freon) or solid-propellant-generated hot gases.

Optimized use of fluids . . . liquid, gaseous or vapor . . . to take advantage of inherently high output-to-weight ratios, proved reliability and instantaneous response of the chosen fluid medium is Vickers contribution to the demands of the aerospace age.

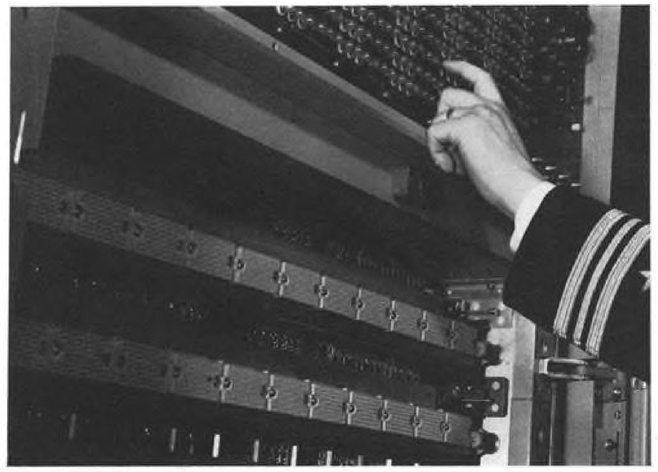
For details about this prototype pulse rocket development and other current attitude and thrust vector control programs asl for Bulletin No. A 5283-Y. Vickers Incorporated, P.O. Box 302, Troy, Michigan.



VICKERS
DIVISION OF SPERRY RAND CORPORATION

1802

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This computer system has been called "the most trouble-free piece of electronic gear in the U.S. Navy today."

Quick! What company makes it?

Those familiar with the Naval Tactical Data System (NTDS) will tell you: UNIVAC.

After weeks of rugged tactical maneuvers, an Admiral recently called this system "one of the finest pieces of machinery the Navy ever got its hands on...the most reliable large-scale system in the fleet today." UNIVAC is responsible for the NTDS computer, the peripheral hardware and for the system integration.

What does NTDS do? It automatically locates and tracks enemy targets, provides for their identification and supplies high-speed computational assistance in the selection of appropriate countermeasures. A high-capability integrated information processing and transmission system, the reliability of NTDS will help assure U. S. naval supremacy.

Is capability like this unusual or uncommon at UNIVAC? Not at all. From yesterday's ENIAC and BINAC, to today's fluid mechanics, microelectronic circuitry and thin-film magnetic memories, UNIVAC has made most of the industry's major technical advances. UNIVAC offers a quick response to every demand...outstanding scientific and engineering talent...total systems programming and management capability. If you'd like to put some of this demonstrated competence to work for you, better call UNIVAC, quick!

UNIVAC DIVISION OF SPERRY RAND CORPORATION

Qualified defense systems analysts and circuit design engineers are invited to investigate exciting career opportunities at UNIVAC, an equal opportunity employer.

AVIATION WEEK & Space Technology

JULY 22, 1963

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Packard Bell Electronics'
Saturn Automatic Checkout System

How the Friden Flexowriter® controls its man-machine communications



By Jerry Slocum, *Manager, Electronic Engineering Section, SATURN Systems, Packard Bell Electronics, Los Angeles, California*

"The SATURN Automatic Checkout System built by Packard Bell Electronics is a computer controlled system used for factory checkout of the SATURN I booster. The first system has been delivered to NASA's Quality Assurance Division at Marshall Space Flight Center, Huntsville, Alabama.

"The system consists of a Central Computer Complex, containing a Master Control Console and multiple PB 250 Computers in a master-slave relationship; and satellite test stations each having the capability of stimulus generation and response measurement of a functional portion of the space vehicle and its ground support equipment.

"At the Master Console a Friden Flexowriter provides direct connection to any computer in the Complex. The Flexowriter is used for the normal paper tape and typewriter data communications with any PB 250 as if it were an off-line computer.

"The majority of operator communications with the system are provided by Flexowriters located at each test station and by an additional (buffered) Flexowriter located at the Master Control Console. These Flexowriters are an integral part of the man-machine relationship necessary for the successful operation of a complex automated system.

"The Satellite Test Station Flexowriters and the buffered Flexowriter at the Master Console participate in all three modes of operation of the Automatic Checkout System.

"In the automatic mode, under computer control, the Flexowriters provide such things as hard copy outputs of test results; tabulation of GO and NO-GO measurements with their identification points; type out of test progress and type out of the actual test steps being executed; and type in and type out of operator instructions where manual intervention is required.

"In the manual mode, the test stations are off line from the computer complex and the Flexowriters are the sole means of command communication with the test station. They provide means for manual data entry via the keyboard or the Flexowriter Tape Reader, and allow such operations as manually single stepping through a program routine; continuous cycling for maintenance purposes; and the manual exercising of various system devices for confidence check of hardware and programming.

"In the single step mode, the Flexowriters aid in the detailed de-bugging of either programs or hardware by allowing manual data entry in combination with the single step sequencing provided by the test station.

"In addition to their function as integral test station devices, means are provided for easily switching the Flexowriters to off-line operation for the more conventional usages such as typing, preparing program tapes, and regenerating existing tapes."



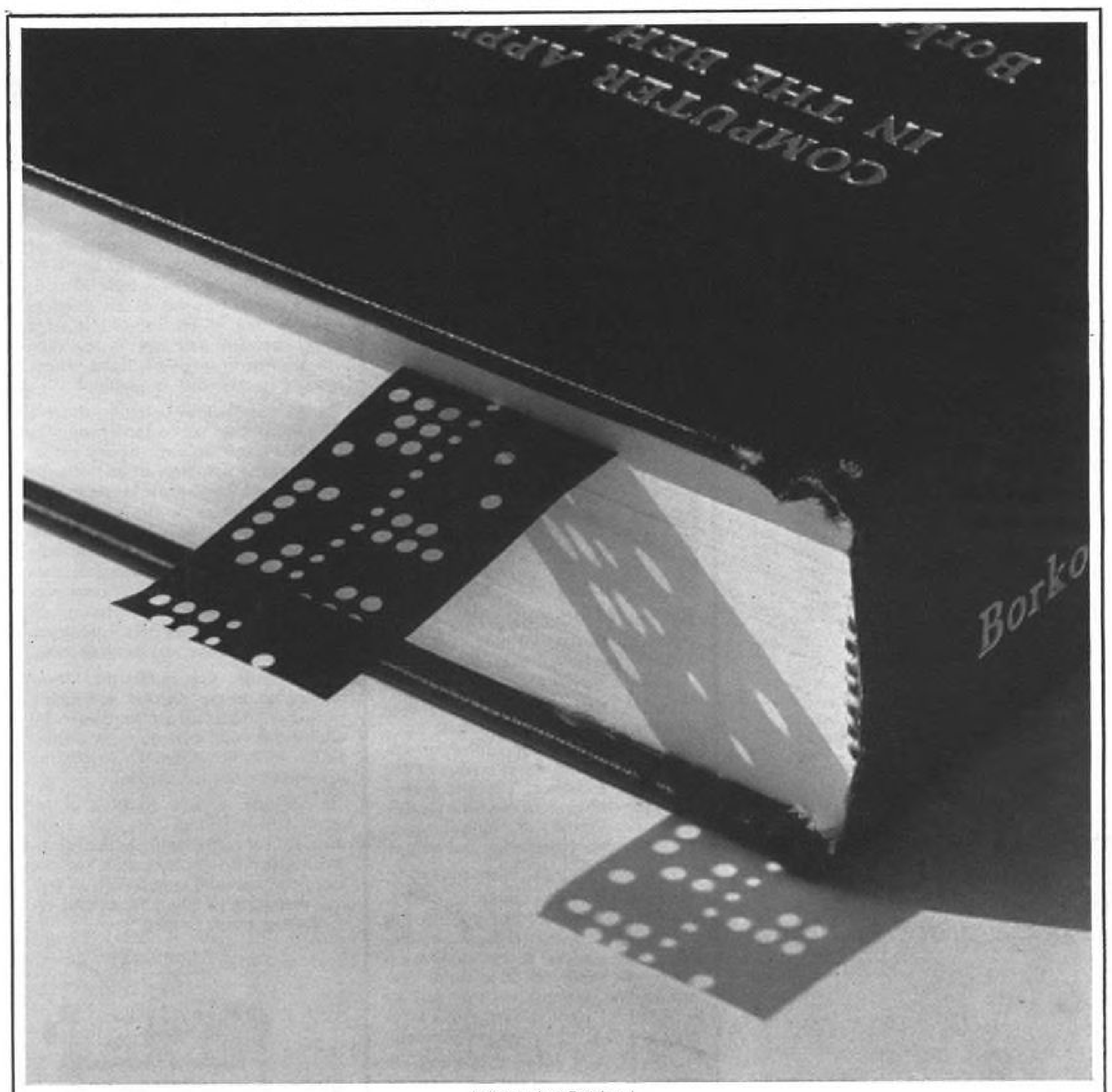
The versatility of the Flexowriter as an input-output medium, a data-lister and data-sorter, make it an invaluable tool in the design and operation of *any* control system. To fully investigate the Flexowriter's versatility, call your local Friden Systems man. Or write: Friden, Inc., San Leandro, California.

And, should you now be using the Flexowriter in an application you would like to share with your fellow engineers in these pages, just write and tell us about it. Address your application story to Mr. George Beeken.

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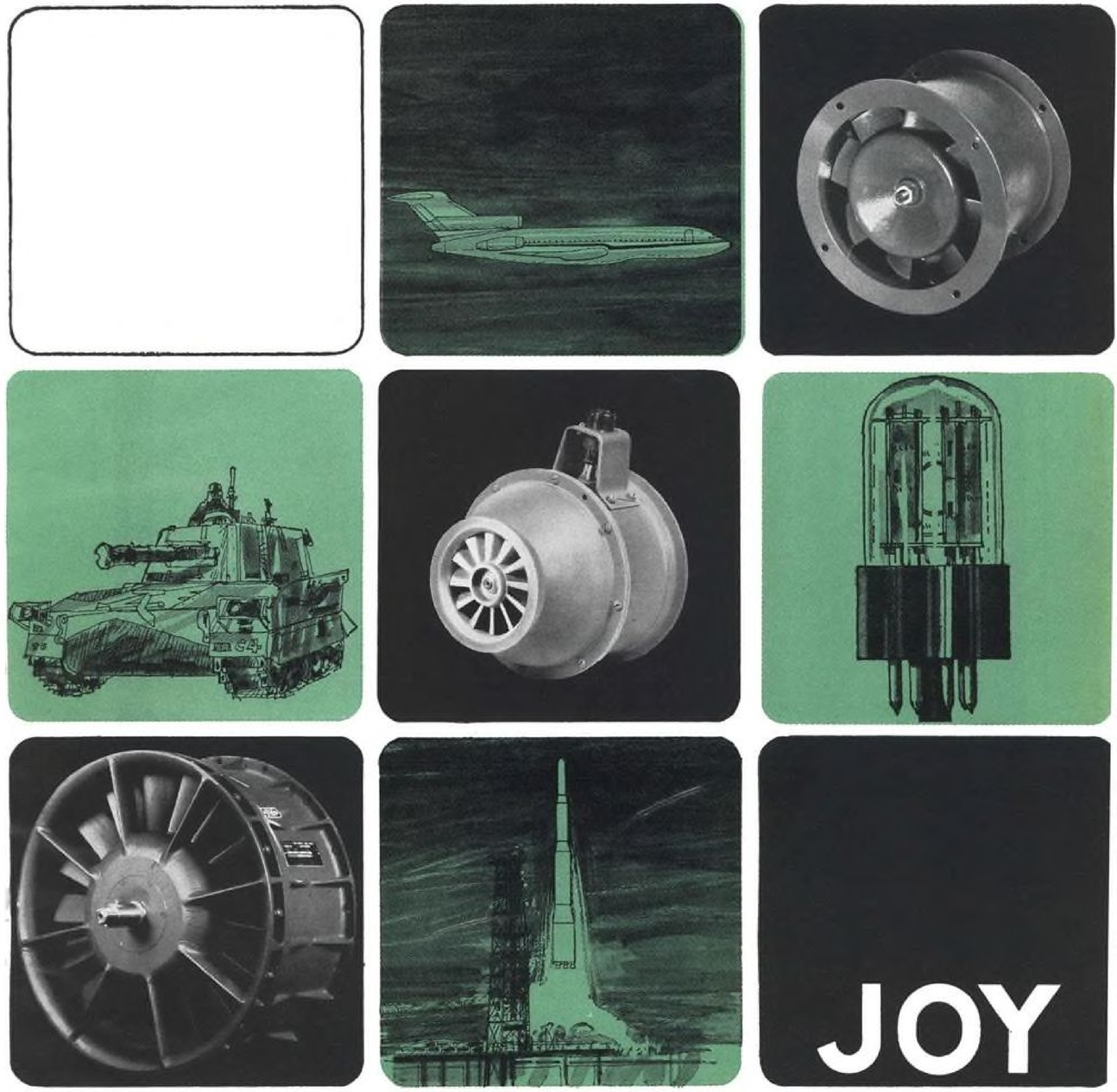
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301



This is the new B.F.Goodrich "Cut-Protected" commercial aircraft tire for main wheel use. As the name implies, and tests have proved, the tire reduces carcass cutting and damage, and increases the number of times the carcass can be re-treaded. This significantly reduces tire cost per landing.

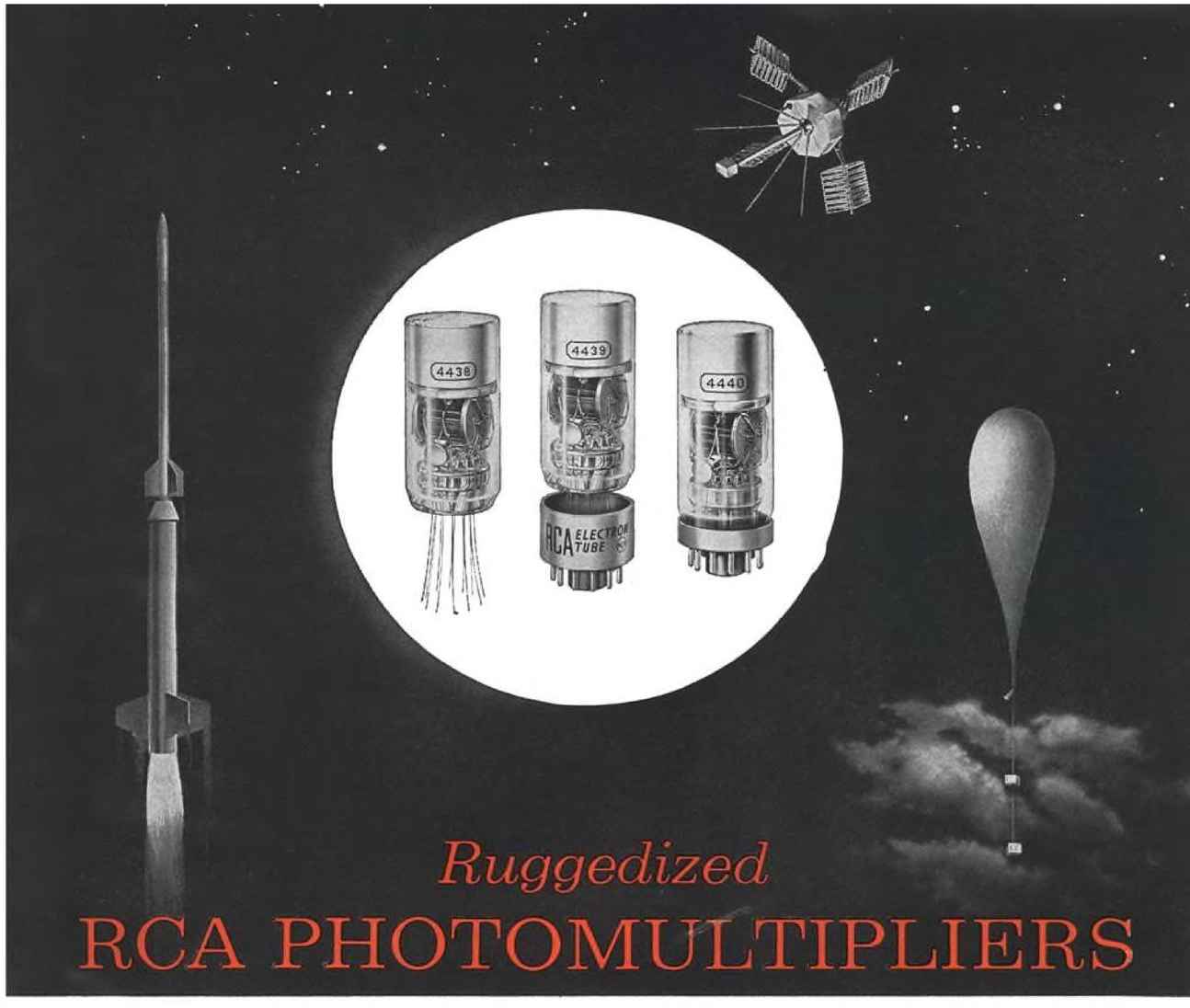
The "Cut-Protected" tire is built with shredded wires distributed through the undertread. This inhibits cuts that do occur from growing, and damaging undertread and ply area. The shredded wire barrier is insulated from the tread by a double nylon shield. This stabilizes the tread rubber when tire is under load and eliminates groove cracking.

The barrier shield also gives the retreader a simple visual reference when buffing. The re-treading operation is made more accurate and economical—and mistakes due to buffing too deep are eliminated.

This new tire incorporates the advanced design and compounding that goes into other B.F.Goodrich aircraft tires—selected time after time for the toughest jobs. For tires you can depend upon, specify BFG. Contact *B.F.Goodrich Aerospace and Defense Products, a division of The B.F.Goodrich Company, Department AW-7B, Akron 18, Ohio.*

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aerospace and defense products

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Ruggedized

RCA PHOTOMULTIPLIERS

help scientists study energetic particles in space

Ruggedized RCA Photomultiplier types RCA-4438, -4439, and -4440, originally known as developmental type C7151, have been of significant value to scientists studying the nature of the energetic particles in space and the nature of the Earth's magnetic field. Used in Explorer satellite experiments, these tubes were found to be extremely effective and reliable. They have now been made available commercially. In addition, as a result of this prototype performance, RCA subsequently extended the application of this family with types RCA-4441 and RCA-C70114.

Developed especially for space study, this tube family, operating in NASA-developed circuitry for Explorer XII, has helped scientists learn:

- The Van Allen Radiation Belt is a trapping region with particles having various characteristics.
- The density of electrons with energies above 40 KEV in the outer zone was about 10^8 particles per cm^2 per second.
- A large population of trapped protons having energies of a few hundred KEV exists in the region from 4,000 miles above the surface of the Earth to the outer edge of the trapping region. Maximum intensity is about 3×10^8 protons per cm^2 per second.
- There are a larger number of solar-proton events emanating from the sun than previously thought.

Since the Explorer experiments began in 1958, RCA has worked closely with NASA's Fields and Particles Branch at the Goddard Space Flight Center, as well as with Dr. James Van Allen's group at the State University of Iowa.

For information on the RCA family of Photomultipliers, see your RCA Industrial Tube Representative or write: Commercial Engineering, Section 6-112-Q-3, RCA Electronic Components and Devices, Harrison, N. J.



RCA-4441. Developed as a result of the performance of prototypes in space, this 1½-inch diameter, 10-stage, head-on Photomultiplier has an S-11 spectral response. It features reduced over-all length for even greater ruggedness, and a photocathode connection which assures continuous cathode contact under rough environmental conditions. Similar to the RCA-4441 is type C70114 which uses copper-beryllium dynodes for greater stability of tube gain over long periods of operation.

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PULSED LIGHT TECHNOLOGY

Need a light?

...for night aerial reconnaissance? . . . as a target for optical tracking of geodetic satellites? . . . to probe life forms on the ocean floor? . . . to stimulate lasing of a ruby rod? At EG&G, many new kinds of light are being cast on the interfaces of physics, geophysics and natural science for the development of weapons and aerospace systems. EG&G is exploring applications ranging from reliable distress signal lights for small boats to the potentialities of electronic flash systems for orbital rendezvous. Current accomplishments include:

. . . a radically advanced air-borne, 2100 watt-second, Xenon Flash System for night aerial photography at extremely high frame-repetition rates. It will be used operationally on military aircraft for very high-speed, low altitude reconnaissance missions.

. . . the Agena Acquisition Light for McDonnell Aircraft Corp., prime contractor to NASA for the Gemini spacecraft. Under development by EG&G, this light source will simulate 3rd magnitude stars at a distance of 20 nautical miles in space for research in orbital rendezvous techniques.

. . . a new series of high-average-power, air and water-cooled flash tubes to light-pump the next generation of high-energy lasers. These tubes will be rated up to 8,000 watts average power with a maximum energy per flash of 2,000 watt-seconds.

Behind these few examples of EG&G's capabilities in pulsed light technology is a continuous innovative effort dating back to the initial development of strobe flash technology by Messrs. Edgerton, Germeshausen and Grier at M.I.T. in the early 'thirties. Today, EG&G provides a full range of pulsed light capability embracing: basic and applied research, components, instruments, integrated packages, and entire systems. Comprehensive laboratory and testing facilities support this capability.

If you would like us to shed further light on this and other EG&G capabilities, write to us. If you are an electronic engineer or physicist, experienced in the detection and measurement of phenomena in the visible spectrum and in the synthesis of electro-optical systems for applications of this kind, we would like to be enlightened about your capabilities. Send your resume to Elton Harris, Dept. AW-73, 169 Brookline Ave., Boston 15, Massachusetts.

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2003

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Command Recovery. Terminal control and landing of spacecraft...energy management, data links, cockpit displays for aerospace missions. These are not just "long-range objectives" at Sperry Phoenix. For example, we are under contract with USAF Aeronautical Systems Division to capture the X-20 Dyna-Soar vehicle upon re-entry from space, then manage its let-down and landing. This will be done with Sperry microwave guidance and control equipment existing today. We believe we can excel in this USAF assignment because it represents a logical extension of years of Sperry Phoenix experience in high-performance pilotless flight... experience greater in depth and breadth than that of any other company. We welcome new challenges in these and related fields. *SPERRY PHOENIX COMPANY, Phoenix, Arizona.*

SPERRY

DIVISIONS OF SPERRY RAND CORPORATION

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Lunar landing gear . . . from the people at Bendix

Landing struts for lunar excursion craft and landing skids for manned re-entry vehicles. □ Other people at Bendix are working on engine control systems, landing gear, rocket equipment, high temperature composite materials and nuclear mechanisms. An Aerospace team of skilled and experienced people . . . skilled in all phases of program management, backed up by complete engineering and production facilities, give Bendix the capabilities to undertake many varied Aerospace programs. □ To find out what this Bendix team can do for you, write: General Sales Manager, South Bend 20, Indiana.

Bendix Products Aerospace Division

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THE Bendix CORPORATION

J-M Dyna-Quartz insulation can withstand 2700F — forever

Johns-Manville Dyna-Quartz is the only insulation material that performs perfectly under continued usage at 2700F. Composed of 99% pure silica fibers, and containing no binder, it is heat-treated for dimensional stability. As a result, it shows less than 1% shrinkage after a four-hour soak at 2750F. It is particularly useful for insulating applications where extreme temperature resistance, light weight and medium load-bearing properties are important. To fulfill these needs, Dyna-Quartz has been chosen for the United States Air Force's Dyna-Soar space vehicle.

Dyna-Quartz is available in semi-rigid tiles and blocks. Very close dimensional tolerances can be achieved with this material due to its semi-rigid form and its ability to be cut, fitted, machined and sanded to size. It is conformable to curved contours, too.

For full details on J-M Dyna-Quartz or on the wide variety of asbestos materials we make for use in reinforced plastics, write to Aerospace Products Group, Johns-Manville, Box 14, New York 16, N. Y. Cable address: Johnmanvil.

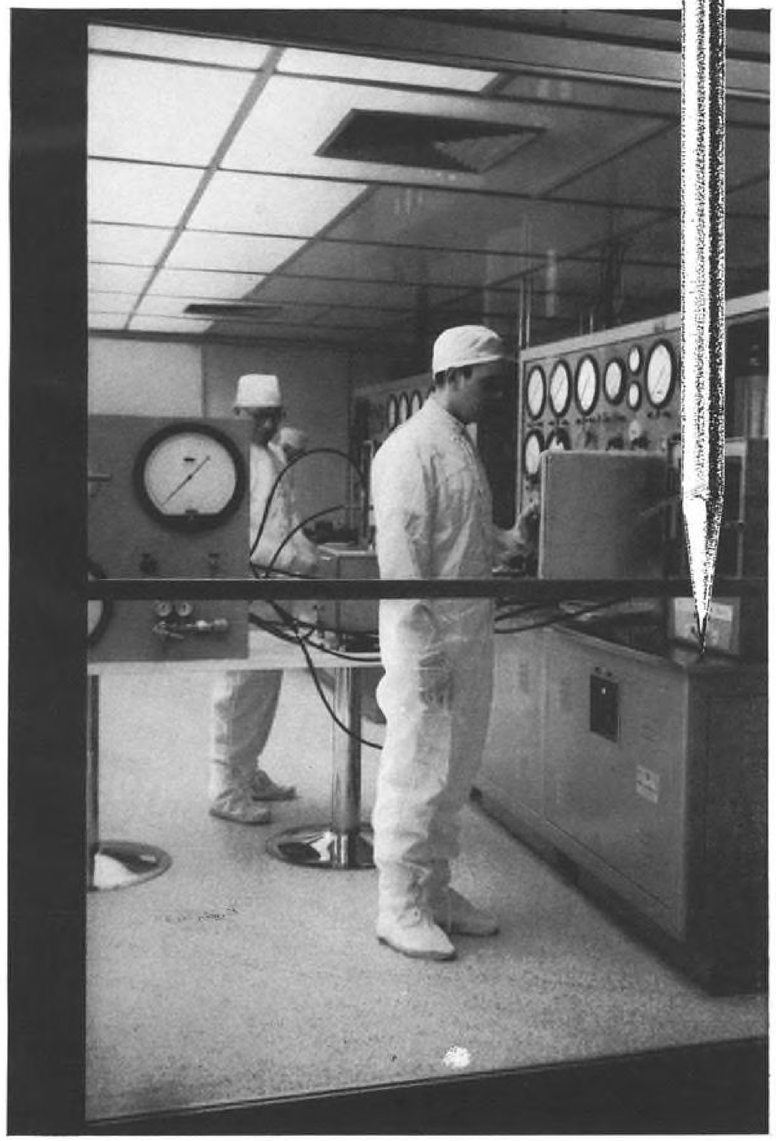


DYNA-QUARTZ, CHOSEN FOR USE ON THE U.S.A.F. DYNA-SOAR SPACE VEHICLE, IS AVAILABLE ONLY FROM...

JOHNS-MANVILLE

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You can take a pencil almost anywhere... but not into THIS room!



When marking, pencils leave tiny deposits of graphite behind them. Particles of matter even **that** small "matter" in the Chandler Evans clean room facility. They represent contamination.

Similarly, ordinary paper contaminates—hence, paper must be "non lint-producing" or coated with polyethylene film. And even then it is thoroughly vacuum cleaned before accompanying its bearer through an air shower into one of three separate clean rooms. Such are the precautions taken in this unusual "laundry" for space hardware.

Technical competence, state-of-the-art facilities, an impressive inventory of high-precision and tape-controlled machine equipment—all combine at CECO to produce aerospace pumps, valves, controls and systems known for their superb performance.

In addition, the ability to manufacture, assemble and test close-tolerance mechanisms has earned high regard for CECO as a subcontractor. Use your letterhead to request a copy of the new Chandler Evans brochure outlining products, facilities and subcontract capabilities. Write to Mr. L. G. Burns, Vice President . . .

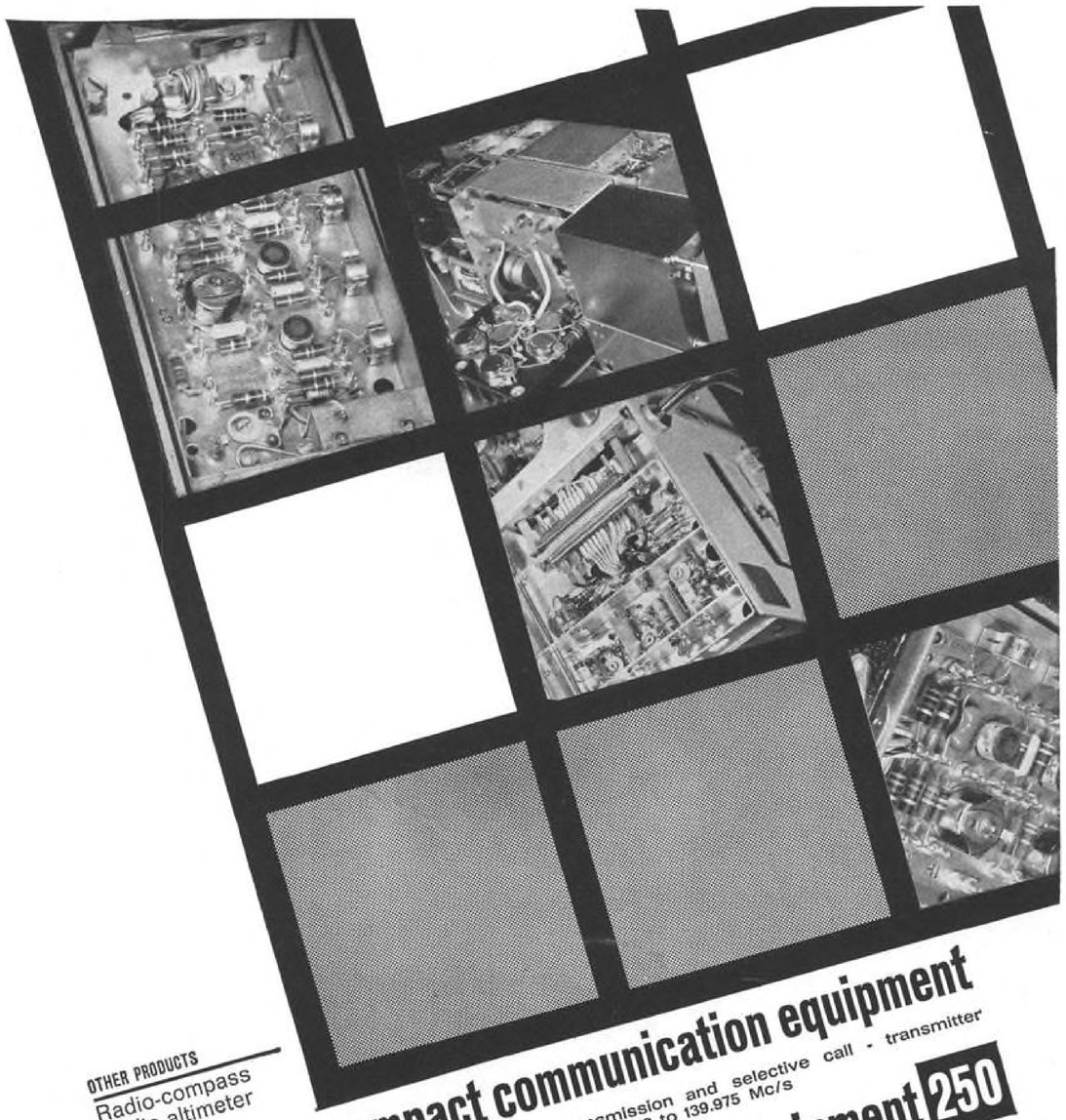
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- aircraft/engine accessories

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power : 25 W frequency band : 118 to 139.975 Mc/s

compact navigation equipment 250

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Circle Number 17 on Reader-Service Card →



1,600,000 Hours of Nuvistor Life Tests DEMONSTRATE:

99.53% RELIABILITY

per 1,000 hours over first 10,000 hours of operation at a

95% CONFIDENCE LEVEL

New data, from continuing tests, substantiate these exceptional reliability figures for RCA nuvistors.

1,600,000 tube hours of actual life tests on the RCA-7586 nuvistor triode have established a failure rate of only 0.47% or less per 1,000 hours—for the first 10,000 hours of operation—at a confidence level of 95%.

Furthermore, during the tests, involving 532 nuvistors, only one tube showed a reduction in transconductance to 50 percent or less of the initial value. The tests also revealed no sustained downward trend in transconductance distribution. Based on these findings, wear-out type failures should be virtually non-existent during the first 10,000 hours of nuvistor tube life.

These facts give you 95% assurance that:

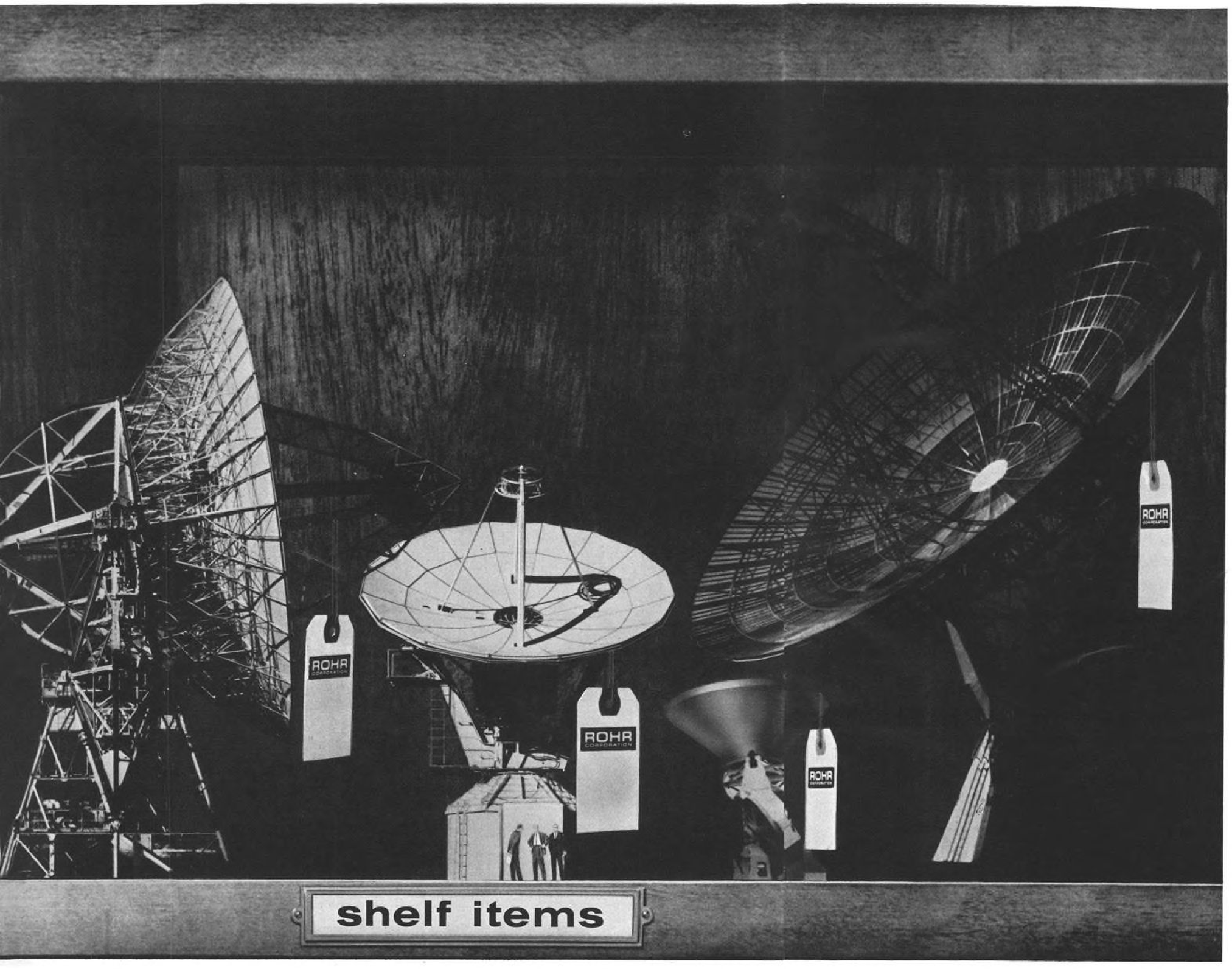
- Of every 200 RCA-7586 type nuvistors in your sockets, 199 will satisfactorily complete each 1,000 hours during the first 10,000 hours of operation.
- Nuvistor characteristics are exceptionally uniform from tube to tube, and remain exceptionally stable throughout tube life

This outstanding reliability is one more reason why you should specify nuvistors for all applicable circuitry. For technical data on specific types, see your RCA Field Representative or write: Commercial Engineering, RCA Electronic Components and Devices, Harrison, New Jersey.

Nuvistor Life Test Conditions		
	Test Conditions =1	Test Conditions =2
Heater volts	6.3	6.3
Heater-cathode volts	100	0
Plate volts	100	—
Plate-supply volts	—	75
Grid volts	−1.85	—
Cathode resistor—ohms	—	100
Grid-circuit resistance—megohm	0.5	0.5
Metal-shell temperature—°C	150	150
Plate dissipation—watts	1	0.75

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Rohr has researched, developed, engineered, built and erected the antennas shown here, along with others. They are among the largest and most precise antenna structures in the nation today. And performance has exceeded customer specifications in every instance.

The unique Rohr capability in the manufacture of this massive, accurate antenna hardware is a natural . . . the application of top antenna talent to a tremendous base of experience in metal forming for the precision production of large aircraft components.

Because of the interdependence of the antenna structure and the servo control and drive, Rohr is ready . . . and actually prefers to furnish fully integrated systems. Both hydraulic and electric drive and control systems have been designed and are available for each antenna structure developed. The antennas shown have been fully engineered and, therefore, represent "off the shelf" economy to Rohr customers, along with short delivery time. Minor modifications can be made to meet individual customer requirements.

All antenna cost quotations reflect the Rohr policy of complete customer service and include design, fabrication, packing, shipping, installation, foundation design, accommodation for RF equipment, field alignment and check-out and acceptance tests to prove performance.

Rohr 85-foot X-Y Antennas (F/D .4) with X band (TO 11 KMC) capability are used as satellite data acquisition trackers. Four have been fabricated . . . the first installed for NASA Goddard Space Flight Center near Rosman, North Carolina, and the second near Fairbanks, Alaska. Preliminary acceptance tests indicate all performance requirements will be met or exceeded.

Rohr 30-foot Az/El Antennas (F/D .4) with K band (TO 33 KMC) capability is a versatile instrument with missions including satellite communications, solar and galactic studies, precise doppler ranging of satellites or planets, missile tracking and telemetry. The first installation has been operational since July, 1962, at the Goldstone Tracking Station near Barstow, California, and all specifications have been exceeded.

Rohr 85-foot Az/El Antennas (F/D .4) with X band (TO 10 KMC) capability are designed for use in solar and galactic studies, precise doppler ranging of satellites or planets and missile tracking. Current Air Force Bahama Islands installation is for the mission of telemetry data.

The above antennas are available with economical mesh surfaces for operation at lower frequencies.

A 15-foot diameter millimeter radio telescope (F/D .3) has been fabricated and is currently being tested at Rohr. With capabilities to 300 GC, over-all operation of the instrument appears to make it the most precise radio telescope for its size in the free world today.

In addition, Rohr is the prime contractor on the 210-foot antenna currently being built for JPL/NASA.

For full information on the Rohr antenna capability and costs, please phone or write: Marketing Manager, Dept. 16 , Rohr Corporation, Chula Vista, California.

Main Plant and Headquarters: Chula Vista, Calif./Plant: Riverside, Calif./Assembly Plants: Winder, Ga.; Auburn, Wash.

Sales Offices in Washington, D.C.; Huntsville, Ala.; Houston, Tex.; and Dayton, Ohio.

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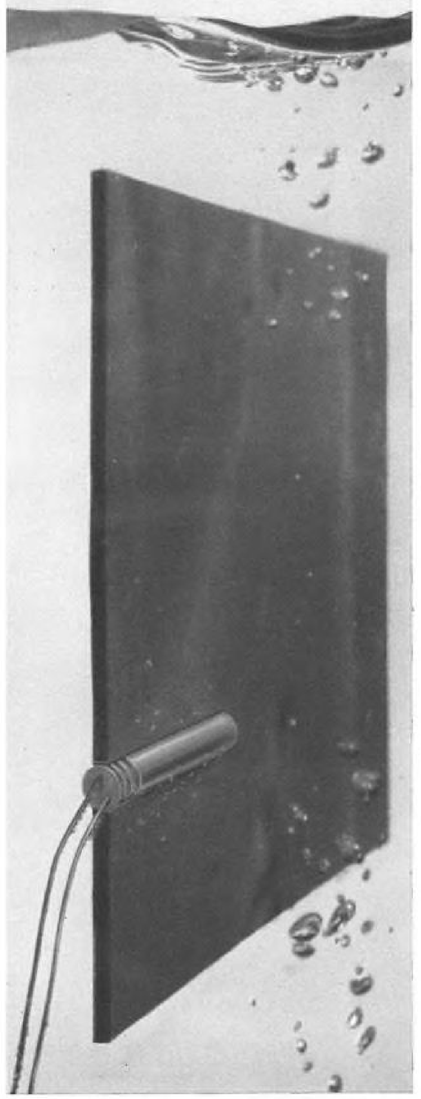
Covina, California / A Divison of Aerojet-General Corporation

GENERAL TIRE T.M.

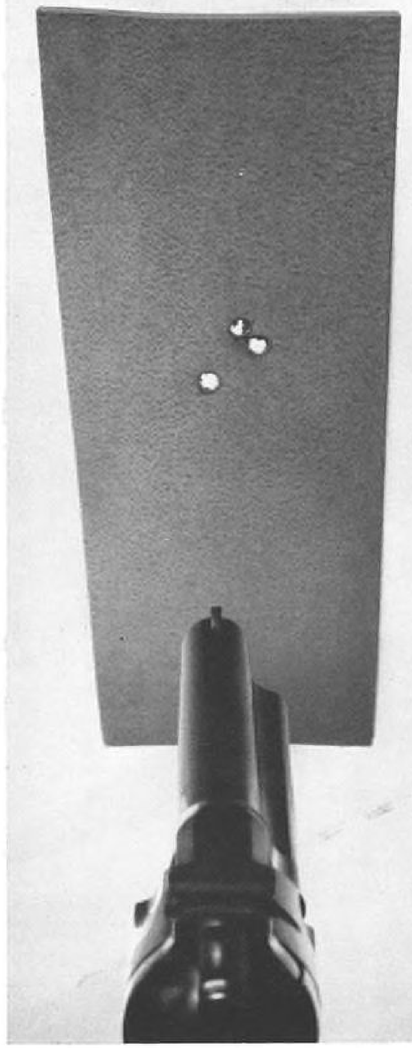


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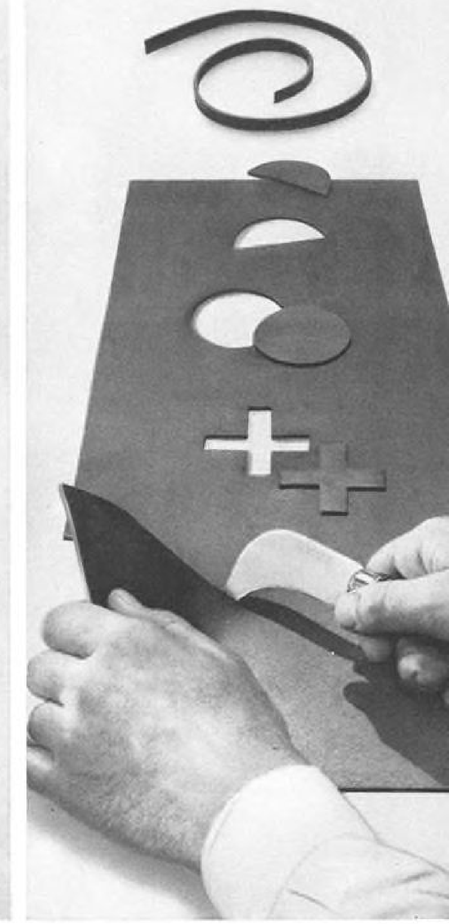
1. WATERPROOF. "Detasheet" EL-506 is unaffected by moisture or water pressure, yet requires no protective coverings. In tests it has been fired at pressures greater than 11,000 psi, equivalent to depths of more than 25,000'.



2. INSENSITIVE TO SHOCK. "Detasheet" EL-506 is insensitive to shock, such as bullet impact—yet a standard blasting cap detonates it. It can be stored safely at temperatures from —40°F. to 165°F. and retains flexibility under these extremes.



3. EASILY CUT TO SHAPE. You can cut "Detasheet" EL-506 to any configuration with an ordinary knife, then shape it to fit any surface. This makes it an extremely versatile explosive where cutting or demolition is required.



Think explosively with "Detasheet®" a unique flexible explosive from Du Pont

MEETS MILITARY SPECIFICATION... MIL-E-46676 (MU)

"Detasheet" EL-506 is one of the most versatile of all explosive materials and is available only from Du Pont.

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Please send me your 20-page guide which gives details on Du Pont explosive specialty products and engineering services including data on "Detasheet" sheet explosive.



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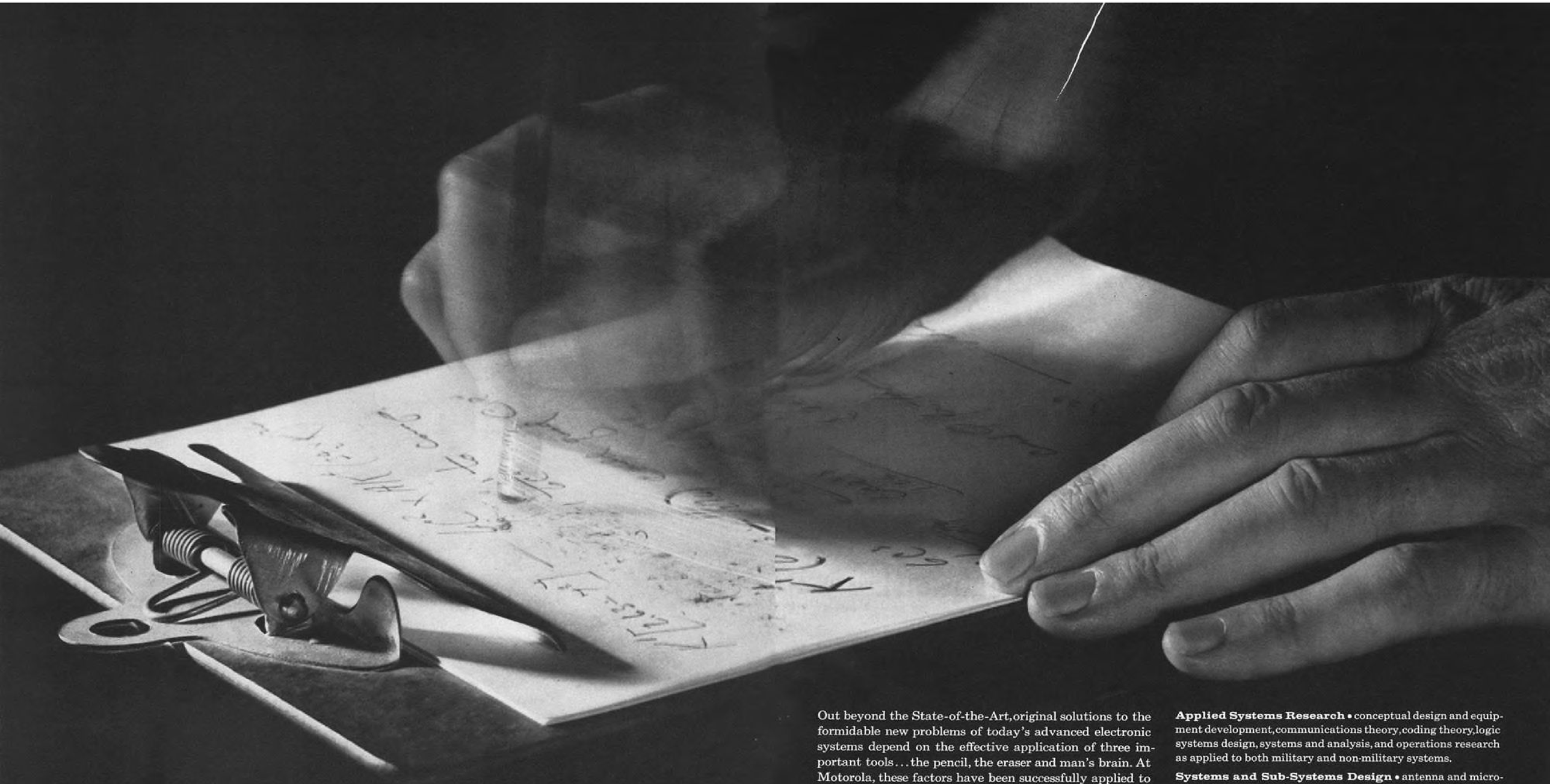
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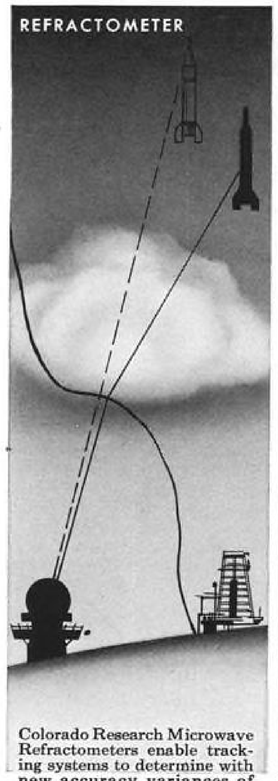
Applied Systems Research • conceptual design and equipment development, communications theory, coding theory, logic systems design, systems and analysis, and operations research as applied to both military and non-military systems.

Systems and Sub-Systems Design • antenna and microwave design, integrated circuit applications, stress analysis and heat transfer, digital and voice communications, command and control, telemetry and tracking systems design, data processing and display, ultrareliability design techniques, radar and guidance equipment.

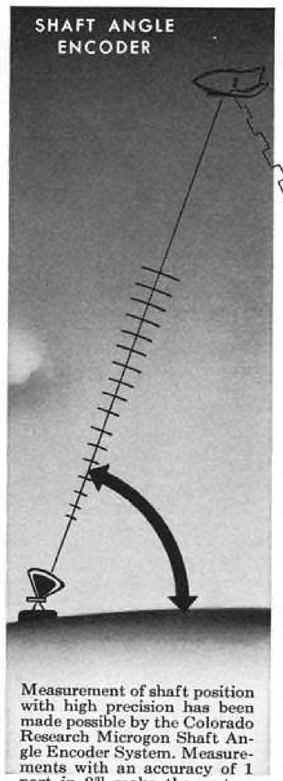
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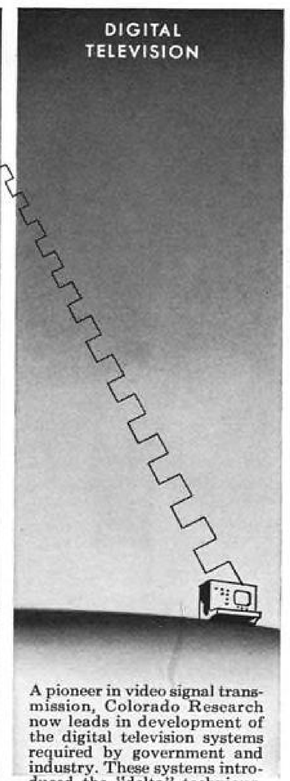
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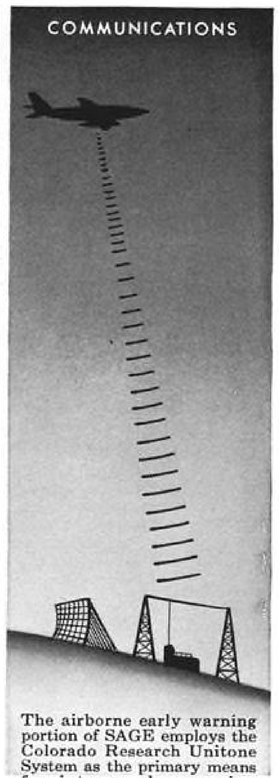
Colorado Research Microwave Refractometers enable tracking systems to determine with new accuracy variances of radar wave velocity caused by variances in refractive properties of the atmosphere.



Measurement of shaft position with high precision has been made possible by the Colorado Research Microgon Shaft Angle Encoder System. Measurements with an accuracy of 1 part in 2^{21} make the system invaluable in the encoding of azimuth and elevation shaft angles of tracking systems.



A pioneer in video signal transmission, Colorado Research now leads in development of the digital television systems required by government and industry. These systems introduced the "delta" technique, which requires less bandwidth, and improves signal-to-noise performance.



The airborne early warning portion of SAGE employs the Colorado Research Unitone System as the primary means for air-to-ground communication over difficult circuits considered unusable or marginal for other encoding techniques.

4 steps ahead in scientific problem solving

► Everything new about the four systems represented here has expanded the capabilities of science, defense establishments and industry, or opened new fields for scientific exploration.

► For example, the CRC Refractometer has given scientists a new yardstick for measuring refractive index... with direct application in the tracking of missiles and satellites, aircraft detection and the study of weather. The CRC Digital TV System allows further video signal processing for special transmission requirements.

► These accomplishments are typical of the creative intelligence with which Colorado Research is approaching a variety of related problems. Work now in progress covers methods of transmitting information at higher speeds, subminiature television camera systems, new techniques for pre-composing messages, new rotary and linear displacement sensing techniques and basic instrumentation research.

► For information on how these capabilities can contribute to your project's success, address Manager of Marketing, Colorado Research Company, Broomfield, Colorado.

STAFF POSITIONS ARE OPEN FOR MEN WHO WANT TO STAY AHEAD IN SCIENTIFIC PROBLEM SOLVING.

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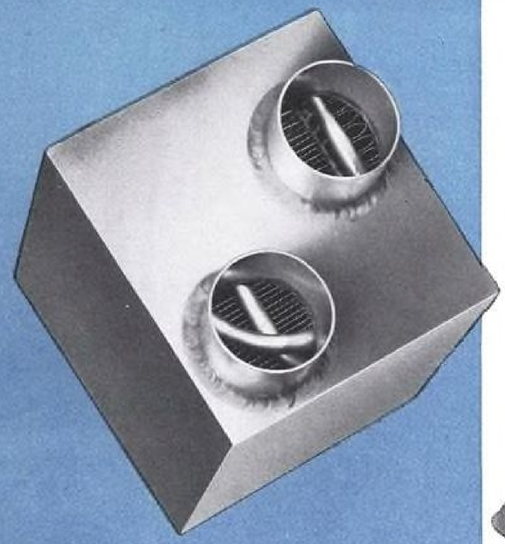
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EXPERIENCE— GM-Harrison experience—leads to important advances in temperature control equipment for the space age. Harrison's answers to heat transfer problems are based on broad experience in many fields—*aero/space, nuclear, automotive, marine and industrial.* And to come up with temperature control equipment *MATCHED TO THE JOB,* Harrison engineering teams choose from a *complete* line of basic designs. At Harrison, it is this *experience* and *selectivity* which provides heat exchangers with an optimum combination of performance, reliability and economy.

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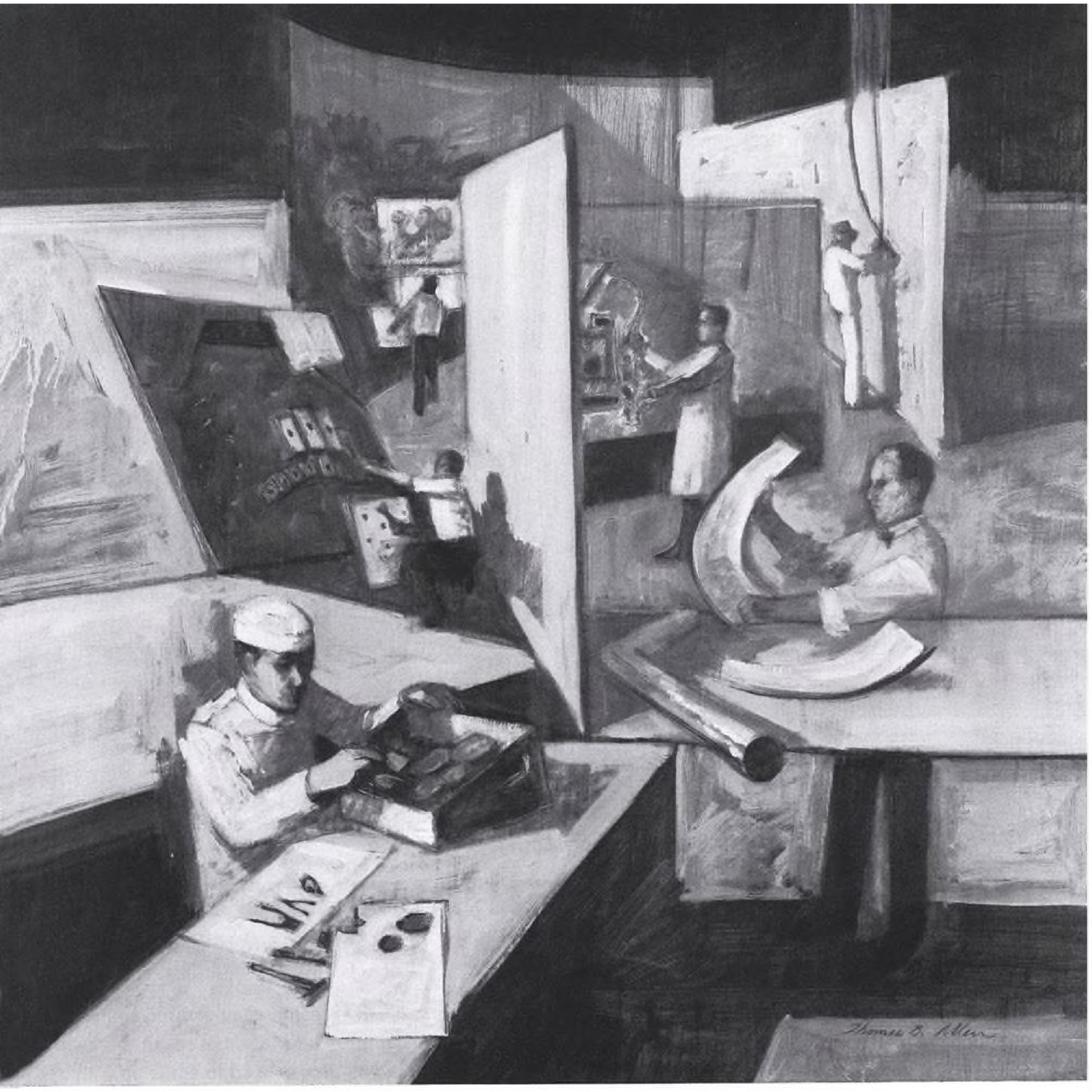
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AERO/SPACE, AUTOMOTIVE, MARINE AND INDUSTRIAL HEAT EXCHANGERS

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THE NEW CRAFTSMEN Fingers are not made for sensing millionths of an inch. Nor can the eye discern such tolerances. Yet every day the production workers of today's aerospace industry turn out instruments and components which are accurate to the millionth degree.

Though they deal in variances as fine as a wave length of light, these men are neither scientists nor engineers. In most cases they were previously untrained for the job. But the parts they produce are so uniform that a precision instrument like the gyro can be mass-assembled from elements chosen at random.

Behind this effort, shaping the techniques that make it possible, are the industry's production experts. Clear-sighted men who know that reliability is not only designed into a product, but also must be *built* in.

Together, these experts and workers have turned production-line manufacturing into an exact science.

These are the new craftsmen—the men-on-the-line in a space-age world.

North American Aviation is at work in the fields of the future through these divisions: Science Center, Atomics International, Autonetics, Columbus, Los Angeles, Rocketdyne, Space & Information Systems.

GOING TO THE MOON?

If your product or service is related to manned space flight you have for-will-have reason to be in Houston. But while reaching for the moon we suggest you keep your feet on the ground with the most competent financial assistance in Houston, the bank of competence is The National Bank of Commerce. We have been helping customers with specialized knowledge for more than 50 years and the space age has not caught us by surprise. Realizing your concern with space-age speed and time, be advised that The Bank of Commerce is bolstered by a world-wide network of banking connections to provide instantaneous service wherever and whenever it is needed. And if you're not already represented in Houston, we remind that The National Bank of Commerce is adept at helping firms move here.

If your plans call for offices in Houston, it is possible to arrange select suites in the National Bank of Commerce Block in the heart of the business district, the block consisting of the Gulf Building, Gulf Building Addition, the Bank of Commerce Building and the Houston Club Building, where all freeways and principal arteries converge. For details write: Gainer B. Jones, Senior Vice President, The National Bank of Commerce, Houston 1, Texas

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ARMY



AIR FORCE



MARINES

THE UH-1 JOINS THE AIR FORCE

The U. S. Air Force has selected the Bell UH-1 to fulfill its missile site support mission, making this versatile turbine-powered helicopter a tri-service aircraft.

The UH-1 brings proven performance capabilities to the nation's air arm. It has served the military throughout the world. Its recorded missions have spanned the globe . . from the Arctic to the South Pole, in the mountains, the jungle and the desert.

Included in its operational history are such missions as: Troop Transport ● Observation ● Fire Fighting ● External-Cargo Transport ● Materiel Transport ● Armed Escort ● Air-Sea Rescue ● Disaster Relief ● Topographic Survey ● Aerial Command Post Flight ● High Altitude Rescue

Bell welcomes this Air Force assignment.

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The tape with the built-in duster!

1000 times greater conductivity than ordinary tapes! That's how "SCOTCH" BRAND Heavy Duty Tapes drain off static charges before they can attract dust. That's the built-in duster that flicks away the growing danger of dust-caused dropout errors . . . a danger greater than ever as higher and higher recorder speeds and tape tensions generate more and more static.

Electrical resistance of the oxide coating of "SCOTCH" Heavy Duty tapes is 50 megohms per square or less. The resulting conductivity, unusual in magnetic tape, not only avoids dust contamination, it minimizes such other static problems as tape drag and skew, noise induced by arcing.



Heavy duty formulation of binder and high potency oxides withstands temperatures from −40 to as high as +250°F to conquer high head heat, assures tapes that outlast standard tapes by at least 15 times. Exclusive Silicone lubrication reduces recorder head and tape wear. And "SCOTCH" Heavy Duty Tapes are offered for all high-speed applications, even for extreme high frequency and short wavelength requirements. 16 different constructions include a variety of backing and coating thicknesses.

TECHNICAL TALK Bulletin No. 4 provides detailed discussion of the effects of static electricity on instrumentation recording, offers helpful information in solving static-caused problems. It's free. Write 3M Magnetic Products Division, Dept. MCJ-73, St. Paul 19, Minn.

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MODEL T-180F

PAYMOVER®

Now you can buy a tractor designed specifically for push-out—the Model T-180F PAYMOVER—that has 4-wheel drive, automatic transmission, and front-wheel steer, and can handle the largest passenger planes. It develops up to 18,000 lb. push-bar effort and can be counterweighted if necessary for winter operations.

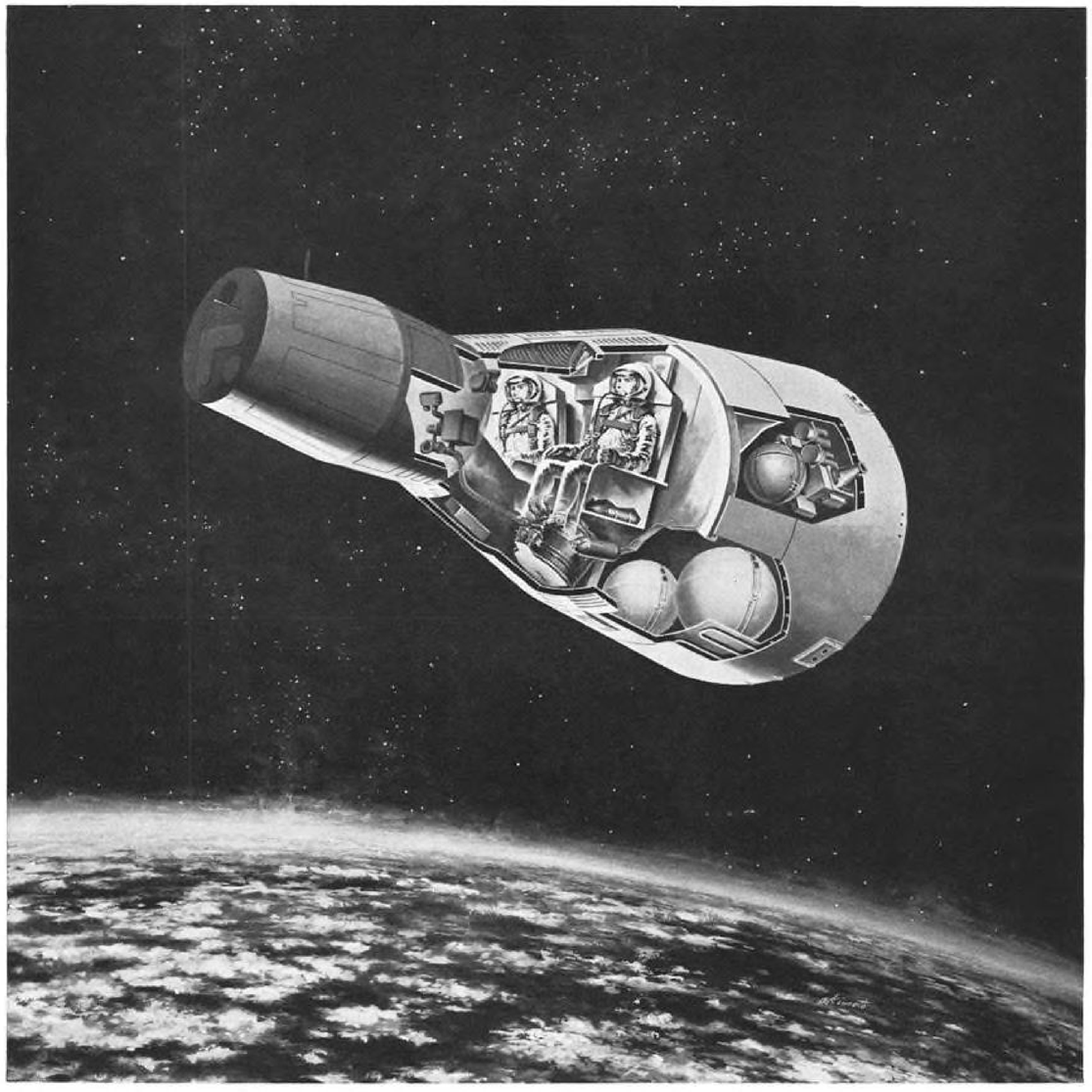
Not only is the T-180F just right for terminal push-out operations, but the price is right too, because it sells for considerably less than any 4-wheel-drive, 4-wheel-steer PAYMOVER tractor heretofore available. In spite of its modest cost, this PAYMOVER is a product of the same high quality of materials, superior engineering and manufacturing know-how that have made PAYMOVER tractors of all sizes the outstanding choice of the world-wide airline industry. B-E-1

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Life support for 14 days in space

The NASA-McDonnell Project Gemini is the major link between Project Mercury and Project Apollo (this nation's first flight to the moon). It will give our space effort vital information on prolonged spaceflight effects and will also be used to test space rendezvous techniques.

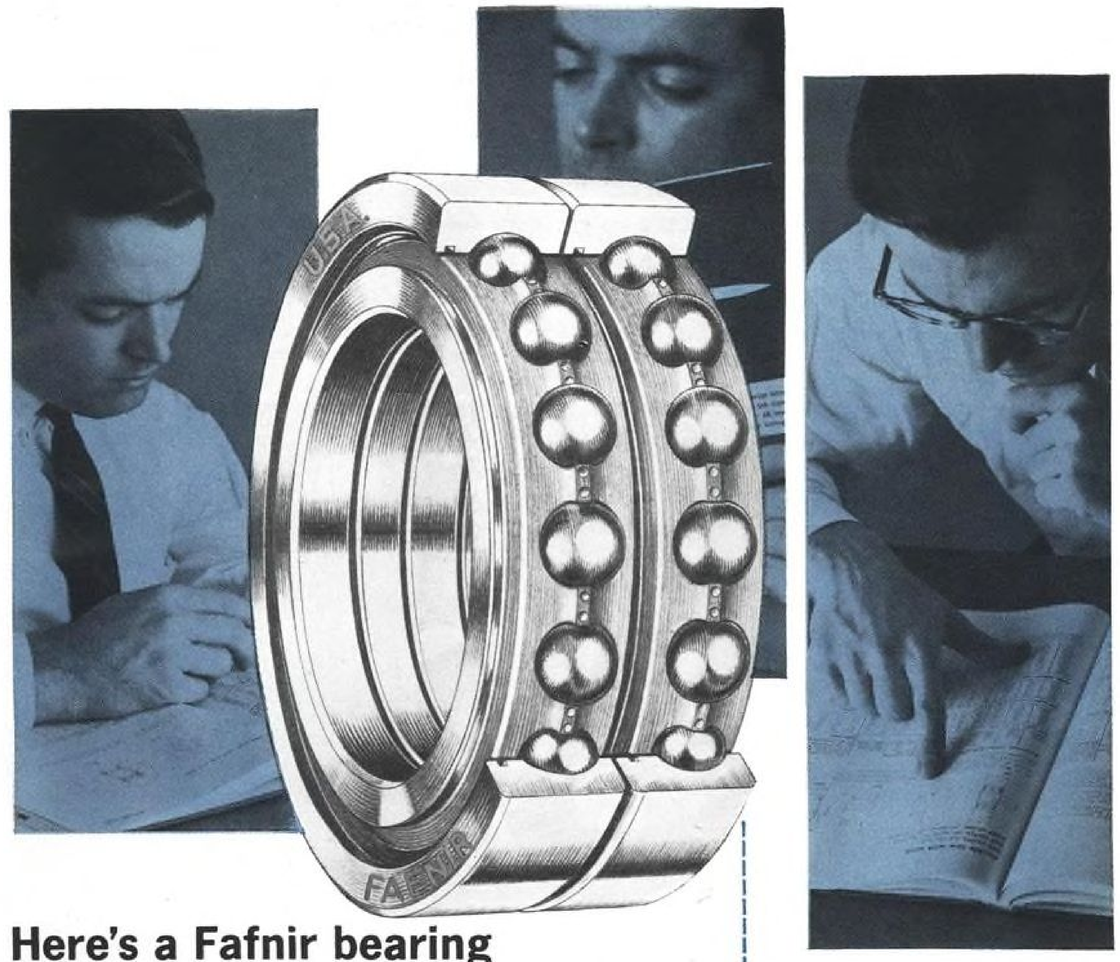
Gemini's advanced environmental system will keep the spacecraft's two astronauts comfortable for two weeks of continuous orbital flight. Garrett-AiResearch builds the system that provides a breathable atmosphere, pressurization, temperature control, ventilation and atmosphere purification in the two-man spacecraft and in both astronauts' suits for the entire flight. AiResearch also supplies the supercritical cryogenic oxygen and hydrogen tankage system for the fuel cell power supply.

This major contribution to the advancement of space travel is one more example of Garrett's proved capability in the design and production of vital systems and their components for man's most challenging exploration.

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Here's a Fafnir bearing you can't find in the catalog . . .

It's a Fafnir jet engine main rotor bearing. You can't find it in a catalog because bearings like this are custom-engineered.

They have to be. These bearings take the brunt of engine thrust — up to 10,000 pounds of it and more. They operate in oven-like temperatures at speeds up to 20,000 rpm. And, under extreme stress of high speed maneuvers, they must hold the critical main shaft in precise position.

At Fafnir, complex requirements such as these have produced new developments in bearing design. Fafnir pioneered radioisotope measurement of bearing wear, for example, and the use of advanced computer techniques to help assure optimum design and reliability.

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FAFNIR
BALL BEARINGS

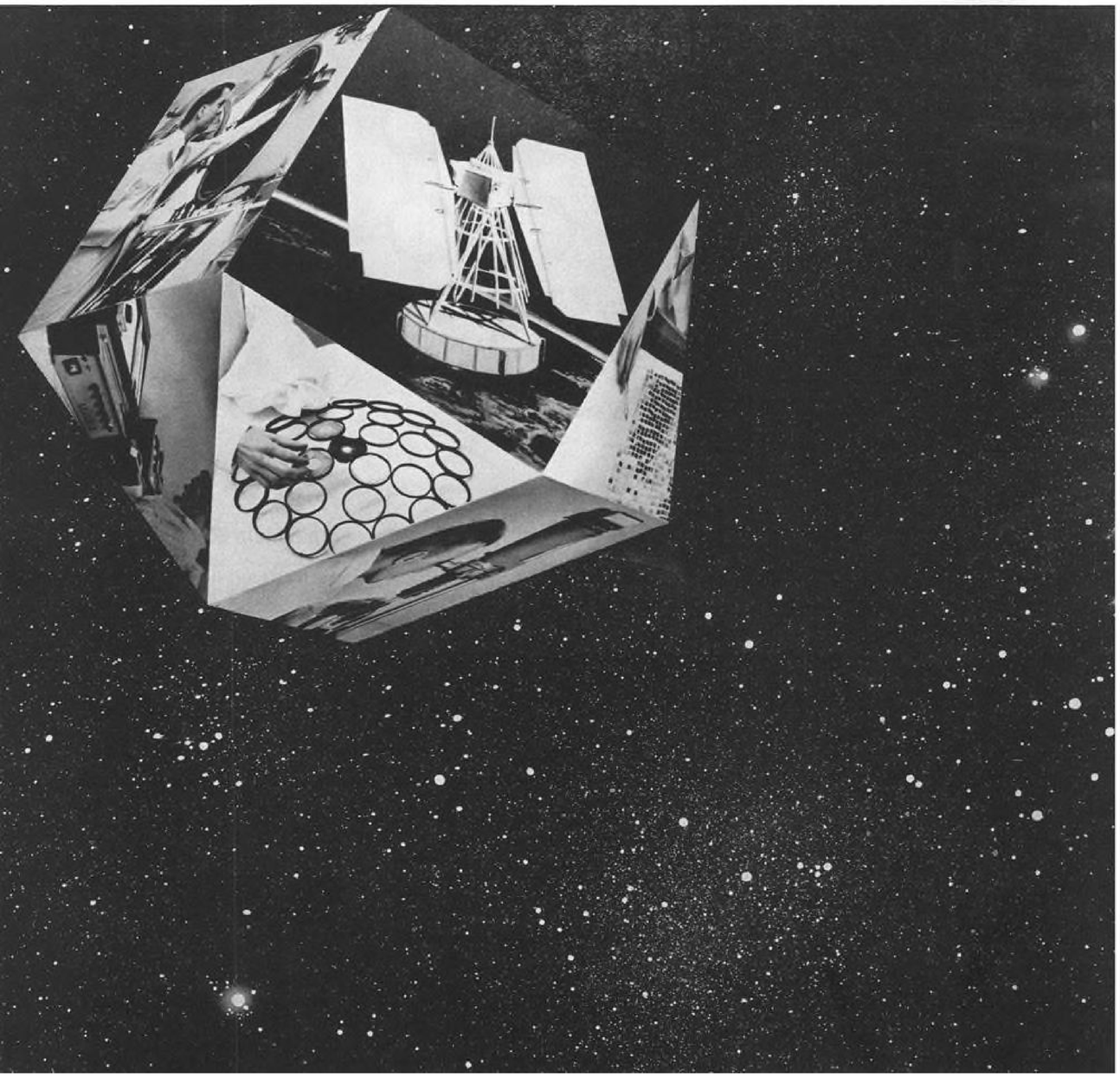
Fafnir Main Rotor Bearings

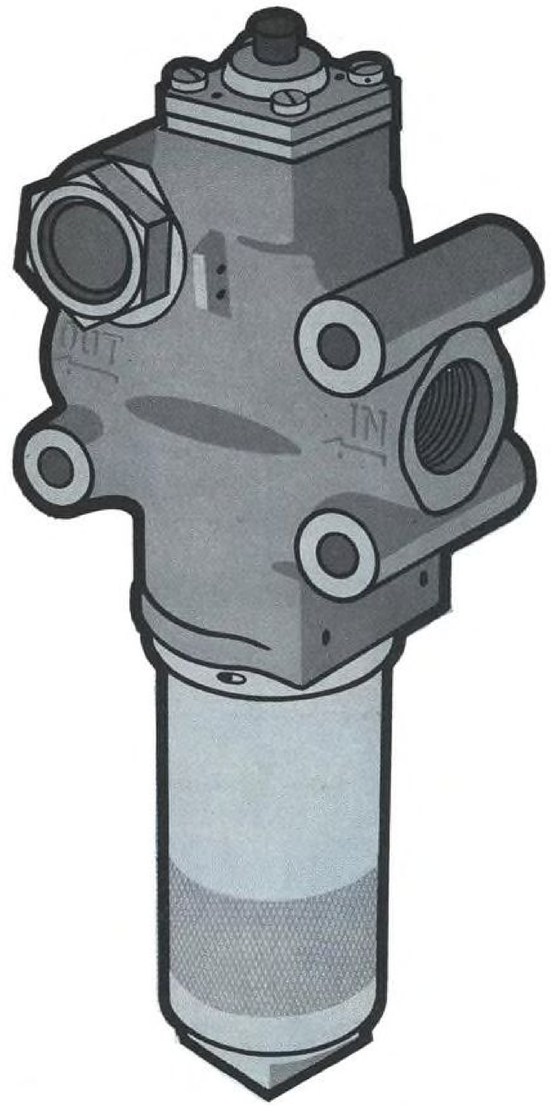
- **Precision**—Dimensional geometry rigidly controlled for extreme accuracy. Balls and races finished to millionths of an inch. Tolerances within ABEC-7 limits.
- **Extra-strength steel**—Long life vacuum-melt M-50 steel retains its high strength at elevated temperatures.
- **Special design** — Fafnir-engineered for maximum performance. Features angular contact bearings incorporating split inner ring construction enabling higher capacity and longer life.
- **Special retainers** — High strength bronze, steel, nickel base alloy retainers for resistance to heat and corrosion. Silver plated for low friction.
- **Reliability-engineered** — Computer techniques developed and applied by Fafnir engineers enable thorough study of alternatives to assure optimum design for maximum reliability.
- **Research proven** — Prototype designs include such advanced techniques as radioisotope testing to detect wear of as little as ten millionths of a gram of steel.

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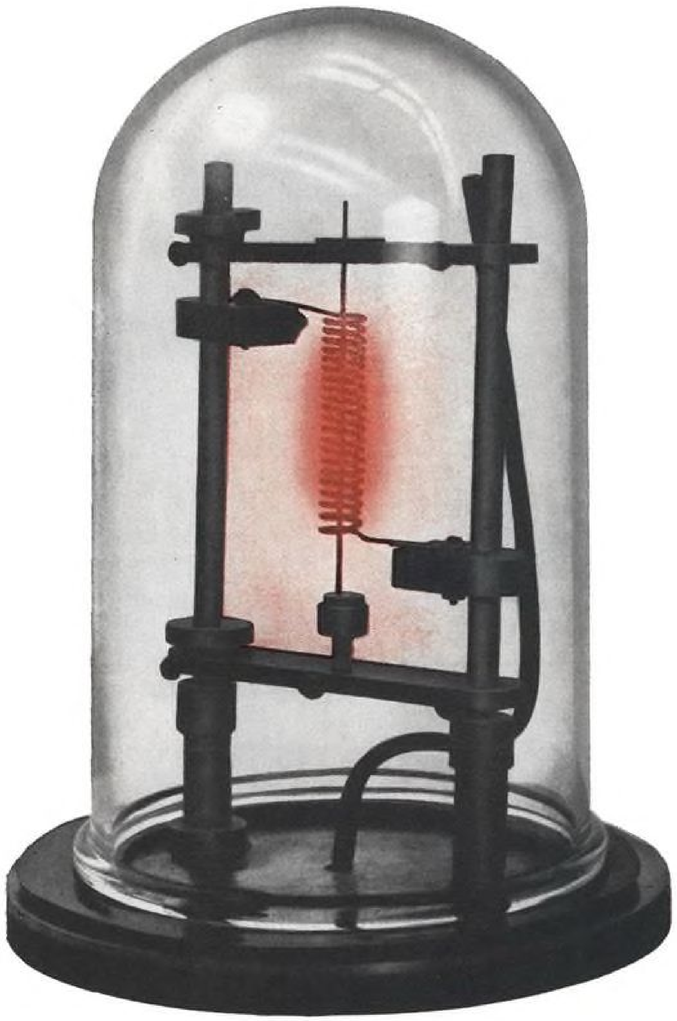
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Need a high-pressure hydraulic filter for aircraft and missiles? One that's complete with differential pressure indicator, automatic shut-off valve? Or how about a simple line strainer? Air-Maze makes them both. Sixteen other filter types, too. More than 3,000, all told. Air-oil separators. Dry and oil bath filters. Even filters that scrub themselves clean. Plus silencers, spark arresters and breathers. Chances are, if you need a filter we have it or can design and make it. For detailed information, write or call Rockwell-Standard Corporation, Air-Maze Division, Cleveland 28, Ohio.

AIR-MAZE FILTERS ARE PRODUCED BY ROCKWELL-STANDARD CORPORATION

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Circle Number 35 on Reader-Service Card



To optimize a TWT . . . use a crystal ball



STC-278, 50 watt pulsed C band TWT, provides superior electrical performance as a driver in radar transmitters, rf amplifiers, and other wide band applications.

"Pyrolytic deposition" is the fancy name for it. In simpler terms, it's Sperry's method of using heat and a controlled atmosphere to put attenuation on TWT support rods in a very precise manner. Result: higher gain and improved efficiency for Sperry traveling wave tubes.

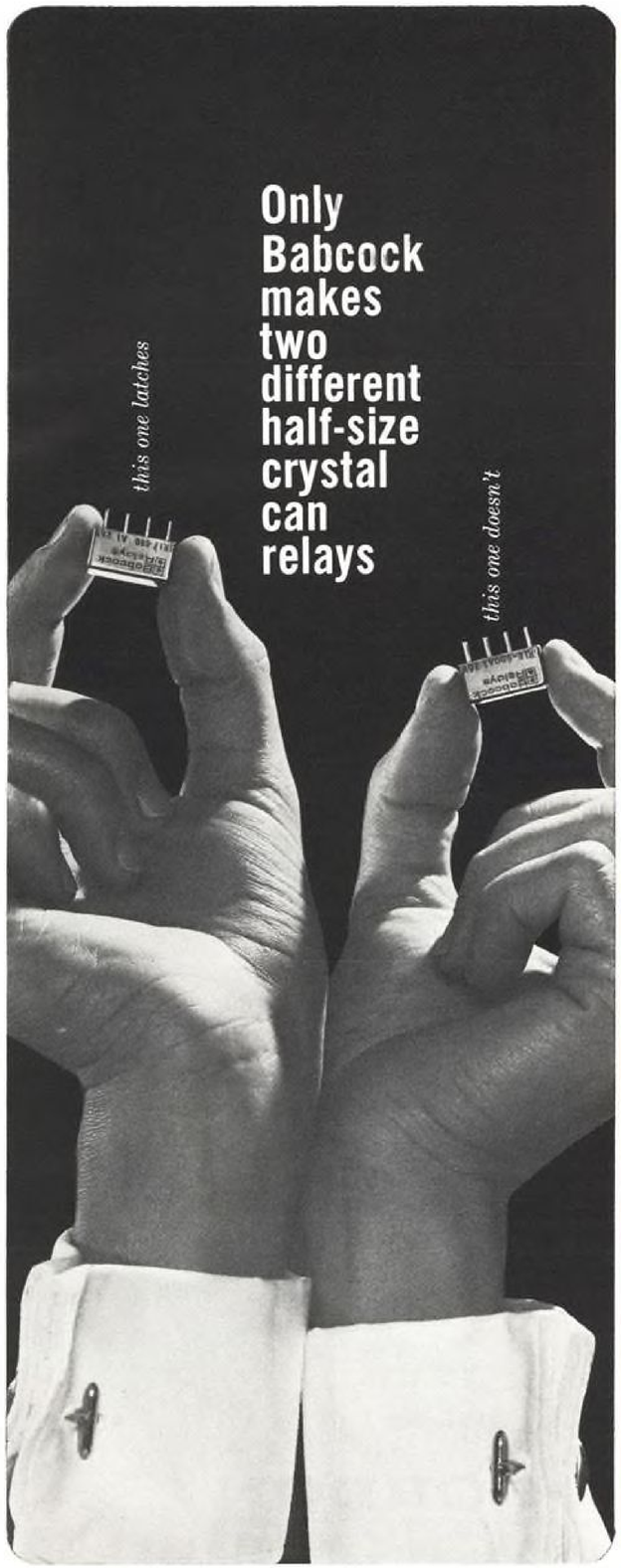
This is only part of the Sperry effort to optimize the electrical parameters of TWT's. Attenuators are important . . . beam focusing, amplitude fine structure, and gun design get their share of attention too. All these programs are devoted to a single objective . . . the production of TWT's with a near-perfect mix of electrical characteristics.

Many of these efforts are already bearing fruit in the form of operational hardware. Production tubes like the STL-405 and STS-101 (200 W performance over octave bandwidth at L and S bands) and the STC-278 (exceptional fine structure and phase linearity characteristics) vouch for Sperry's success.

A NEW TECHNICAL PAPER gives full engineering and scientific details of the considerations involved in electrically optimizing traveling wave tubes. For your copy, write Sperry, Gainesville, Florida, or contact your Cain & Co. representative. In Europe, contact Sperry Europe Continental, Paris.

SPERRY ELECTRONIC TUBE DIVISION
SPERRY RAND CORPORATION
GAINESVILLE FLORIDA

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Only Babcock makes two different half-size crystal can relays

Designed for low profile mounting, Babcock's new half-size crystal can relays are available for latching (BR-17) and non latching (BR-16) application. Both types feature exceptionally high sensitivity and durability. Remarkably efficient coil operation requires only 175 mw pull-in power to switch any load from dry circuit to 2 amps. Predicted failure rate on the BR-16 and BR-17 is less than 0.1% in 10,000 operations with a 90% confidence factor.

These exclusive Babcock high reliability features are the reasons why;



High-flux armature action. Balanced armature is located inside coil along path of maximum flux concentration. High density of magnetic force lines in core allows armature movement with minimum field excitation.



Heat sink / magnetic flux conductor. Coil cover of high permeability alloy lowers heat generation through improved magnetic circuit efficiency, while functioning in dual capacity as heat conductor-radiator.



Activated Vycor getter. Exclusive to Babcock, this porous glass getter prevents contact contamination by adsorbing outgassed organic substances, following production degassing at 200°C under less than 5 microns vacuum.



Welded-header construction. Automatic sealing process gives stronger header-case bond and prevents solder flux contamination. Leakage rate is less than 10^{-8} c.c. per sec. by mass spectrometer.



Self-wiping, gold-plated contacts. Contacts of AgMgNi alloy with specially-designed configuration assure miss-free performance under load and minimize low level contact resistance.

The BR-16 is available in SPDT and DPDT versions, the BR-17 as DPDT only. Various mounting arrangements and either plug-in or solder hook terminals can be supplied as standard. Send for complete details.

BABCOCK BR RELAYS

A DIVISION OF BABCOCK ELECTRONICS CORPORATION
3501 HARBOR BLVD., COSTA MESA, CALIF. • 546-2711

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VEHICLE, ENGINE OR BOOSTER

the advanced-project forgings are developed at Wyman-Gordon

Parts such as these show why Wyman-Gordon is so often entrusted with forging the shape of things to come in space hardware. Size-and-configuration barriers have been breached, in light metals through superalloys, by pioneering work of the forging industry's largest, most thoroughly space-oriented research program. Even more significant pioneering is evident in Wyman-Gordon's single-pass extrusion of Titanium and roll forging of high-temperature alloys. Both are extending performance and reliability potentials of top-project propulsion systems—nuclear as well as chemical. But such developments merely highlight the unique breadth of experience and know-how Wyman-Gordon brings to every space-forging problem —whatever the project mission or environment.



This super-booster's structural beam of 7179 Aluminum measures 83" in length and weighs 178 lbs.



Manned boost-glide vehicle "hot" structural component of Rene 41 measures 18x8" with a forged weight of 162 lbs.



Spacecraft structural forging of Rene 41 measures 13x13x5" with a forged weight of 139 lbs.



Contoured Rene 41 spacer ring for 1.5 million-lb.-thrust engine measures 38x4½" with a weight of 500 lbs





2149-lb. Inconel X injector for lunar landing launch vehicle engine measures 44x7½".

Extruded reactor case of nuclear engine is 51x36" with a weight of 745 lbs. in 5A12½Sn Titanium alloy.

WYMAN-GORDON

Forgings of Aluminum, Magnesium, Steel, Titanium and Beryllium, Molybdenum, Columbium and other uncommon materials

WORCESTER, MASSACHUSETTS
HARVEY, ILLINOIS — GRAFTON, MASSACHUSETTS
DAYTON, OHIO — DETROIT, MICHIGAN — LOS ANGELES, CALIFORNIA

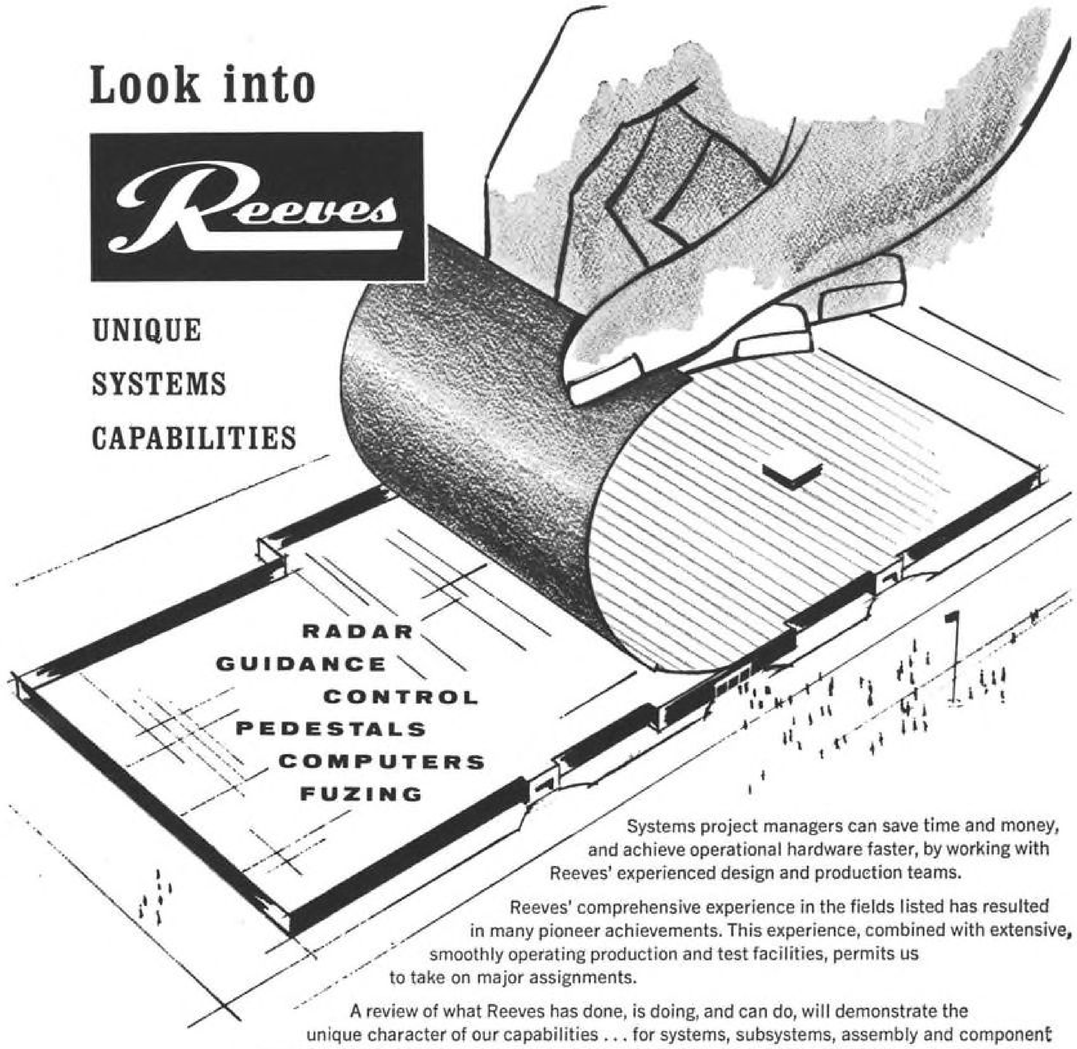
AMS

WG

Look into

Reeves

UNIQUE
SYSTEMS
CAPABILITIES



Systems project managers can save time and money, and achieve operational hardware faster, by working with Reeves' experienced design and production teams.

Reeves' comprehensive experience in the fields listed has resulted in many pioneer achievements. This experience, combined with extensive, smoothly operating production and test facilities, permits us to take on major assignments.

A review of what Reeves has done, is doing, and can do, will demonstrate the unique character of our capabilities . . . for systems, subsystems, assembly and component development, engineering, production, supply and field service. Data file 707 on request.

FOR EXAMPLE: PEDESTALS

A major contribution to today's most sophisticated radar, tracking, and range systems are the ultra-high precision antenna pedestals developed by Reeves . . . the most advanced pedestals now available. They include 10-second accuracy 2- and 3-axis radar pedestals; optical pedestals, with angular accuracies of 5 seconds of arc, capable of sustaining a 250,000 lb. load; and air-transportable pedestals with accuracy of ±0.5 degrees in both axes.

Pedestal and related system problems are readily solved through our experienced, up-to-the-minute engineering and production capabilities.

Qualified engineers who are seeking rewarding opportunities for their talents in this and related fields are invited to get in touch with us.



REEVES INSTRUMENT CORPORATION *A Subsidiary of Dynamics Corp. of America, Roosevelt Field, Garden City, N. Y.*

Reeves *Systems* *engineering...management...production...field services*

4RV63

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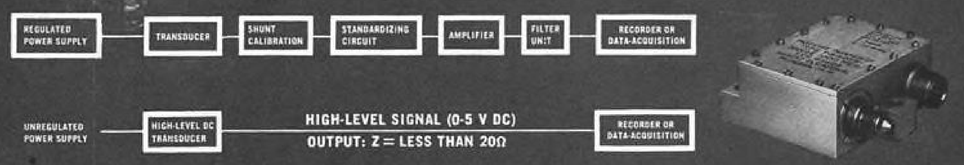
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American Gyro



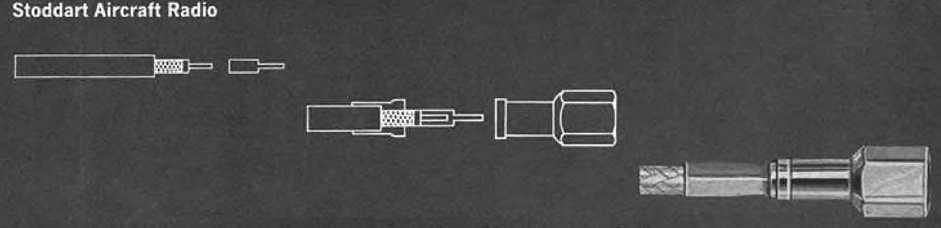
35,000+ hours' reliability on T-38 in flight!

Wiancko Engineering



Simplify static testing with this new high-level transducer

Stoddart Aircraft Radio



Assembles in 45 seconds!

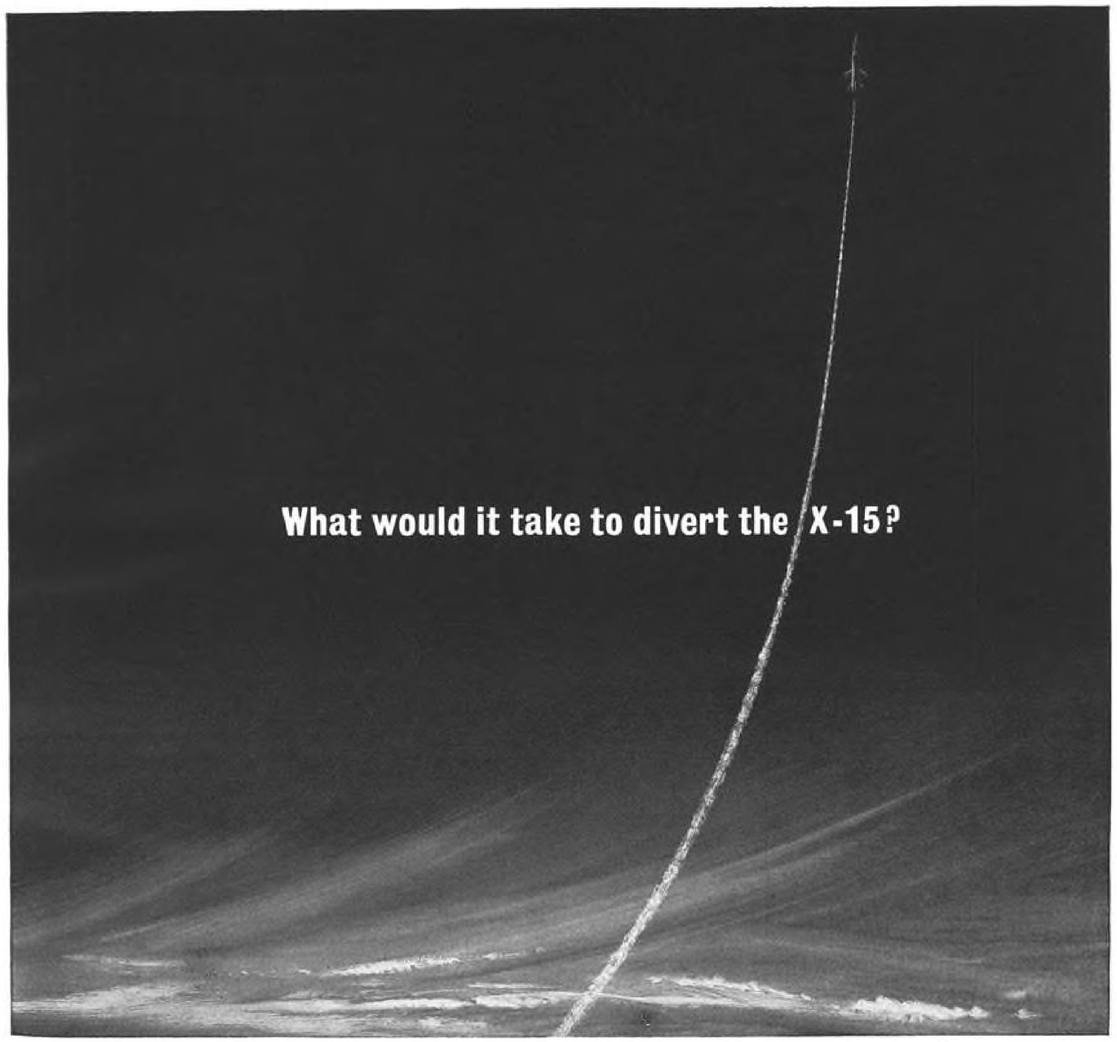
Tamar: three typical contributions to electronics

Tamar Electronic Industries, Inc., is creating advanced electronic devices and systems for both industry and the military. Among the recent achievements of three of the corporation's divisions and subsidiaries are: AMERICAN GYRO—provides Northrop's USAF T-38 supersonic twin-jet trainers with miniature rate gyros which have achieved a reliability in excess of 35,000 hours in flight. WIANCKO ENGINEERING—simplifies static testing with a high-level transducer which drives galvanometer recorders, strip-chart recorders, and automatic data systems directly. STODDART AIRCRAFT RADIO—offers the Tamar-created matched 50-ohm micro-miniature connector which assembles in 45 seconds and requires no soldering of contacts. For more information about Tamar's wide-range capabilities in electronics, please contact Robert Case, vice-president of marketing.

Visit **WESCON BOOTH #1401-2-3.**

TAMAR ELECTRONICS INDUSTRIES, INC.
California Headquarters: 1360 South Los Angeles Street, Anaheim, California

Circle Number 40 on Reader-Service Card



Dirt that can't even be seen with the naked eye could throw the **X-15** 'way off the long true line of its soaring flight. Let these microscopic particles lodge in one of the extremely fine tolerance orifices or valves of the hydraulically operated flight control system—and things begin to happen! The trouble is, this would be happening at an awesome 4000-mph-plus that converts the slightest erratic control response to enormous errors in actual flight path.

This problem of maintaining hydraulic system purity was solved in the early days of the X-15's development by installing two specially designed Purolator filters. Of compact design in weight-saving aluminum, these filters remove 100% of all particles 25-microns or larger. The elements are of thermal shock-resistant stainless steel wire cloth—capable of functioning efficiently through a −65°F to +400°F temperature range.

Purolator's creative design and development of the X-15's high pressure hydraulic filters is just one of its many contributions to aerospace progress. Purolator filters have helped solve filtration problems for virtually every type of airborne and ground support equipment produced by the aerospace industry. For more information in terms of your filtration needs, write today. No obligation . . . and we'll send you a copy of Purolator's new quarterly publication "Aerospace Filtration". It's packed with features and articles of particular interest to companies active in the aerospace industry.

Write to *Purolator Products, Inc., Rahway, N. J.*



This is Purolator's filter G-413-3, 2gpm flow capacity, about 3¾" long. It has a replaceable, line-type element of stainless steel wire cloth. It provides 100% filtration of particles 25 microns and larger, and 98% filtration of all contaminants as fine as 10 microns. Designed for 3000 psi operating pressure, it has a maximum differential pressure of 40 psi, and is fitted with internal relief valves.

1933-1963 40th ANNIVERSARY

Filtration For Every Known Fluid

PUROLATOR
PRODUCTS, INC.
RAHWAY, NEW JERSEY, LOS ANGELES, CALIFORNIA

Circle Number 41 on Reader-Service Card

nothing but talk...talk...talk...

LEACH SATELLITE RECORDER/REPRODUCERS are now in orbit storing lots and lots and lots of data . . . playing back when and where needed.

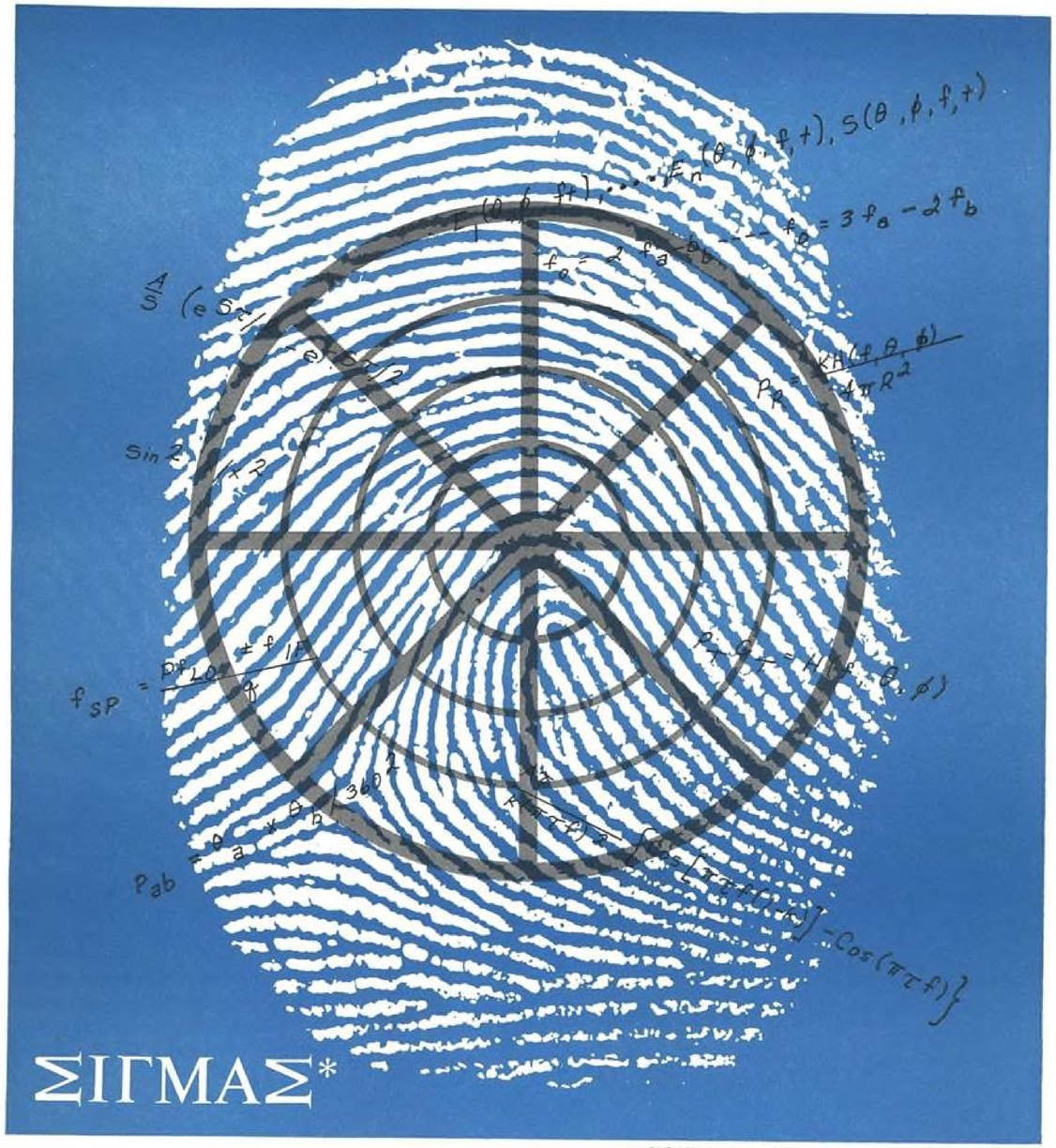
The unit shown here records on ¼-inch Mylar-base magnetic tape up to 210 minutes at 1.8 ips . . . transmits back to earth in 8:07 minutes. As it transmits, it erases itself and records all over again.

Seven pounds light and seven inches narrow, this Leach Satellite Recorder/Reproducer has taken the rockiest launch in stride, works in temperatures from —30°F to 130°F with an average power consumption of only 4 watts.

If you're in the satellite making business, you should make it your business to know more about this recorder/reproducer and how it can be adapted to your needs. You can know, too. Just send a line to Leach. You will get complete specs on this specially engineered recorder as well as other high environmental tape recorders—in the return mail.



LEACH
CORPORATION
CONTROLS DIVISION
717 North Coney Ave. • Azusa, Calif.
Export: Leach International S.A.



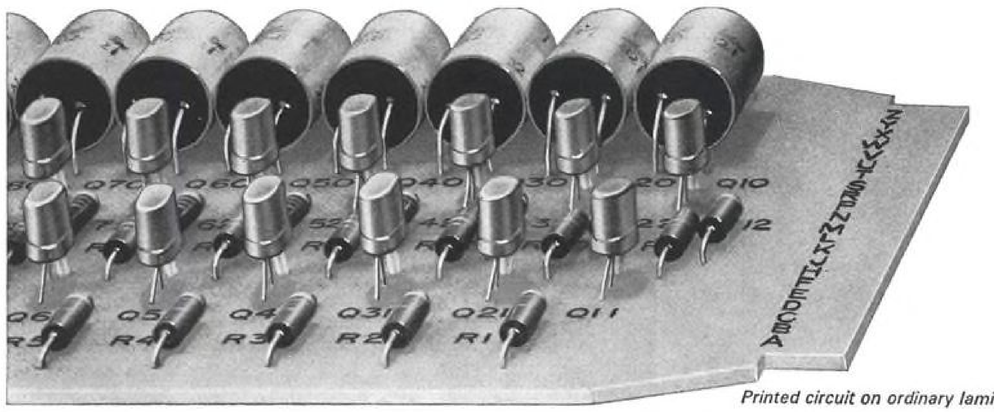
* SIGMAS – *Signal Measurement and Analysis System*

Radar Fingerprint Expert. SIGMAS is an integrated, modularized, electronic/microwave instrumentation system for *Spectrum Measurements, Spectrum Surveillance* and *Radiometric Mapping*. It provides the stimuli, receivers, programming, control, measurement, and test functions for the determination of electromagnetic radiation and susceptibility of all RF systems. □ Basically the equipment consists of a combination receiver-spectrum analyzer, high and low power signal sources and necessary test antennas, data recorders, and ancillary equipment. □ Problems solved in designing the spectrum signature measurement system provides excellent background and necessary experience for spectrum surveillance systems development. This experience, plus related research and development, clearly places Sperry/Clearwater in a unique position – with *engineering* and *production* capability for spectrum surveillance systems. □ For additional information and SIGMAS brochure, write or call *SPERRY MICROWAVE ELECTRONICS COMPANY*, Clearwater, Florida.

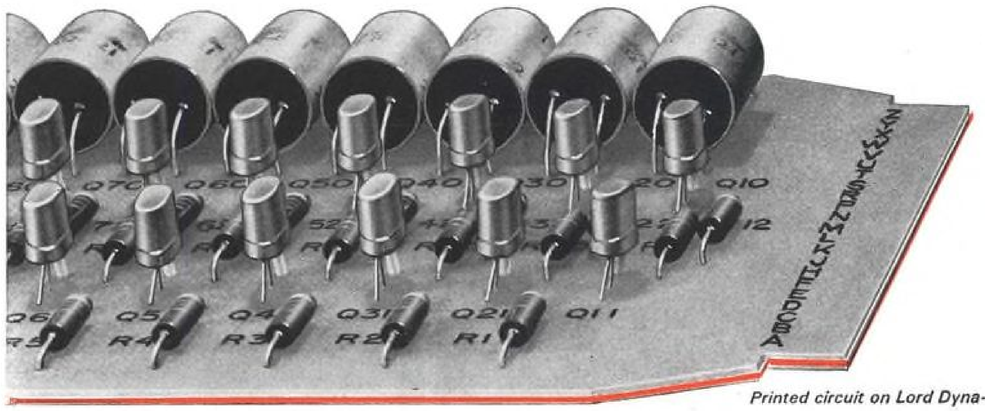
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DIVISION OF
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Printed circuit on ordinary laminated board



Printed circuit on Lord Dyna-damp® board

The difference is reliability
The reason is Lord Dyna-damp®

We don't make printed circuits. But we do add reliability to them with Dyna-damp laminates. ■ The circuits shown here—visual twins except for the damping layer—are far different in performance. Random vibration tests by a leading electronics firm showed that Lord Dyna-damp boards reduce the acceleration response level on the components by a factor of 5 or more. ■ The reason for this superiority is Dyna-damp's integral damping medium which dissipates vibratory energy and controls resonant response. The result is built-in reliability. ■ To add this kind of reliability to your printed circuits, contact: Lord Manufacturing Company, Erie, Pa. Field Engineering Offices in principal cities. In Canada: Railway & Power Engineering Corp., Ltd.

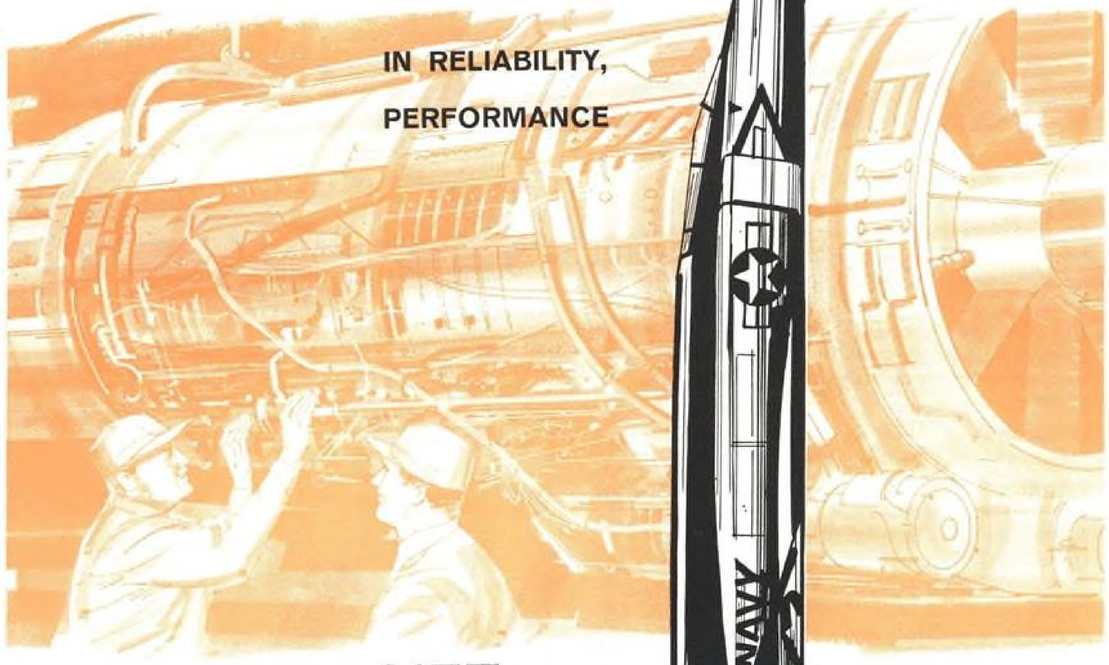
LORD®

TYPE 1307 FUEL CONTROL IS

HIGH

IN RELIABILITY,

PERFORMANCE



YET–

LOW IN WEIGHT

AND COST

As aircraft speeds range into the supersonic and beyond Mach 2, engine control needs become more and more critical and exacting. The J-79 engines on the record-setting F4H aircraft have Woodward controls which quickly and accurately sense and act upon the slightest input variation.

Type 1307 Fuel Control on the F4H is a striking example of the capability of a compact precision control to meter fuel precisely under swiftly changing conditions. Write to Woodward for your aircraft governor needs.

World's oldest and largest manufacturer of prime mover controls exclusively

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S-135

ELECTRO-COMBUSTION DEVICES AND SYSTEMS

for land sea and space applications



hi-shear developed Electro-Combustion Devices serve a dual function. First, they act as high strength fasteners, connectors or as a means of containment. Secondly, on command, the devices are electrically initiated, releasing energies produced by combustion to mechanically push, pull, spin, separate, sever, jettison structure, components or activate other functional systems.

Hi-Shear's controlled energy principle uses a small charge of low pressure type powder to achieve an instantaneous, mechanical action.

Standard electro-combustion hardware designed by Hi-Shear may be used, or the Hi-Shear controlled energy principle may be applied to custom applications you may have as exampled by the release of external stores from aircraft, operation of undersea devices, time delay mechanisms, missile tie-down in silo, stage separation or for a variety of applications on space vehicles.



CAPABILITIES A combination of Hi-Shear capabilities are offered: electronic and ordnance talents of an experienced staff; design, manufacturing and quality control skills as a long established precision hardware manufacturer; as well as complete laboratory facilities for ordnance, metallurgical, physical and environmental testing and instrumentation.

U. S. AND FOREIGN PATENTS APPLIED FOR

hi-shear **CORPORATION**

2600 WEST 247TH STREET • TORRANCE • CALIFORNIA



SEPARATION NUT
For joint separation, this Nut can be used in combination with a standard diameter, high strength bolt at its full design allowable. Captive and non-captive configurations available.



CLAMP SEPARATOR
Provides instant release of ring or circular type clamp. Also imparts a separation impulse to the clamp or band itself to free the latter from the structure. Will carry full tensile loads of MS bolts.



SHEAR BOLT
Fabricated to standard diameter sizes, Hi-Shear's bolt fails a shear pin to produce a controlled, non-fragmenting separation.



THRUSTER
Functions as a mechanical fastener until commanded to separate and then imparts its energy to direct separation of structure or component. is controllable to desired velocity and distance.



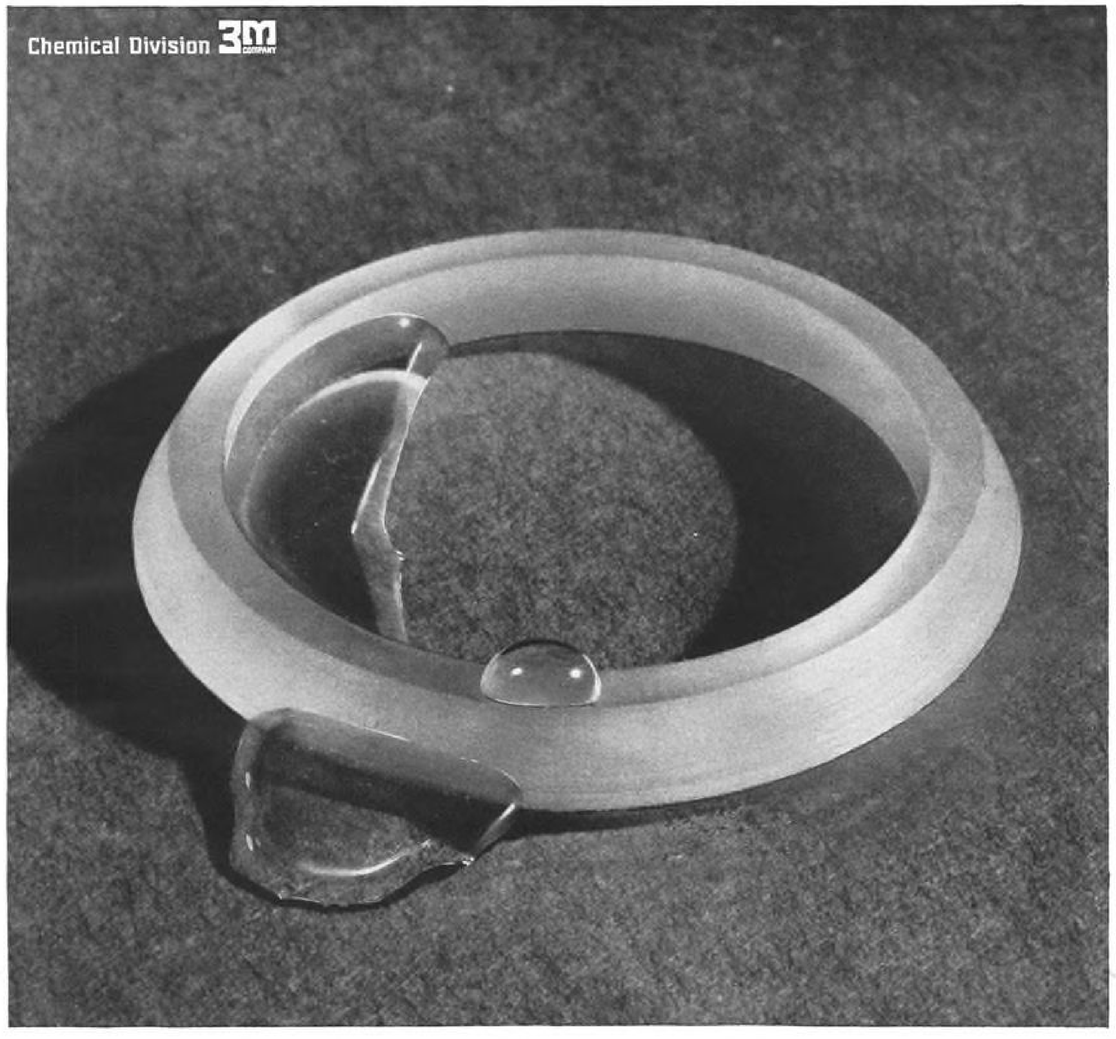
ROD OR CABLE SEPARATOR
Used to separate a rod or cable under tension. Eliminates need for guillotine mechanism or fracture ring method. Capable of carrying full tensile allowables of the rod or cable.



POWER CARTRIDGES
Provides combustion energies for the initiation of mechanisms for separation or ejection systems as well as explosively actuated components. Is certified to comply with AFMTC Ordnance Standards, 1 amp, 1 watt, no-fire, for Radiation Hazards.



PIN PULLER
Allows release of pin or rod without need to sever or fragment high tensile strength material.



Will it penetrate? Maybe...in a hundred years!

The drop is water. The seal is KEL-F® 81 Brand Plastic. And the manufacturer* who uses this seal in high vacuum valves figures it would take a hundred years for the drop to penetrate. Of more immediate interest, there just isn't any measurable absorption of water by KEL-F 81 Plastic even after weeks of immersion. Permeability to moisture, vapor and chemicals is in fact the lowest of any pure plastic!

For valve components and seals, this material permits higher pressures. Seals as thin as .020" can do jobs requiring ⅛" thicknesses of other fluorocarbon materials. Low thermal expansion makes possible seals, gaskets that hold tight even in cryogenic temperatures.

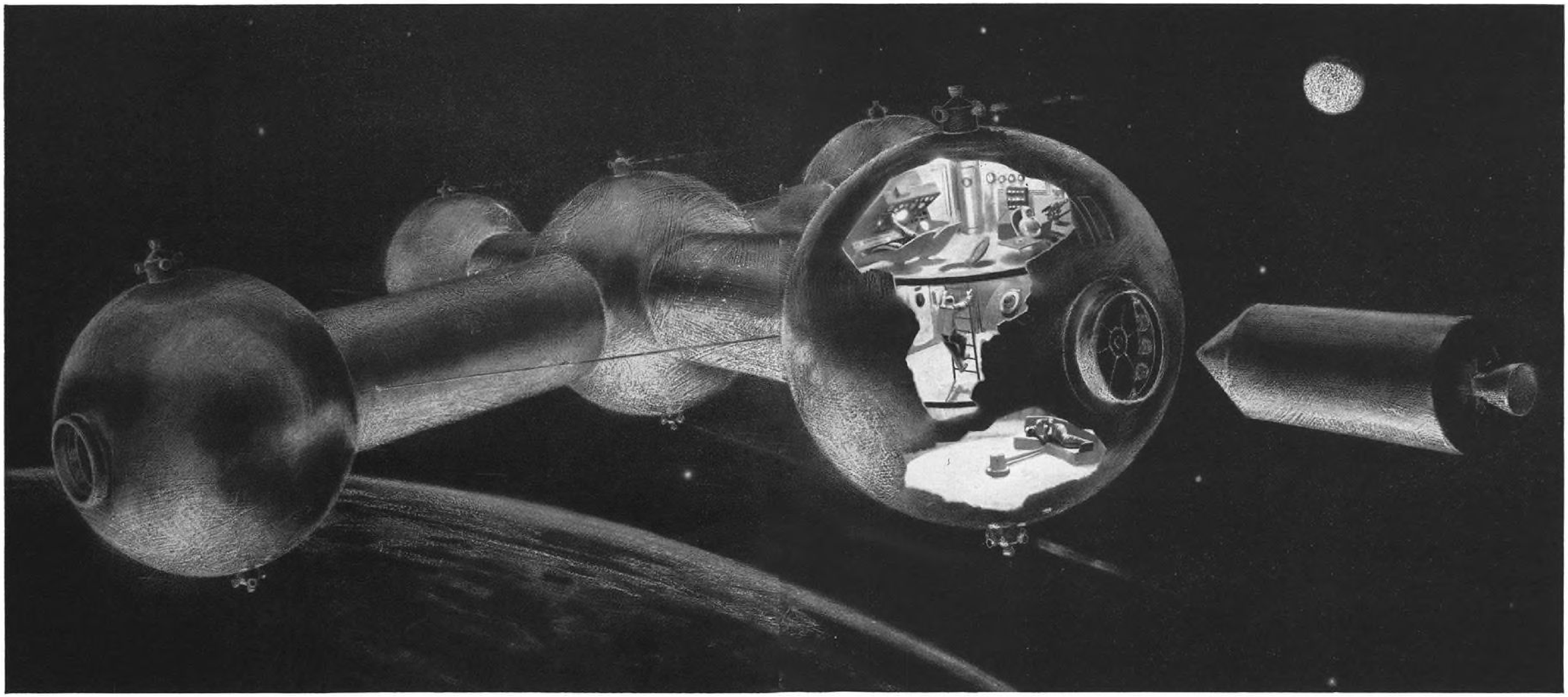
For electronic applications, low permeability plus high dielectric strength and resistivity assure low flash-over and leakage. Arc resistance is greater than 360 seconds. Low dielectric constant gives high impedance values, prevents disruptive capacitive effects.

Other advantages are high structural strength, chemical inertness, molds and machines to fine tolerances. For more data, contact one of the processors below, any 3M Chemical Division branch office, or write 3M Company, Dept. KAW-73, St. Paul 19, Minn.

*VACTRONIC LAB EQUIPMENT, INC., EAST NORTHPORT, N.Y. "KEL-F" IS A REG. TM OF 3M CO.

3M MINNESOTA MINING & MANUFACTURING CO.

AUTHORIZED PROCESSORS OF KEL-F 81 PLASTIC: **Arizona:** Phoenix, The Fluorocarbon Co. **California:** Alameda, Allied Nucleonics Corp.; Anaheim, The Fluorocarbon Co., Thermech Engineering Corp.; Burbank, Pli-O-Seal Mfg., Sub. of Zero Mfg. Co.; Culver City, W. S. Shamban Co.; Fullerton, Raybestos-Manhattan, Inc., Pacific Div.; Los Angeles, L. W. Reinhold Plastics, Inc., Saunders Engineering Corp., Unit Industries, Div. of L. W. Reinhold Plastics, Inc.; Palo Alto, The Fluorocarbon Co.; Santa Clara, Saunders Engineering Corp. **Florida:** St. Petersburg, Thermotech Industries, Inc. **Indiana:** Ft. Wayne, W. S. Shamban Co. **Massachusetts:** Maynard, Bonny Mfg. Corp. **Minnesota:** Hopkins, Thermotech Industries, Inc. **New Jersey:** Caldwell, Fluorulon Laboratories, Inc.; Camden, Garlock, Inc.; Parsippany, Carmer Industries, Inc.; Pine Brook, Timely Technical Products, Div. of The Fluorocarbon Co.; Union, Adam Spence Corp. **New York:** Auburn, Auburn Plastics, Inc.; New Rochelle, Gries Reproducer Corp. **Ohio:** Dayton, Modern Industrial Plastics, Div. of Duriron Co., Inc. **Pennsylvania:** East McKeesport, Rockwell Mfg. Co., Plastics Plant. **Texas:** Garland, Tube Turns Plastics, Inc., Halochem Products Div. **Vermont:** Bethel, G-W Plastic Engineers, Inc. **Wisconsin:** Racine, Moxness Products, Inc.



A space craft docks in the Douglas designed module of an assembled space station. As crew members go about routine duties, one crewman in the module's lower cabin is gravity-conditioned on a centrifuge.

How do you reduce the cost of building a manned space station?

...another complex problem which Douglas and the aerospace industry are helping NASA solve

The race for space supremacy is too critical to risk victory by pinching pennies. But the men most concerned also know that success depends on squeezing every ounce of value from the dollars and skills invested.

An example of this is a Douglas proposal for a way to utilize expended vehicles which will already be in orbit (like Saturn S-IV and S-IVB tanks) in building space stations from which various space missions could be launched. This method would sharply cut the great expense of launching new components to serve as space living quarters and laboratories. Time and effort would also be saved.

As conceived by Douglas engineers, key element in the new technique is the SPACEBALL, a unique modular space vehicle easily boosted aloft. SPACEBALL would be designed to link expended space vehicle stages and dock many types of space craft ...like the Gemini and Apollo capsules.

Any number of these modular units could be joined to provide space stations or even space ships of almost any size that might be needed.

DOUGLAS

Major Douglas Divisions are located in Santa Monica and Long Beach, California, Tulsa, Oklahoma, and Charlotte, North Carolina.



How can we support life in this anti-life void?

So far, man has entered space for only a few brief orbits. The real problem is to support him in comfort and safety over long stretches of time while he performs useful missions.

Nothing is friendly to flesh and blood in this savage vacuum. If man is to conquer it, we must build him a little world of his own—then shield it from the void.

We must know how to protect him from radiation and meteoroid impact...keep the partial pressures of his enclosed atmosphere finely balanced, prevent cabin temperatures from building past the point of tolerance...prevent disorientation and claustrophobia... keep tensions from building up between crew members.

A life-support system cannot be developed by bits and pieces. It requires a total systems approach—which no organization is yet able to provide. But the Research and Development Division of Lockheed Missiles & Space Company has been steadily building toward this goal, and now stands on the verge of total competency in life-support systems for space.

Lockheed

Lockheed Missiles & Space Company, Sunnyvale, California
A Group Division of Lockheed Aircraft Corporation



Guidepost

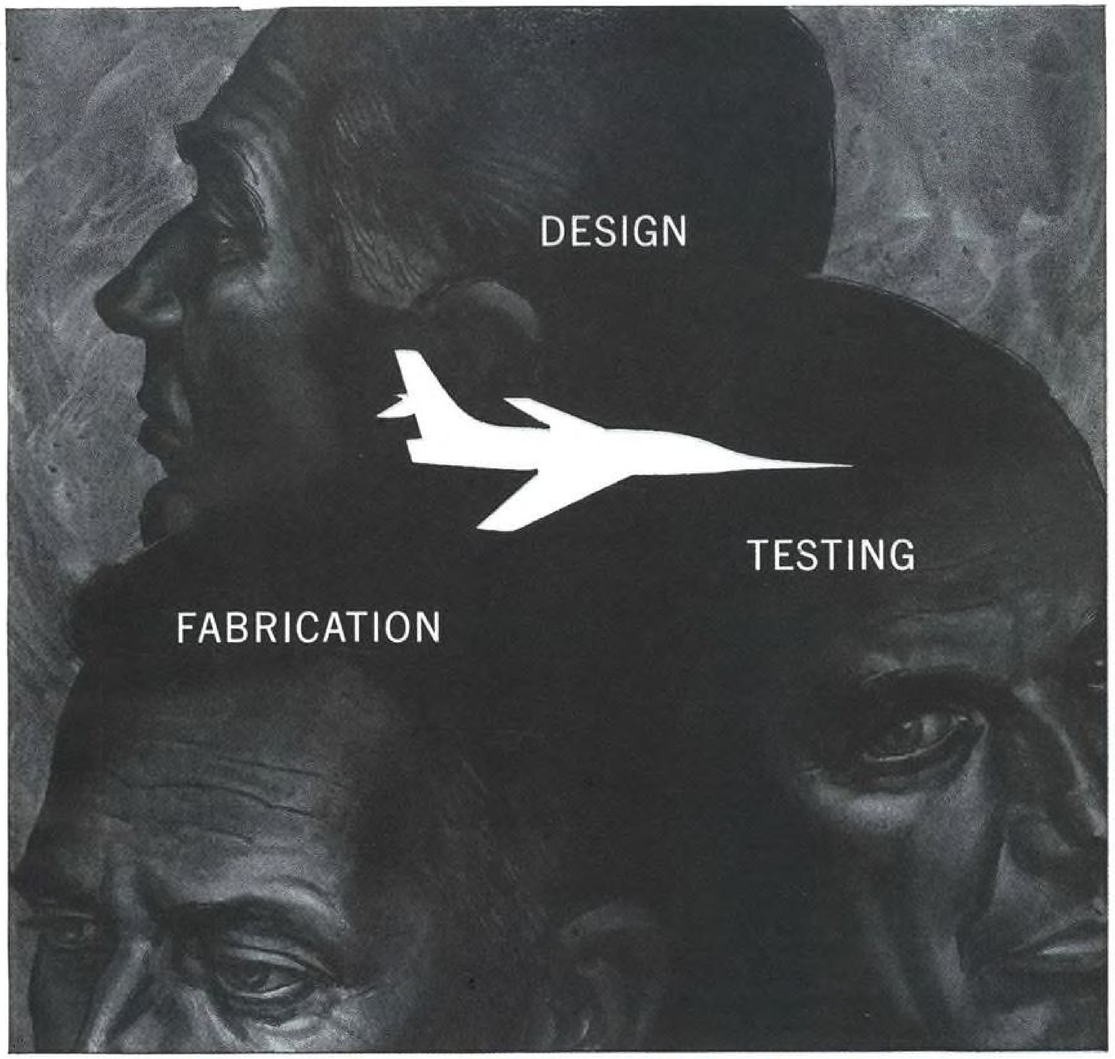
The constellation Scorpio is one of the most familiar sights in space. When many problems of guidance are solved, it could well become an important guidepost for astronauts during their journey to the moon.

Guidance sensitivity is one of the most critical areas of America's manned space flight program. What precise point in space is best for mid-course maneuvering? What are the references, the guideposts for such maneuvers? How much energy should be expended for a correction at any given time?

Bellcomm is now at work analyzing many of these problems, searching for unknowns that could affect guidance in the mysterious reaches of space. It is part of the total job Bellcomm is doing for NASA, planning and evaluating manned flight systems.

Such stimulating work offers rewarding opportunities for men well qualified in such fields as physics, chemistry, engineering, psychology, mathematics, flight mechanics, computing and programming, propulsion, aerodynamics and aeronautical engineering. If you are such a man, your résumé would be welcomed by Mr. W. W. Braunwarth, Personnel Director, Bellcomm, Inc., Room 1117C, 1100 17th St., N. W., Washington 6, D. C. Bellcomm is an equal opportunity employer.

BELLCOMM, INC.
A Bell Telephone System Company



REINFORCED PLASTICS...IDEAS TO REALITY!

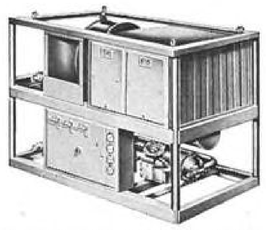
From submarines to space vehicles, many "unsolvable" environmental problems are now being solved by reinforced plastics. Do you have a low temperature pressure vessel or chamber need? Are your high temperature radar performance characteristics stymied by lack of an electronic window material capable of withstanding the heat? Do you need a high strength underwater vehicle to withstand extreme pressures? Brunswick's Defense Products Division may have the solution to your environmental, electrical and structural problems. Experience gained on programs such as F4H, A2F, Polaris, Falcon, underwater "towed fish" and Brunswick's Hi-temp silica work has established a development and manufacturing facility which is a leader in its field.

Let our talents and resources serve your needs.

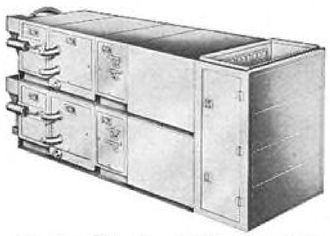
MAKES YOUR IDEAS *WORK*
Brunswick
BRUNSWICK CORPORATION • DEFENSE PRODUCTS DIVISION
1700 MESSLER STREET • MUSKEGON, MICHIGAN

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FROM AAF ENVIRONICS PRODUCTS OF ENVIRONMENT CONTROL PROGRESS



Packaged Brine Cooler. Self-contained unit incorporates refrigeration compressor, brine chiller, all associated components, controls. Cooling output, 67,000 BTU/hr. Refr. effect, at 120° F. condensing temp.; and 100° F. ambient temp., 3000 ft. altitude.

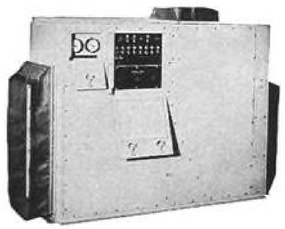


Air Conditioning Unit. Complete, modular constructed unit has supply fan, chilled brine supplied air cooling coil, air filter, automatic temp. control and alarm sensors. Fresh air filtration capable of removing 99.97% of all particulate matter over 0.3 microns in size.

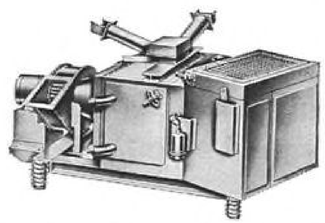
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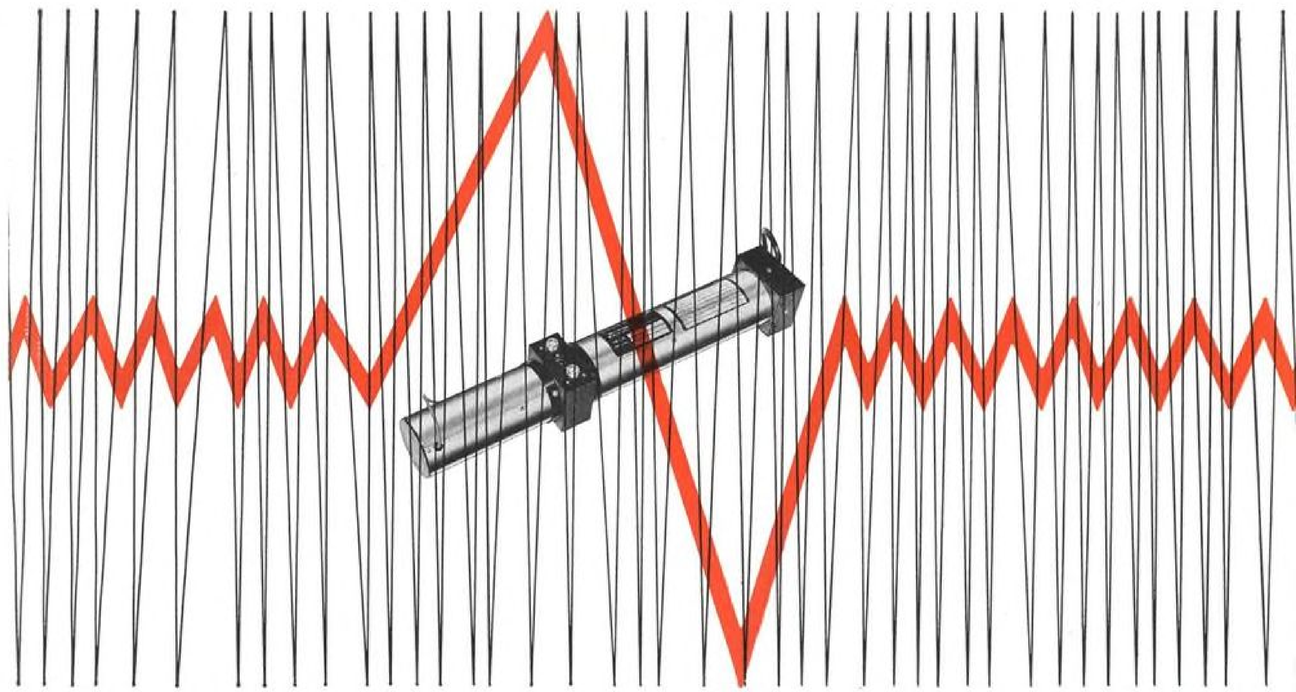
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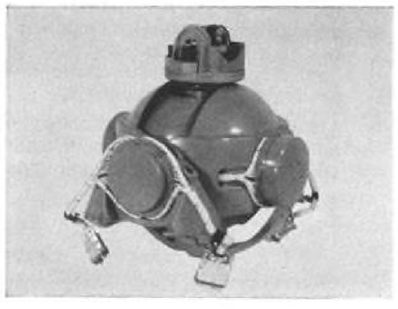
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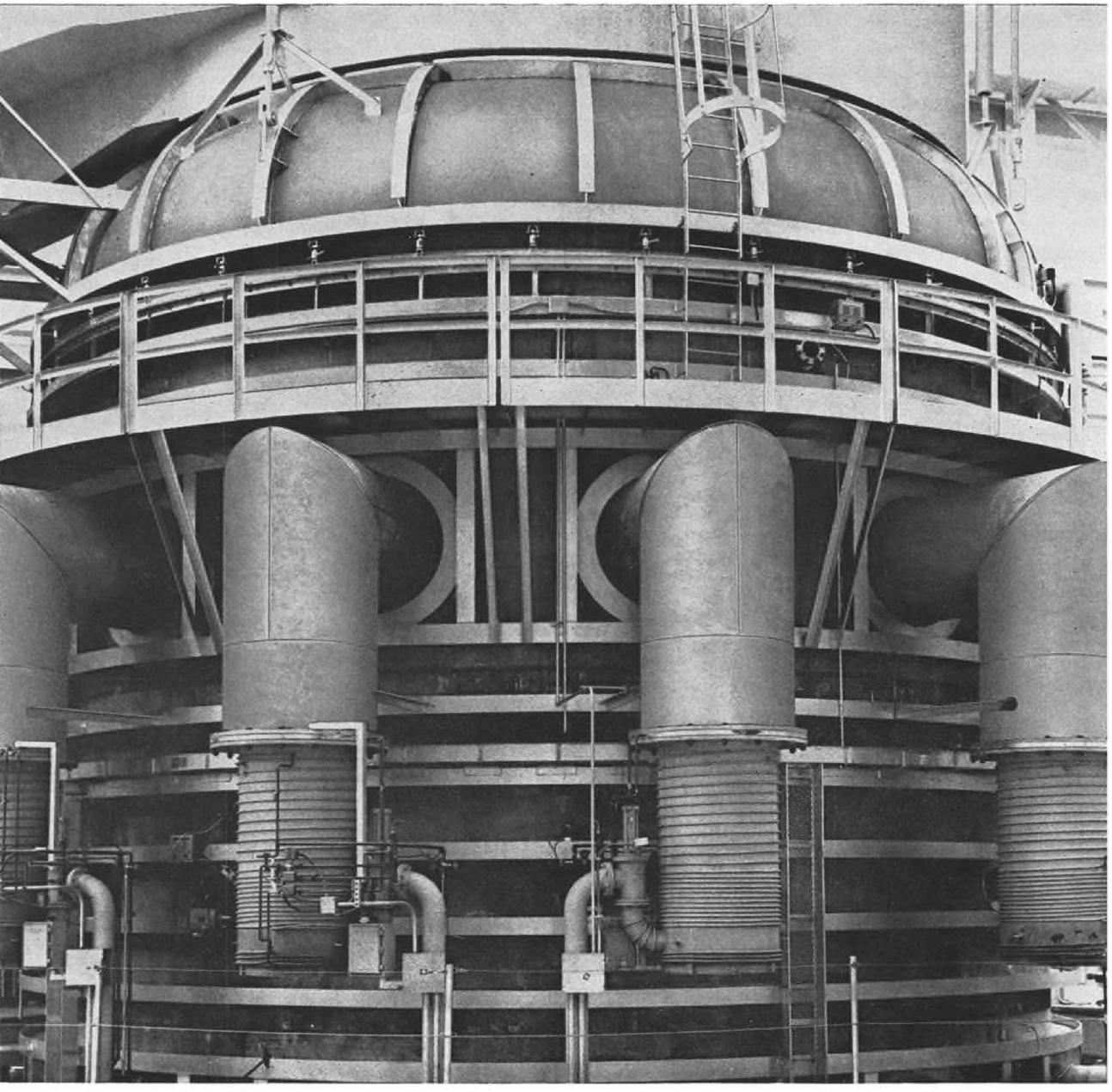
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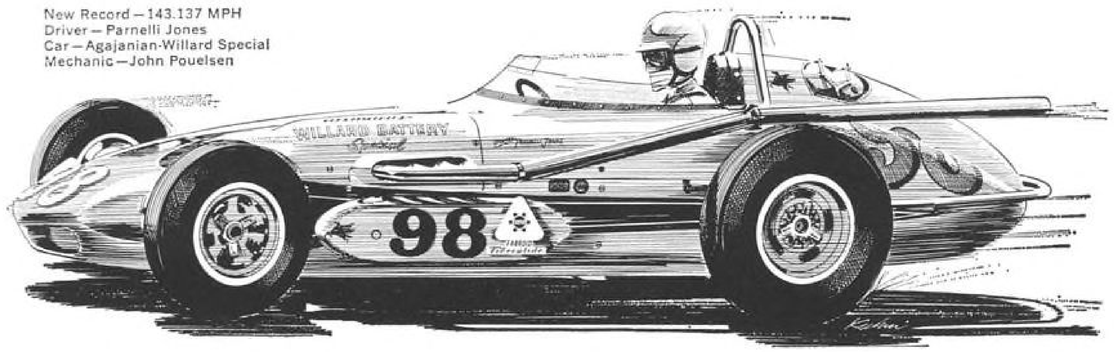
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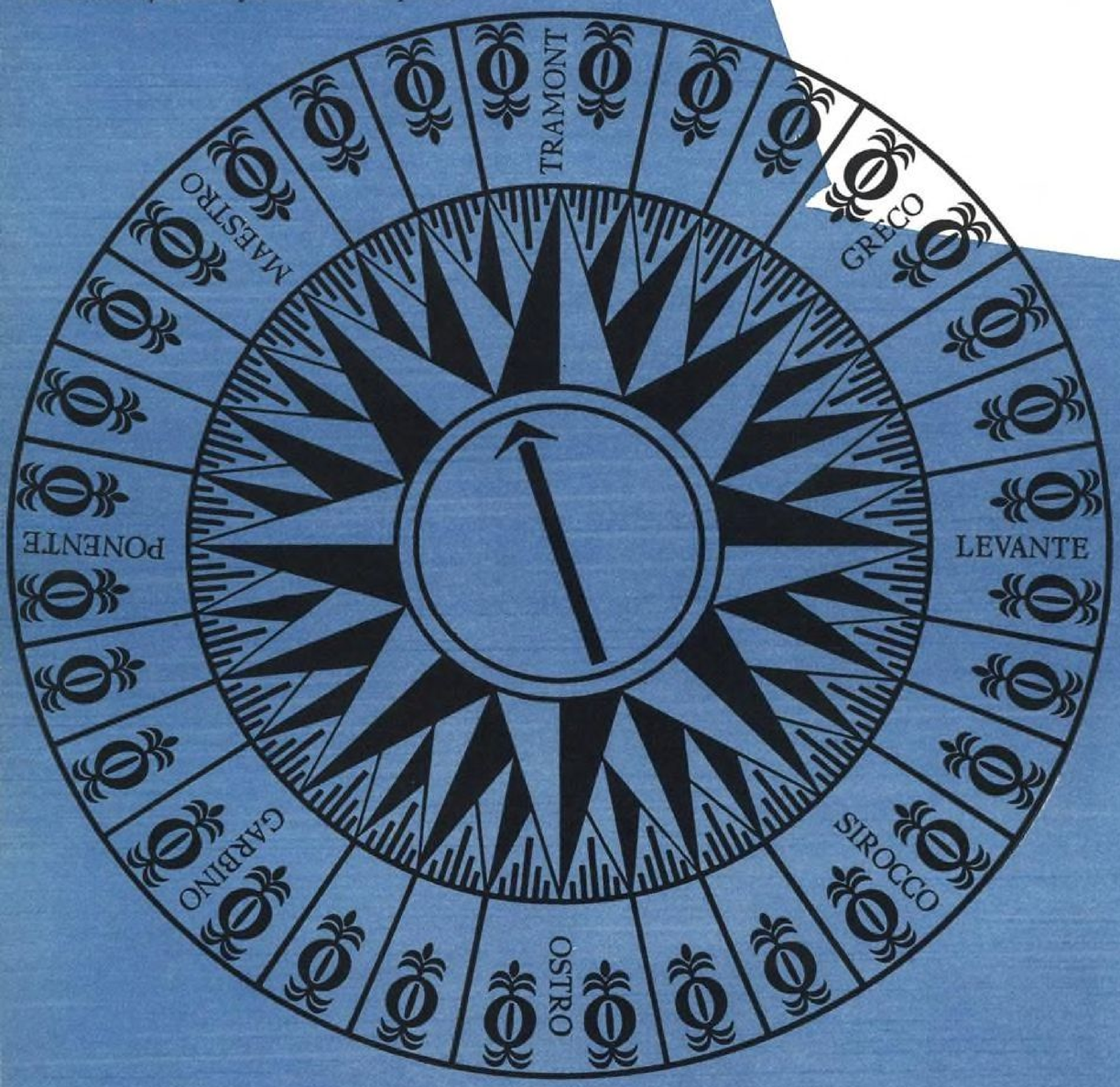
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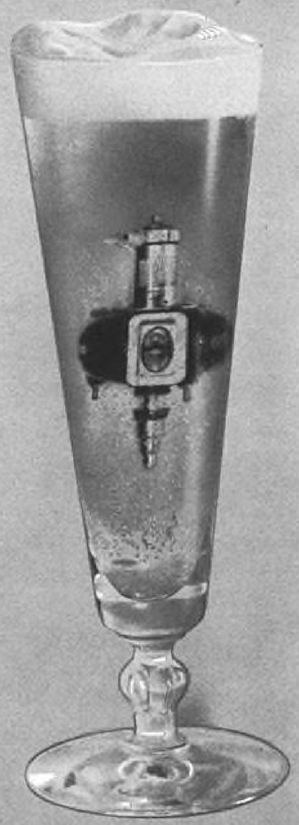


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Volume 79
Number 4

Aviation Week & Space Technology

July 22, 1963

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COVER: Final Mercury Mission, MA-9, begins its flight from Cape Canaveral, Fla.

This special issue devoted to U. S. civilian and military manned space flight and to Soviet space flight was written and edited by a special Aviation Week & Space Technology team with the cooperation of the National Aeronautics and Space Administration and the Air Force. The team was directed by Evert Clark, Washington Bureau Chief and first Space Technology Editor of AW&ST. The team consisted of Edward H. Kolcum and Alfred P. Alibrando, Space Technology Editors; Donald E. Fink, C. M. Plattner and Roderick D. Hibben, Engineering Editors; Erwin J. Bulban, Dallas Bureau Chief; George Alexander, Cape Canaveral Bureau Chief; Barry Miller, Avionics Editor, and Larry Booda, Military Editor, assisted by Ann Dunphy, with art direction by Lawrence J. Herb, Art Editor. Members of the team visited civilian and military space management centers and the manufacturing facilities of key industrial firms involved in manned space flight.

Space Flight Enters New Period to Exploit Capabilities of Man for Probing Universe

Man has taken his first small steps toward realizing his age-old dream of soaring to the stars. The manned orbital flights of four Mercury capsules and six Vostoks have demonstrated the technical feasibility of putting man into space. Both the United States and the Soviet Union are committed to extending man's capability for operating in space to reach the moon before the end of this decade, with the goal of exploring Mars looming with increasing intensity as an objective to be reached before the 20th Century's end.

The world is well launched into the era of manned space flight. Little is known about the technical results achieved in the Soviet Vostok flights but they were certainly fully successful in demonstrating sound capability for manned space operations. Project Mercury, which finished last May 16 with the 22-orbit flight of Maj. Gordon Cooper, was one of the very best technical endeavors this nation has ever executed. It exceeded all of its original technical goals by a wide margin, had a perfect safety record and, once its initial inertia was overcome, it clicked off its schedules with admirable precision. The pace of manned space flight is quickening, its scope is expanding and its future is growing brighter. This is why AVIATION WEEK & SPACE TECHNOLOGY organized a special editorial task force at this time for an intensive three-month effort to distill the essence of knowledge gained from the pioneer ventures in manned space flight, to report on the progress of the future programs already under way and to perceive its future paths as clearly as possible from this point in time. These findings are reported in the subsequent pages of this issue.

The Apollo manned lunar landing program to which this nation is now firmly committed is an effort more technically complex and managerially demanding by several orders of magnitude than such programs as the Manhattan Project to develop the atomic bomb, or the projects which resulted in the creation of the intercontinental ballistic missile. Apollo has been shaped so far by two basic decisions:

- **President Kennedy's determination** in May, 1961, to establish the manned lunar landing goal as a top priority national objective and his pledge to support it fully through as much of its critical development phase as his tenure in office might permit.
- **National Aeronautics and Space Administration's** decision in July, 1962, to switch to the lunar orbit rendezvous technique as the method to achieve manned lunar landing substantially sooner and at less expense than other methods.

Now the Apollo program is facing a third decisive phase in which will be determined the measure of public support (reflected in congressional appropriations) that it can expect to have during the most critical phase of its technical development progress. When President Kennedy called for the Apollo program as a top-priority national goal, he made it clear to Congress and the American people that he was asking them to sign a long-term mortgage to support the program through a seven- to 10-year phase of complex development before success would be possible. Congress responded to this challenge with virtually unanimous endorsement of the NASA budget for Fiscal 1963. Initial successes of Soviet cosmonauts and Mercury astronauts in orbital flight whipped public enthusiasm to an equally high pitch.

Some of this enthusiasm and glamor is already fading, particularly as the main focus of the manned space flight effort shifts from spectacular orbital shots projected by intercontinental television networks, to the tough engineering, managerial and hardware development problems that must be solved in the next few years. Achieving the Apollo goal requires no new scientific discoveries or major technical breakthroughs. Its problems are primarily engineering, management and funding, with solutions equally dependent on industry, NASA and the public.

Apollo is not proceeding at a "crash program" pace in the sense of the military ballistic missile efforts. But it is an effort that must be pushed at its maximum feasible technical pace if it is to produce any of the dividends its investments make possible. Manned space flight has just emerged from its Kitty Hawk stage and is progressing at a pace so rapid that it is difficult to measure by past experience. As just a crude measure in speed it is worth noting that it was in 1947 that Col. Charles Yeager first flew past the speed of sound —about 760 mph. at sea level. A decade later, in 1957, Sputnik 1 achieved an orbital speed of 18,000 mph. A decade after that, in 1967, we expect to be ready to assay earth escape velocities of 25,000 mph. in the Apollo lunar trajectory. Clearly, this decade is no time for the American public or its leaders to lose the courage of their convictions that took them into their initial successes with manned space flight.

It would be a national tragedy for public and congressional support for Apollo to fail at the very time that the greatest technical strides were being taken in the laboratories, factories and testing grounds toward achievement of its goals. NASA officials and industry leaders must assume heavy responsibility for making the significance of this phase clear to the public that is paying the bills and to report promptly and accurately on technical progress as it is achieved.

There is certainly no sign that the Soviet Union is slackening its pace in developing expanded capabilities for manned space flight operations, although there are some indications they plan to reach their ultimate goals by different paths than we have chosen. It may well be that they will develop a multi-manned orbital space station or laboratory as their next step before shooting for the moon, while the U. S. program has the moon landing as its primary goal with space station development accorded a later priority. Only history will be able to tell which course is the wiser, although it is certain that both operations will be necessary for a useful manned space capability.

A major policy problem that must be solved simultaneously with Apollo's technical problems is the inevitable growth of the military role in manned space flight development and its integration with the efforts already under way in NASA. Earlier confidence in NASA that it could carry the entire manned space flight research and development load has melted at about the same rate as top-level Defense Dept. skepticism over the need for manned military space flight capability has dissipated.

Initial efforts at NASA-DOD liaison produced some educational shocks in both agencies. As a result there now appears to be a possibility for a more realistic foundation on which to develop a fully effective national space program as a joint complementary effort.

It is evident that the military has some special requirements to develop its manned space flight capability that lie well outside the present scope of NASA's interest.

The pace of Soviet manned space flight and satellite reconnaissance developments has made it clear that the Pentagon cannot wait for NASA to complete all of its research efforts before any military applications are attempted as follow-on programs. The military space developments, particularly in manned flight, must be done concurrently with the NASA effort, using all of the facilities and knowledge available in both agencies. Hopefully, the development of such a national effort can become effective in the programs now looming beyond Apollo.

With the foundations for manned space flight laid firmly by Mercury, and with Apollo pushing hard to blaze the lunar trail, this nation is now faced with the determination of its future goals for the manned exploration of space. Manned space flight projects will always be tremendously expensive because they require swift advances across an extremely broad spectrum of technology, including greatly improved knowledge of man himself and the functioning of his subsystems.

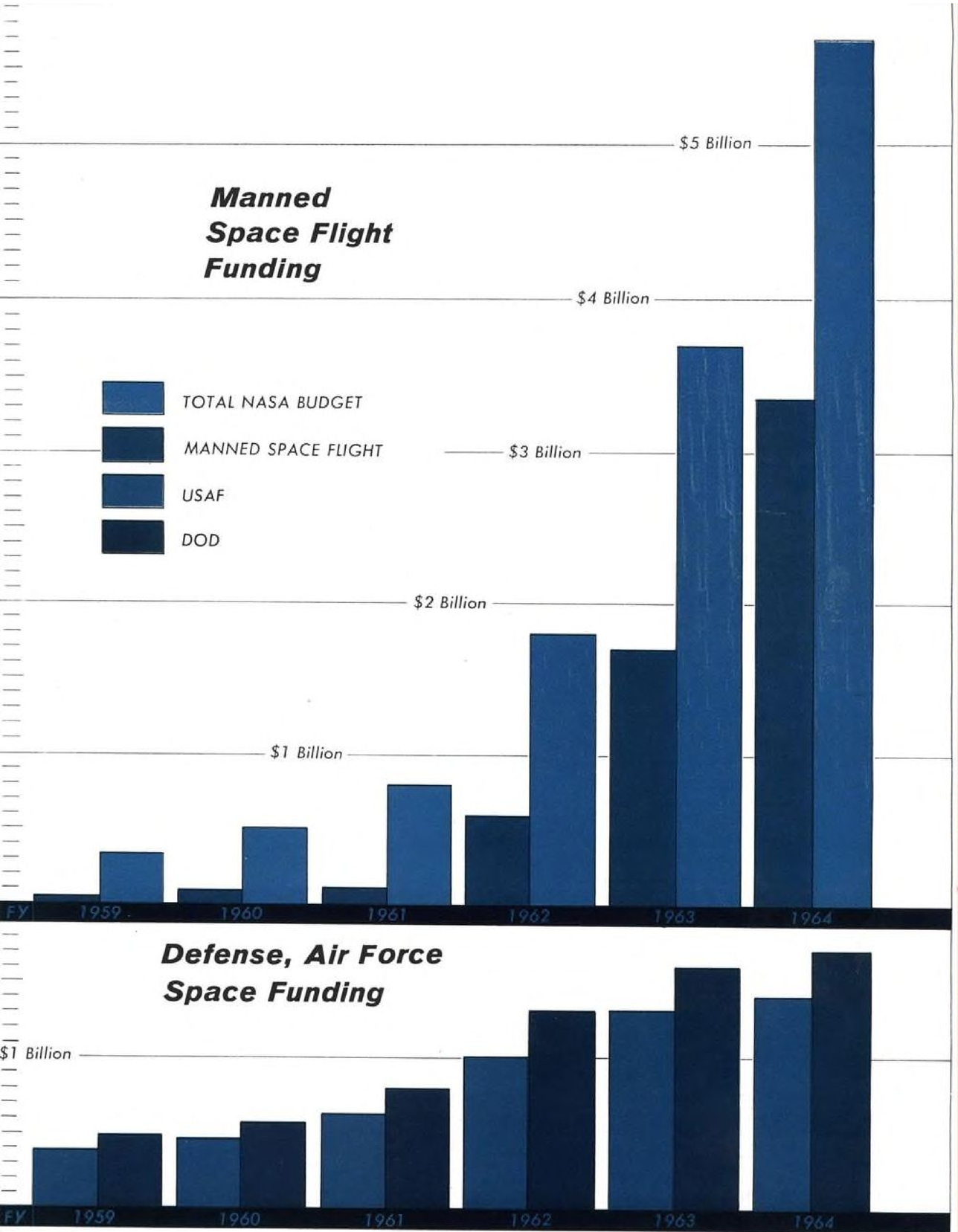
It appears unlikely that this nation or any other will be able to carry a large number or wide variety of manned space flight programs simultaneously to their operational phase because of their financial and technical magnitude. But, while the current goals are being translated into hardware and achievement, it is necessary to be planning and laying the technical base for the steps that lie beyond.

Thus in 1963, at the time that its major effort is devoted to developing the Apollo system, the policy-makers of this country must make some basic decisions on what comes after Apollo and a successful round trip to the moon.

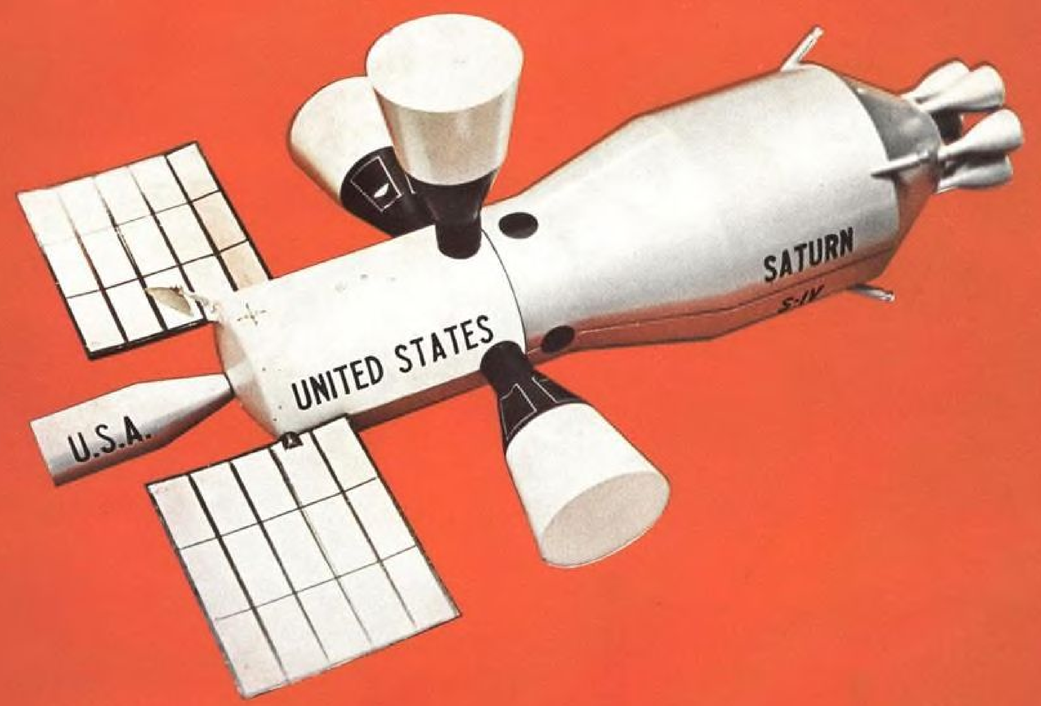
Preliminary scanning of the technical horizon brings the multi-manned space station sharply into focus as the next logical step in expanding the national capability in manned space operations. Most of the basic hardware required for this effort is already being developed in the Apollo program. The multi-manned orbital space station offers an extremely wide variety of uses for both military and civil purposes. It would provide a scientific laboratory with unparalleled opportunity to study both man and his universe. It would be an engineering development and test laboratory for materials, hardware and techniques for space operations. It would provide a command and control post for strategic military operations of extremely low vulnerability and a base for inspection of unknown or hostile satellites. It would also provide a proving ground not available on earth for all of the new space operations and equipment required for extended exploration of interplanetary space beyond the moon.

It would be fruitless at this time to predict the ultimate course of manned space flight through the remaining years of the century. But it should be noted that even the rosiest prophets of space progress in the pre-Sputnik era have been proved to be gross conservatives by the rapid pace of actual space flight in the past six years. And the pale red light of Mars beckons far beyond the moon.

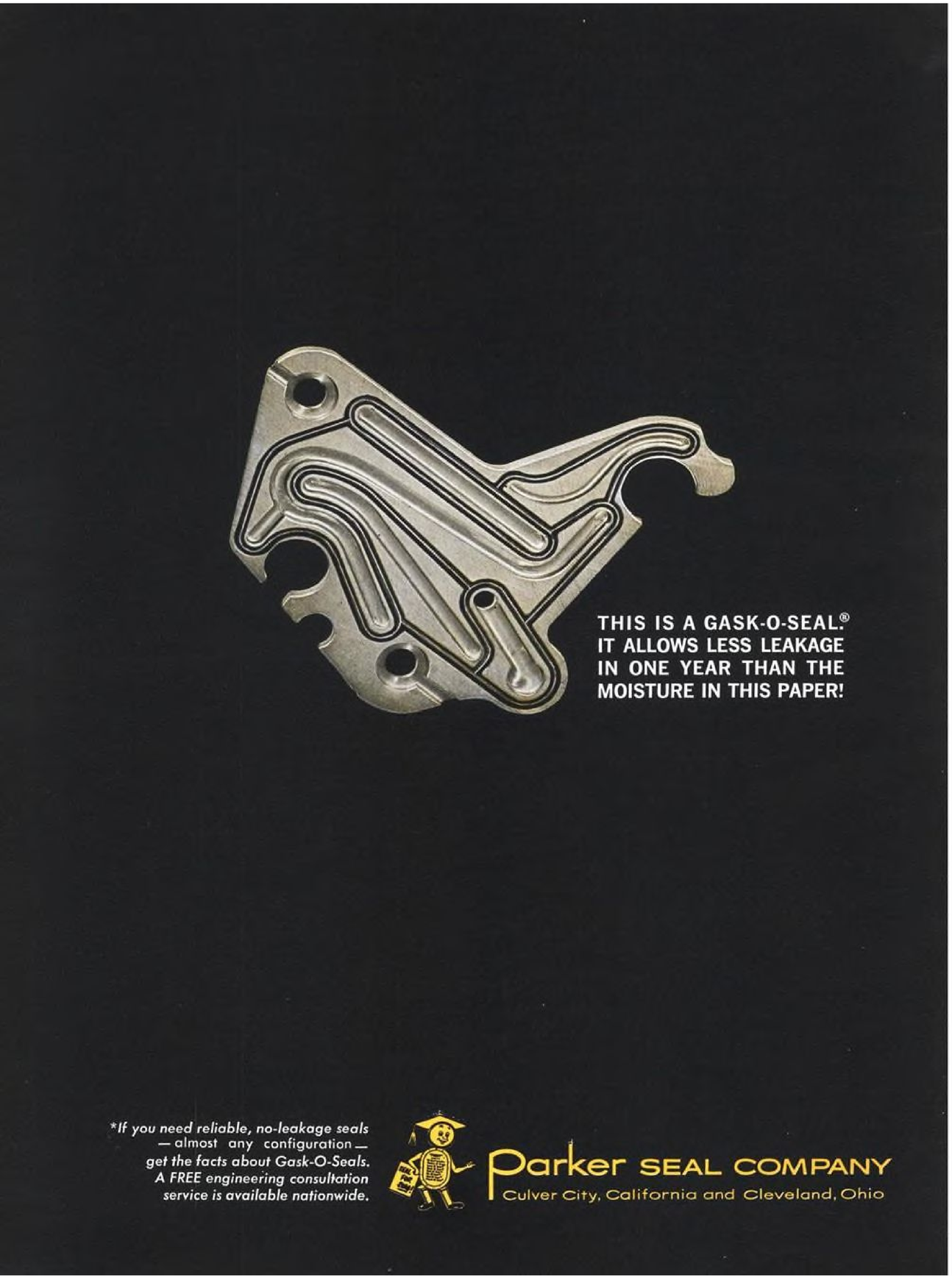
—Robert Hotz



Future Programs



Model shows representative concept of a 4-6 man orbiting laboratory designed by NASA's Langley Research Center and now being studied by industry. Laboratory module has docking ports for three McDonnell Gemini ferry vehicles and Lockheed Agena D resupply vehicle. Spent Douglas Saturn S-4 stage is for possible use as a centrifugal weight to impart spin to laboratory.



U. S. Facing Decisions on Manned Flight

Washington—U. S. is rapidly reaching the time when it must make hard, basic decisions on what major manned space programs it will undertake beyond Apollo. It must do so at a time when space goals to which the nation is already committed are under the most severe attack since the space age began.

This has become the "year of re-examination" for a space effort that, after President Kennedy's approval of the Apollo program early in 1961, seemed to be out of its uncertain adolescence at last and on its way to acceptance as a vital national requirement.

Doubts about the wisdom of space flight that had not been voiced since shortly after Sputnik now are being repeated and reinforced by challenges to the cost, scientific usefulness, demand on national resources and over-all necessity of putting man on the moon—or anywhere else in space.

But the President and the Congress have committed the U. S. to seeking pre-eminence in space, and the current criticism seems not to have lessened their conviction—only to have put another hurdle in the way.

National Aeronautics and Space Administration, the chief executor of national space policies, is now planning projects far beyond Apollo, but it must do so conservatively and responsibly, and in spite of an apparent decrease in public support.

In this way its role is similar to the role of the military services in peacetime—it must learn to live with lessened appreciation and popularity and depend for consolation on the knowledge that it is doing a necessary job that will be recognized and applauded at some future time. Even U. S. and Soviet manned flights no longer have a rallying effect on the public attitude.

Defense Dept., which is showing an increasing interest in the military potential of manned space flight and is becoming a more serious competitor for the national resources involved, has been brought to the same realization NASA has about the magnitude of the resources now consumed by manned flight programs.

NASA's primary interests for future manned projects lie in three basic areas —a space station, a voyage to the vicinity of Mars, and a more or less permanent base for lunar exploration.

Air Force, acting as the operating agency for most Defense Dept. space programs, is seeking approval for a manned orbital station for exploring military man's usefulness in space and for developing the tools he would use there.

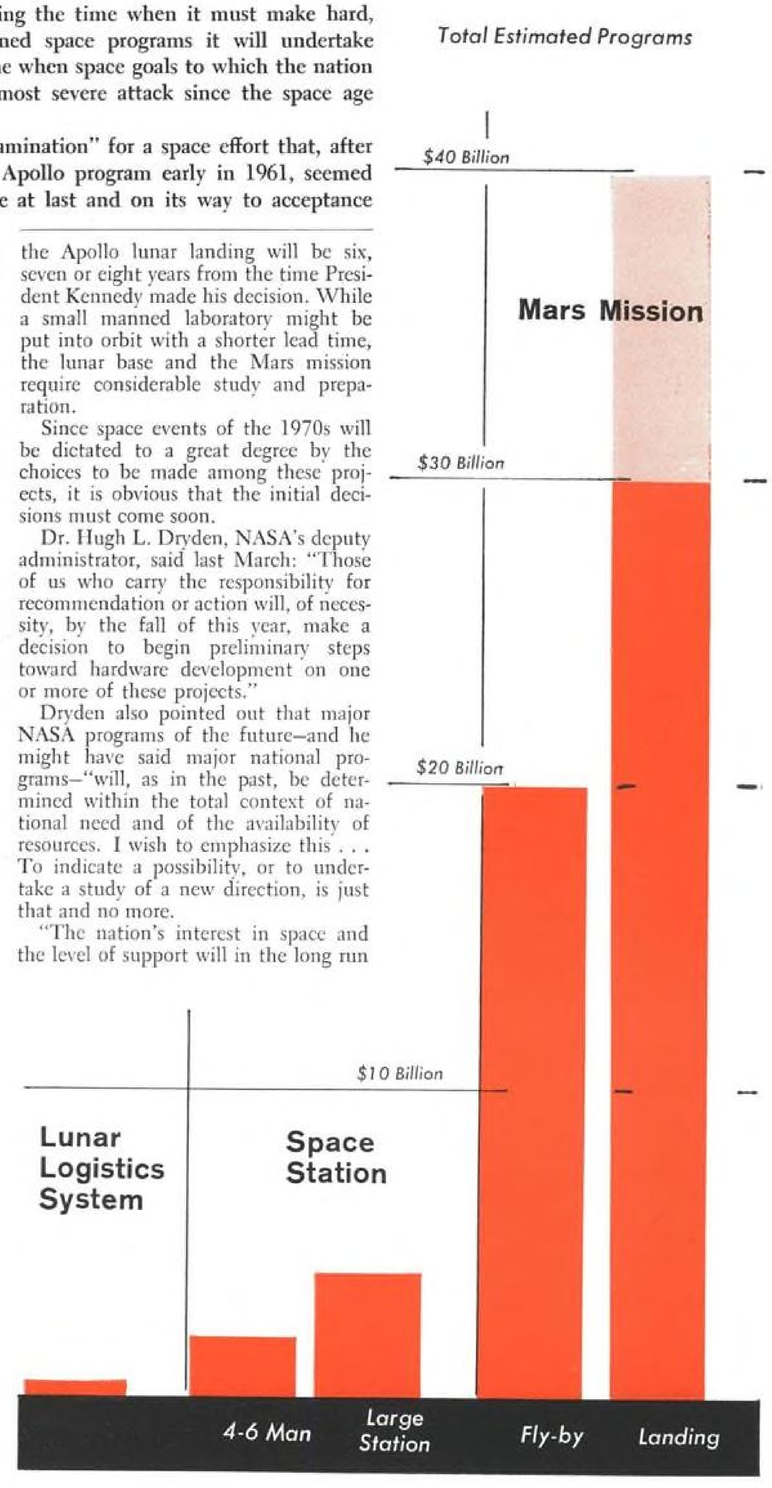
If and when these projects will be done, and which of them will be joint NASA-DOD programs, must be decided in the near future. Lead time for the Apollo lunar landing will be six, seven or eight years from the time President Kennedy made his decision. While a small manned laboratory might be put into orbit with a shorter lead time, the lunar base and the Mars mission require considerable study and preparation.

Since space events of the 1970s will be dictated to a great degree by the choices to be made among these projects, it is obvious that the initial decisions must come soon.

Dr. Hugh L. Dryden, NASA's deputy administrator, said last March: "Those of us who carry the responsibility for recommendation or action will, of necessity, by the fall of this year, make a decision to begin preliminary steps toward hardware development on one or more of these projects."

Dryden also pointed out that major NASA programs of the future—and he might have said major national programs—"will, as in the past, be determined within the total context of national need and of the availability of resources. I wish to emphasize this . . . To indicate a possibility, or to undertake a study of a new direction, is just that and no more.

"The nation's interest in space and the level of support will in the long run



Scientific Debate Focuses on Apollo Landings

Decision to attempt a manned lunar landing in this decade has developed into one of the most controversial actions of the Kennedy Administration. The most vocal critics have come from the ranks of the scientists.

Dr. Philip H. Abelson, director of the Geophysical Laboratory of the Carnegie Institution of Washington, and editor of American Assn. for the Advancement of Science's SCIENCE magazine, said he surveyed a number of scientists not associated through contracts or grants with the National Aeronautics and Space Administration and found that only two out of ten of those questioned approved of the Apollo program.

The question of man vs. machine in space exploration will be a subject of increasing debate as the program matures and as the full impact of its cost is felt. Nevertheless, some feel that for scientists to talk about it outside their community has been one of the unforeseen benefits of the program.

Congress recently provided a forum in which scientists—most of them involved in the space program in some way—were asked to air their views.

Among the comments:

• Dr. Abelson: ". . . Manned space exploration has limited scientific value and has been accorded an importance which is quite unrealistic. Most of the important scientific questions concerning the moon and the other planets could be studied at relatively low cost employing unmanned vehicles. Making man a part of the scientific exploration of space has two important drawbacks.

"It increases costs and it will probably slow down, at least for some years, the pace of getting valuable results. . . . Our recent Mariner 2 probe to Venus cost a few tens of millions. To send men on a comparable mission might cost a hundred billion dollars and could not be done for many years." He added that life support for humans is expensive, and that vehicles for man cost approximately 100 times more than electronic probes.

• Dr. Harold C. Urey, University of California: ". . . The real reason for undertaking the space program is an inate characteristic of human beings . . . to try to do what might be thought to be impossible—to try to excel . . . to try to do what has never been done before.

". . . From the purely technical side, a certain vigor in a program is required, for otherwise we cannot attract competent men to do the job.

"The principal reasons for doing the space program are not primarily scientific but the most durable results of the program are almost certainly the scientific facts which will be learned and studied."

• Dr. Martin Schwarzschild, Princeton University Observatory: "The idea of a man leaving this earth and flying to another celestial body and landing there and stepping out and walking over that body has a fascinating and driving force that can get the country to a level of energy, ambition and will that I do not see in any other undertaking."

Dr. Schwarzschild said that if the U. S. drops out of the space race, "we would relax to a . . . lethargic state . . . we were in . . . after the last war."

• Dr. Polycarp Kusch, department of physcis, Columbia University: "It is my belief that the present space program attempts too much too fast. I suggest as a possible national goal that outweighs in its importance the space effort, the preservation and repair of our continent.

"I find it difficult to believe that the exploration of space is a more compelling goal that the exploration of the planet we inhabit."

• Dr. Lee A. Du Bridge, president of the California Institute of Technology: "We are dealing with a complex scientific and technical problem; we are dealing with a problem with great but unforeseeable political, military and economic repercussions.

"I place the spirit of adventure high on the list of valid objectives of the space program."

Dr. Du Bridge outlined a course of space exploration which would be conducted even if there were no Apollo program and suggested that "at some state we would run out of observations which could be adequately made by unmanned instruments alone—and by then we would have enough knowledge and enough reliable technology to send out manned spacecraft. They will acquire knowledge that instruments alone could not obtain."

• Dr. Lloyd V. Berkner, president of the Graduate Research Center of the Southwest, Dallas, Tex.: "Because of the very primitive and deep-seated instinct to conquer the unconquered, the space race between the U. S. and USSR is inevitable. Men everywhere see in the conquest of space the peaceful demonstration of the superiority of one of the two competing systems of economic organization. . . .

"To do a genuine job, the astronaut team must be a well-rounded team including great scientific skills. So we should get on with training some scientist-astronauts without delay."

• Dr. Simon Ramo, vice chairman of the board of directors, Thompson Ramo Wooldridge, Inc.: ". . . the manned lunar program is a marvelous opportunity for world-wide benefit or for utter failure. By doing this program right, by choosing sensible goals, by being clear as to what we want and sticking with it, we can take a giant step toward learning how to really use science in the national interest. . . .

"We should see to it that the program provides a whole range of future capabilities to the military."

• Dr. Frederick Seitz, president of the National Academy of Sciences: ". . . The great exploration of the extra-terrestrial space . . . is a continuation of the . . . search and migration that has motivated man throughout his history. . . .

"Man's adventure in space will stimulate many branches of scientific work in a quite natural and automatic way, provided the scientists are given their rightful place in the whole space program."

• Dr. H. H. Hess, chairman of the National Academy of Science's Space Science Board: "I don't believe we could explore the moon in any satisfactory way from the point of view of the scientists without having a scientist there."

Dr. Hess suggested a corps of 500 reserve scientist-astronauts who would spend some time in space flight training each year, but who would spend most of their time in the laboratory maintaining scientific skills.

• Dr. C. S. Pittendrigh, department of biology, Princeton University: In justifying Apollo, care should be taken so that the elements of challenge and adventure are not stifled, because these "are essential parts of science."

He also made a plea for more extensive biosciences flight program, and he suggested that U. S. take a national policy position on sterilization of spacecraft intended for Venus and Mars flights.

be determined by the large policy decisions of the American government."

Both NASA and USAF are beginning, largely with Fiscal 1964 funds, to lay the foundations for these "large policy decisions." Both are undertaking space station studies intended to narrow down the unknowns and provide the basis for choices of approach, techniques, hardware and timetables (see p. 77 and p. 214).

The manned orbiting station—a project which really should have been undertaken before Apollo if the challenge of Soviet space progress had not been so large a factor—may see the most complete merger of civilian and military space efforts yet. The cost of having two separate programs appears prohibitive, particularly when the cost of the current space effort—about $7 billion for Fiscal 1964—is being effectively challenged.

Flights to Mars seem almost as certain to happen, eventually, as prolonged stays in earth-orbiting stations are (see p. 84). The type of decision that may be required in this case, however, is when to do it. Booster hardware, which has been the pacing item in most of the U. S. program since Sputnik 1, probably will pace Mars flights unless public attitude, cost or man's own ability to withstand long space flights assume more relative importance than they appear to have now.

If the family of vehicles being developed in the lunar program has enough versatility for the Mars mission it might come in the early or mid-1970s. If a new family of super-boosters is required —and particularly if nuclear stages are essential—the date may be somewhat later (see p. 89).

A large lunar base program, at least a separate, major undertaking beyond Apollo, seems at the moment to be the least likely of the future projects.

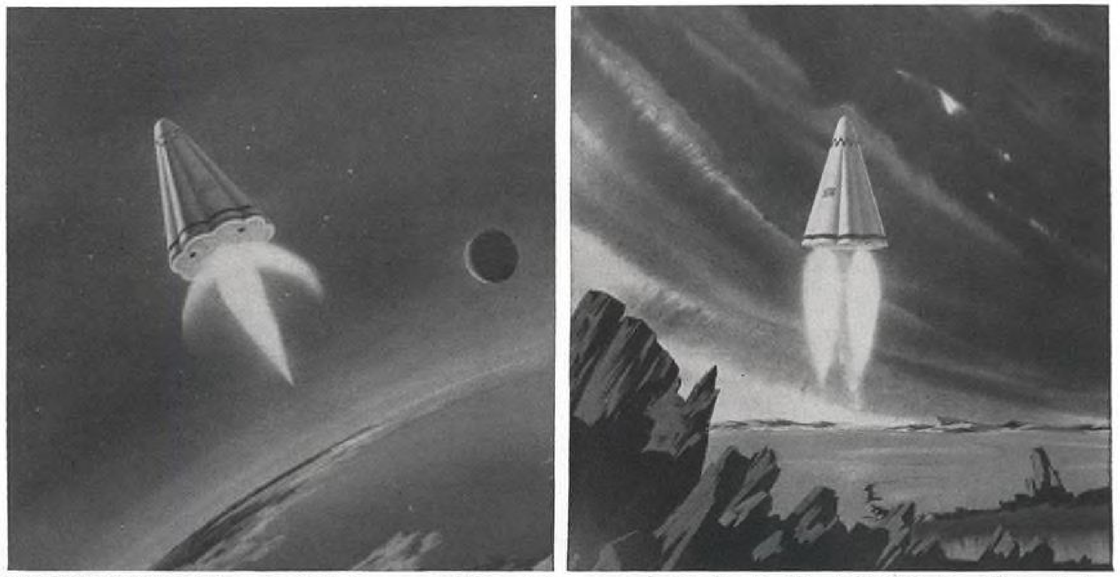
There is some doubt within NASA that it can bring sufficient return, and a strong feeling that the Apollo program, extended beyond the initial landing of two men, may be able to provide as much exploration of the lunar surface as man will want to do. But the moon base idea, too, is under study and its relative value must be weighed against other proposed programs which now appear more attractive.

Whatever project or projects are decided upon, there is no question that further manned flight will follow Apollo. It is impossible to look at the amazingly short span of 20 years from the first flight past Mach 1 in 1947 to Sputnik in 1957 to the possibility of lunar landings in 1967 or 1968 and believe that man will not go beyond this.

James C. Elms, deputy director of NASA's Manned Spacecraft Center, put the attraction, evolution and the inevitability of space exploration this way:



F-1 1.5 MILLION LB. THRUST ENGINE is test fired in a stand at Edwards AFB, Calif. Engine, being developed for the National Aeronautics and Space Administration by Rocketdyne, will power the first stage of the Saturn 5.



SINGLE-STAGE NUCLEAR launch vehicle for a manned Mars mission as conceived by Douglas Aircraft Co.'s Missile and Space Systems Div. would remain integral during descent and ascent from Martian surface.

"I've often thought how strange this space business would be if we had no moon at all. Would you tell your astronauts, 'Just go out about 200,000 mi. and mess around.'? That's like telling aircraft engineers, 'Just make an airplane that goes sort of fast.'

"The moon happens to be out there and we've made it a goal. This goal business is a marvelous way to get engineers to think. . . We will go and we may find something we aren't looking for.

"Columbus was a failure. He was looking for a passage to India. Instead, what he found was wheat fields and factories and harbors—the United States.

"The human race is going to do these things and it's pretty necessary to have us in the forefront."

Neither the space station nor the lunar base are considered goals in themselves. The space station will help determine how long man can operate in space, what he can do there and what he needs to help him. Within the military framework, it probably also will help decide whether he will eventually make war there.

The lunar base would have as its purpose the extension of exploration done initially by the first lunar landing parties. If it can prove itself on the basis of practical need—military necessity, an astronomical observation station free of the earth's atmosphere, a mining base for minerals that can be used on earth—then it might become an end goal rather than an extension of an earlier goal.

But the exploration of Mars, which a few years ago belonged in the realm of science fiction, is seen as the next logical step beyond the moon from the standpoints of interest, the physical laws of the universe and man's ability to operate within these laws.

"The Martian program, I think, will be done primarily because of the lure of exploration—not because it is economically feasible or because of any over-riding necessity to go there," Dr. Joseph F. Shea, deputy director for Systems in NASA's Office of Manned Space Flight, said.

"It will be done purely and simply because of the adventure of the exploration. It is the next challenging goal and focus for what we are trying to do."

Dr. Carl Sagan, assistant professor of astronomy at Harvard University, recently talked to the Harvard Club of New York about the lure of Mars. He pointed out that "observations suggest but do not prove that there are microorganisms on Mars." He said "we have no evidence either for or against the existence of more advanced life forms," but said exploration of the planet—first by fly-bys, then by orbiters and then by man—would directly investigate the possible existence of life on Mars.

"[It is] our immense good fortune to be alive at the first moment in history when the tantalizing problems of the beginning of life on earth and the possibility of life on other worlds can be approached with rigor and in detail," he said.

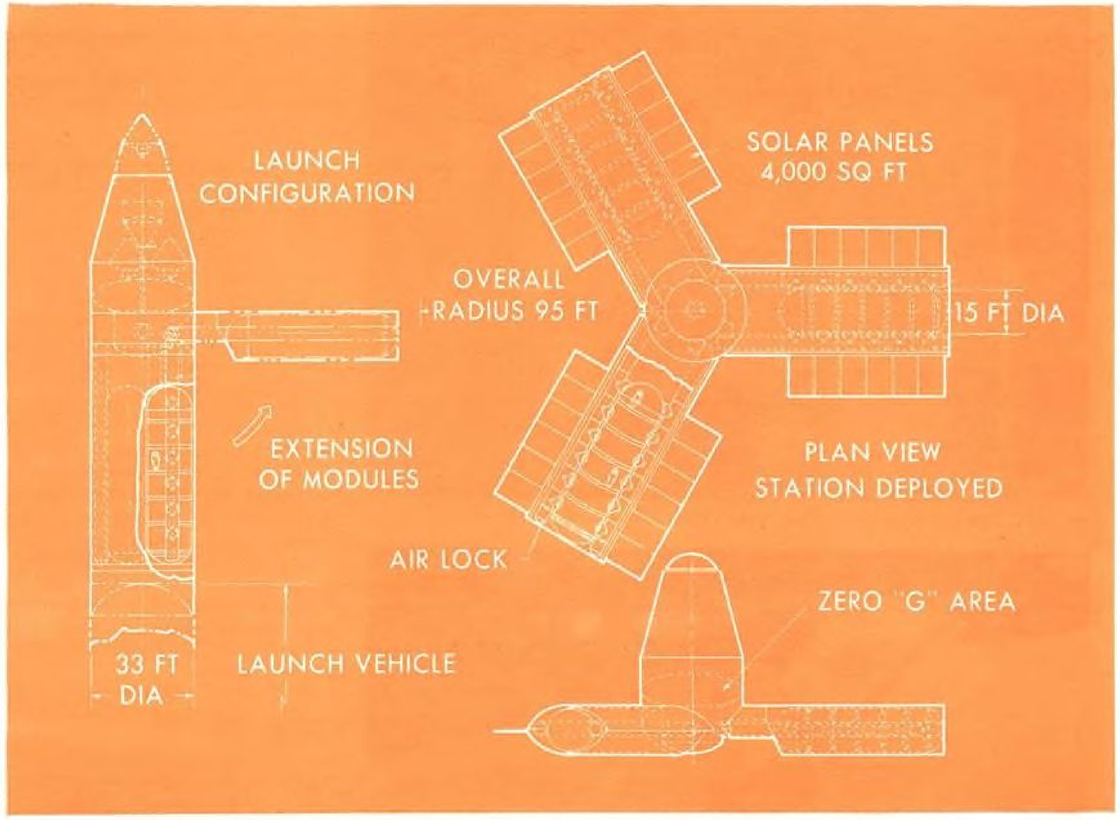
"To hold in our hands the keys to these ancient riddles is a triumph of the highest order; it heralds an age of exploration and discovery unsurpassed in the history of mankind."

Hard Core Funding—Manned Space Flight

Category	Spent Through FY63 (Billions)	Requested FY64 (Billions)	Estimated FY65 Through 69 (Billions)	Total (Billions)
Flight Programs*	$1.23	$1.59	$4.43	$7.24
Vehicles, Engines	1.56	1.22	4.27	7.05
Support (Industry)	.52	.62	2.22	3.36
Support (NASA)				2.12†
Totals	$3.31	$3.43	$10.92	$19.76

*** Flight programs in the Hard Core category are Apollo, Gemini and Mercury. Above estimates could increase substantially if other programs are approved before the end of Fiscal 1969. Through Fiscal 1964, Apollo spacecraft funding (for command, service and Lunar Excursion Modules) will have totaled $1.4 billion of an estimated final spacecraft cost of $4 billion. For the same period, $643 million will have been spent on the complete Gemini program. Total cost through the life of the Gemini program is estimated at $1.1 billion.**

† This category is for personnel, institutional and operating costs by NASA and other government agencies which directly support the manned space flight Hard Core program.



ROTATING EARTH-ORBITAL space station envisioned by Manned Spacecraft Center could support up to 24 men. Zero-gravity would exist in the hub, which would serve as laboratory and docking port for ferries. Gravity would be about 0.4g around the rim. Radius now being considered is 75 ft. and not 95 ft. as above.

NASA Building Space Station Technology

National Aeronautics and Space Administration has begun to develop a broad technological foundation for a manned space station, which it feels certain will be the next major project to be initiated.

The effort at this time revolves around two concepts, which can be categorized as small laboratory vs. large station. Studies will be completed in the next year by NASA, Air Force and industry in an attempt to distill a large number of sizes, configurations and operational approaches into hardware specifications on which the first flight phase can be based.

From concept and design viewpoints, NASA is confident that it can be ready by next July to begin a space station program. But the agency is aware that economics and management resources will dictate the pace at which the program will proceed.

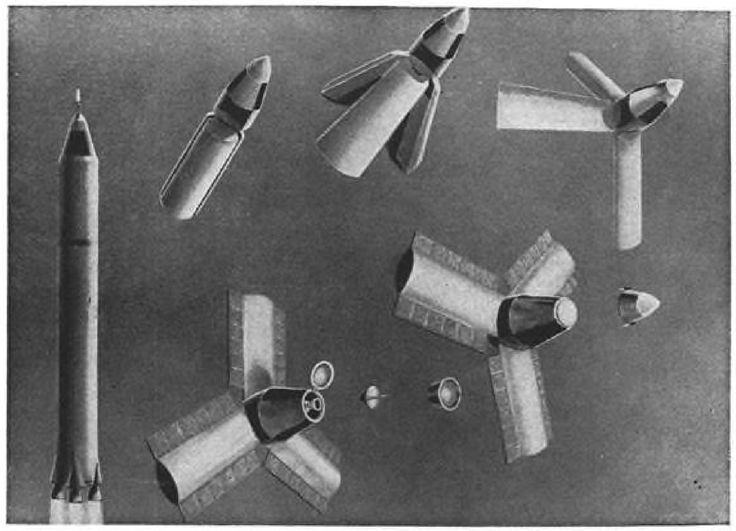
Air Force recently has taken the position that an orbital space station is its top priority space program (see p. 214). NASA has not yet placed a space station in its "hard core" budget category (see p. 76), and these two facts are expected to have a bearing on who manages a national space station program. Both agencies agree that the country will have only one manned space station program, which must be designed to meet both civilian and military demands.

In any event, the station that results will be influenced greatly by the current NASA studies. Leadership in the studies of a small laboratory is at Langley Research Center, and for the large station concept it is at Manned Spacecraft Center. This does not mean that the two centers are competing for the project. Manned Spacecraft Center will be given supervision if a NASA-managed station becomes an approved program.

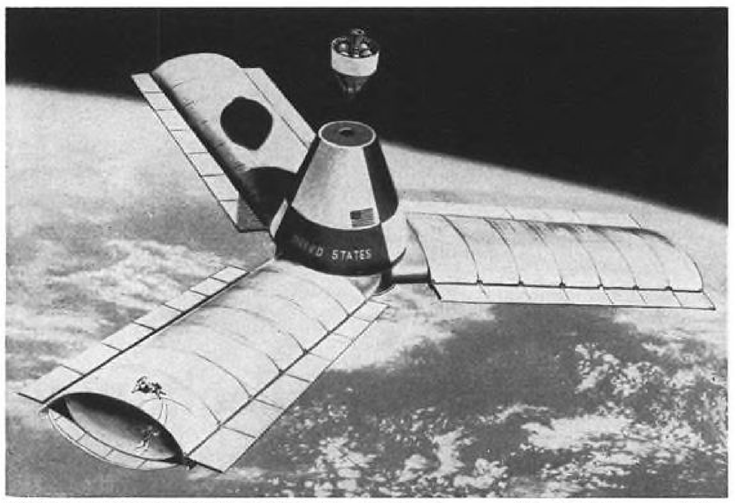
Charles J. Donlan, associate director of Langley, said the space station first was considered seriously early in the Mercury program as Apollo lunar mission concepts were evolving. Donlan then was assistant director of Space Task Group which managed the Mercury project. In 1960, because Apollo was then based on the Saturn 2 launch vehicle with a 16,000 lb. lunar payload capability, the Apollo mission would have been circumlunar.

There was considerable debate within NASA as to whether a circumlunar flight or a space station would provide the most return. The idea developed that if the lunar flight could not be done, the hardware developed for Apollo could be used instead for the space station. President Kennedy settled the matter in May, 1961, when he established manned lunar landing as a national goal, and the more ambitious Apollo program now under way was begun.

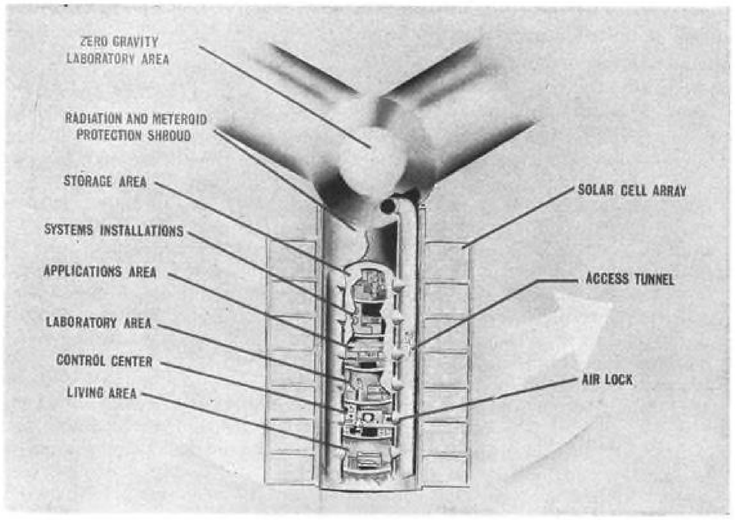
The space station then became a low-keyed study program, with Langley carrying the in-house load and managing a few modest industry study contracts. The center concentrated until a year ago on very large stations which



ARTIST'S DRAWING shows stages of space station launch and deployment.



MANNED APOLLO FERRY DOCKS (above) with the now fully-inflated space station. Below, a cutaway view of one of the station's modules.



could be inflated or erected in space. Last July, Langley was host to an inter-NASA conference which reviewed studies and research in space station technology.

Largely as a result of this conference, Langley re-oriented its thinking toward a smaller station. Donlan pointed out that the motivating factor for a space station is to study the behavior of man—not as a clinical specimen but as a human being doing useful work—under weightlessness for extended periods. At the same time, the station could provide a platform from which to conduct a wide variety of scientific and technical experiments.

From these factors, the concept for a small station called Manned Orbiting Research Laboratory (MORL) was developed. Its size, Donlan, said, was predicated on the smallest laboratory that could satisfy requirements for observing man's behavior and yet be large enough to conduct useful scientific experiments.

It also would have to be compatible with existing programs and could not interfere with the Apollo manned lunar landing mission.

The system that resulted is a four-man canister, 154 in. in dia. and 271 in. long, which, with a jettisonable fairing, is aerodynamically identical to Apollo. This laboratory would be launched by Saturn 1 or Saturn 1B, depending on its ultimate weight. Goal is to keep the weight between 15-20,000 lb.

Other parts of the system are the McDonnell Gemini as the crew ferry vehicle, launched by the Martin Titan 2, and a resupply spacecraft launched by General Dynamics-Lockheed Atlas Agena D.

Models of the station (see p. 79) show the Saturn second stage remaining attached to the laboratory, in case it is necessary to induce artificial gravity for crew comfort. Donlan said, however, that the laboratory as it is now conceived will operate at zero-gravity. These are the essential parts of the MORL concept:

• **Laboratory spacecraft** would be launched, unmanned, into a circular orbit (180-230 mi.) from Cape Canaveral at a 28-deg. inclination. The canister would contain provisions for sustaining the spacecraft and a two-man crew for 15 days. Critical on-board systems would be activated on ground command to determine proper operation before the lab was manned.

Launch site and inclination angle are influenced by the location of Gemini tracking and telemetry sites.

• **Ferry spacecraft** would use the identical operational approaches being developed for the Gemini mission in launch, rendezvous, re-entry, landing procedures and landing sites. It would be launched about 15 days after the laboratory, and one of its pilots would be scheduled to remain in the laboratory for a year.

• **Resupply spacecraft,** unmanned, would be used to carry a 90-day supply of expendable cargo to the spacecraft. Another of its primary missions would be to adjust the MORL orbit with its on-board propulsion. Atlas Agena D combination can carry more than 5,000 lb. into a 300 mi. orbit.

In operation, the resupply vehicle would be launched any time within 15 days after the first ferry has reached the laboratory. Launch would be into a catch-up orbit and Agena propulsion would be used for the transfer maneuver. Terminal rendezvous would be controlled by the laboratory crew, using transponder radars for range, range-rate and position information.

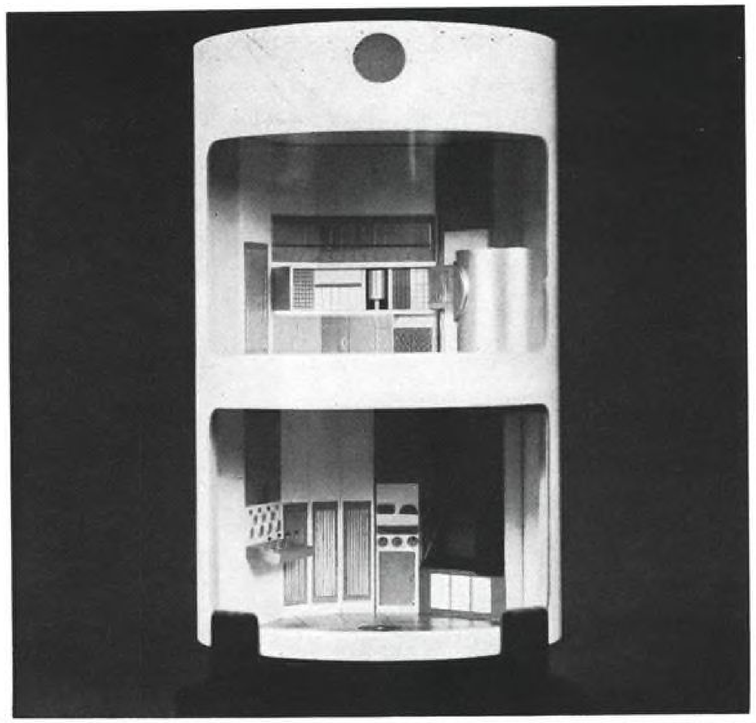
• **Primary design considerations** are that the life support system will be partially closed, the laboratory will be sun-oriented, and the initial design will have a storm cellar which can be removed without radical change if the radiation level is low enough to indicate the shelter is unnecessary. Life support system will recycle urine and humidity, and discard fecal water and carbon dioxide.

Typical mission schedule (see chart below) would have crewmen staying in the laboratory for varying periods, ranging from just a few hours to 360 days. "But," Donlan said, "we're not planning just to send a guy up for a year in solitary. We'll be watching a laboratory in operation in detail; we have worked out a routine for a series of exercises and good use of his time."

The exercises will be mainly of the dynamic tension type, and were developed by Eddie Block, trainer of the Baltimore Colts football team, who also is a consultant to the Martin Co. Among the exercises are use of bungee devices, breathing, isometric tension, use of hand and vibrator massagers, cuff compression of the veins, and possibly use of a small on-board centrifuge as a conditioner.

Donlan also said Langley has developed what it calls a "staple shopping list" of experiments for physiological and behavioral measurements and of engineering and scientific experiments. He cautioned that the following are the kinds of experiments, rather than the specifics, and that they may be changed:

• **Physiological,** which will result in standard clinical measurements. Readings will require an oral thermometer, blood pressure cuff, manual pulse timer, respiration rate, blood smear and count and urinalysis. Cardiovascular examinations will measure cardiac output, rhythm and electric qualities, blood volume and fluid distribution, peripheral resistance and blood flow. Nutrition absorption, transport and utilization will be measured, as will muscle tone, protein balance and calcium balance.



MODEL OF THE FOUR-MAN small zero-g laboratory space station being studied for NASA's Langley Research Center by Boeing and Douglas, features living quarters in top and lab in bottom of cylindrical station.

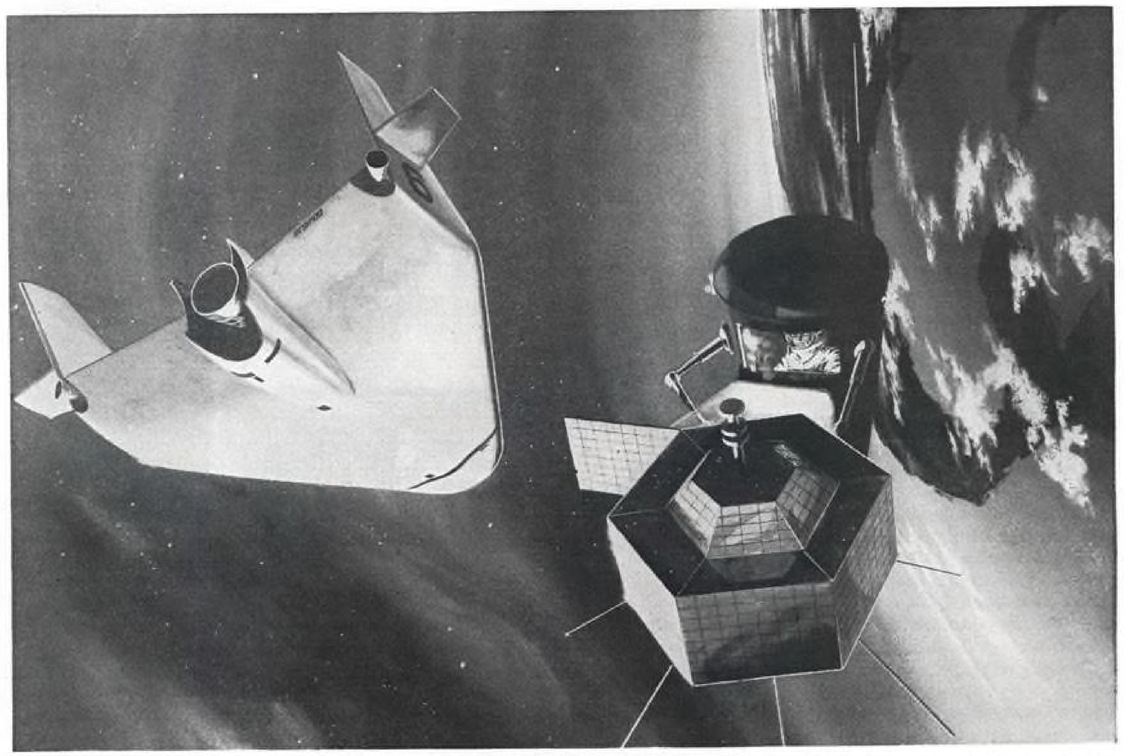
Other measurements will be made of pulmonary ventilation, diffusion, and metabolic rate; stress hormones and glucose tolerance and the vestibular and central nervous systems.

• **Psychiatric and behavioral** measurements will be made in the areas of gross and fine motor, kinesthetics, vigilance, learning, retention and problem solving.

• **Engineering and scientific** experiments. Prime candidates deal with high resolution celestial photography, cellular physiology, oxygen recovery systems, extra-vehicular suit and biopack operations, fabrication and repair techniques, high-vacuum material fatigue, micrometeoroid and cosmic dust collection, plasma composition, particle radiation characteristics, drag measurements, studies of liquids in

Typical Manned Orbiting Research Laboratory Mission Schedule

System	Launch Time (days)	Pilots Going	Spacecraft Returning	Pilots Returning	Crewmen in Lab	Pilot Time in Lab (days)
Laboratory	T-15					
Ferry No. 1	0	A and B			A and B	A-360
Re-supply No. 1	T+15					B-60
Ferry No. 2	T+30	C and D			A, B, C, D	C-120
Ferry No. 3	T+60	E and F	Ferry No. 1	B and F	A, C, D, E	D-210
Re-supply No. 2	T+105					E-300
Ferry No. 4	T+130	G and H	Ferry No. 2	C and H	A, D, E, G	F-0
Re-supply No. 3	T+195					G-210
Ferry No. 5	T+240	I and J	Ferry No. 3	D and J	A, E, G, I	H-0
Re-supply No. 4	T+285					I-120
	T+360		Ferries 4 and 5	A, E, G, I	None	J-0



DELTA-WINGED space vehicle, called Astro by Douglas Aircraft Co., would be a re-usable vehicle for personnel ferrying, logistic supply and/or maintenance of malfunctioning satellites, as pictured above.

zero-g, surface erosion and surface potential tests, evaluation of space navigation systems, and measures of noise and vibration levels.

With these general guidelines, Boeing and Douglas last month won three-month study contracts which are expected to tell Langley how its concept—the four-man can—could best be implemented, and also how the companies would configure a laboratory without regard to Langley's concept. One of these companies will be awarded a phase 2 contract to optimize selected systems, prepare a preliminary design, and price the system through its development cycle.

Human factors, engineering, operations, mission tasks, schedules and economic considerations all enter into design requirements for a station, but the size and configuration may well be influenced strongly by what Soviet Russia develops.

Human factors considerations are considered the most demanding in space station design, however, because the station must provide a livable environment, facilities for operating and experimenting, and facilities for eating, recreation, personal needs and rest.

Engineering factors which influence the large space station design are:

• **Space allocation** to meet crew requirements and for experimentation.

• **Growth potential** for a variety of tasks that may not be planned when the station first becomes operational. Olling and Charles W. Mathews, the Gemini project manager, feel that laboratories become useless if they are not adaptable to changing requirements.

• **Reliability,** so that the station can remain useful from 1-5 years.

• **Redundancy,** so that critical experiments can continue even if a system malfunctions.

• **Hazard protection,** particularly radiation, but also protection against meteoroid penetrations and resulting decompression, and against the vacuum of deep space.

Manned Spacecraft Center studies also include a 12-man winged logistics spacecraft with a lift/drag ratio of 2.5, or five times that of the Apollo shape. Advantage of the winged vehicle is its lateral maneuvering capability on reentry. Apollo shape can maneuver about 200 mi. on either side of a centerline; the winged vehicle could increase this capability to 2,000 mi.

• **Docking and stowage** to the rotating station would require that the docking port be in the hub, which Houston now conceives as being a non-rotating part of the system. With the hub as a hangar, it would be necessary to stow the logistics spacecraft so that they will not cause oscillations. Same problem exists when the ferry vehicles are removed from the hub-hangar.

• **Safety and emergency** procedures.

On-board system design criteria include ease of service and maintenance, flexibility of installation, long-duration capabilities, minimum of resupply and expendable requirements, ability to operate under decompression and radiation, protection from radiation and meteoroids, and minimum toxicity.

Mathews pointed out that the space station resupply is an important part of the over-all project, since a ferry would carry food, life support and power cargo to keep the station in operation and would be the means for setting up new experiments and rotating crewmen.

As a first-generation ferry vehicle, Manned Spacecraft Center is studying a modification of the three-man Apollo command module into a six-man vehicle. Mathews summarized a possible mission sequence of an 18-man station and six-man ferry:

• **The station and a six-man crew** in the logistics ferry would be launched into a 345-mi. circular orbit with a single Saturn 5 vehicle. In orbit, the crew would transfer to the station, activate the systems, establish a crew routine and prepare to receive additional supplies and crewmen. Logistics spacecraft would be launched at one-month intervals, with the normal crew rotation cycle being three months.

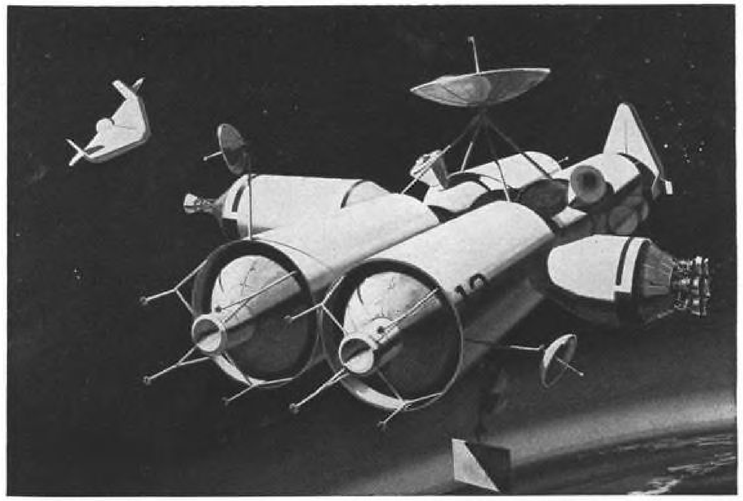
NASA Space Station Study Contracts

Following is a complete list of the industry studies on space stations and systems being conducted under National Aeronautics and Space Administration funding. The first three are managed by Langley-Research Center, the next eight by manned Spacecraft Center, and the last two by Lewis Research Center.

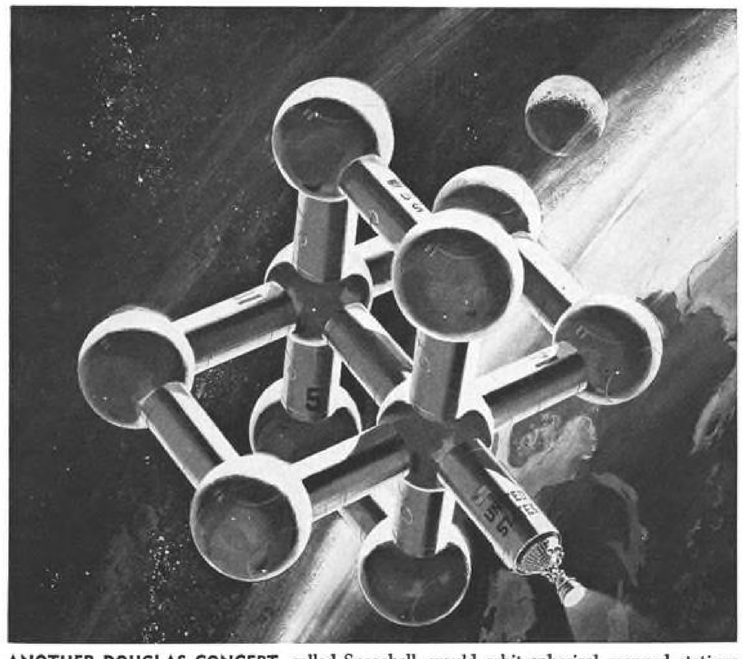
Company	Study Subject	Contract Value	Completion Date
Boeing	MORL concepts	$400,000	9/5/63
Douglas	MORL concepts	200,000	9/5/63
*	MORL preliminary design		
Lockheed	Large rotating space station	300,000	3/1/64
Douglas	Large zero-g space station	150,000	3/1/64
Lockheed	12-man ballistic logistic spacecraft	100,000	2/1/64
Boeing	12-man winged logistic spacecraft	100,000	1/25/64
North American	Modified 6-man Apollo ferry vehicle	100,000	1/2/64
Lockheed	Operations, logistics requirements	98,000	12/1/63
Lockheed	Electrical power system requirements	52,000	12/7/63
Hamilton-Standard	Life support system requirements	36,000	1/2/64
General Electric	Reactor heat sources	83,000	7/1/64
Martin	Isotope heat sources	40,000	5/1/64

* Either Boeing or Douglas will be awarded a 9-month contract for this project in October or November.

MORL—Manned Orbiting Research Laboratory.



EXTREMELY LARGE space station is considered feasible before 1970 by Douglas. Station could be a relay point for lunar shuttles or supply depot.



ANOTHER DOUGLAS CONCEPT, called Spaceball, would orbit spherical manned stations atop spent S-4B third stages of Saturn 5 launch vehicles.

Manned Spacecraft Center foresees a requirement for a large station able to sustain up to 24 men. It would have extended capabilities for scientific experiments and ultimately might reduce considerably the need for separate launches of scientific satellites because it could function as a national orbiting research center.

Edward H. Olling, head of the Space Station Project Office at Houston, feels the station is an essential and necessary precursor to manned planetary flight.

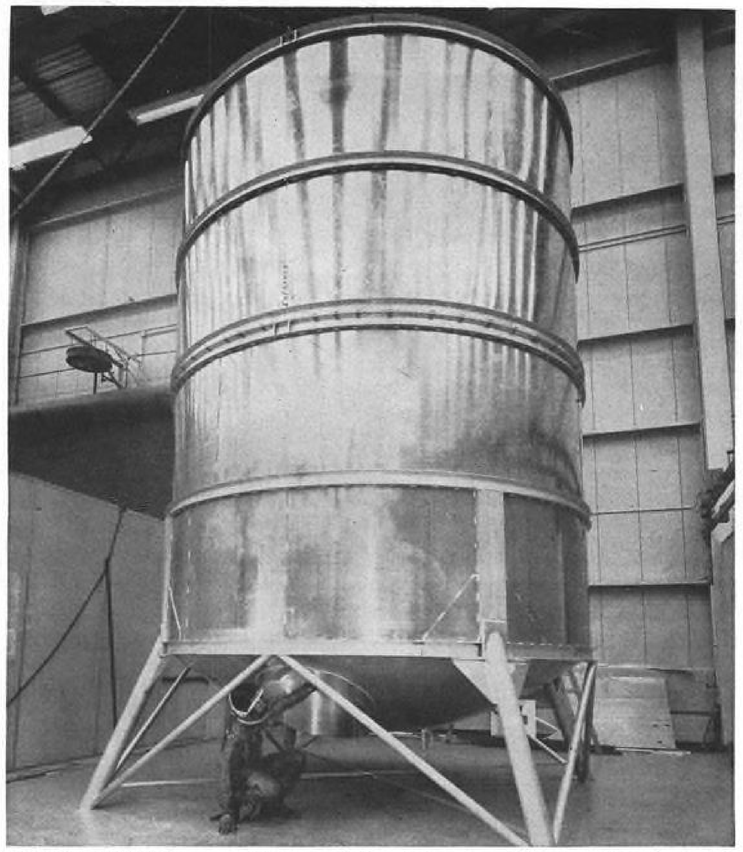
"The space station provides the research facilities to determine man's capabilities for long duration in the space environment," he said. If it develops that man has serious physiological limitations, he said, the space station can be used to determine criteria and solutions to overcome these limitations.

Olling said space station crewmen also could investigate and establish environmental criteria for planetary flight, conduct research with plants, animals, finishes, processes and equipment and proof-test such systems as basic structure and airlocks. The station could also be used to qualify and train the crew and perhaps serve as an orbital launch facility—all in support of planetary missions.

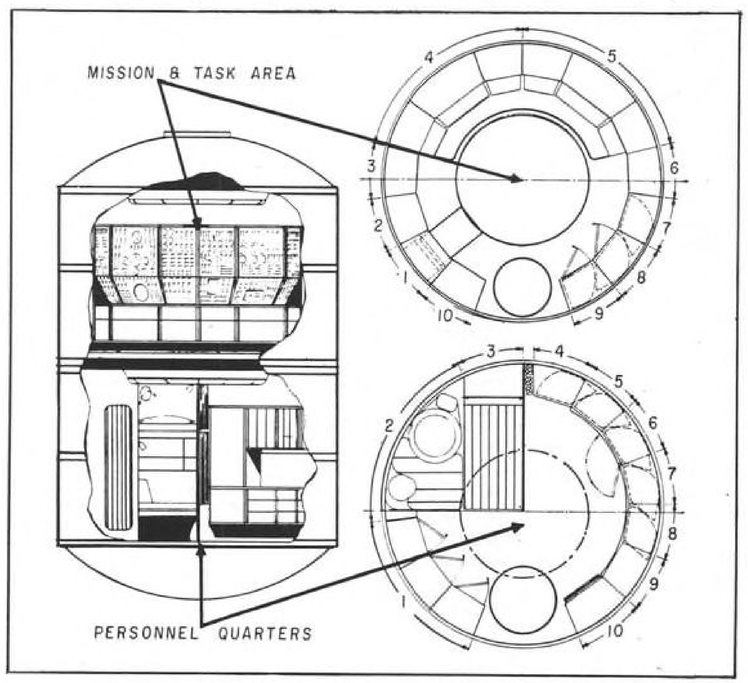
As other potential space station missions, Olling gave these:

• **Lunar base support,** a function similar to that for manned planetary exploration. The station could also act as a trans-shipment point for supplies between the earth and moon.

• **Science and technology.** If the orbital inclination satisfies requirements, the station could house scientific experiments and operational systems in the disciplines of astronomy, navigation, meteorology and communications and provide a means for long-term investiga-



GENERAL ELECTRIC space station simulator exterior view (above) and interior layout. Numbers indicate the following spaces in the mission and task area: 1) checkout and repair; 2, 3, 6, 7 and 10) instrumentation; 5 and 6) display consoles, and 8 and 9) storage. In the personnel quarters area: 1 and 4) suit storage; 2) toilet facilities; 3) sleep, and 5 through 10) food preparation, storage, eating and waste. Note similarity to NASA concept (p. 77).



tions of biological, physiological, psychological and hereditary factors in man, plants and animals.

While many scientific space experiments are conducted in separate launches and produce useful results, they are expensive in terms of money, manpower and facilities, Olling said. By providing a common base for research equipment and applications projects with men on board, the payloads can be serviced, maintained, repaired, overhauled and re-oriented, he said, and experiments can be co-ordinated.

Like the Langley concept, the Houston station is based on existing technology, launch vehicles, launch sites, range and tracking facilities. Houston is studying two fundamental configurations: a zero-gravity canister, and a rotating vehicle consisting of a hub with three radial modules. The logistics vehicle would be a modification of the Apollo command module. A Saturn 5 vehicle would launch the radial module space station, and a Saturn 1B would launch the logistics vehicle.

Operational factors are essentially the same for both rotating and zero-gravity stations. They are: a lifetime of at least a year, orbital altitude of 230-345 mi., launch vehicles developed under existing programs, resupply by logistics spacecraft, and the use of redundant modules with emergency escape.

The rotating station, weighing about 200,000 lb., would have a 75-ft. radius and would spin around its axis of symmetry at 3-4 rpm. The hub would be a combination zero-gravity laboratory and hangar for checkout and service of logistics spacecraft. The gravity levels would be about 0.25 near the hub to 0.4 at the periphery. Each spoke would have six compartments, 15 ft. in dia. by 8 ft. high, for experimenting and living.

The zero-gravity station would be 33 ft. in dia., and 100 ft. long. It would be launched in sections and assembled in orbit.

Mathews pointed out that a number of factors enter into the choice of a logistics vehicle, but no matter which type is selected, it must be capable of refurbishing and re-use. It is possible, therefore, that a paraglider with a lift/drag ratio of about 1, incorporated into the Apollo-type vehicle, might satisfy requirements for lateral maneuvering.

For the Houston concept, it is likely that the Apollo configuration will be specified as the shuttle on early missions, during which time development will be conducted on a winged, second-generation logistics spacecraft.

This conclusion fits closely that of Air Force in its space station conceptions. Candidates for the shuttle vehicle for the Air Force station are Gemini and Dyna-Soar. Second-generation shuttle might be the first version of the Aerospaceplane (see p. 245).

Future Bioastronautics Research Outlined

U. S. has precisely defined the bioastronautics requirements of its current Gemini and Apollo programs, but manned flight beyond the lunar landing poses questions to which the nation will seek answers for many years to come.

In an attempt to determine the effects of long space flight on man and what is required to protect him, sustain him and permit him the fullest use of his capabilities, National Aeronautics and Space Administration has elected to concentrate its bioastronautics research efforts on what it considers the three most critical unknown characteristics of man's functioning in space:

- Zero-gravity and reduced gravity over long periods, such as man would encounter on a Mars mission or as a lunar base crewman. At this point, zero-gravity is considered the top priority human factors concern, particularly as it affects man in combination with the added stresses of noise, vibration and temperature extremes and is followed by high re-entry decelerations.

Space Laboratory Needed

Consensus is that a realistic evaluation of the effects of weightlessness is possible only with a space laboratory in operation for at least a year. Its key objective would be to determine if artificial gravity is mandatory for extended manned space flight missions, or if man can fly a 500-day planetary round-trip without paying the engineering and weight penalties artificial gravity would impose.

- Radiation. The nation has accumulated considerable confidence that solar flares can be predicted and avoided, and that man can survive a dash through geomagnetically-trapped radiation and flight through incident cosmic radiation. Although acceptable dose levels of the past are considered overly conservative, NASA wants to investigate anti-radiation drugs, foods which could build up immunity against sickness caused by radiation from nuclear propulsion units, and solar and cosmic radiation.
- Magnetic fields. There is concern that the extent of magnetic field force has an effect on biological rhythms and space-time perceptions.

NASA has begun its first concentrated research effort on biotechnology and human factors research by organizing a group with that name in the Office of Advanced Research and Technology, under Dr. Eugene B. Konecci. The group looks at specific missions and then relates these missions to human research, biotechnology, and the integration of man and machine.

As its first realistic step, the group is now surveying all U. S. facilities and capabilities which can contribute to the research effort.

Specific areas in human factors research that have grown out of planning for long manned space flight missions are the development of biological fuel cells and advanced techniques in medical monitoring telemetry.

Biological fuel cells that are designed to convert human waste into electrical power are under study and three NASA contracts totaling about $250,000 are currently in effect in this area. Companies holding these contracts are Aeronutronic Div. of Ford Motor Co., Magna Products, a subsidiary of Thompson Ramo Wooldridge, and Marquardt Corp. Magna is also conducting research in biological fuel cells under Navy sponsorship.

Workable prototype biological fuel cells to convert the energy of human waste into electricity are not expected to be available before the long-duration space missions planned for the post 1970s according to NASA's space power technology manager, Walter C. Scott.

Advances in medical monitoring telemetry have resulted from NASA's Biological Investigation of Space (Bios) program which began in April, 1961 (AW May 20, p. 79). Ames Research Center is directing this program, which consists of obtaining real time data of respiration, eye movement, blood flow, electrocardiograms (ECG) and electroencephalograms (EEG) from orbiting primates.

General Electric's Space Sciences Laboratory recently operated a 500-kc. transmitter continuously for eight hours from electrical power generated from a living rat (AW July 15, p. 30). NASA's Ames Research Center awarded GE a $77,328 contract to develop a power source for sensors and transmitters that could be used with experimental animals.

The question of whether cell division, fertilization and various metabolic processes can occur in a weightless environment are to be investigated in the Bios program.

Although Bios is primarily directed towards a fundamental understanding of life processes in plants as well as animals, much technological fallout is expected to accrue to the manned space program from its findings.

A biomedical computer which would integrate all medical information obtained into a single reading to indicate the overall conditions of the astronaut is being developed at the bioinstrumentation facility at NASA's Flight Research Center, Edwards, Calif. The computer would reduce telemetry power requirements and make possible better selection of astronauts, according to Dr. Konecci.

A seven-channel biomedical magnetic tape recorder weighing 3 lb., which will record medical information on the Gemini spacecraft flights, has been designed by the Cook Electric Co., Morton Grove, Ill.

Life Support Debate

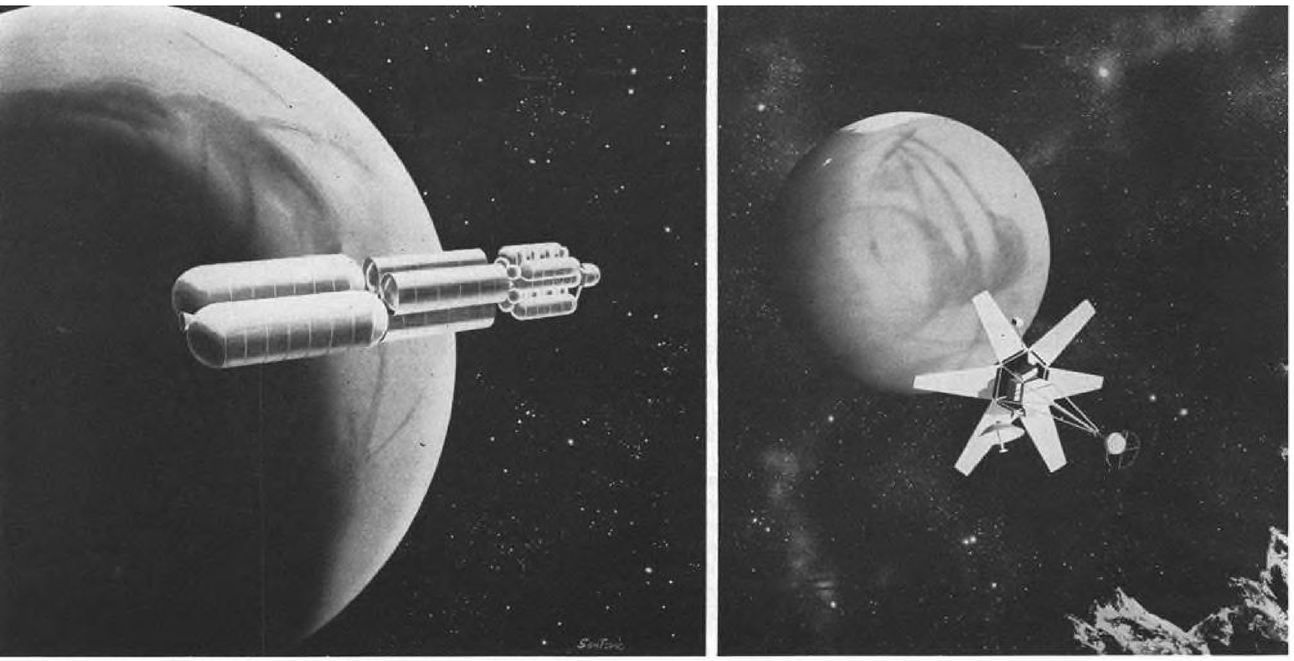
Life support requirements necessary for missions beyond Gemini and Apollo have been the subject of much debate, and considerable controversy over a single gas versus man's natural mixed-gas environment has resulted (AW May 13, p. 85). Both sides agree that there is no evidence of physiological problems which would prevent the crew from performing their tasks for two-week missions but that not enough is yet known about human physiology to make a decision as to which system is the better for periods longer than this.

USAF also is heavily involved in bionics research which will aid engineers and scientists to design better avionics equipment. A recent USAF bionics study showed that myoelectric signals —those associated with muscle contractions—can be used to control a servo boost system (AW Mar. 25, p. 69).

The servo would enable an astronaut to move his arms during the high acceleration environment of spacecraft re-entry. Air Force's Aeronautical Systems Div. funded the work which is being done by SpaceLabs, Inc., Van Nuys, Calif.

Grumman Aircraft Engineering Corp. and Alderson Research Laboratory have signed an agreement for collaboration in production of instrumented anthropomorphic dummies for use in human survivability tests of aerospace vehicles.

The companies have developed a flesh-textured dummy with a 12-channel instrumentation package as their first joint product.



MARS MISSION concepts are depicted in these General Dynamics/Astronautics drawings, which illustrate NASA's Project Empire studies. Vehicle is assembled in space (left). At right, a probe launched by crewmen approaches a Mars moon.

Mars to be Next Space Goal After Moon

Manned flight to Mars is almost certain to become the focus of the U. S. manned space flight program after the Apollo lunar landing, even though technical obstacles and the cost of such a mission could delay it until the late 1970s or early 1980s.

National Aeronautics and Space Administration officials differ considerably over what is required for a manned Mars mission, particularly in the areas of launch vehicles, spacecraft, guidance, communications, power supply and flight mode. But there is general agreement that Mars is the next logical target for manned exploration, and that the mission will be undertaken.

NASA increased its Mars mission study effort considerably during the past year. Both Marshall Space Flight Center and Manned Spacecraft Center performed or contracted with industry for studies which clearly showed that the Mars mission is feasible.

"We now need three or four years of very serious, detailed study," said Dr. Joseph F. Shea, deputy director for systems in the Office of Manned Space Flight. "What we have done so far is in the nature of preliminary study."

Estimates on when the U. S. can accomplish a manned landing on Mars vary greatly. David M. Hammock, who has directed much of the Mars study work at the Manned Spacecraft Center, believes manned exploration of the planet is feasible with the present technology, and could be carried out during the favorable flight period of 1972-73.

"The Apollo guidance and navigation system techniques are adequate for the Mars mission," he said. "Most of the subsystems and equipment of the Apollo command module are adequate for earth re-entry. The greatest advance in technology is required in the area of heat-protection systems for earth re-entry for velocities ranging from 45,000 to 60,000 fps.

"It appears feasible to accomplish the mission using the Saturn 5 as the launch vehicle and with chemical propulsion in the spacecraft." He said nuclear propulsion is "highly desirable but not essential."

NASA headquarters and Marshall Space Flight Center are less optimistic.

Douglas R. Lord, a program planner in the Office of Manned Space Flight, said "I think we'll do the Mars mission in the late 1970s. It's possible we'll need a Nova vehicle. If, after a year or two of solid mission studies, we decide we need a Nova, then we should proceed on the basis of developing a planetary flight system."

Harold B. Finger, director of the NASA-Atomic Energy Commission Space Nuclear Propulsion Office, believes that a nuclear upper stage must be used in the Mars mission and that the mission cannot be attempted for 15 years or more.

"This may come as a shock to many of the so-called planners whose reports talk of what would be required to do a manned planetary mission in 1971 to 1973," he said. "I think that in their hope to sell the mission, they are completely fooling themselves as to [its] complexity and difficulty. . . ."

Another obstacle to an early manned Mars mission is the heavy funding required for such a program—$40-$50 billion—in face of a growing interest in space station development.

It is unlikely that the U.S. will fund a large space station and a manned Mars flight system at the same time. And, since many NASA advocates of interplanetary manned flight feel that space stations will be required to check out Mars spacecraft systems and determine the effects of very long weightless flight on the human system, there is little likelihood of a Mars mission before 1975.

Whatever time period is selected for manned flight to Mars, a great number of divergent considerations remain unresolved, ranging from a basic justification for the flight to radiation shielding in the spacecraft. Recent studies and papers have suggested many areas of investigation, which include:

• **Justification**—The possibility that life exists on Mars is a powerful and appealing argument for undertaking a Mars mission. Terrestrial micro-organisms placed in different kinds of soils and subjected to a simulated Martian environment have survived.

Dr. Carl Sagan, assistant professor of astronomy at Harvard University, suggests that there may be more advanced life forms on Mars and urges both an unmanned and manned Mars flight program.

Shifting canals on Mars and changes in the shading of the topography continue to be a mystery.

Dr. G. De Vaucouleurs of the University of Texas Astronomy Dept., said "the practical limit of resolving power has effectively been reached for earth-bound observations and decisive progress, and hopefully the solution of the [topographical] mystery, will come only through close-up, high resolution photography and television from interplanetary probes. The Mariner B mission . . . in late 1964 may resolve the riddle . . . or, perhaps send back to earth more tantalizing glimpses of an unearthly activity of which we have no conception."

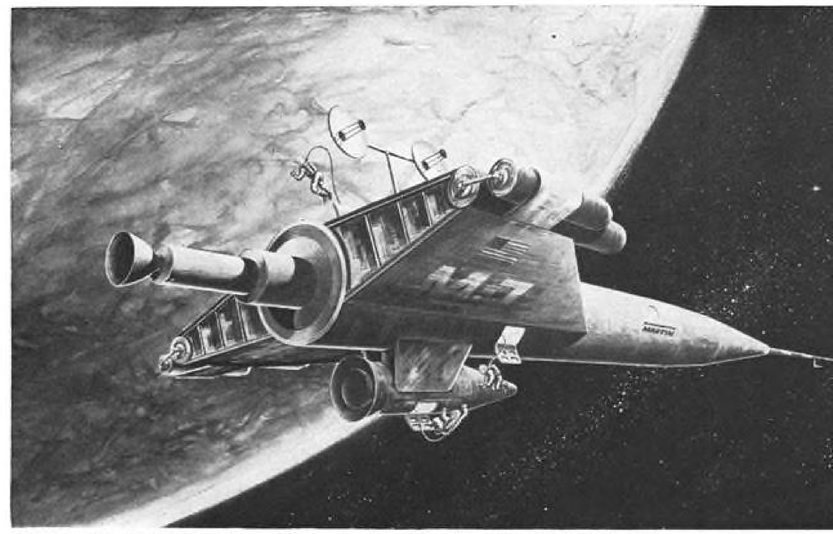
Dr. De Vaucouleurs also urged more precise mapping of Mars for selection of landing sites required in manned flight to the planet.

• **Launch vehicles**—There are wide differences of opinion on propulsion requirements for a manned Mars mission. Some believe that Saturn 5 and chemical propulsion units in the spacecraft could accomplish the mission. Dr. Harry O. Ruppe, of the Marshall Future Projects Office, feels nuclear propulsion will be required for the mission and that some form of electric rocket would be desirable.

Dr. W. H. Clohessy, director of Space Research Laboratories, Martin-Denver, says development of propulsion systems will pace the Mars exploration mission, and it has not been established that nuclear rockets are the answer. He believes that a 1973 Mars landing is extremely optimistic and recommends an intensive five-year study program, including work on electric engines, to determine what is possible and most desirable as a propulsion combination.

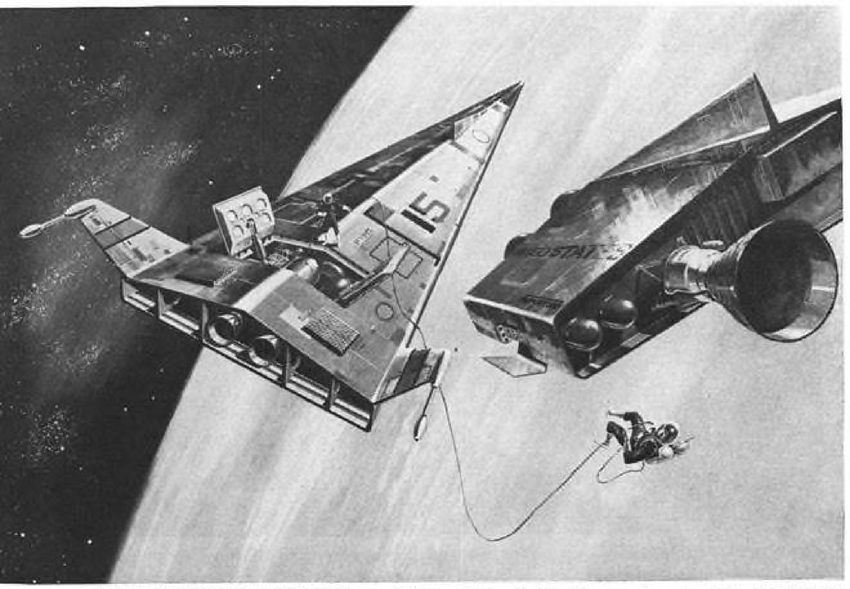
• **Spacecraft**—Crew safety and the increased probability for mission success in the launch of two or more spacecraft systems are important factors in establishing spacecraft requirements.

Spacecraft system as presently conceived by the Manned Spacecraft Center, will involve two independent space vehicles. Each will contain a mission module, a command module and a Mars landing or excursion module. A failure of either vehicle during any phase of the mission will not constitute a mission abort. In case of an emergency in either vehicle, the crew aban-



CREWMEN ASSEMBLE Mars vehicles in these drawings showing Martin Co. concepts.





ASTRONAUTS TRANSFER between Mars vehicles for landing on the planet in this Martin Co. concept. Opinions differ greatly on when such a mission can be conducted.

dons the impaired spacecraft in the command module to rendezvous with the other. Each vehicle will be capable of supporting a peak crew of six.

The mission and command modules will operate in a variable gravity field of from 0 to 0.6g. The mission module will be the primary living module. The command module will protect the men during launch and re-entry and enable pilots to transfer between vehicles during a mission emergency.

In this flight concept, the Mars excursion module would be abandoned in orbit about Mars after crew transfer to the mission module. The mission module would be jettisoned before earth re-entry.

Ruppe's concept also involves launch of two spacecraft systems, one containing a crew and the other a radio-controlled cargo-carrying spacecraft. The cargo vehicle would carry shelter, equipment and supplies for the stay on Mars and could accommodate the crew of the command module in an emergency.

• **Crew size**—Only preliminary work has been done on the crew requirements for a Mars mission, and it appears that the crew will range in number between three and eight. In view of the strong sentiment that trained scientists be sent on lunar and Mars missions, it is likely that crew members for the latter will be both pilots and scientists.

• **Life support system**—Progress in the development of chemical regenerative systems over the past few years indicates that the atmosphere and water required in the Mars spacecraft will be at least partially supplied and maintained through reconstitution of waste materials.

A mixed oxygen-nitrogen gas system similar to the earth's atmosphere probably will be selected. This will impose a need for a tighter cabin than was required with the use of the 5 psi. oxygen system in Mercury, Gemini and Apollo. However, the oxygen-nitrogen combination at a pressure of between 7 and 15 psi. seems to be preferred for missions beyond Apollo because of the danger of fire and explosion in the pure oxygen system and the suspicion that more than two or three weeks on all oxygen may be extremely harmful to the human system.

Because the trip will be a long one, food will have to be better than barely palatable and living conditions as attractive as possible. Spacecraft design will probably include facilities for body washing, exercise and recreation.

• **Crew protection** — Crew protection against radiation now appears to be one of the most complicating factors in the consideration of the manned Mars mission. A 330-420-day mission in the early 1970s, during the quiet sun period, will require about one-fourth as much shielding as a 450-500-day mission during the least favorable period for flight to Mars in 1980.

However, there is considerable optimism that further study will find ways around the shielding problem. Some of the possible solutions are anti-radiation drugs, flare prediction, dietary planning to strengthen the human system's resistance to radiation damage, and development of more effective, lighter weight shielding materials.

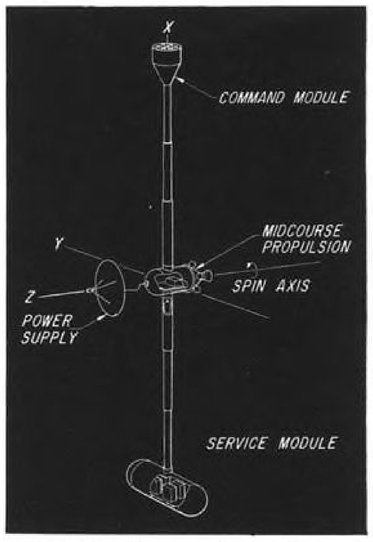
• **Psychological effects**—There has been much speculation that confinement for a year or more in a spacecraft in the space environment might seriously reduce the capability of a space pilot. Dr. Julien M. Christensen of the Air Force Behavioral Sciences Laboratory at Wright-Patterson AFB recently observed that "there will be . . . facilities for communicating with earth stations and with each other. The members will not suffer stimulus impoverishment, in fact, just the opposite, if their vehicles and their jobs are properly designed."

". . . The crew should be provided with a clean, well-lighted vehicle with comfortable and attractive work stations and rest areas, good food and palatable liquids.

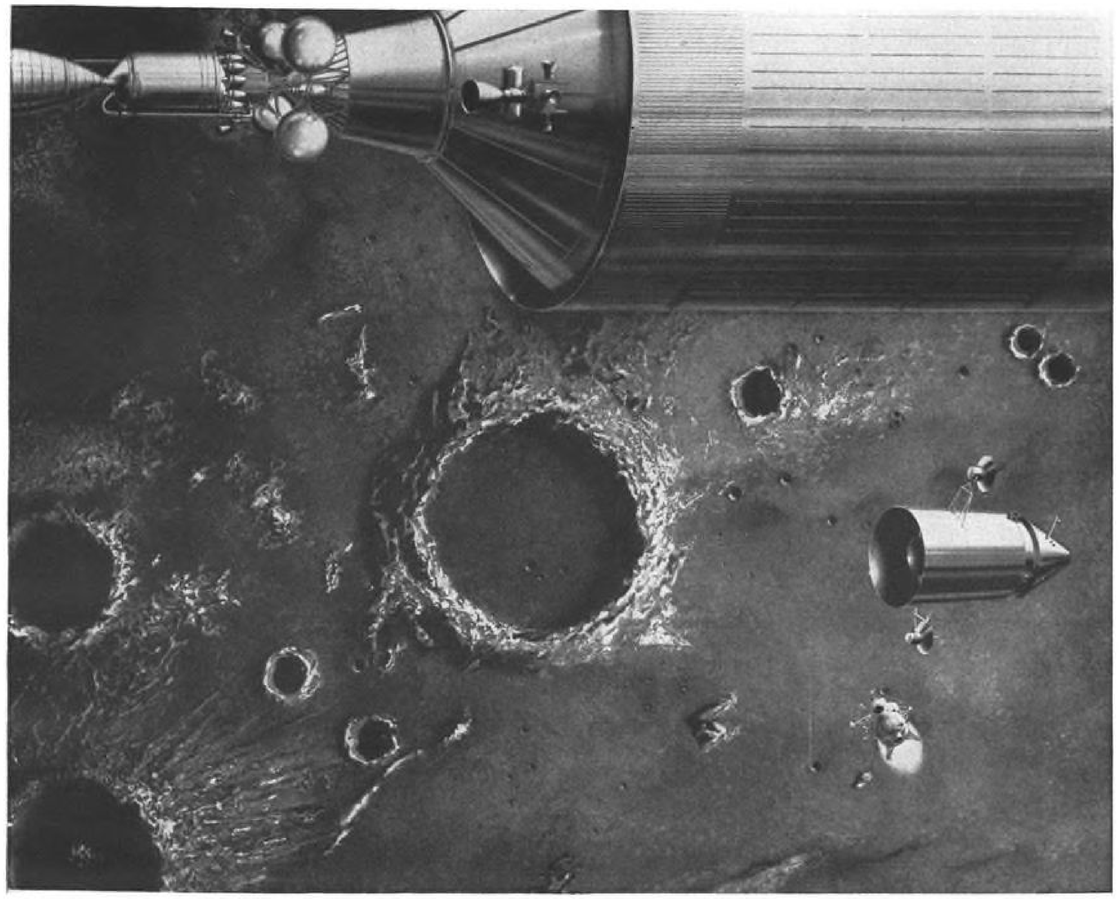
"The real challenge will be to design a system that will require and use the crew members in essential jobs that are challenging enough to prevent monotony and boredom, yet sufficiently below their maximum level of capability to allow for possible performance deterioration or for emergencies."

• **Physical effects**—"The effect of prolonged immobility," according to Donald R. Young, Ames research scientist, "may well be the most serious problem encountered during space travel."

Deterioration of the muscles and circulatory system lead to a general loss of fitness, he said. Loss of muscle tone results, as it did in the flights of Mercury Astronauts Walter Schirra and L. Gordon Cooper, in pooling of the blood in the legs. This slows the return of blood to the heart and causes dizziness, as the experience of Schirra and Cooper indicates.



THREE-MAN Mars or Venus flyby spacecraft as conceived by Lockheed. The rotating vehicle consists of Apollo-type module (x), propulsion (y), and power unit (z).



LOCKHEED NUCLEAR lunar vehicle concept, with nuclear stage in a moon orbit and the manned vehicles (below) detached.

Potential of Lunar Base Being Studied

Comprehensive two-year study program is being conducted by the National Aeronautics and Space Administration to determine the potential value of a lunar base, which the agency now feels has the lowest priority in its future program.

NASA, however, includes the lunar base among its three most likely post-Apollo missions and will base its decision on this program on the series of studies now under way. At this point, the manned laboratory-space station (see p. 77), and Mars planetary exploration (see p. 84) appear to the agency to offer more for the investments they will require.

Some officials feel that the Apollo capability may provide as much exploration as is needed on the moon, particularly when the system is augmented by a supply truck which can provide shelter and mobility for the explorers. Other NASA officials believe Apollo is capable of only the most cursory type of exploration, and that it must be followed by more thorough exploration.

With these reservations, NASA will leave open the decision on the lunar base program until late next year when the current series of studies will have been completed and evaluated. The study program includes:

• **Lunar surface construction** techniques, investigated under a $100,000 contract by the Army Corps of Engineers. Report was submitted last spring.

• **Prefabricated modular base,** either above or below the lunar surface and capable of sustaining 2-18 men for a minimum of three months. This $196,000 four-month study was won July 2 by Boeing.

• **Nuclear powerplants** and complementary regenerative power systems for providing power to a lunar shelter and scientific instruments will be studied under a contract being managed by the Corps of Engineers.

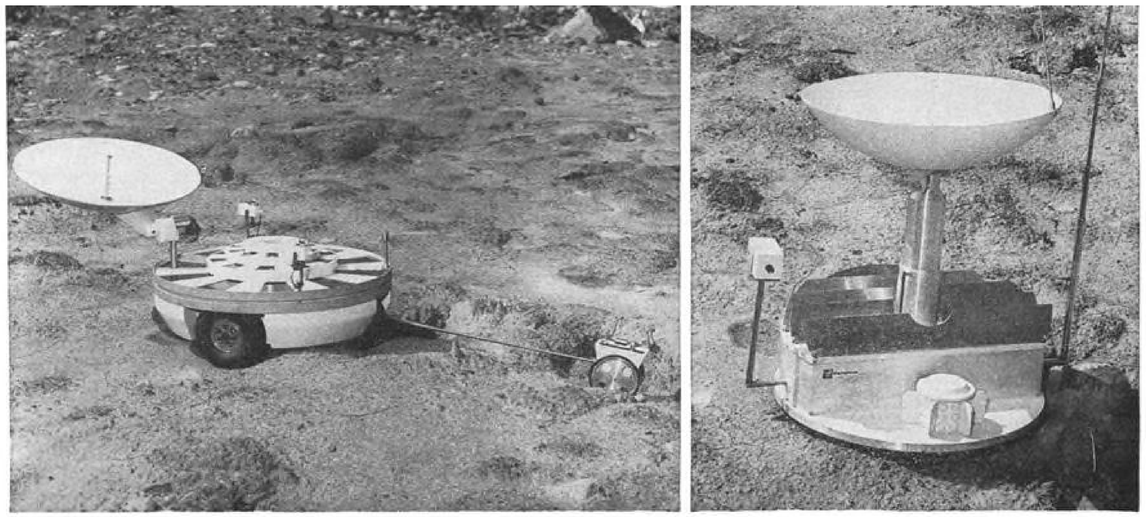
• **Life support system** required for a lunar base will be studied under contracts from the Manned Spacecraft Center.

• **Subsystems required** for a lunar base and operation of the base are to be studied under contracts to be awarded during Fiscal 1964.

• **Final study** tying all of this together will begin about mid-1964 and NASA expects to make a firm decision by the end of 1964 on whether to seek funding for a lunar base.

Weight of modules of the lunar base will be restricted to 25,000 lb. Modules must be designed for one year unattended storage on the moon prior to use.

Lunar base envisaged by NASA must be adaptable to both temporary and permanent installations. Elements



LUNAR ROVING VEHICLE (left) and a lunar communications package, both designed by Westinghouse as supply system payloads.

must be suitable for outposts with useful lives as short as 90 days and for more permanent installations with life expectancies of many years.

Lunar base design, the space agency said, should provide for temporary installations on the moon by 1970 and for "additional modules for permanent installations having a high degree of logistic independence in the period from 1972 to 1974." It was also suggested that the design be based on the possibility that only one successful Apollo or Saturn 5 flight will be available for lunar base operations or resupply every eight weeks.

Subsystem requirements outlined for the conceptual study being conducted by Boeing are:

• **Personnel shelter is** to be the basic module of the lunar base system. It would have its own life support, power and communications equipment and must function by itself as the principal element of a small temporary outpost.

• **Central life support** system would be used in all but the most temporary outposts. The central system would consist of modules and in larger, more permanent stations, would include regenerative equipment for developing life support materials from lunar resources. Lunar base environment would make possible stays of up to six months for individual crew members.

• **Nuclear powerplants** will be used in all but the smallest installations as the basic source of energy.

• **Vehicles required** for construction, operation of the base and travel over the lunar surface probably will be chemically-fueled. Regenerative power systems and production of fuels from lunar materials also will be studied.

• **Communication and control** system will be required for both local and earth-moon communications. Because the value of a man-hour on the moon is calculated to be worth between $60,000 and $100,000, it is likely that the communications system will include monitoring of systems on earth—probably from a control center at the Manned Spacecraft Center in Houston.

No cost estimate is available from NASA on a lunar base program, but in its Project Pilgrim study on establishment of a lunar base beginning in 1968, General Electric estimated that putting 10 men and 500,000 lb. on the moon with 200 Saturn 2 vehicles would cost $8 billion.

NASA's present interest in a moon base marks a distinct change in the agency's policy. Eighteen months ago, the agency had little interest in a lunar base and was content to leave it to the Defense Dept.

About a year ago the Office of Manned Space Flight began to express some interest in the lunar base, and NASA top management included it, with interplanetary manned flight and the space station as a candidate for the post-Apollo period.

Justification for the lunar base is that it will permit a much more detailed scientific study of the moon than Apollo.

Astronomers and geologists believe that since the moon has no atmosphere the history of the solar system may be etched on its surface.

Study of the lunar surface also should reveal the history of high energy bombardment of the moon by both cosmic rays and particles from the sun.

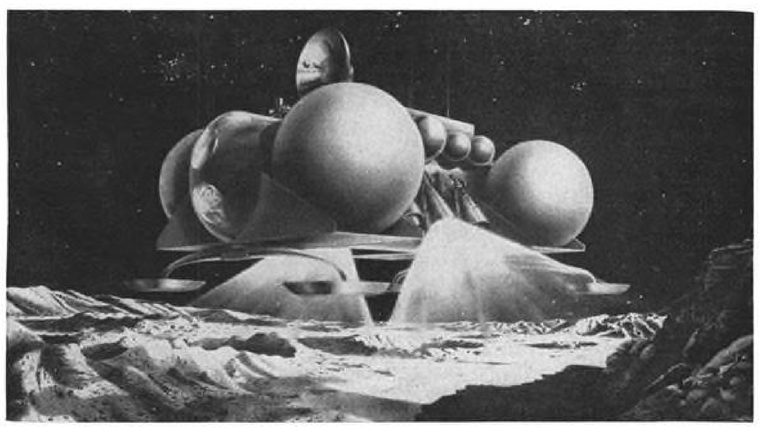
Even early lunar bases would permit deep drilling for study on the geological formation of the moon and heat flow. Other possible scientific tasks in a moon base operation include:

• **Study of lunar** gravity and its relation to the moon's surface formation.

• **Micrometeorite and radiation** detection and measurement.

• **Chemical and physical** analysis of lunar surface material, both in moon base and earth laboratories.

Principal scientific study using the moon as a base rather than the object of inquiry probably will involve optical and radio astronomy. It is felt that location of a radio telescope on the noise-free back side of the moon would pay great scientific dividends.



TYPICAL of the lunar vehicles studied under National Aeronautics and Space Administration is this Lockheed lander, which would operate like a lunar excursion bug.

Nova Studies Focus on Radical Designs

Los Angeles—Nova super-booster for future planetary exploration will remain in the conceptual study phase for at least another year. Studies will focus on radical vehicle design and propulsion concepts that promise greater operating economy and smaller size than would be possible with state-of-the-art engines that could be developed by 1975.

The switch in emphasis to the study of advanced Nova concepts, which could not be available before the late-1970 or early-1980 time period, indicates the high level of confidence National Aeronautics and Space Administration now places in the feasibility of developing less sophisticated boosters for a mid-1970 manned Mars exploration.

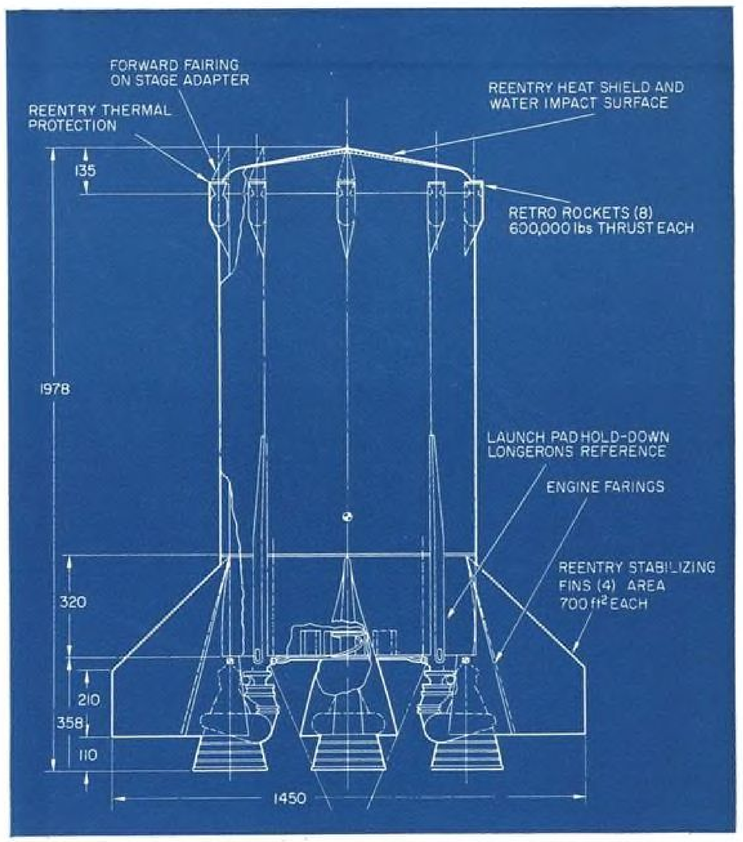
Lead time of 10 or more years for development of the Nova booster is considered the pacing element of a sophisticated Mars mission, although a fly-by or orbiting flight could be made earlier with Saturn hardware and a Martian landing may even be a possibility with Saturn. Therefore, a decision to develop a Nova vehicle could be made sometime in 1964 if a 1975 Mars landing goal is established. For planning purposes, a July 1, 1964, target date for a go-ahead decision has been set. A national policy decision is not expected much before then, since the Mars mission will not be fully defined until some time next year.

Extensive studies funded by NASA's Marshall Space Flight Center over the past year were primarily aimed at defining configurations which could be available for the earliest feasible manned Mars missions and lunar base support, using Nova-type vehicles. Studies have established that the 1975 Mars mission could be launched by liquid or solid first stage Nova booster. Liquid boosters are preferred, however, because of the relatively larger size of the solids.

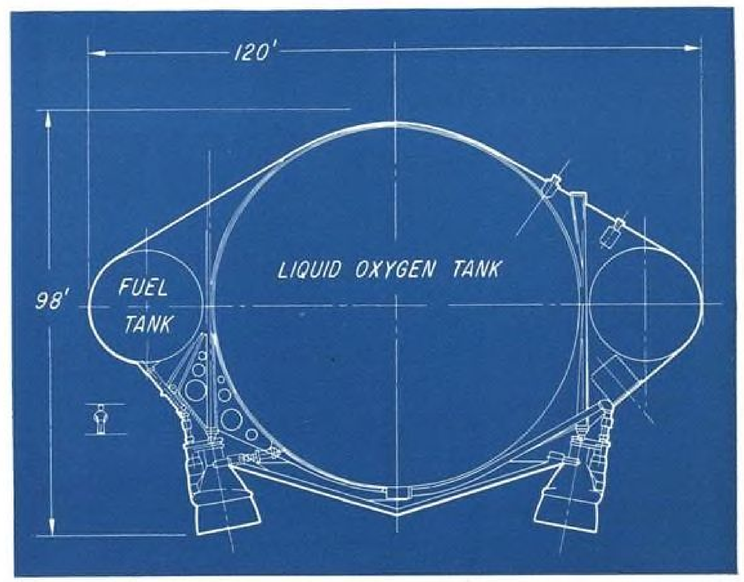
For a 1977 launch, a more advanced booster of conventional configuration, employing more efficient propulsion, could be available. For the 1981 or 1983 Mars windows (1979 window is not considered feasible), unconventional configurations and higher-performance propulsion might be ready.

In anticipation of the long development lead time, NASA devoted about one-third of its Fiscal 1963 future space activities study funds to Nova definition. MSFC Future Projects Office devoted about half of its budget or $3.2 million to Nova studies. Funding level is expected to increase in Fiscal 1964.

The Nova study program is under direction of MSFC, which has the re-

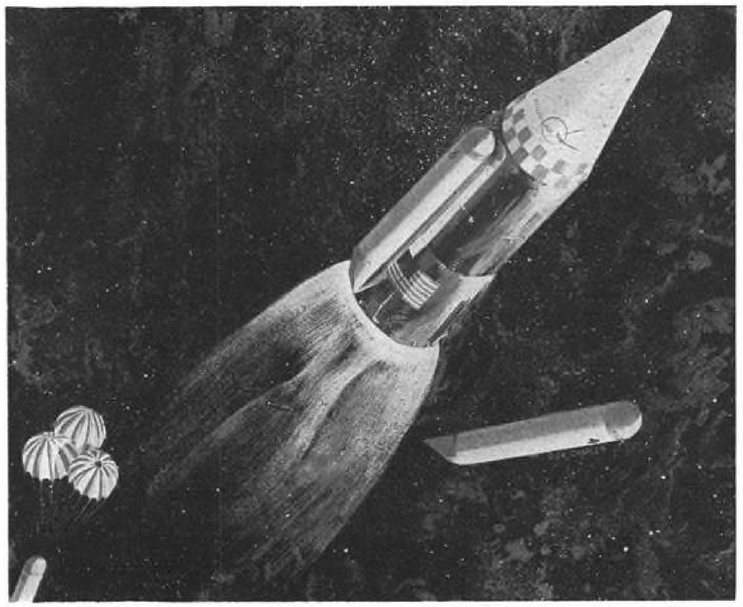


PROPOSED NOVA LAUNCH VEHICLES developed by General Dynamics/Astronautics are shown in diagrams. Above is Class One launch vehicle with recovery equipment installed. Below is aerodynamically stable booster proposed for Nexus, Class Three Nova.





ROMBUS OPERATIONS SEQUENCE is depicted, starting with launch vehicle (above) and eight strap-on liquid hydrogen propellant tanks required for initial boost phase.



STRAP-ON TANKS are jettisoned as liquid hydrogen is expended to increase booster performance. Tanks are lowered by parachute and are recovered by LSD ships.



BOOSTER RETURNS to earth after making 16 orbits during one earth revolution. Landing would be similar to the LEM lunar landing.

sponsibility for developing the superbooster. The Marshall-sponsored studies have resulted in classification of potential configurations into three groups (AW June 10, p. 34). Class One vehicles will consist of two stages, using 1.8-million-lb. thrust up-rated Rocketdyne F-1 engines and 1.5-million-lb. thrust Aerojet M-1 engines. Class One boosters could be available by early to mid-1970s.

Class Two is marked by a lower confidence level and somewhat later operational time—mid to late 1970s. New engines, which would be a logical progression past Class One engines, are considered. Class Two vehicles will be either 1½ (first stage and sustainer engine) or 2-stage boosters with engine recovery systems and possible first-stage recovery systems. Altitude compensation devices are recommended.

Class Three boosters will use unconventional means of propulsion with full recovery of the single or 1½-stage vehicle. Far-reaching advances in design that would be required would postpone availability to the late 1970s and early 1980s.

An unparalleled cooperative effort between industry and government agencies has been established in the Nova study program. Supervision is provided by the Future Projects Office at MSFC under the direction of H. H. Koelle, who has spearheaded the drive for complete cooperation and interchange of information. Typical of the study teams formed is the 30-man Nova Management Team, headed by Frank L. Williams, deputy director of Koelle's office.

The team consists of representatives of NASA headquarters, Lewis Research Center, Manned Spacecraft Center, Air Force, Launch Operations Center and MSFC members. Working closely with this team, a number of industry teams are performing the following Nova-oriented studies:

• **Detailed definition** and preliminary design, conducted in parallel but coordinated efforts by General Dynamics/Astronautics and Martin Co.'s Space Systems Div. Both studies are funded by the Future Projects Office. GD/A team is headed by Andrew Kalitinsky and Martin-Baltimore team is headed by John Youngquist. Contract technical supervisor is Williams.

• **Launch facility requirement** for Nova vehicles are being studied by Martin's Denver Div. under Howard Keyser. Study includes general planning for launch site requirements and is funded by LOC and supervised by Owen Sparks.

• **Test and checkout** of booster will be studied by Martin-Denver under a recently-awarded MSFC contract. Such items as test site layout, approximate construction cost and number and placement of test cells will be included.

• **Post-Nova chemical-nuclear** (Class Three) launch vehicle studies are being conducted by GD/A and Douglas Aircraft Co. Nuclear propulsion investigations will be limited to upper stages, since it is not planned to use nuclear power under 100,000-ft. altitudes. Krafft Ehricke heads the GD/A team and the Douglas team is headed by Philip Bono. Studies are funded by MSFC and contract supervisor is James L. Sanders.

Nova management team primarily is concerned with supervision of the GD/A and Martin-Baltimore studies but Williams, working closely with the two industry teams, actively promotes a free exchange of information and ideas with other study groups.

Although GD/A and Martin-Baltimore would be competing directly for a role in the Nova hardware program, this has not adversely affected the interchange of information. Neither contractor could reasonably expect to gain an advantage by holding out information, since NASA is already aware of the details of each company's efforts and would easily recognize concealment. Since the cost of developing a Nova booster is expected to be at least $5 billion, both industry and NASA feel there would be tasks for both contractors.

Findings of the launch facility studies also are exchanged, being fed to both systems definition contractors to alert them to possible design restrictions resulting from launch limitations. Martin-Denver's study on test facilities also will involve a frequent interchange of information.

Major reviews of all Nova and post-Nova studies are held periodically. Two have been held, one last December and one in March, and another is scheduled for next month. Contractors say they fully support MSFC's "big team" systems approach and have cooperated freely in the unique non-proprietary atmosphere, although the companies were wary of the idea when it was first proposed.

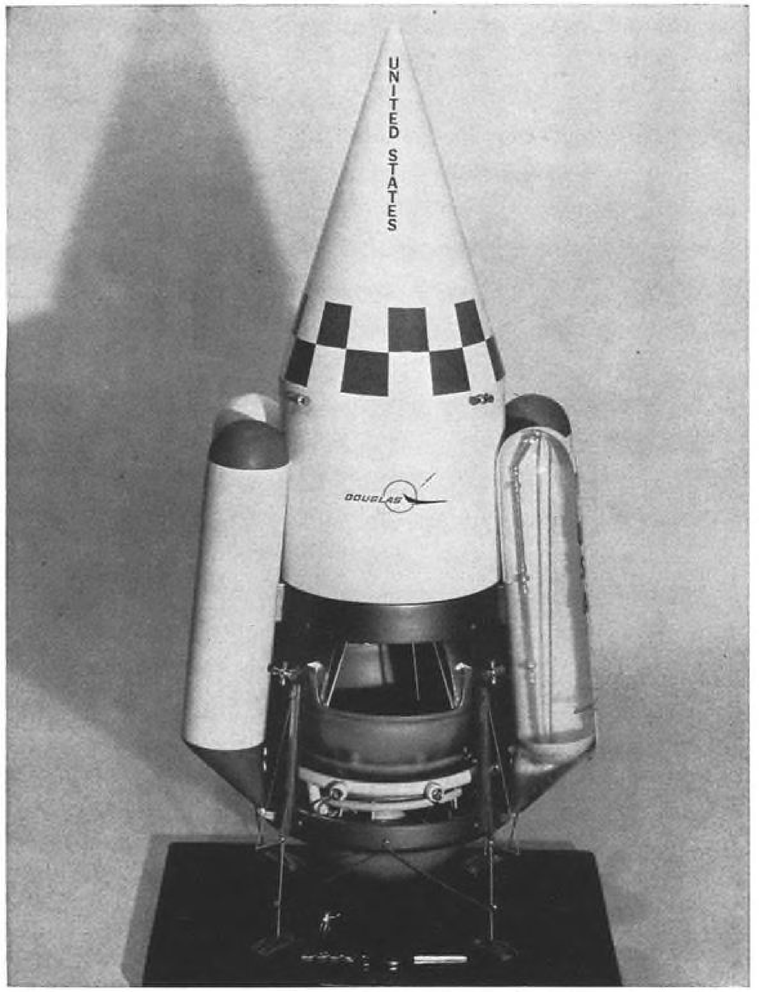
One ground rule established for definition of the Nova booster is that it be capable of supporting all missions requiring a booster larger than Saturn 5. The manned Mars exploration mission, however, will be the primary sizing requirement.

Other missions currently being contemplated are:

• **High-energy unmanned probes** to planets and other celestial bodies that are far enough away to require high earth-departure velocities in order to arrive within reasonable operating lifetimes for the equipment.

• **Support of a 20- to 50-man** lunar base.

• **Launch of heavy space stations** into difficult orbits.



CUTAWAY MODEL of Douglas Rombus shows plug nozzle design and plumbing in strap-on liquid hydrogen tank (right). Light ring around nozzle is hydrogen manifold.

• **Deployment of spacecraft** into earth orbit with enough fuel to be truly spacemaneuverable.

• **Manned exploration and fly-bys** of other planets.

Although Nova is envisioned basically as a means of transportation to earth orbit, using either a 1, 1½ or 2-stage vehicle, addition of a third stage would allow direct shots on such missions as lunar base support. Assembly in orbit for a Mars mission also would be necessary. Current planning calls for connecting from one to four 1.5-million-lb. spacecraft in orbit. The convoy concept used for booster sizing was generated by the MSFC-sponsored Empire (early manned planetary-interplanetary roundtrip expedition) studies.

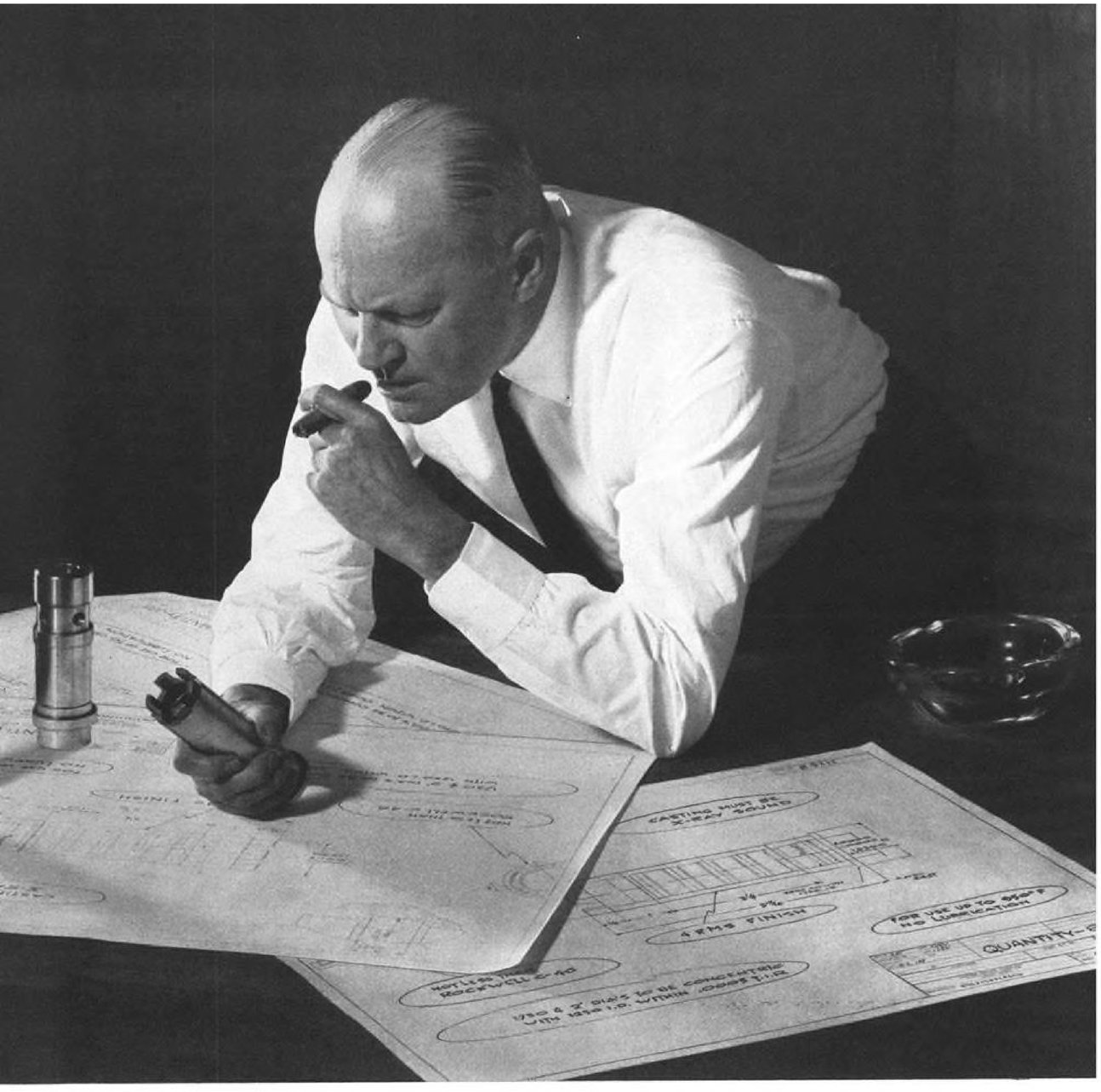
Other guidelines set down for the Nova studies are:

• **Approach anticipated** technology development and state-of-the-art breakthroughs in a realistic manner. Division of conceptual Nova boosters into three classes is representative of this approach.

• **Boosters would have to be** capable of placing a 1-million-lb. payload into a 300-naut.-mi. earth orbit to provide a significant payload advantage over Saturn 5. Further Nova system sizing resulted from the requirement that several vehicles be assembled in earth orbit for the Mars mission. The addition of this requirement as well as other basic considerations forced a detailed investigation of launch rate, reliability, launch facilities, and the use of the module approach to payloads.

• **Rigorous cost-effectiveness** approach must be maintained to make any ambitious space exploration program economically feasible and acceptable to policymakers.

A typical advanced study integration technique is being employed to define the Nova vehicle. This technique in-



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volves three different levels of study—conceptual design, preliminary design and systems definition. After evaluation, concepts are eliminated, filed for future use or forwarded to the next level for consideration.

Nova Class One studies now have progressed to the preliminary design and are moving into the systems definition phase of study. Class One studies will be well into systems definition phase by this time next year and a hardware program could be initiated within a reasonably short time.

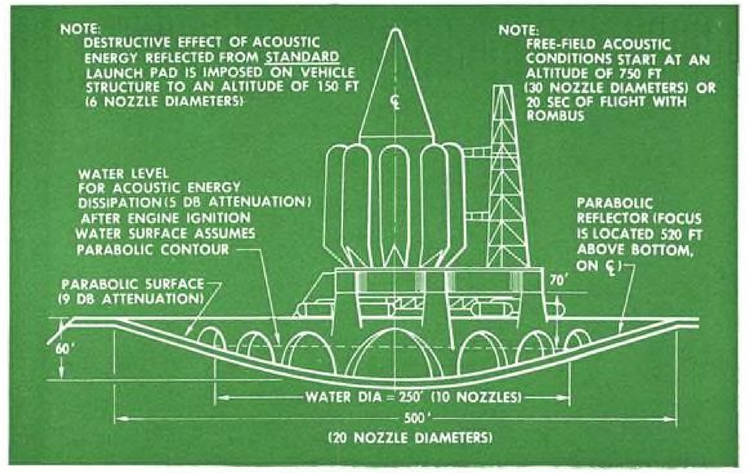
Prior to its definition as a planetary exploration vehicle, Nova was thought of primarily as propulsion unit for the lunar mission. This mission was finally dropped in mid-summer of 1962, when the lunar orbit rendezvous (LOR) decision was made. Original Nova concept was born at Huntsville, where in 1959, Army planners began studying a large space exploration booster employing F-1 engines.

This study effort was continued when Wernher von Braun's Huntsville team became part of NASA in July, 1960. Studies to define a 6- to 12-million-lb.-thrust booster capable of going directly to the moon eventually were undertaken. The vehicle was named Nova during this period. Following the decision to build Saturn 5, Nova became the vehicle for a backup method for reaching the moon directly, rather than with rendezvous.

At the time that the Nova lunar mission was discontinued, shortly after the LOR decision, Marshall was close to a possible hardware development program. Requests for proposals already had been issued and bids had been submitted on preliminary design studies of an F-1, M-1 booster capable of placing 500,000 lb. into a 100 naut. mi. earth orbit. Vehicle was to have been further defined over a six-month period and by January, 1963, using Fiscal 1963 funds, initial hardware activities were to have been started.

In the evaluation that followed, GD/A and Martin-Baltimore were selected to study the Nova booster, which had been redefined as a 1-million-lb. payload to orbit vehicle, capable of supporting missions beyond the capability of the Saturn 5. Nova became known at this time as a post-Saturn 5 booster. Contracts with the two companies were signed by mid-August of 1962. In line with pre-LOR decision plans, the launch facility study also was begun, providing information on practical limitations of boosters that could be launched from the Atlantic Missile Range.

An indication of the level of confidence gained in the booster system studies is shown by the gradual shifting of study effort from almost exclusively Class One vehicles last year to major



ROMBUS LAUNCH facility is shown above. Acoustic energy dissipation dictates design.

emphasis late this summer on Class Three boosters. The following dates and breakdown of study effort illustrate the shift of emphasis:

- **September, 1962.** Shortly after initiation of the studies, approximately 90% of the effort was devoted to Class One vehicles, and the rest to Class Two.
- **January, 1963.** By this time, emphasis on Class Two boosters had increased to 30% of the study effort, with 70% still devoted to Class One.
- **March, 1963.** A major review of the studies indicated that Class One vehicles were receiving only about 40% of the study effort, Class Two 50% and Class Three 10%.
- **September, 1963.** With confidence that Class One vehicles could be made available in selected configurations, the study teams will be spending about 60% of their time on Class Three vehicles, 35% on Class Two vehicles and only 5% on Class One boosters.

Marshall now wants to raise the confidence level for the advanced boosters so a decision on which type to develop can be based on as much fundamental knowledge as possible.

Post-Nova teams, meanwhile, are studying various advanced Nova configurations as well as applications of nuclear propulsion to Nova systems. Class Three Nova studies also have considered nuclear power, but only for a third stage. Post-Nova design considerations focus on re-usability and advanced liquid oxygen-liquid hydrogen engines to gain economy and optimum vehicle design for the large payloads considered.

First steps toward post-Nova studies were taken by MSFC when RFPs were originated in March, 1962, for studies of a follow-on booster to the F-1, M-1, 500,000-lb.-payload Nova. Contracts for phase one were subsequently signed with Douglas, GD/A and Rand Corp. in mid-summer. Post-Nova studies required redefinition, however, since a Nova concept did not exist following the LOR decision. Post-Nova studies were therefore defined as an investigation of Class Three Nova vehicle concepts. Subsequent post-Nova phase two and current phase three studies were awarded only to GD/A and Douglas.

A representative post-Nova configuration called Rombus (reusable orbital module, booster and utility shuttle) has been detailed by Bono at Douglas, which recently received a phase three $300,000 contract extension for further definition of the vehicle.

The Rombus, GD/A's Nexus and Martin-Baltimore's Renova (AW June 17, p. 53) will be studied in greater detail in the future.

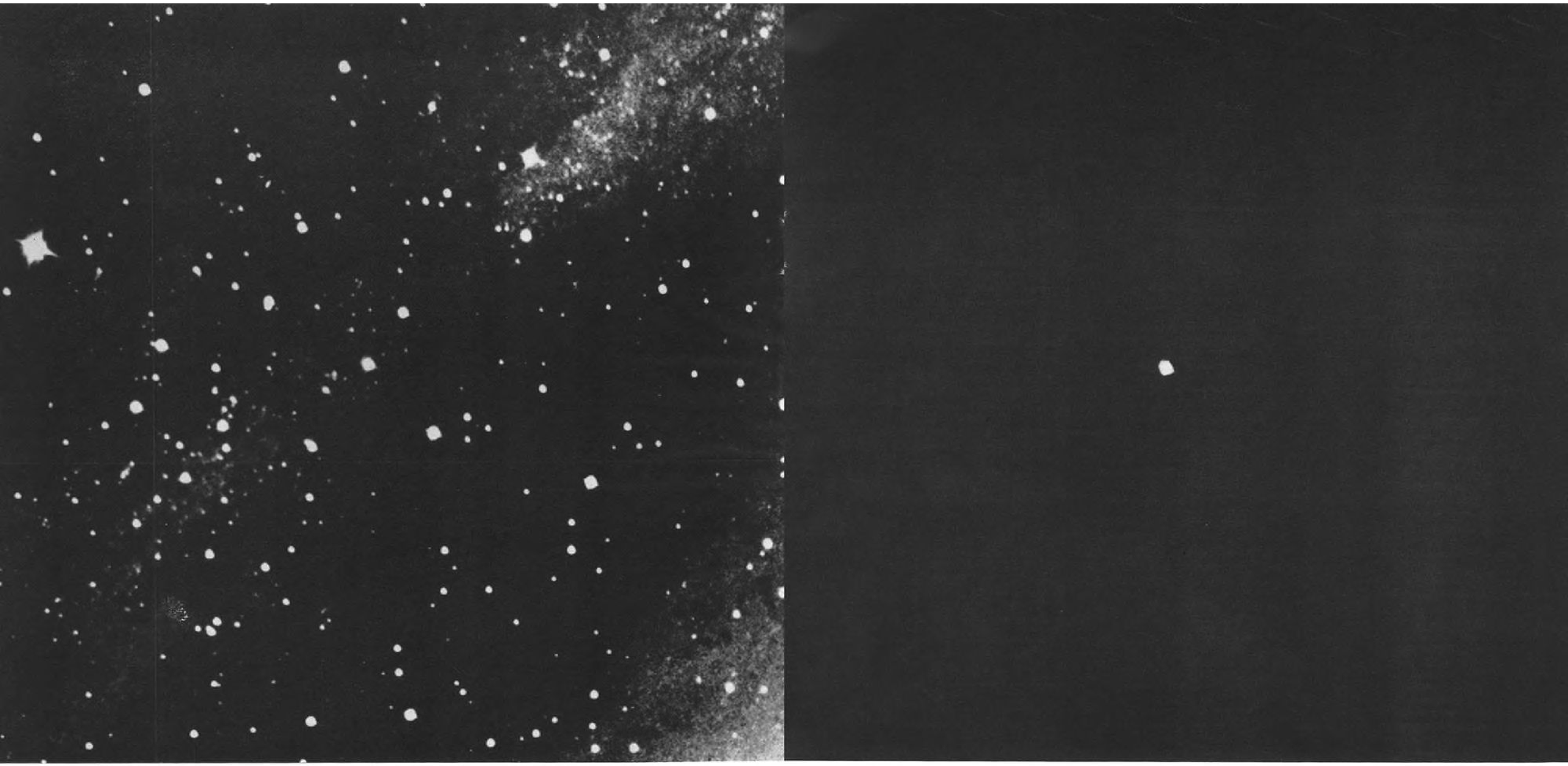
Rombus would use a conjectural altitude-compensating plug-nozzle engine, surrounded by an annular combustion chamber with or without nozzles. The 80-ft.-dia. isentropic plug could be surrounded either by 36 annularly-configured segments producing 0.5 million lb. of thrust each or by 80 250,000-lb.-thrust nozzles with a 23 to 1 expansion ratio. Either arrangement might satisfy the requirements.

A 200 to 1 vacuum expansion ratio is provided by the plug-nozzle arrangement. The 80-ft nozzle diameter is valid only for vacuum conditions when the nozzle is flowing full. Equivalent nozzle diameter at sea level is 25 ft. due to the atmospheric pressure which forces the exhaust stream along the contour of the plug down to its minimum diameter, producing between 18 and 20 million lb. thrust at lift-off.

The Rombus plug-nozzle arrangement serves the following multiple functions:

- **Provides main thrust** for orbital injection.
- **Provides retro-power** for recovery

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from orbit. After injection of payload, the booster would make 16 orbits during one revolution of the earth, bringing it into a synchronous position to be recovered near the launch site. Retropower would be applied prior to re-entry after stabilization and control system had oriented the vehicle.

• **Spherically-shaped plug** would act as heat shield during reentry. Cooling would be effected by passing liquid hydrogen behind the plug face and then to the injectors, where it would be dumped overboard through the annular throat. The effect of a flame on the lower portion of the structure due to ignition of the hydrogen has not yet been determined, however.

• **Landing retro-thrust** would be provided prior to touchdown, after deployment of the parachute recovery system.

One goal of the Rombus study is to reduce direct operating costs to $25/lb. of payload in orbit. Equivalent cost for a Class One vehicle would be about $150/lb. Direct operating cost funds assumed to be available were $1 billion for each year for 10 years. A figure of $25/lb. in earth orbit is defined as total operational dollar costs of an average successful launch divided by pounds of payload placed into a 300-naut.-mi. earth orbit.

Booster Recovery

Direct operating costs would be minimized through recovery and reuse of the eight jettisonable, side-mounted hydrogen tanks and the main vehicle, containing the engines and oxygen tankage.

The Rombus booster is designed to support relatively small payload missions and to act as a launch platform for a nuclear upper stage. Hydrogen tanks could be removed and the oxygen tank partly filled to support these missions. Rombus development cost is estimated at $5.1 billion, at the current value of the dollar.

One solution to the extremely high acoustic energy associated with Nova booster launching, suggested by the Douglas study, is the use of a parabolic dish located below the launch stand, which would focus part of the acoustic energy at some point above the launch vehicle. About 9 db. of acoustic energy might be attenuated this way. Preliminary studies also indicate that partially filling the dish with water would result in a further reduction of 5 db.

Investigation of Nova recovery aspects has indicated that recovery of engines or of a complete first stage is feasible and could cut over-all program costs by as much as 20%. Class One vehicles are not planned to be recoverable but Class Two boosters will incorporate recovery of engines or recovery of the entire stage. Class Three vehicles will be completely recoverable.

Economic justification for recovery is to reduce program costs by reusing recovered engines and stages, limiting total production. A secondary justification is the ultimate increase in reliability resulting from first-hand inspection of components that have failed. A high degree of confidence exists that weights on the order of 1 million lb. can be recovered with parachute and retro-rocket systems.

Other recovery systems employing parawings, rigid wings, balloons, and rotor blades would require too great an extension of current technology, officials say. The parachute-retro-rocket system also weighs less than any of the other tentative systems.

Costs Offset

Investigations have shown that it is not economically feasible to recover second stages, since additional costs in such areas as first-stage manufacturing and additional R&D costs more than offset the gains in reusing the second stage.

Launch operations aspects of the Nova studies over the past year have established the feasibility of building facilities that will accommodate the boosters now contemplated. NASA is acquiring land for the Nova launch facility north of the present Cape Canaveral area. The Nova launch area will be called Merritt Island Launch Facility (MILA) and will be about 10 times as large as the present Cape area.

Early guidelines set down for the launch facility study with respect to the Mars mission were that the launch site must be able to handle enough launches to assemble four 1.5 million-lb.-thrust spacecraft within six months. Since the spacecraft itself has been the least defined of various key aspects of the Mars mission, some difficulty was experienced in realistically sizing launch facilities.

These recommendations concerning spacecraft packaging were made:

• **Payload capabilities** of both Nova and Saturn 5 launch vehicles should be used to the greatest extent possible to minimize number of launches.

• **Payloads should be,** as much as possible, identical, and variations in packaging should be minimized. Large number of different payloads would require a correspondingly large number of backup packages in case a payload was damaged or destroyed.

• **Allowances must be made** for long orbit stay times of early payloads, since the reduction in length of the over-all six-month launch window greatly influences facility size and expense.

• **Packaging should be** as compact as possible. Long, spindly spacecraft will generate facility servicing and construction problems and during the early flight phase, aerodynamic pressures would cause additional problems. Payloads must be prepared for rapid assembly and minimum post-assembly servicing to reduce launch holds, since it is desirable to plan for a maximum eight-hour hold for an individual launch.

Pending further definition of both launch vehicle and spacecraft, three launch facility concepts now are under study. A hybrid complex—based on both fixed and mobile concepts — would utilize two primary buildings, a stage check-out building and a launch building. Stage check-out building would be used to check out the liquid stages, transported to the site vertically to minimize handling, prior to their mating in the launch building. Solid stages, transported horizontally, would be checked out in another area.

The enclosed launch building would be used for fueling, final checkout and launch. Trap doors in the top of the building would be opened for launch and inner walls would be insulated against blast effects. Propellant boiloff and other adverse environmental effects could be minimized with the launch building concept.

Two other concepts under consideration are the mobile concept, similar to Saturn 5 launch operations, and the fixed concept employing a launch building which would also be used for stage checkout.

Sea-launch concepts such as Aerojet-General's Sea Dragon are not considered feasible at this time but other concepts and off-shore launch will be more fully investigated in future studies.

Nova Size Illustrated

Los Angeles—Relative size of current definitions of the Nova class boosters is difficult to visualize. The following points, developed in studies of Nova launch facilities, emphasize the magnitude of the vehicles:

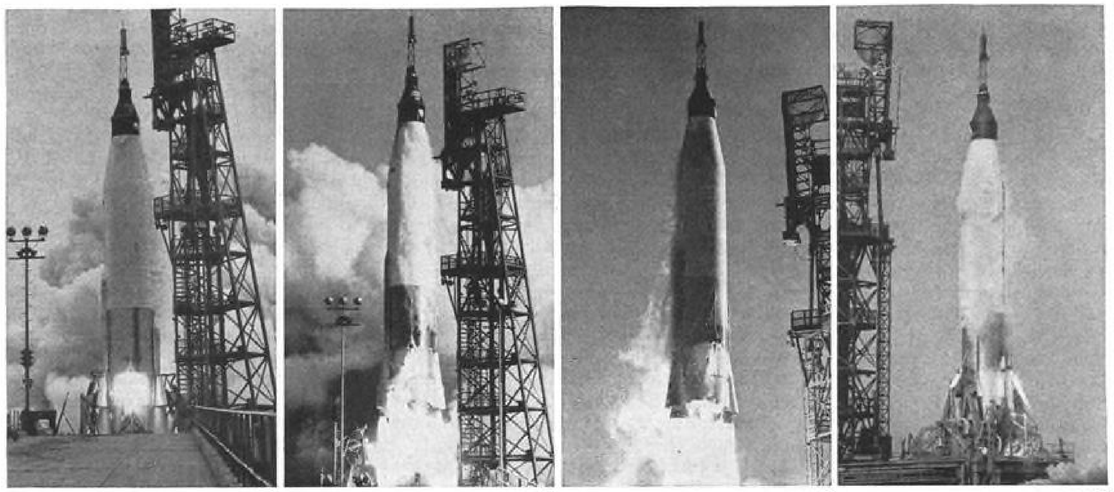
• For an eight-hour hold on an open launch pad, the cost of liquid hydrogen boiloff would be about $1 million.

• Present 2,500 gallon per minute high-speed pumping systems used to fill ICBM propellant tanks would not be able to keep up with the boiloff of a Nova booster, let alone fill its tanks. Systems capable of pumping 30,000 gpm. will have to be developed to fill Nova propellant tanks.

• Size of rockets required for stage separation is roughly that of a Pershing guided missile (32.5 ft. long and 3.3 ft. in dia.).

• One approach being considered for environmental control at a Nova launch complex is a launch building, enclosing the booster with a trap-door roof, which opens during launch. Such a building would stand 650 ft. tall—almost 100 ft. taller than the Washington monument—and cost $150 million to build. Four probably would be required.

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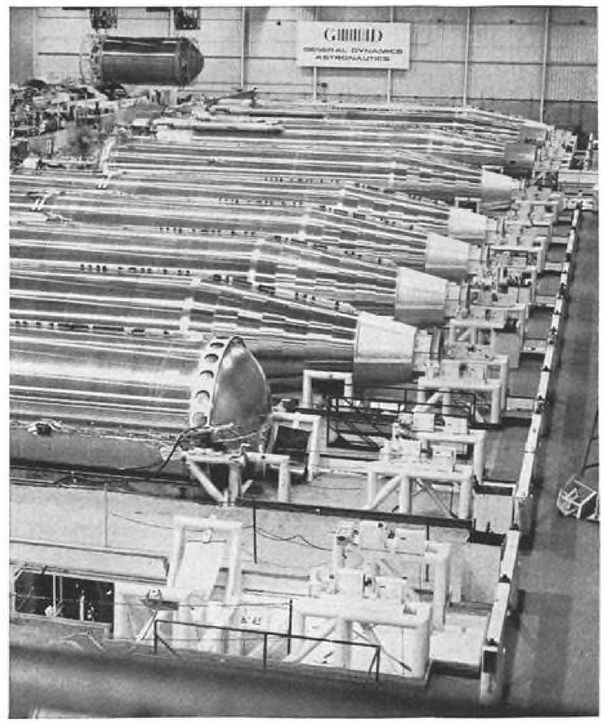
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The 100% Atlas success in launching all U.S. Manned Orbital Flights springs from combined management action by the Air Force, NASA, and industry – including General Dynamics | Astronautics as Atlas integrating contractor. And the knowledge gained can benefit many other aspects of the national space program, as well as future Atlas-launched space systems and Atlas weapon systems.

Demonstrated Atlas Reliability Now Applied to Atlas SLV-3

The latest outgrowth of the continuing Atlas program is the United States' first *Standardized* Space Launch Vehicle, Atlas SLV-3. Atlas SLV-3 is already specified, and in production, for several USAF and NASA space programs, involving over 30 launches.

Each SLV-3 is tailored to specific payloads and flight profiles with "plug-in" guidance, programing, telemetry, tracking and other components . . . yet without affecting the integrity of basic Atlas reliability, accumulated by Mercury-Atlas and more than 160 other flights.



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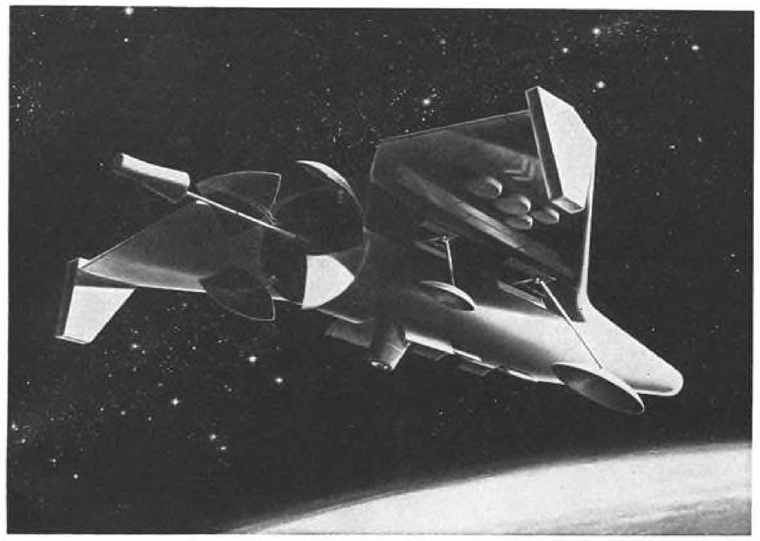
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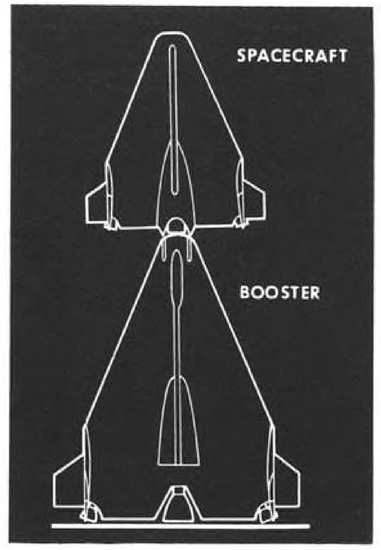


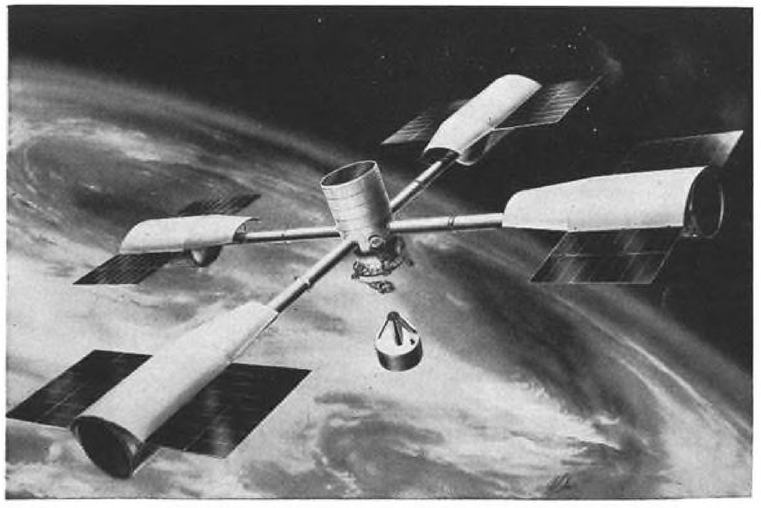
The Astrolabe, held high in the hand of the statue of Samuel de Champlain facing the Parliament Buildings in Ottawa, Canada, was an ancient navigation instrument of great assistance to the early explorers of the New World. It symbolizes the progressive spirit of this company in its programmes of exploration and discovery in the broad spectrum of science in the service of man.

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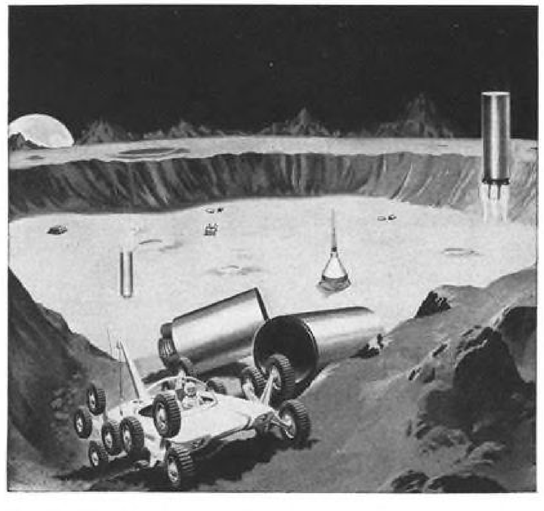


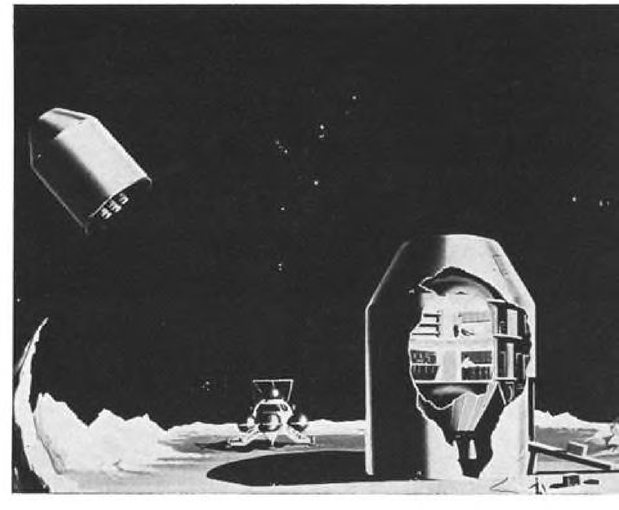




Industry Studies Future Concepts

The large number and variety of U.S. industry studies of advanced manned space flight programs is indicated by these artists' concepts. At upper left is a 1958 General Electric observation-communications vehicle. Above is a line drawing of the Douglas ferry, called Astro, with a recoverable booster. Rotating space station (left), designed by Boeing, closely resembles a three-spoke station being studied by NASA (p. 77), using an Apollo command module as a ferry. GE Project Pilgrim studies resulted in a lunar base operation concept illustrated below, left. The other sketch shows a laboratory in operation on the moon.







How to get someplace by going around in circles

The rotating Space Station Simulator shown here is only one of the many new facilities increasing Grumman's capabilities in the space field. Administered by Grumman's Space Sciences and Human Factors Group, the Simulator is yielding valuable information on the factors that affect man's tolerance of rotation—especially at velocities that exceed generally accepted limits. A program of continuing tests will help show how astronauts can live and perform in an artificial gravity environment.

■ Bioscience is just one facet of Grumman's expanding space studies, which include such basic disciplines as orbital mechanics, propulsion, guidance, structures, and reentry dynamics. Grumman is integrating and applying these disciplines into such long-range NASA programs as the OAO for Goddard Space Flight Center, and the LEM for the Manned Space Flight Center.

One answer to man's survival in space travel is a rotating space station which would roughly simulate gravity conditions. To study the effect on humans of the Coriolis and gyroscopic coupling forces which attend such rotation, Grumman has adapted the company's giant centrifuge as a rotating Space Station Simulator. Experiments in this room are monitored by movie camera, from which these photos were taken. This equipment is also valuable for sustained acceleration testing of unmanned space vehicles and components.

GRUMMAN

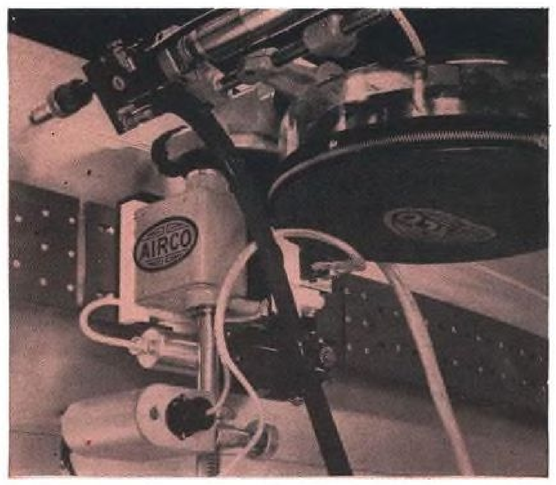
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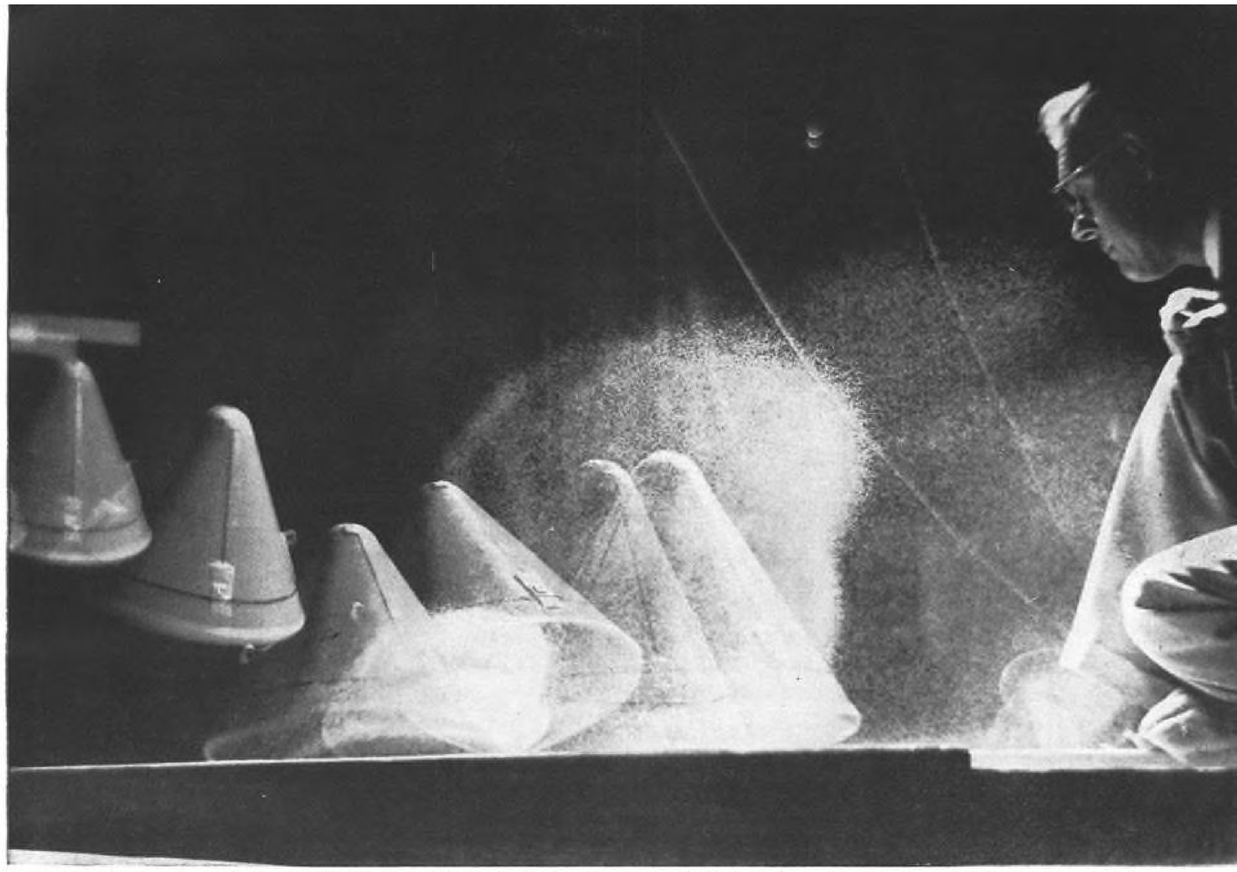


Full-scale boilerplate model of the NASA-North American Apollo command module undergoes ground impact tests at El Centro, Calif., after being dropped from USAF-Douglas C-133 at 13,000 ft. Northrop 88-ft. ringsail parachutes deploy at 10,000 ft.



House power for our moon men will come from an efficient new fuel cell developed by Pratt & Whitney Aircraft for the National Aeronautics and Space Administration's Manned Spacecraft Center. The fuel cell will generate life-sustaining electrical power during the Apollo spacecraft's round-trip voyage to the moon. Pratt & Whitney Aircraft provides design and manufacturing leadership in power for many applications, in and out of this world.

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EARLY APOLLO scale model is subjected to impact tests at the Langley Research Center's impacting structures facility in this multiple-exposure photograph. This is one of a number of government and industry programs contributing to lunar landing.

Apollo Reflects Technical Skill of U. S.

Apollo manned lunar landing program is rapidly unfolding into a measure of the total technical competence of the nation through the engineering and scientific advances it requires and the industrial and management capabilities that must be marshalled to carry it out.

The multiplicity of elements which constitute the program make Apollo the most demanding publicly-stated, tightly-scheduled national goal that the U. S. has set for itself in peacetime.

At this point, with all the hard decisions regarding Apollo having been made, the magnitude of the manned lunar landing task is just now being realized. Its problems, benefits and demands are emerging clearly to give the nation an understanding of the challenge it faces to land men on the moon in this decade.

In the three and one-half years of its existence, Apollo has matured from a profane word in the Eisenhower White House to a major element of government spending and to a focus of the competition between the U. S. and Soviet Russia. In the process, it has become one of the Kennedy Administration's most controversial actions. Criticism ranges from the sober depreciation of the scientific value of the project to the blunt exclamation by former President Eisenhower that the country "is nuts to spend $40 billion to go to the moon."

Both viewpoints complicate the extensive efforts of the White House and National Aeronautics and Space Administration to enlist widespread public support for what, in fact, has been one of President Kennedy's most dramatic decisions since he took office.

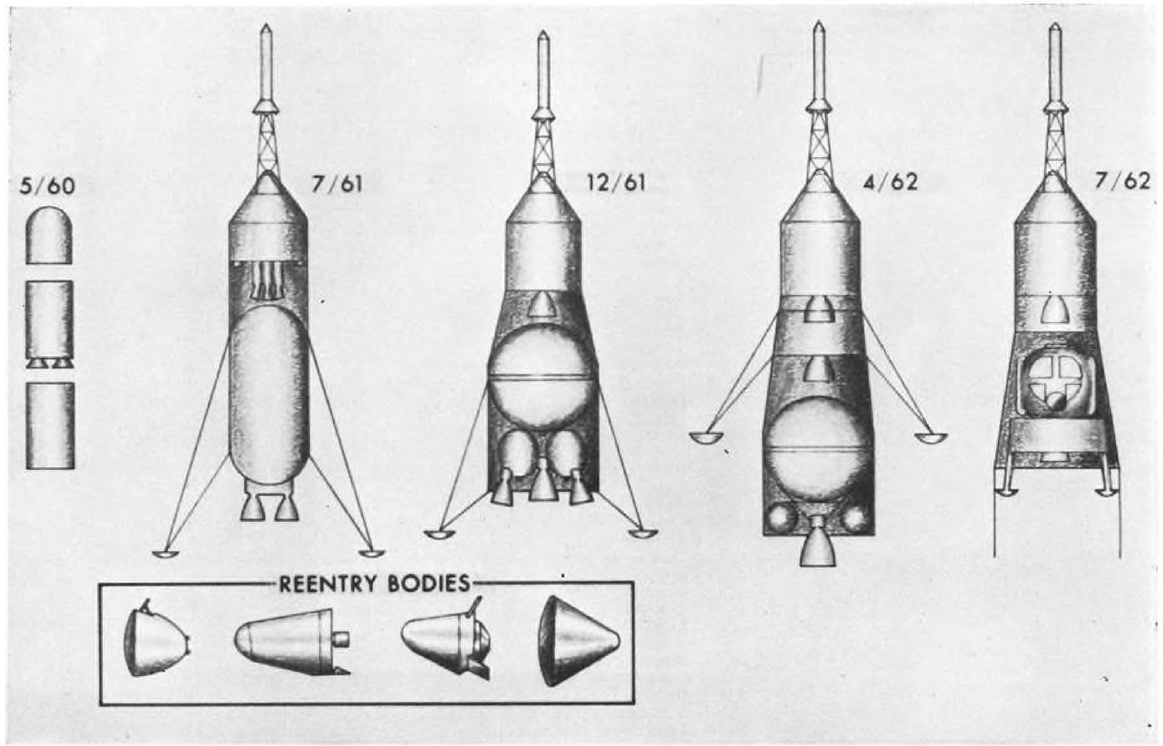
The Administration selected lunar landing in the face of criticism because it recognized that flight to the moon also was a goal of Soviet Russia. Lunar flight requires technical and industrial advances and great resources—so that essentially, the U. S. has a chance to wipe out Russia's advantage in boosters and start the race on even terms.

The President made the lunar landing decision in May, 1961. In the 26 months since then it has become obvious that NASA's major challenge in the program is management, and that the engineering problems that must be solved to assure Apollo's success probably are no more difficult than translating for the public the more subtle objectives and by-products of the program.

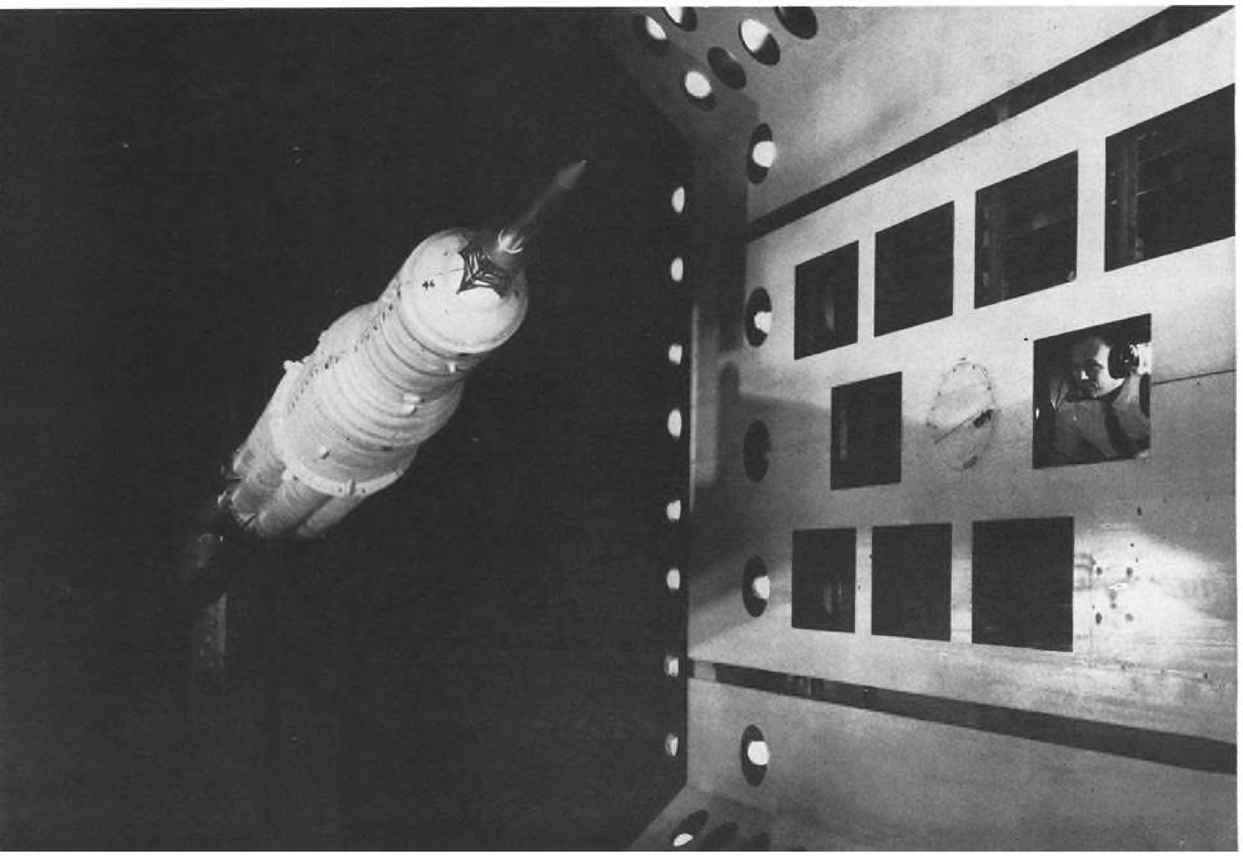
Apollo is stimulating technology throughout the country. It is being used as a powerful economic tool. Its success will be measured largely in national prestige and in the scientific, technical and military advances that are almost certain to accrue. The hardware—launch vehicles, spacecraft and components—being developed for lunar landing are flexible enough for military applications and for use in space station and planetary exploration projects.

These elements of the lunar landing are less often discussed than the landing itself, and the landing is the facet on which critics center their arguments.

The Apollo program will graduate



APOLLO SPACECRAFT configuration underwent the fundamental changes sketched above until the current shape was frozen, in July, 1962 (shown at right above and in a Langley wind tunnel test below). Re-entry body at right was finally selected.



into its flight development phase next month. In its brief history, it has passed a significant number of management and engineering milestones on a reasonably valid schedule, and it has uncovered its share of problems.

The flight development phase will open with a pad abort test and qualification of the launch escape system, both to be conducted at White Sands Missile Range (see p. 281). The over-all development program will include a number of qualification flights of the four major pieces of hardware which make up the spacecraft system—command and service modules, lunar descent stage and lunar ascent stage—and of the thousands of individual components in these modules.

Pad abort test involves igniting the Lockheed solid propellant escape rocket while the command module is on the ground, to simulate a failure shortly after liftoff. Launch escape system will be verified in a General Dynamics/Convair Little Joe 2 launch, which will loft the command module to the region of maximum dynamic pressure, where the escape system will ignite.

The other major milestone on the Apollo schedule this year is the launch in September of the fifth Saturn 1 test vehicle, which will be the first to carry a live Douglas S-4 second stage. This stage is powered by a cluster of six Pratt & Whitney RL10-A3 hydrogen-fueled engines.

Throughout NASA and its contractors, the feeling is that the major problem facing the program is the attainment of reliability and confidence within the constraints of money and time. Because of the cost of launch vehicles, it will not be possible to qualify systems through a large number of development launches. As a result, the basic approach being used is to design reliability into the system and to determine quickly which systems must be redundant.

Robert O. Piland, acting Apollo spacecraft manager at Manned Spacecraft Center, cautioned that NASA must be exceptionally careful "not to hide our design problems by carrying spares."

As part of its reliability effort, the center insists that each contractor maintain a reliability data center which will be the focal point for information on qualified parts, limited-life items and their status, a correlation of environmental data and tests, failure-mode analysis and corrective-action records.

Another problem developed when NASA was unable to make formal the prime contract with North American Aviation, prime contractor for command and service modules and spacecraft intergration. This was caused partly by the timing of the lunar ren-

Major Apollo System Contractors

COMPANY	SYSTEM	VALUE (Millions)*
North American Aviation, Downey, Calif.	Prime for command and service modules	$900
Honeywell Co, Minneapolis, Minn.	Stabilization, control	50+
Collins Radio, Cedar Rapids, Iowa	Telecommunications	45+
Pratt & Whitney, East Hartford, Conn.	Fuel cell	30+
Aerojet-General, Azusa, Calif.	Service module engine	20+
AiResearch, Los Angeles, Calif.	Environmental control	20+
Avco, Wilmington, Mass.	Heat shield	18+
Marquardt, Van Nuys, Calif.	Reaction control engines	10+
Northrop, Newbury Park, Calif.	Recovery System	10+
Link, Binghamton, N. Y.	Spacecraft mission simulators	9.5
Beech Aircraft, Wichita, Kan.	Supercritical gas storage	8+
Lockheed Propulsion, Redlands, Calif.	Escape motor	6+
Bell Aerosystems, Buffalo, N. Y.	Reaction control positive expulsion fuel tanks	5+
Aeronca, Middletown, Ohio	Honeycomb panels	4+
Allison and Airite Products, Indianapolis and Los Angeles	Fuel components (joint contract)	3+
Radiation, Melbourne, Fla.	Telemetry data processing for Apollo and S-2 stage	2.5+
Thiokol Chemical, Bristol, Pa.	Tower jettison motor	2+
Simmonds Precision Products, Tarrytown, N. Y.	Propellant mixture control	2+
Radio Corp. of America, Camden, N. J.	Television cameras	2+
	Main communications antenna	2+
Giannini Controls, Duarte, Calif.	Fuel gaging	1.5+
Westinghouse Electric, Lima, Ohio	Static inverter	1+
Elgin National Watch, Elgin, Ill.	Sequencer	1+
Grumman Aircraft Engineering, Bethpage, N. Y.	Prime for lunar excursion module	387.9
Rocketdyne, Canoga Park, Calif. and	Descent engine (parallel development)	†
Space Tech. Laboratories, Redondo Beach, Calif.	" "	†
Bell Aerosystems, Buffalo, N. Y.	Ascent engine	†
Hamilton Standard, Windsor Locks, Conn.	Environmental control	†
Marquardt, Van Nuys, Calif.	Reaction control thrusters	†
Radio Corp. of America, Camden, N. J.	Radar, engineering services	†
Radio Corp. of America, Burlington, Mass.	Communications, Instrumentation UHF transponder power amplifier VHF transmitter OMNI, directional, erectable antennas Television Personal (extra-vehicular)	†
‡	Display	
‡	Stabilization, control	
‡	Fuel cell, peaking battery	
‡	Sequencer	
‡	Cryogenic tankage	
‡	Ground support equipment	
Massachusetts Institute of Technology, Cambridge, Mass.	Associate prime-guidance, navigation	40
AC Spark Plug, Milwaukee, Wis.	Inertial measuring unit, power servo assembly, ground support, system assembly, test, inertial reference integrating gyro	35
Raytheon, Bedford, Mass.	Computer	15
Kollsman Instruments, Elmhurst, N. Y.	Optics	6

Notes: * Indicates estimated contract value through May, 1965;
† Under negotiation; ‡ Not yet selected.



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dezvous mode decision last July—eight months after North American was selected. NASA's timetable called for 11 months of negotiations and a formal contract by last November. But it has taken another eight months to definitize the prime contract, which must be done before North American can definitize subcontracts.

John H. Disher, assistant director for Apollo spacecraft development in the Manned Space Flight Office at NASA headquarters, said the North American contract probably could have been signed last November if the choice of rendezvous mode had not changed. Until last July, the mission had been planned around earth orbit rendezvous and the specifications were written around this technque. Disher pointed out that no major configuration changes in the spacecraft system have been made since lunar orbit rendezvous was selected.

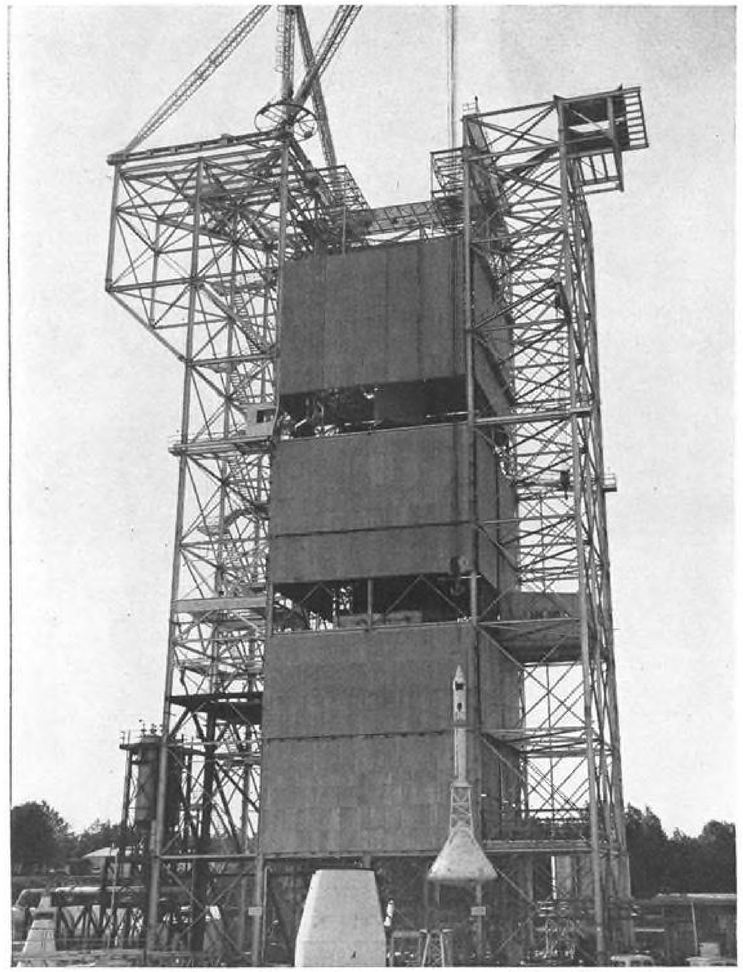
The most critical development problems that have arisen so far deal specifically with crew safety and environment —which demand the highest degree of reliability. Another specific problem is in the development progress of the service module propulsion system.

While NASA is not happy with these problems, it does not feel they are serious enough to delay the over-all program.

The problems are effectively balanced by the large number of engineering milestones passed since lunar orbit rendezvous became the mission mode. The most significant are:

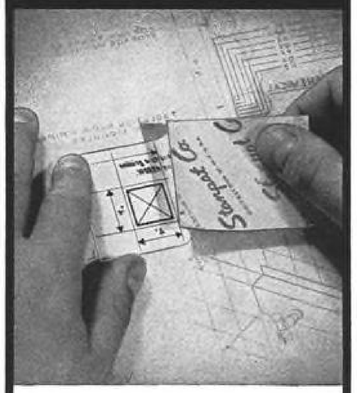
• **Completion of a "soft" mockup** of command and service modules last December.

• **Over-all configuration freeze** of command and service modules last spring. In the same period, all major subsystem interface requirements were defined. Lunar Excursion Module configuration



FULL-SCALE COMMAND module with launch escape tower is hoisted into the dynamics test stand at Marshall Space Flight Center for one of many hardware tests.

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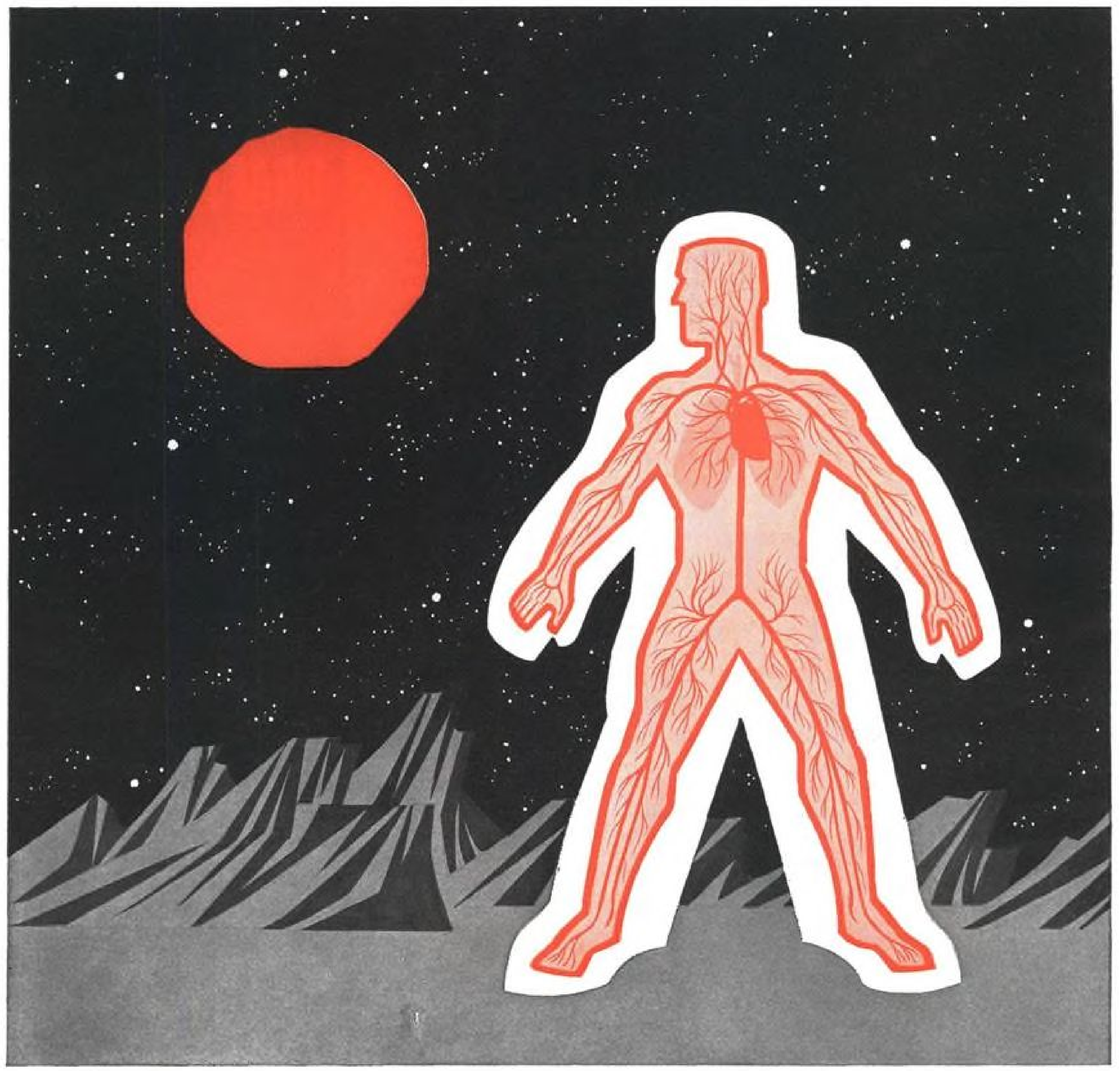
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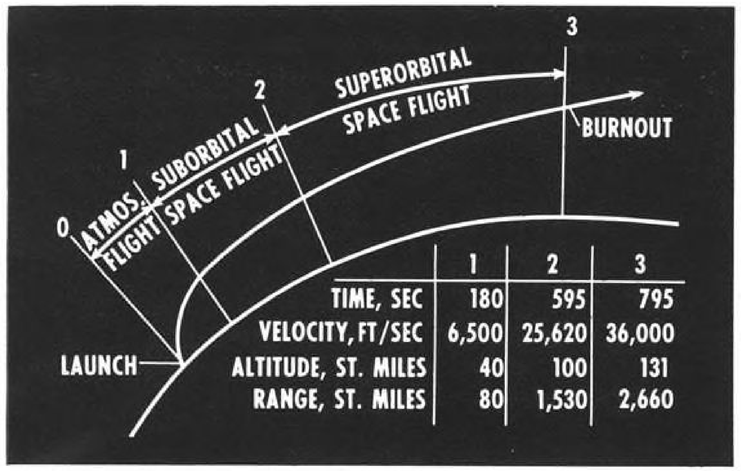


APOLLO SUIT

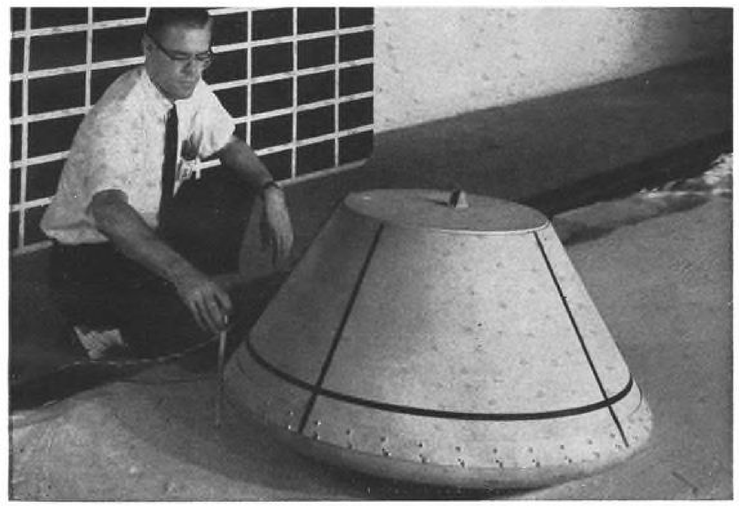
The first integrated space-suit assemblies are being developed by Hamilton Standard for Project Apollo, under contract to NASA. They will provide comfort and mobility for astronauts outside the craft in deep space and on lunar exploratory missions. Hamilton Standard, as prime contractor, is managing the program, and designing and building life support packs. The packs must supply oxygen and pressurization and control temperature, humidity and contaminants. Subcontractor for the suits is International Latex Corporation.

The space-suit project, an important portion of Hamilton Standard's life support program, applies diversified experience in hydraulics, pneumatics, mechanics, electronics, and packaging. Hamilton Standard blends and develops these basic technologies to achieve an integrated systems approach to life support equipment.

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FLIGHT REGIMES of Apollo plotted against critical boost phases are shown above. Below, a one-fourth scale model of the command module is tested at Langley.



was frozen earlier this month (see p. 141).

• **Impact attenuation,** water handling and parachute drop-test boilerplate command and service modules have been manufactured and delivered (see p. 124). There are 17 boilerplate command modules in the North American contract order.

• **Subsystem test objectives** for the coming pad abort and launch escape tests have been established.

The Apollo program has now evolved into two distinct missions, each with its own set of requirements and objectives. They are the lunar landing phase and the later lunar exploitation phase—which involves stretching Apollo's capabilities to explore the moon and determining whether a lunar base is desirable or even necessary.

The configuration has undergone a fairly significant evolution (see drawing, p. 108), so that it now reflects the method of flight—lunar orbit rendezvous—based on the use of the Saturn 5 launch vehicle.

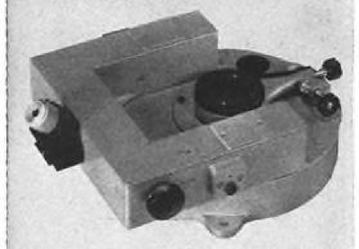
NASA had mustered its arguments for a lunar landing program from studies which began in early 1960, and Dr. Hugh L. Dryden, deputy administrator, presented them to President Kennedy as soon as he took office. This was just after the Fiscal 1962 budget, prepared by the outgoing Administration, was presented to Congress. It contained a statement to the effect that funding of manned space flight projects beyond Mercury would await analysis of Mercury missions.

NASA first generated concepts for the lunar mission because it felt the moon was the logical area for manned space flight after earth orbital missions had been conducted.

Highlights of the actions leading to the present program are:

• **February-March, 1960.** Space Task

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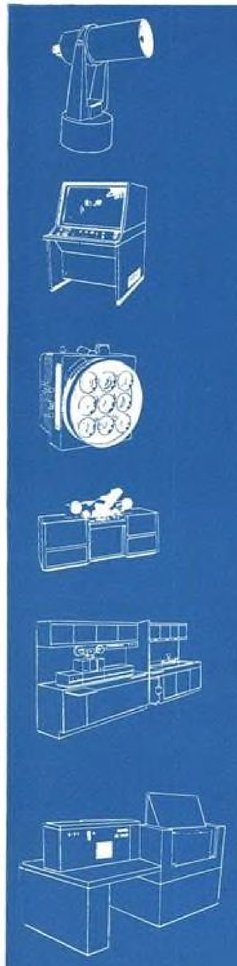
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Group appointed an in-house study unit, headed by Piland, to draw mission guidelines. Primary objective was to be manned lunar reconnaissance, because at that time the mission would have used the Saturn 2 launch vehicle, which had only a 16,000-lb. lunar payload capability. Studies indicated that work-rest duty cycles would require a three-man crew. Other mission guidelines: blunt re-entry vehicle capable of both water and ground landings would be used; 14-day environmental and power supply systems would be specified, and the system would be able to abort a launch safely, maneuver in space and protect the crew from radiation.

The study unit was named immediately after a NASA committee, headed by Dr. Harry J. Goett, director of Goddard Space Flight Center, decided that a lunar mission should be the post-Mercury manned space flight target.

• **April, 1960.** Lunar goal recommendation and mission guidelines were given to Keith Glennan, then NASA administrator. Later that month, Robert R. Gilruth, director of Manned Spacecraft Center, led the lunar study team on a "road show" to NASA headquarters and centers to present the guidelines and solicit ideas.

• **July, 1960.** The lunar project was given the name Apollo.

• **September, 1960.** NASA announced that feasibility study contracts would be awarded to industry. These contracts were awarded in November to General Dynamics/Astronautics, General Electric and Martin. The six-month studies were based on a circumlunar mission.

• **May, 1961.** President Kennedy's decision, and conclusion of the feasibility studies.

• **November, 1961.** Decision was made to develop the Saturn 5 vehicle and to defer development of the Nova launch vehicle, which might have been used for direct-ascent manned flight or as a cargo vehicle. North American was selected as prime Apollo command and service module contractor.

• **December, 1961.** An ad hoc committee of NASA, Defense Dept. and industry, headed by Dr. Nicholas E. Golovin, recommended after a three-month study that the U. S. utilize earth orbit rendezvous and in-orbit assembly of spacecraft as the quickest way to land men on the moon. This group backed the decision on the Saturn 5 as the launch vehicle for the program.

Minority opinion in favor of lunar orbit rendezvous was voiced by two Golovin Committee members, Dr. John Houbolt, then of Langley Research Center, and Kurt Stehling of NASA headquarters. The technique was conceived by Houbolt as a way to save time and money. The earth orbit rendezvous technique called for multiple Saturn 5 launches and the landing of the entire spacecraft on the moon.

Houbolt's concept was adopted last July—over the objections of Golovin and Dr. Jerome B. Wiesner, presidential science adviser. Grumman Aircraft Engineering Corp. was selected last December as contractor for the Lunar Excursion Module.

Apollo Growth Potential

Apollo manned lunar landing program will be followed quickly by a program to exploit the Apollo system for lunar exploration. First part of the exploration would involve use of existing hardware, with crewmen ranging a few miles out from the lunar landing bug.

Advanced phase would require development of a supply system, probably based on the capabilities of the bug as a cargo carrier, to enable the crew to explore the moon for as long as 14 days. National Aeronautics and Space Administration feels that the 14-day stay time may provide all the scientific return that is available from the moon.

Following an intensive survey of the primary scientific areas of interest in the moon, NASA decided these are, in rapidly descending order of priority: selenology, astronomy, particles and fields, exobiology and vestigial atmosphere. Comprehensive experiments in these areas could be handled using only standard Apollo hardware and a cargo version of the lunar bug, NASA decided.

Apollo also is considered a candidate for an early space station program. Without major modification, the Apollo system can support two men in orbit for at least 100 days. This period can be stretched significantly with minor modifications.

As a space station, the system could test components for manned planetary spacecraft and it could determine if artificial gravity is required to sustain a crew for extended space missions.

Another potential use of the Apollo system now under development would be to use the command module as a lunar reconnaissance module, which with very few modifications could overfly the entire lunar surface in a polar orbit and thereby supplement the findings made in manned landings.

One NASA official said that if this country were not in a race with Soviet Russia to the moon, the procedure probably would call for an extended manned reconnaissance before manned landings on the moon.



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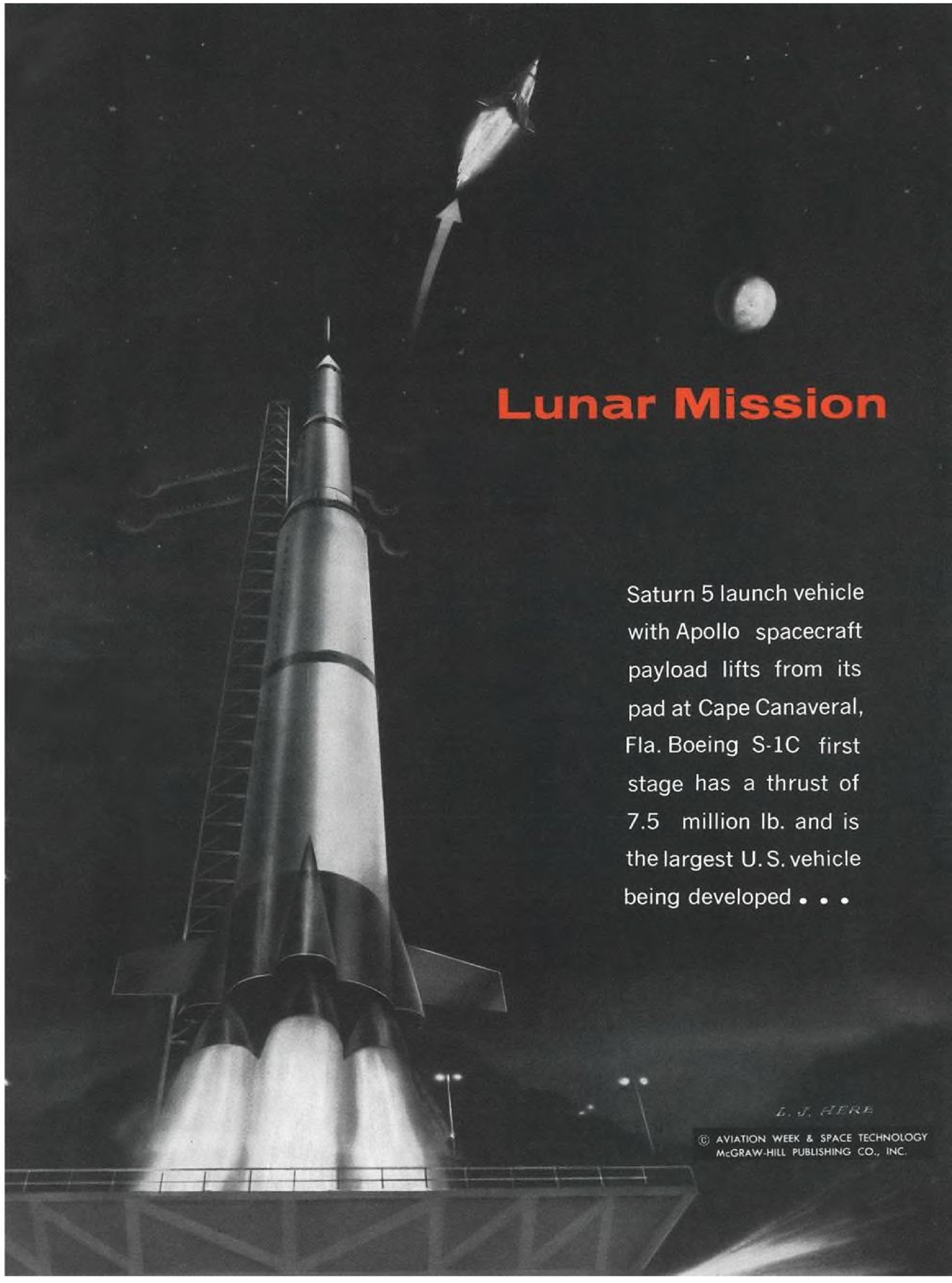
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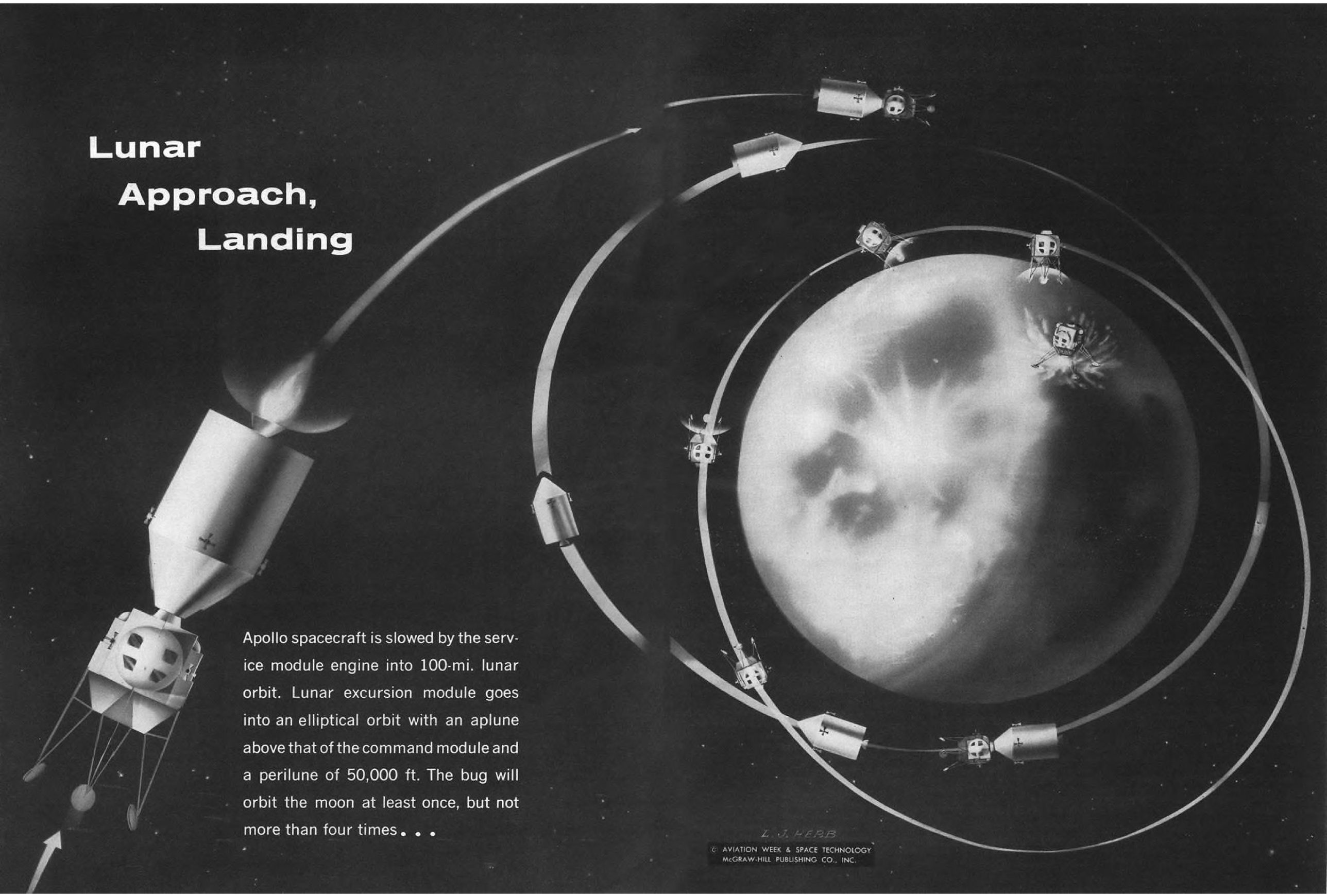


Translunar Maneuvers

Sequence starting at upper left shows first stage separation; injection into an earth-moon trajectory and jettison of the North American S-2 stage; command and service module turn-around (lower left); separation of the Douglas S-4B stage, coast and midcourse correction . . .

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Lunar Approach, Landing



Apollo spacecraft is slowed by the service module engine into 100-mi. lunar orbit. Lunar excursion module goes into an elliptical orbit with an aplune above that of the command module and a perilune of 50,000 ft. The bug will orbit the moon at least once, but not more than four times. . .

L. J. HEBB

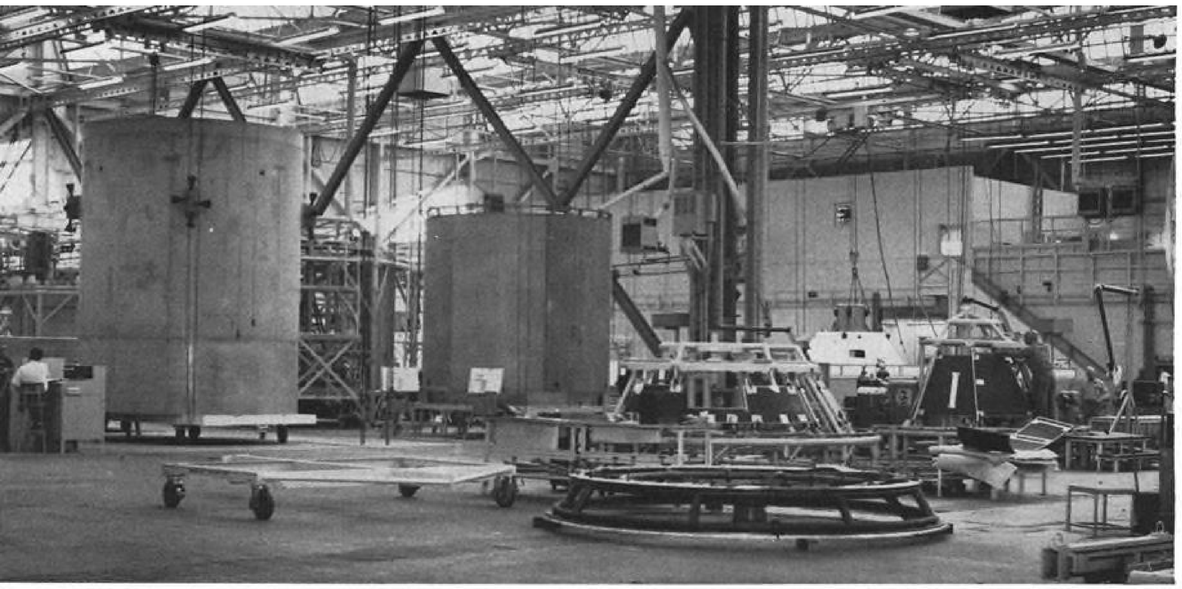
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Takeoff, Return

Lunar excursion module leaves the moon with its two pilots to rendezvous with command and service module. The bug is jettisoned after crewmen transfer into the command module. The service module is jettisoned after the final midcourse correction. Primary landing point is in Texas.

L. J. HERB

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BOILERPLATE APOLLO COMMAND MODULE (right) starts to take form on a jig in North American's Downey, Calif., plant. In background (right) is a nearly-finished command module and (left) two boilerplate service modules.

Critical Apollo Test Modules Produced

Downey, Calif.—Well-established aircraft manufacturing techniques being used to build Apollo boilerplate command and service modules have permitted North American Aviation's Space and Information Systems Div. to cut the estimated manufacturing time of initial test vehicles by as much as 50% and allow the company to meet a tight production schedule.

North American is now moving into the production of actual flight hardware, and there are estimates that as many as 30 command modules may be required to develop the confidence and reliability required for the manned lunar landing mission.

Through the use of proven aircraft manufacturing methods, North American has met all boilerplate delivery dates defined in the original letter contract with the National Aeronautics and Space Administration. Even more important, the company foresees no delays as flight hardware production begins.

Boilerplate production effort will decrease toward the end of this year, when 11 of the 17 boilerplate command modules on order will have been delivered.

Tooling for production of the command module is now about 75% complete, and major subassemblies of inner and outer panels for this module already have been finished. Service module production tooling is about 50% complete, with major subassemblies for this unit also fabricated.

North American's responsibility in the Apollo program is the design, development and production of the command module, service module, service module adapter and titanium tower to support the launch escape system. The contractor also will integrate all spacecraft systems.

In fulfilling what is perhaps the most critical contract of the manned lunar landing program, North American's approach is to give priority first to reliability, then schedules and cost.

Early subsystems testing and confirmation of the basic design is now under way, with about one-third of the boilerplate hardware in use. Component reliability will be established as critical systems are delivered and more sophisticated boilerplates become available for flight testing.

The boilerplate test program has been under continuing review to assure maximum cost and mission effectiveness. Number of boilerplate command modules has been reduced from the original order of 25 to the present 17 because test objectives of the eight which have been dropped can be incorporated into other phases of the test program.

Reduction in the number of boilerplates has been partially responsible for reducing the dollar value of the North American contract, which last November was estimated to be slightly more than $1 billion, and now is just under $900 million.

North American has attempted to meet design problems by sheer brute-force engineering. This method is similar to a logging operation where the branches of a tree are removed before the tree is felled, thereby eliminating all small problems in progression. Similarly, in Apollo, as problems arise in design and early production, they are met and solved with an eye toward a completely integrated system.

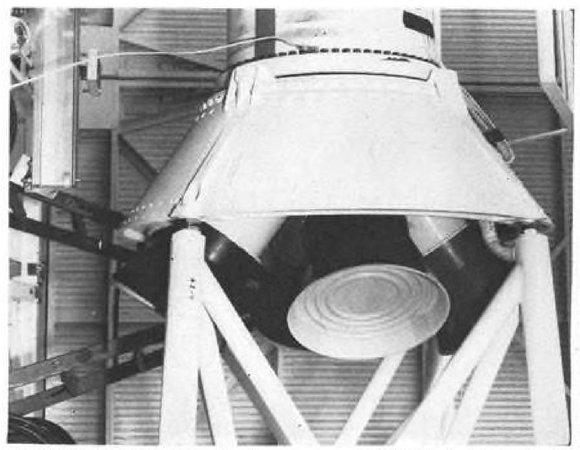
Thus, the gap between concept and delivered hardware in essentially uncharted manufacturing regions is being bridged by an all-out engineering effort. While this is more costly than building with a set of pat blueprints, it is keeping the spacecraft development program on a reasonable schedule.

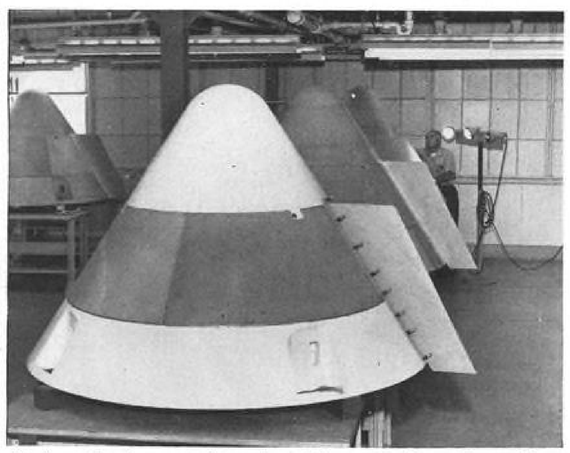
A number of systems and concepts associated with command and service modules still remain to be defined. Details of configuration and interior arrangements often vary from month to month as studies and tests either disprove or validate design concepts. This has caused NASA to be chary of committing itself to a final design, a factor reflected by North American and its subcontractors in discussing the Apollo system.

The addition of strakes to ensure proper trim, for example, has caused a lively debate as to the necessity for these appendages. Wind tunnel runs and analytical studies have indicated that during an inflight abort at low dynamic pressures, the command module has a tendency to trim nose forward—an undesirable characteristic because it affects parachute deployment.

Some engineers argue that the strakes are not necessary because the pilot can orient the spacecraft. Whether they will be included will be determined from Little Joe 2 launch escape system qualifications at White Sands.

The lack of precedent on which to base design focuses a heavy qualification reliance on testing programs. The

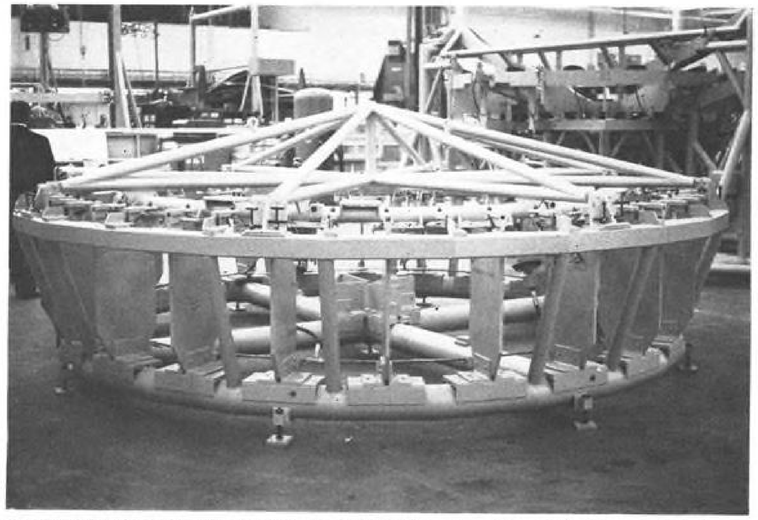




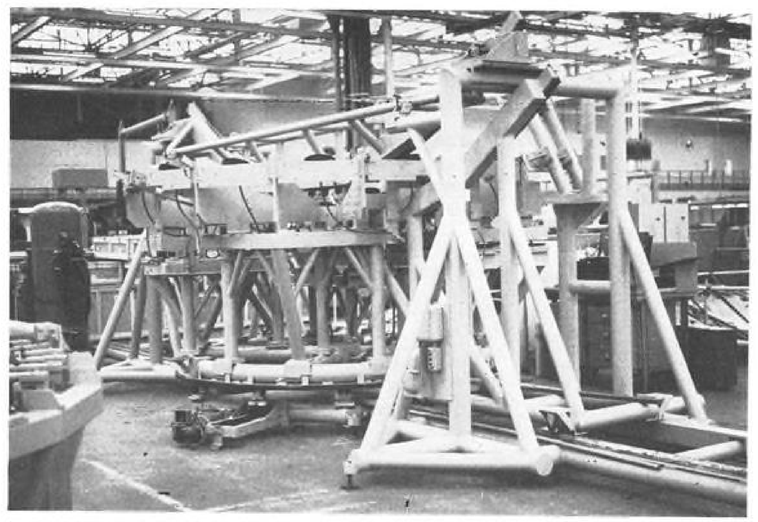
CLOSE-UP VIEW of the Apollo escape rocket (left), built by Lockheed, shows the four canted nozzles of the motor. Spare forward heat shields of Apollo boilerplate models (right), show steel ballast plates and stabilizing strakes.



NORTH AMERICAN technicians cement 30-lb. lead ballast plates to a boilerplate heat shield to locate the unit's center of gravity.



FLANGING FIXTURE will be used to contour the outer edge of the brazed steel honeycomb of the Apollo aft heat shield. Fixture was specially built.



AFT HEAT SHIELD will be built up from pie-shaped segments on this jig. Segments will be welded together on this fixture and then trimmed before contouring.

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boilerplate test program, therefore, is considered the pacing element of the early phase of the spacecraft development program. Primary objectives of the boilerplate tests (see box) must be accomplished on a no-delay basis to keep the program moving to its goal—landing men on the moon before the end of this decade.

The boilerplate manufacturing program relies heavily on standard production line techniques to minimize time spent on fabrication. Readily-available and less expensive materials are employed whenever possible. Among the techniques which illustrate this approach are:

• **Aluminum skin and stringer** construction with riveting at attachment points. No honeycomb structures are used in the outer skin and welding is kept to a minimum.

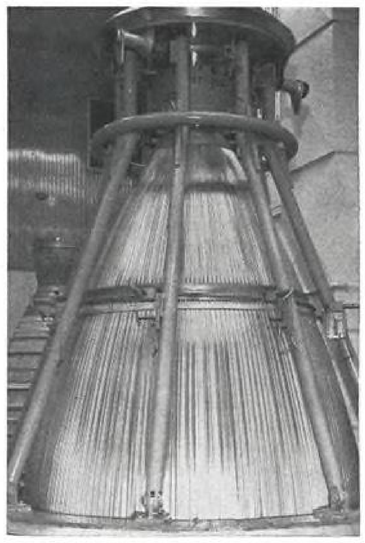
• **Cork sheets,** ½-in.-thick, are bonded to outer surface of command module to simulate ablative material for test purposes.

• **Glass fiber** and aluminum honeycomb construction simulate the large aft heat shield. Aluminum honeycomb is added to reduce weight.

These shields invariably crack during impact with the ground and are readily replaced.

• **Lead ballasting** is used to locate the center-of-gravity. On the command module, 30-lb. flat lead plates are bonded to the heat shield to simulate the low, offset CG.

Tooling for boilerplate production began in June, 1962, and the first boilerplate command module constructed of mild steel was finished last August. Six additional units, all made of aluminum,



REGENERATIVE COOLANT tubes on the Rocketdyne-built J-2 engine are stacked and prepared for brazing.

have been built and delivered for testing since then.

In the design and manufacturing of the command module, North American is working to develop a production team concept. Since each boilerplate is generally of slightly different construction, depending on its mission, the manufacture of each is done largely on an individual basis. Aim of the team approach is to have highly efficient production teams with authority given to a single individual who can slash red tape and take corrective action.

A project engineer for each spacecraft has over-all responsibility, but as the unit moves out of the design phase into the manufacturing phase, executive responsibility shifts to a manufacturing crew chief. During the test phase, a test crew chief has final responsibility. Ideally, the same team would be assigned to the manufacture of a production module similar to the boilerplate produced. In this way, experience in boilerplate production can be applied to actual spacecraft hardware production.

In conceptual planning, NASA specified and North American designed the Apollo spacecraft with three basic considerations:

• **Vehicle must function** as a spacecraft. It must be capable of carrying its crew through space to a destination and return safely.

• **Command module** must be flyable. Capability to maneuver during re-entry is required. The 0.5 Apollo lift-to-drag ratio differentiates it from a pure ballistic vehicle.

• **Command module** must be able to survive a water landing. This dictates that the center of gravity be placed so the module will float upright. Location of the center of gravity affects both flight and flotation characteristics and has resulted in an optimization of both by locating it low and slightly forward toward the edge of the heat shield opposite the cabin windows.

Production command modules will consist of two parts, an inner and an outer capsule. The outer capsule is the heat shield and the inner capsule, the crew compartment.

The outer capsule is built of 45 brazed honeycomb steel panels, preformed and fabricated by Aeronca Corp., Middletown, Ohio. The steel honeycomb is a sandwich of 0.09 in. sheets and approximately 0.5-in. honeycomb.

The outer capsule has three major sections:

• **Forward heat shield.** This is the cone-shaped forward lid which is jettisoned prior to deployment of the parachute recovery system. The airlock lid is included in this section.

• **Mid-section,** fabricated in two parts,

Apollo Boilerplate Tests Programmed

Missions for 15 boilerplate Apollo command modules, nine boilerplate service modules, nine boilerplate adapter fairings for the service module and 10 launch escape systems have been designated by National Aeronautics and Space Administration.

Tests by NASA and North American Aviation, prime contractor for these systems, are now under way. They are intended to confirm fundamental design and to qualify earth recovery, launch escape and shock attenuation systems. Flight tests using Little Joe 2 and Saturn boosters are scheduled to start this fall and early next year.

Missions assigned for boilerplate modules already delivered are:

• Boilerplate 25, the first command module boilerplate, delivered last August, to demonstrate equipment handling in land and water recovery and to develop recovery procedures.

• Boilerplates 1 and 2. Test command module earth attenuation and crew shock absorption systems, at North American's impact facility in Downey, Calif.

• Boilerplates 3 and 19. Qualify Northrop-Ventura command module earth recovery system, being done by Northrop at El Centro, Calif.

• Boilerplate 9. Demonstrate dynamic structural compatibility with a dummy Douglas S-4 Saturn stage. The unit also will be subjected to shaker, bending and stress tests.

• Boilerplate 6. Qualify launch escape system in an off-the-pad abort, to be conducted at White Sands Missile Range.

Mission assignments for boilerplates to be delivered soon are:

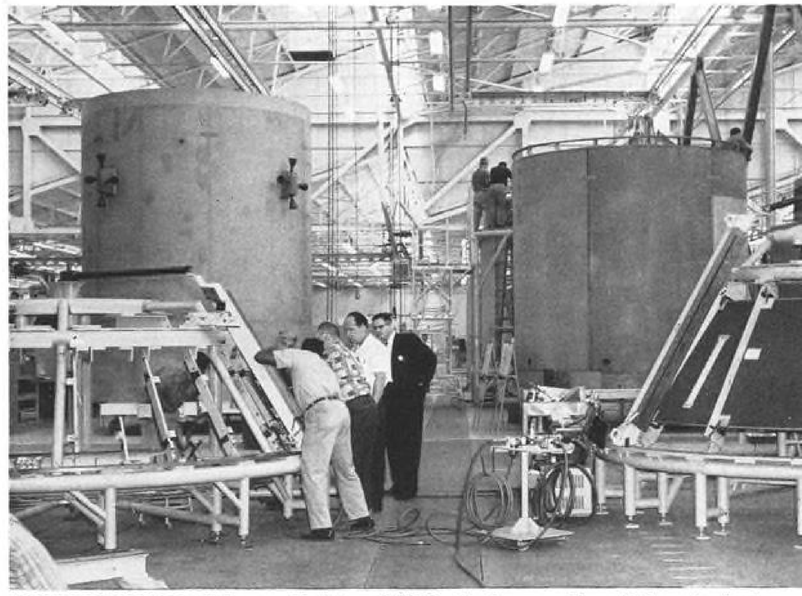
• Boilerplate 12. Verify launch escape system at maximum dynamic pressure in a Little Joe 2 launch at White Sands.

• Boilerplate 22. High altitude launch escape test and reaction control system verification in a Little Joe 2 launch at White Sands.

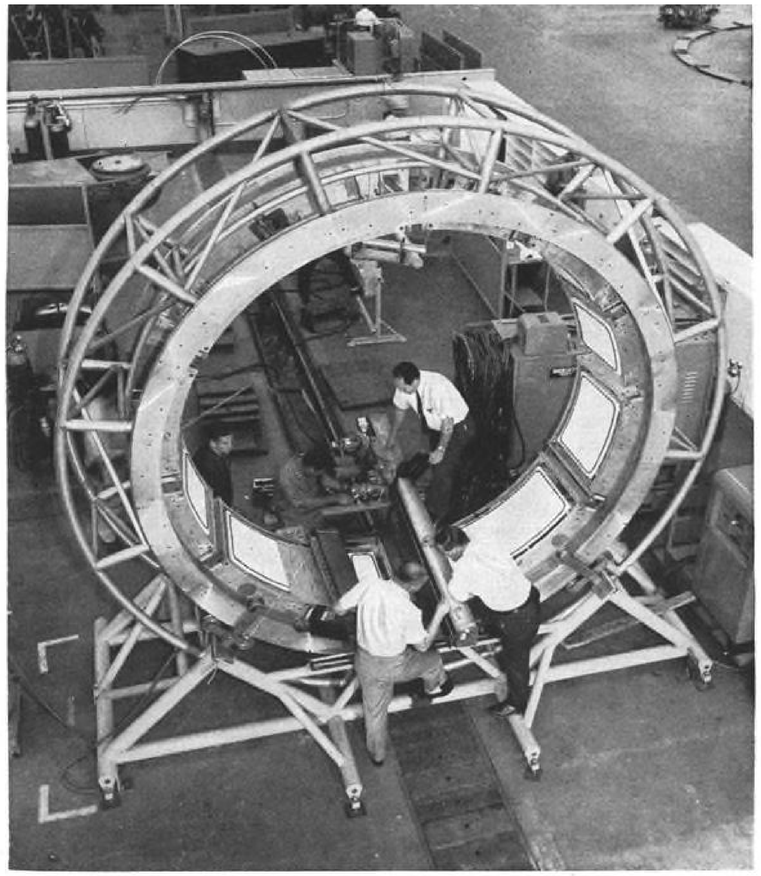
• Boilerplates 13 and 15. Non-recoverable earth orbital tests launched by Saturn 1 to determine spacecraft-launch vehicle compatibility. Boilerplates 16 and 18 will be similar, but more advanced tests using Saturn 1 or 1B vehicles. Launch system in the latter tests will be jettisoned, and a number of subsystems qualified.

Boilerplate 23 is a backup for Nos. 6 and 12, and Boilerplate 14 is to be used to check systems compatibility. Two additional models will be built under the existing contract, which may be extended.

Boilerplates 9, 12, 13, 14, 15, 16, 18, 22 and 23 are complete Apollo configurations, consisting of command and service modules, service module adapters and launch escape systems.



APOLLO TOOLING includes a weld fixture (left) for the lower portion of the outer heat shield and an assembly jig for honeycomb panels of the mid-section.



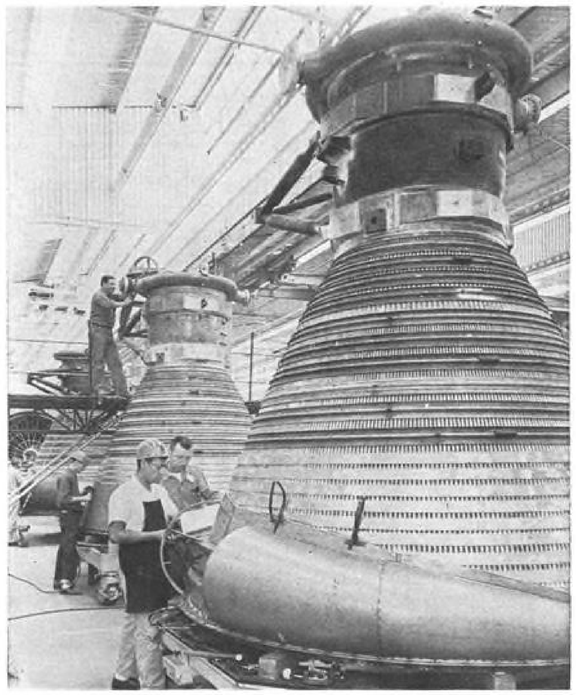
WELDING HEAD of this fixture moves along track to join sections of the lower inner wall of the command module. Fixture is called the "squirrel cage."

upper and lower. Semicircular jigs are used to mate and weld panels for the units, which are welded to form 360-deg. sections. The two 360-deg. sections are placed one atop the other for the final weld to form the mid-section. Access panels may be located in the lower portion of the mid-section of the heat shield.

• **Aft heat shield.** Pre-formed, pie shaped sections of brazed steel honeycomb are welded together on a special dish-shaped jig to form this section. It is placed on another jig used to flange the outer edges. This section of the outer heat shield is subjected to the highest heat flux and is called the command module heat shield. It is mated to the aft bulkhead section of the outer heat shield mid-section.

The inner crew compartment installed within the outer heat shield is built of aluminum honeycomb in two sections. The upper section is shaped like a truncated cone and the lower section is cylindrical. The panels are formed with the aid of bonding fixtures and final bonding takes place in North American's 13-ft.-dia. autoclave pressure oven at 200 to 250 psi. and a temperature of 400F. Both 180-deg. and 360-deg. bonding fixtures will be used to fabricate the upper and lower sections.

After the panels are formed, they are joined in a circumferential welder to form the main portion of the inner crew compartment. Prior to installing the inner crew compartment in the





F-1 ENGINES on the Rocketdyne production line (left) and an **F-1** (right) undergoing water flow tests to check tubing.

outer heat shield, a number of mechanically-locking fasteners are bonded to the outer skin of the inner crew compartment. A matching fastener is welded to the inner skin of the outer heat shield so the two capsules can be rigidly mated.

Heat Shield

After the two capsules are mated and basic systems installed, the command module will be shipped to Avco Corp.'s Research and Advanced Development Div., Wilmington, Mass., for installation of the ablative heat shield. Avco will cover the outer portion of the module with steel honeycomb, filling in the honeycomb with ablative material. Entire outer portion of the spacecraft with the exception of the windows will be covered with the material, which will vary in thickness, depending on the expected heat flux. Command module will then be returned to North American for final systems checkout.

The service module houses the propulsion, electrical, environmental control, and related subsystems required to support the command module and its crew.

Basically, it is a large compartmented cylinder mated at one end to the command module and closed at the other end except for the service module engine nozzle.

Outer skin of the service module is sandwich construction—2.0-in. aluminum honeycomb bonded between 0.05-in. aluminum sheets. Panels are fastened using hinges and bolts or rivets with inserts. The service module is not welded; instead, the interior is divided into six pie-shaped compartments, with radial beams milled from aluminum plates for structural integrity.

Space Radiators

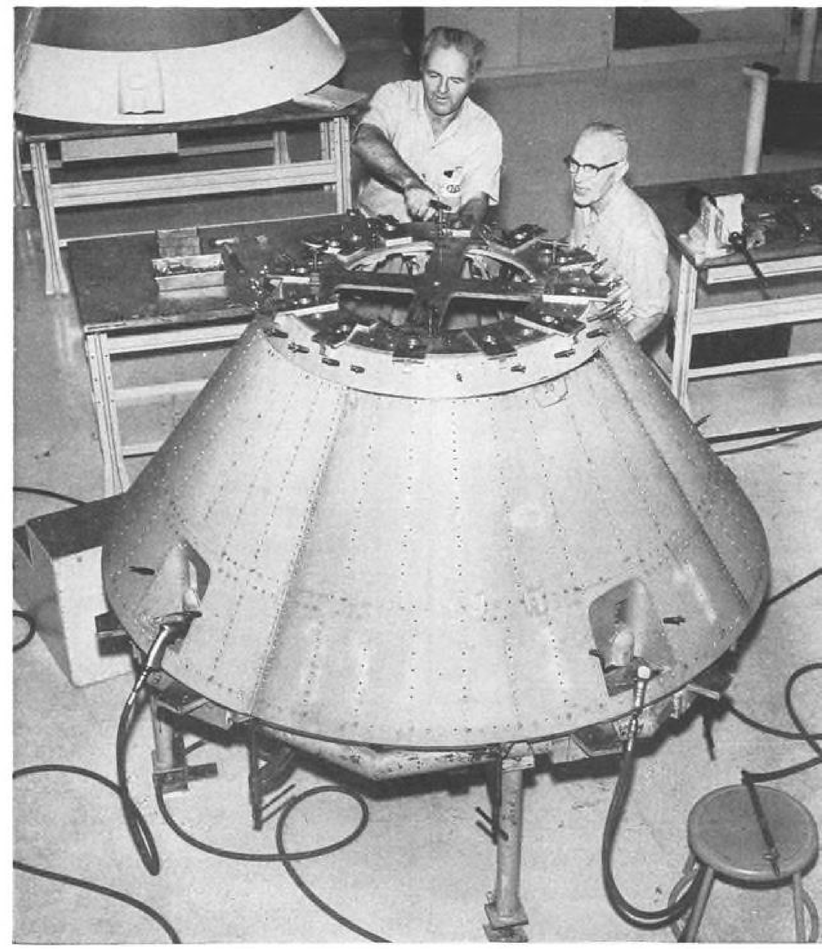
Space radiators will be located on the outer surface of the service module. Pattern of the liquid radiators and their size has not yet been determined by North American since the amount of heat to be dumped is not accurately known at this time.

The radiators will provide cooling for the electrical power system and for the environmental control systems. Passive cooling technique is used to cool the service module itself. This is done by painting the outer surface with reflective or absorbant paints.

Space radiators will be fabricated of two sheets of 0.05-in. thick aluminum. They will be bonded together with adhesive, layed on in such a way as to place adhesive everyhere except the desired route of the coolant. Sheets are then bonded together and air pressure blows the panels apart where there is no adhesive. This creates a ⅜-in. or



APOLLO BOILERPLATE NO. 12 (above) includes heat shield, cabin and service module. Below, the forward segment of the command module. Note nose cap in background.





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* Pat. 2904072

larger diameter passageway for the coolant.

The service module outer panels are routed to accommodate the installation of the space radiators, which will circulate a water-glycol solution as the coolant.

Honeywell is prime contractor for the stabilization and control system, which includes the reaction control system (RCS), being developed for the service module by Marquardt and consists of four pulse-modulated, pressure-fed rocket engines. Each engine, with four symmetrically-arranged nozzles, produces 100-lb. thrust which will stabilize the spacecraft and control its attitude throughout the Apollo mission until the service module is jettisoned shortly before re-entry into the earth's atmosphere.

Fuel Supply

Propellant for each engine is supplied by a set of two tanks, one containing the nitrogen tetroxide oxidizer, and the other the fuel—an equal mixture of unsymmetrical dimethylhydrazine and hydrazine. Bell Aerosystems positive expulsion tanks have a bladder made of a triple layer of Teflon, 3-mil thick, and are pressurized by helium. The casings will be made of either titanium or aluminum.

A radioisotope gaging system, developed by Giannini Controls Corp., will be used to measure the remaining propellant under zero-gravity. System works by directing radiation through the propellant tank from a radioisotope source to detect the amount of radiation on the other side of the tank not attenuated by propellant.

Main propulsion unit for the Apollo spacecraft is the service module engine. The 21,900-lb.-thrust ablative-cooled engine is under development by Aerojet-General. Hypergolic propellants are the same used in the reaction control system, and for the Lunar Excursion Module. The engine can be gimballed ±10 deg. and it is capable of as many as 50 re-starts.

Engine Uses

Engine will be used for translunar mid-course corrections, injection into and ejection from lunar orbit and for lunar orbit corrections. It also can be used to drive the command module in the active role of seeker during lunar rendezvous, in the event the Lunar Excursion Module is unable to assume this role.

Over-all length of the engine is 160 in. Fuel and oxidizer tanks will be built by Allison Div. of General Motors and will be pressurized by helium. Propellants will be pressure-fed into thrust chambers.

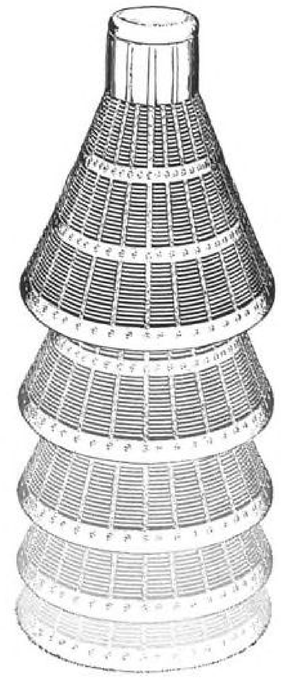
The primary source of electrical power will be three fuel cells, being developed by Pratt & Whitney. The cells will use potassium hydroxide liquid electrolyte and dual-porosity, sintered-nickel electrodes. Three solid state inverters, built by Westinghouse Electric Co. will convert part of the fuel cell output to 115/200 v, 400 cps. power. Cells also will generate crew drinking water.

When the command and service modules, LEM adapter and launch escape tower for a specific spacecraft have been completed, they will be mated and checked in North American's system integration and checkout facility, now under construction. Following system checks, units will be disassembled and shipped individually.

The complete Apollo spacecraft is 1,014 in. long. Command module and service module mated together are 295.7 in. long—from the tip of the command module nose cone to the bottom of the service module. Exit nozzle of the service module engine extends approximately another 116 in. The launch escape system measures 405.4 in. from the bottom of the titanium tower to the tip of the nose cone capping the pitch control motor. The tower is attached to the command module 50.1



STATIC-FIRING of the Lockheed solid-propellant Apollo escape motor.



Houston Business is on the Way Up

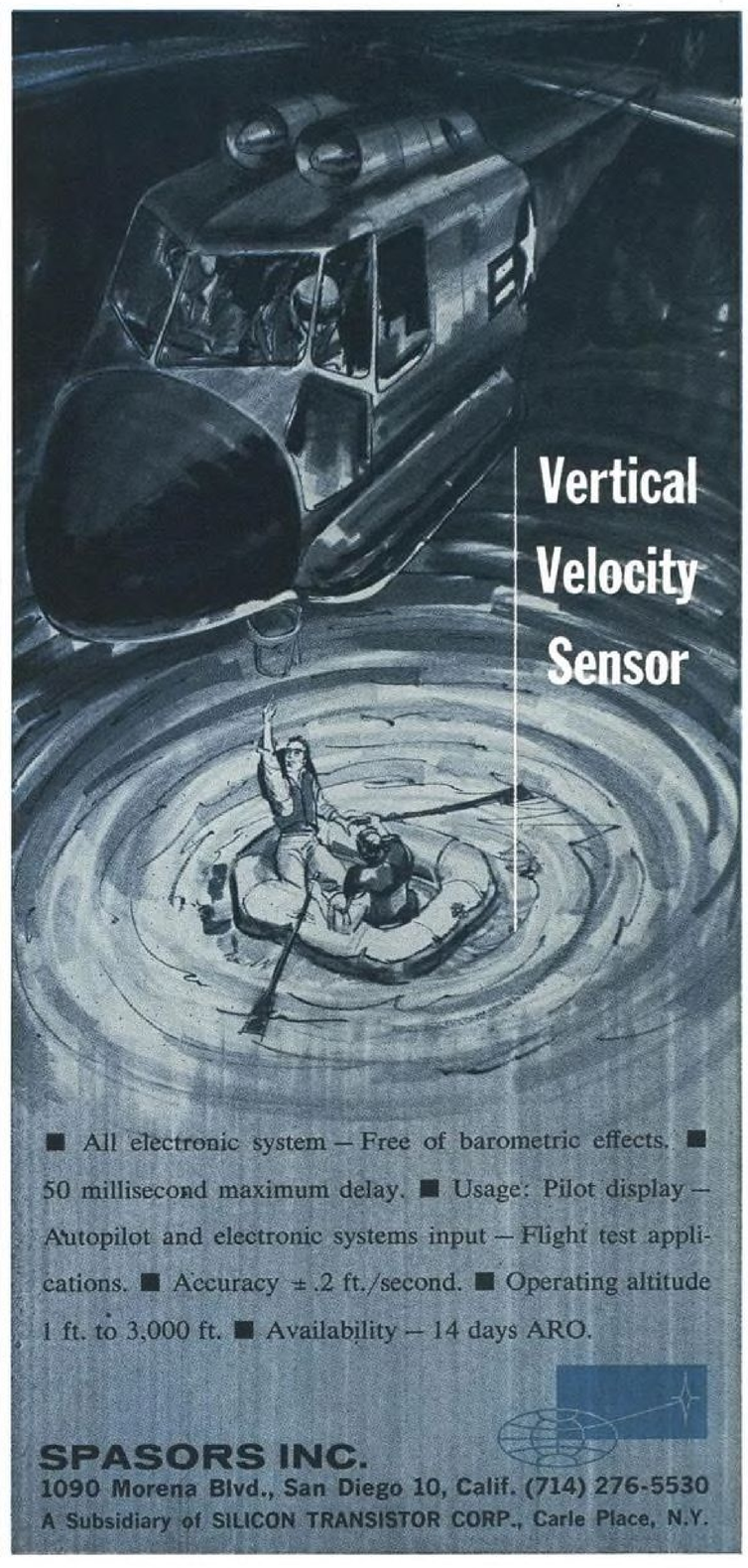
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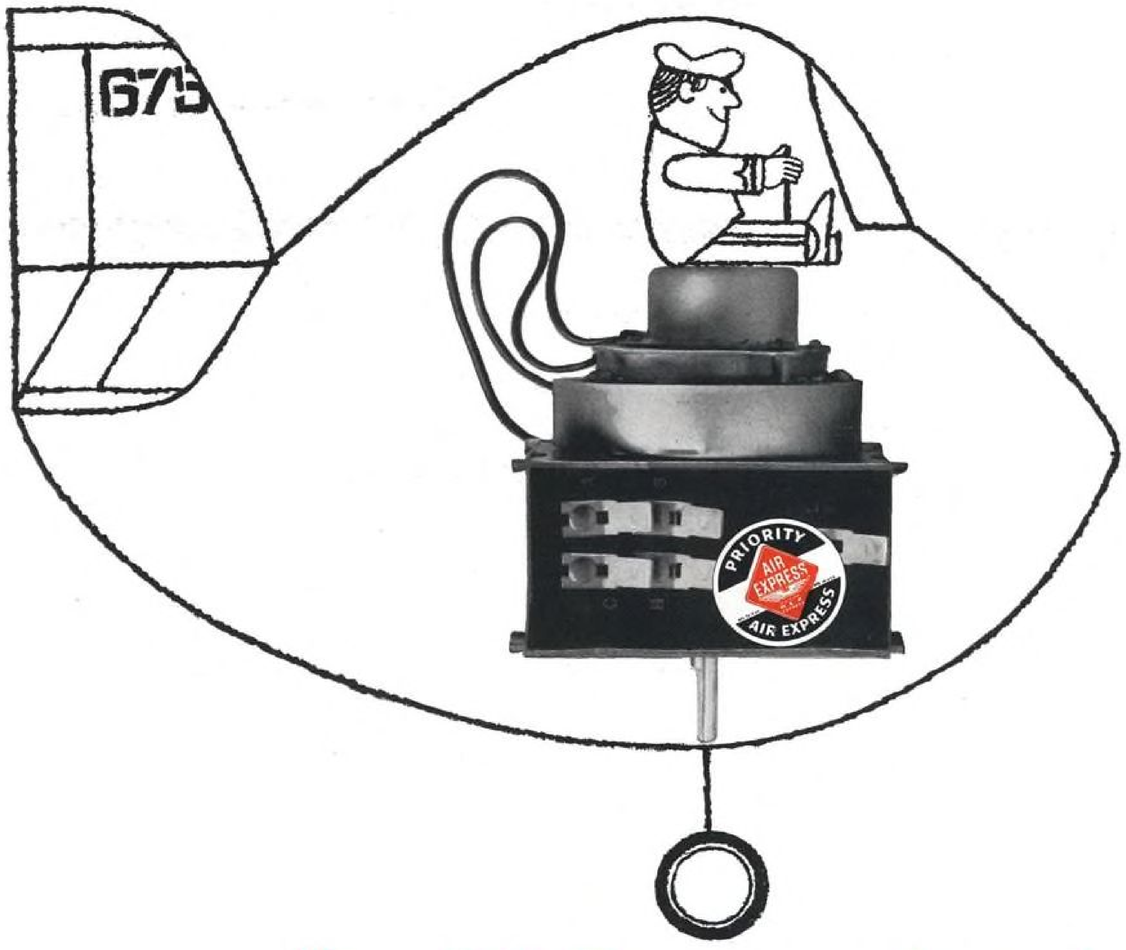


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"Use of Air Express saved enough inventory costs to enable us to increase capital improvements and extend research even further."

—Tad Fraissinet, Plant Manager, Mallory Timers, Warsaw, New York

AIR EXPRESS DIVISION OF REA

132

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Mallory Timers reduced inventory two-thirds by shipping Air Express!

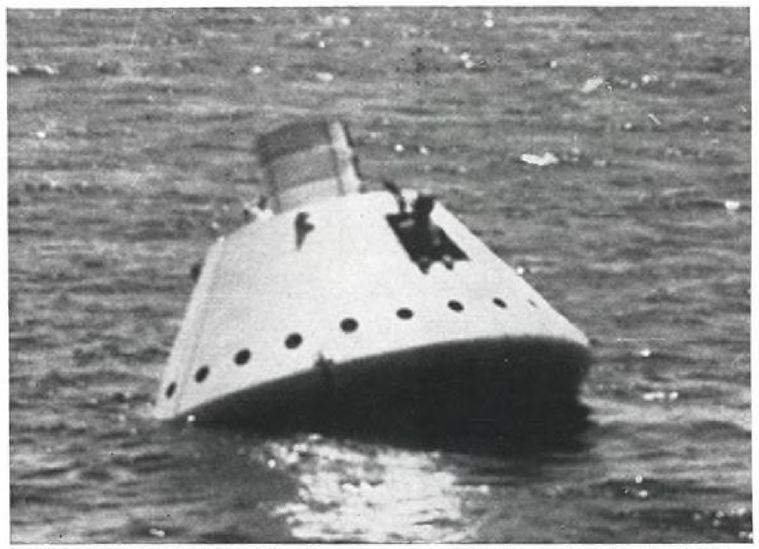
In three years, Air Express helped Mallory cut their inventory by two-thirds—without compromising production in any way. Here's how it works in a typical situation:

A large washing machine manufacturer in the Midwest puts in a rush order to Mallory for special timing devices. Mallory immediately orders a vital part for these timers from its supplier in Mattoon, Illinois, and gets overnight delivery by Air Express. At the end of that workday the timers are ready and are shipped to the washing machine company, again by Air Express. From initial order to final delivery, only 48 hours elapse.

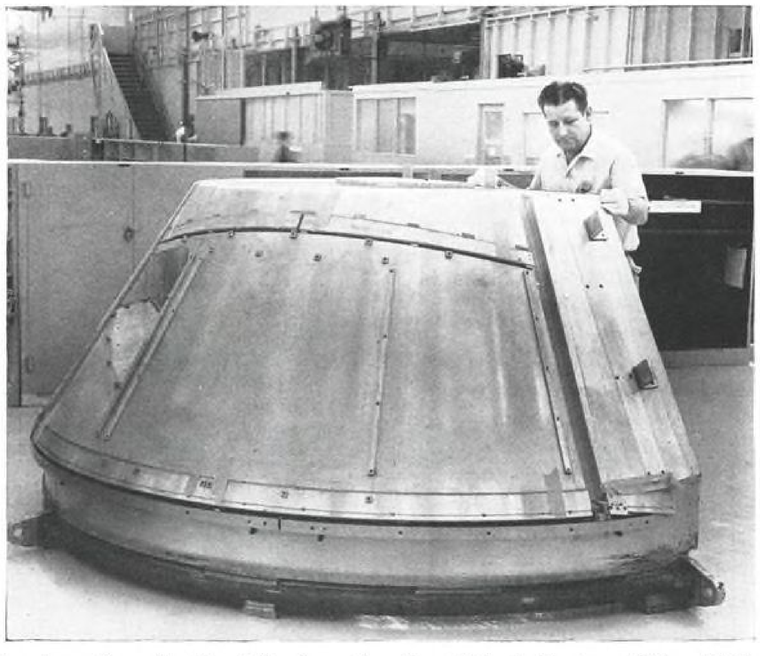
Air Express is also used to expedite customer crash programs, ship samples for testing and help customers keep their inventory low, too.

Mallory is convinced that Air Express is the one way to get dependable, economical, overnight delivery to and from any part of the country. See for yourself.





APOLLO COMMAND MODULE underwent a series of flotation tests in the Pacific Ocean off Downey, Calif. Cap has been jettisoned, as it would be on a flight. Below, worker inspects a bonding fixture for the inner wall of the command module.



in. down from the tip of the forward heat shield of the command module, giving a total combined length of launch escape system and command and service modules of 651 in.

The command module measures 133.7 in. perpendicularly from the tip of the nose cone to the bottom of the aft heat shield. Like the service module, it has a maximum outside diameter of 154 in. The service module is 182 in. long. The LEM adapter aerodynamic fairing between the service module and the S-4B stage will be slightly over 30 ft. long. During boilerplate flight testing, an insert or service module adapter will be employed to join the service modules to Little Joe or Saturn launch vehicles. The boilerplate inserts vary in length depending on the test mission and the boost vehicle that is being used.

Command module recovery system, called the earth landing system, is being developed by Northrop-Ventura.

(*Continued on p. 134*)



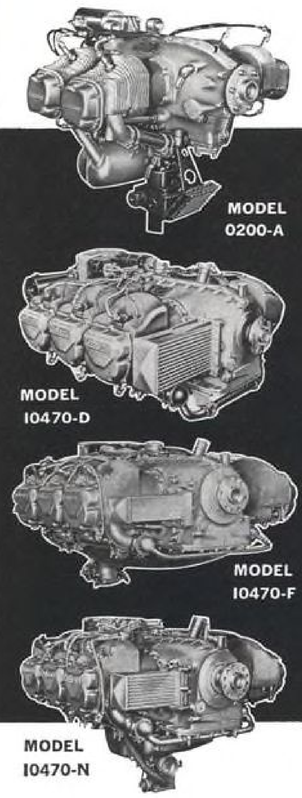
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The company has been qualifying the system since last December with two boilerplate command modules, dropped from a specially-configured Douglas C-133A at El Centro, Calif.

The parachute system, armed by the astronaut prior to re-entry, is activated by four mortars mounted around the airlock cylinder on the upper deck of the inner crew compartment. After arming the automatic sequencer, which provides the signal for jettisoning the forward heat shield, the chutes are deployed as follows:

- **Conical ribbon drogue,** with a 13.7 ft. maximum diameter, is mortar-ejected at 25,000 ft. Sabots are used to fire the chutes from the mortars. The drogue chute stabilizes the vehicle and is jettisoned prior to main chute deployment.
- **Three pilot chutes,** attached to the three main parachutes, are mortar-ejected at 15,000 ft. Pilot chutes are 10-ft. ringslot chutes and main chutes are 88-ft. dia. ringsail type.
- **Main chutes** are deployed in a reefed condition for 6 sec. Pyrotechnic cutters then cut the reefing line and main chutes bloom between 13,500 and 14,000 ft. to reduce final descent velocity to about 25 fps. Only two chutes are required to meet a 30-33 fps. specified velocity, and the third is included for higher reliability.

Command module is designed to withstand a 78g impact. Earth impact shock attenuation is provided by a seat suspension system with three degrees of freedom at all attachment points. Some attenuation also will be provided

Apollo Experiments

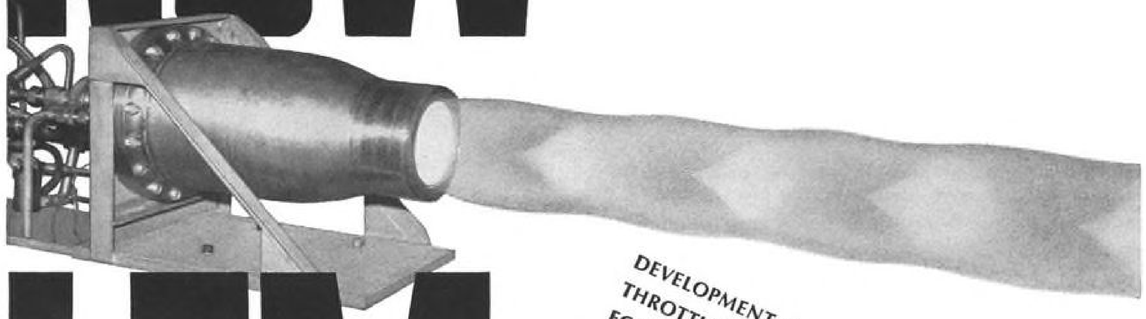
Two hundred pounds in weight and 10 cu. ft. in volume have been allotted for scientific equipment that will be carried to the moon in the first Apollo manned landing. Experiments will be carried in the Lunar Excursion Module (LEM) to the moon's surface and about 100 lb. of samples and data will be taken back when the lunar bug leaves the moon to rendezvous with the command module.

A NASA in-flight experiment panel will consider what experiments will go on board the craft. Maxime A. Faget, assistant director of the Manned Spacecraft Center for engineering and development, said selection will be made on the bases of scientific value, weight, volume and time required to operate the experiment, flight safety compromises required and acceptability to the Apollo crew.

First experiments are expected to deal mainly with selenology, including seismic soundings, and measurements of radiation and magnetism.

674

NOW LEM



DEVELOPMENT OF THE LEM THROTTLEABLE DESCENT ENGINE FOR PROJECT APOLLO IS NOW UNDERWAY AT STL'S SPACE TECHNOLOGY CENTER.

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PROGRESS REPORT ON STORABLE LIQUID PROPELLANT ROCKET ENGINES AT UTC

Projected space missions involving upper-stage storable liquid propellant rocket engines impose certain rigid performance requirements:

1. The propellant must be space-storable. Future flights will last for weeks or even months, and most conventional earth-storable propellants can seriously deteriorate before the missions are completed.

2. Engine weight will be critical, particularly when the task involves orbital rendezvous.

3. Specific impulse must be improved over the current performance level of earth-storable propellants.

4. Variable thrust control will be required for maneuverability in space.

■ At United Technology Center we are now devoting major efforts toward development of engines to meet these demanding performance requirements.

■ New fluorine-based propellants, proved in more than 20 recent test firings at UTC, provide 20-25% higher I_{sp} than conventional fuels; and these new propellants are storable in space.

■ Engine weight has been reduced significantly by using filament-wound propellant tanks and highly efficient ablation-cooled thrust chambers. (Our recent test-firing using ablative chambers with fluorine-based propellants is an industry first.)

■ We have developed engines of various sizes which will stop and start in space, and which have thrust control over a range of 1 to 100. The advanced throttling techniques use aeration and variable area injectors.

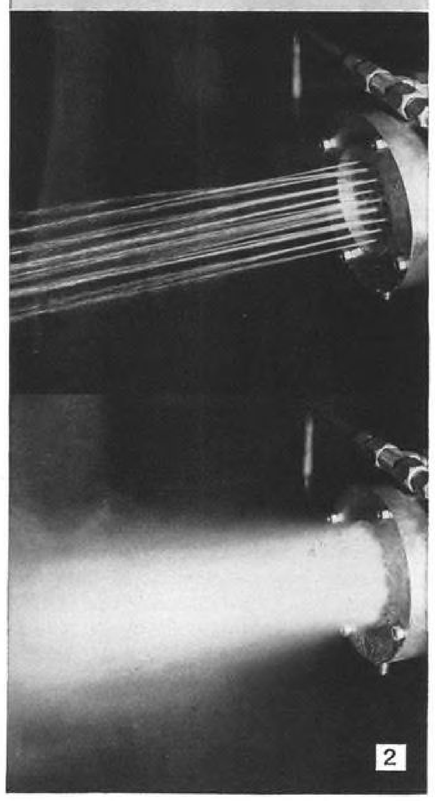
■ In addition to our work in liquid engines, we are developing hybrid rocket engines which will combine the best qualities of both solid and liquid propellant engines. And UTC is the prime contractor for the first stage of the Air Force Titan III C, which includes two 120-inch diameter segmented solid rocket motors. Together, these motors will generate over 2 million pounds of thrust at lift-off, more than 80% of the vehicle's total thrust.

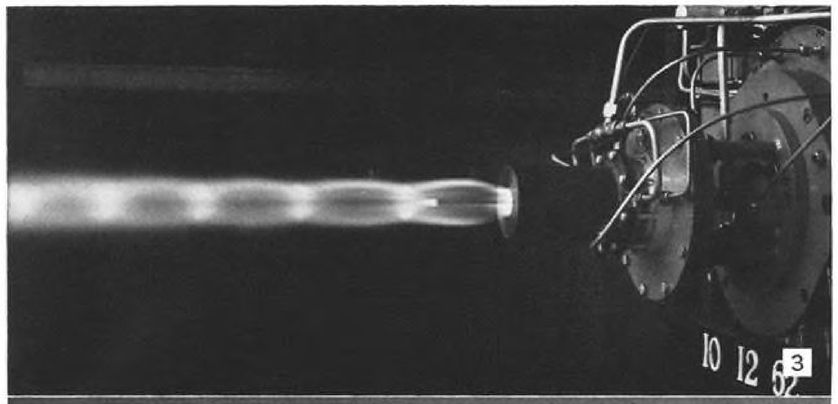
■ UTC's Sunnyvale headquarters have recently been enlarged and the Coyote Development Center's facilities are modern and extensive. Our 2,500 people provide us with a reserve of experience and talent. We have the men and machinery. This manpower and these facilities are devoted to advancing the state of the art for space propulsion.

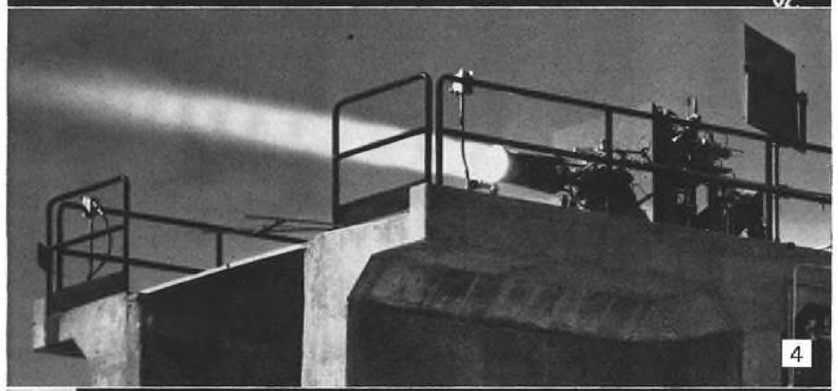
UNITED TECHNOLOGY CENTER

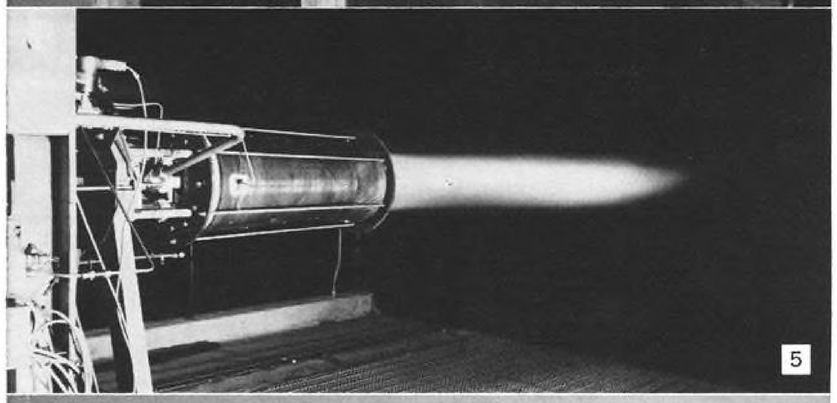
DIVISION OF UNITED AIRCRAFT CORPORATION

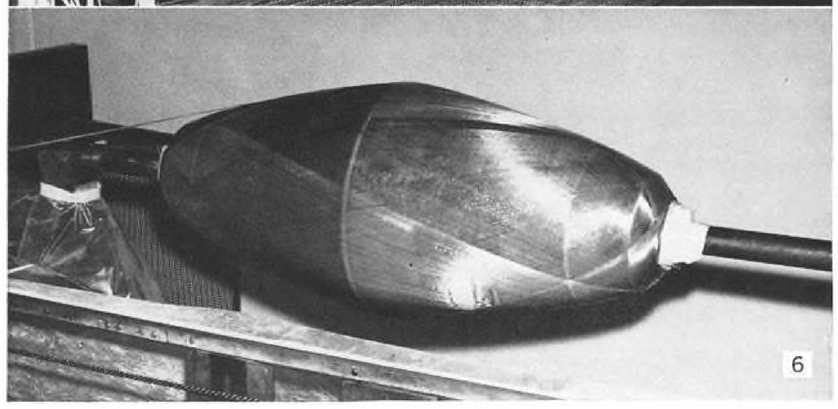

1


2


3


4


5


6

1. ABLATION-COOLED THRUST CHAMBER literally boils off its liner in order to cool itself. Ablative liners eliminate heavy, expensive tubing required for regenerative cooling systems.

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2. VARIABLE THRUST CONTROL over a 1 to 100 range is now possible with UTC's technique of aeration. Conventional propellant injection (top) does not allow reduction of rate of flow without danger of unstable combustion. Aeration throttling (below) diffuses propellant and gives precision control.

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3. SPACE SIMULATION TESTS prove the start-stop capability of advanced liquid propellant rocket engines. Flight-scale engines are hot fired in our test cells.

■

4. OVER 3,000 TEST FIRINGS have already been conducted at our three major test stands. This picture shows an engine using new fluorine-based propellants.

■

5. EXTENDED DURATION FIRING of lightweight storable liquid propellant engine achieved stable combustion and high efficiency over a period of almost twenty minutes in a recent test at UTC.

■

6. GLASS FIBER FILAMENT WINDING, a weight-saving fabricating technique, is being used for liquid propellant bottles for upper-stage engines.

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by the honeycomb structure from which the heat shield is jettisoned.

During pad abort, the automatic sequencer deploys the chutes automatically, and trajectories as low as 3,600 ft. would still give time for all chutes to deploy.

Normal pad abort maximum trajectory altitude is about 5,000 ft.

Launch Escape

The launch escape system used during pad abort or escape during the first phase of the flight employs a tubular tower framework to connect the command module to the launch escape motor. A tower jettison motor is mounted atop the launch escape motor, which in turn is topped by a pitch control motor and a nose cone. All motors are solid-fueled. Pitch control and launch escape motors are made by Lockheed and Thiokol makes the tower jettison motor.

In the event of an in-flight or on-the-pad abort, the 150,000 lb.-thrust launch escape motor would be fired to lift the command module away from the service module after the two modules are separated. Shortly thereafter, the 4,000-lb.-thrust pitch control motor would be fired, providing a sideways thrust for a ballistic trajectory. Explosive bolts jettison the tower from the command module and the earth recovery system sequence is then started.

Tower Jettison

In a normal flight, the tower jettison motor would be fired to remove the escape motor and its framework from the spacecraft. Pitch control motor would be fired at the same time. It is not desirable to fire the large escape motors for normal jettison in order to avoid flame or exhaust damage to the command module. The titanium tower framework will be coated with buna rubber to prevent oxidation and subsequent erosion during firing of the launch escape motor.

The Apollo spacecraft hardware program, although only 19 months old, has accumulated considerable research data. The wind tunnel program, which will be completed by the end of this year is expected to have provided a total of 4,600 hr. of wind tunnel test time, with 37 models undergoing tests.

Initial fabrication in the spacecraft program consisted of wooden mockups. A total of nine of these mockups were built and several still are used to keep up with program changes. Primary purpose of the mockups was to evaluate engineering designs, determine location of various equipment and interior cabin arrangement of systems and subsystems. The Lunar Excursion Module, being built by Grumman, is now in this phase of its development.

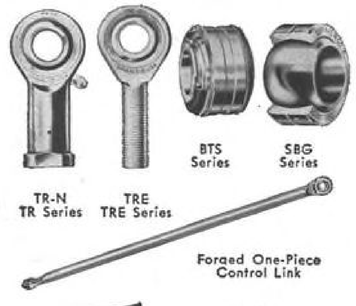
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Jack Faulkner speaks with authority on stress-relieved aluminum forgings

This man can help you make forgings behave during machining

ALCOA

ALCOA PROCESSES FOR LOW RESIDUAL STRESSES IN FORGED PRODUCTS

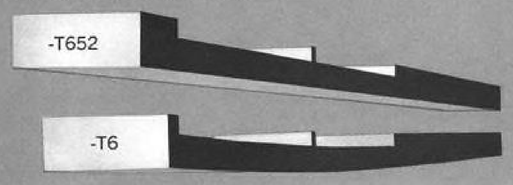
PROCESS	TEMPER. DESIG. (1)	ALLOY	PRODUCT (3)	"TYPICAL" REDUCTION FROM -T6 (1)		
				WARPAGE	STRENGTH (4)	STATUS
STRESS RELIEF (2)						
MECHANICAL DEFORMATION (STRETCHING)	-T651	ALL	HAND FORGINGS (5)	95% (6)	ZERO EXCEPT LONGITUDINAL CYS 5%	COMMERCIAL
MECHANICAL DEFORMATION (COMPRESSING)	-T652	ALL	HAND FORGINGS (5) DIE FORGINGS (7)	90% (6)	ZERO EXCEPT TRANSVERSE TYS 5%	COMMERCIAL

NOTES: (1) The use of the -T6 version of various tempers is for convenience only. The -T4 or -W temper is also available. (2) Processing is performed after heat treat and quench. (3) Products comprise hand forgings (including rings), die forgings and machined parts. (4) Guaranteed values, available on specific part inquiry. (5) Except parts tapered in thickness or otherwise impractical to process. (6) Based on observations by users; these values representative but subject to variation with geometry and machining details. (7) Subject to geometry of individual part; deformation may be all stretching, all compressing or a combination. Some parts cannot be effectively stress-relieved by this technique—see context.

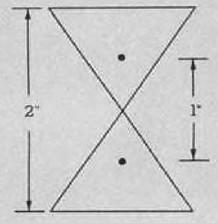


Jack Faulkner speaks with authority on stress-relieved aluminum forgings

Alcoa has recently instituted an identification system which provides positive evidence of proper compressive reduction. Prior to cold working, forgings are bench-marked with a special 1- or 2-in. gage length stamp. Measurement after working of the reduced distance between the punch points indicates the amount of compression obtained, thus permitting positive control within the specified range.



This photograph shows the warpage difference after machining in two pieces of a large hand forging (5 x 11½ x 140 in.); the -T6 piece bowed over 2½ in. compared to a little over ⅛ in. in the stress-relieved -T652.



Residual stress built up during quenching of aluminum forgings can cause trouble later when the forgings are machined. Machining unbalances these stresses. When a tool bites into a non-stress-relieved forging, it tends to warp, even jump out of the fixture or jig.

Little was known about stress relief until 1944, when Alcoa's Kirby Thornton first explained the principle of *stretching*. This method is still used on extrusions, plate and rolled shapes.

Stretching, however, proved impractical for some geometrical shapes—die and hand forgings and rolled or forged rings. But *compression* was found to relieve stresses just as stretching did!

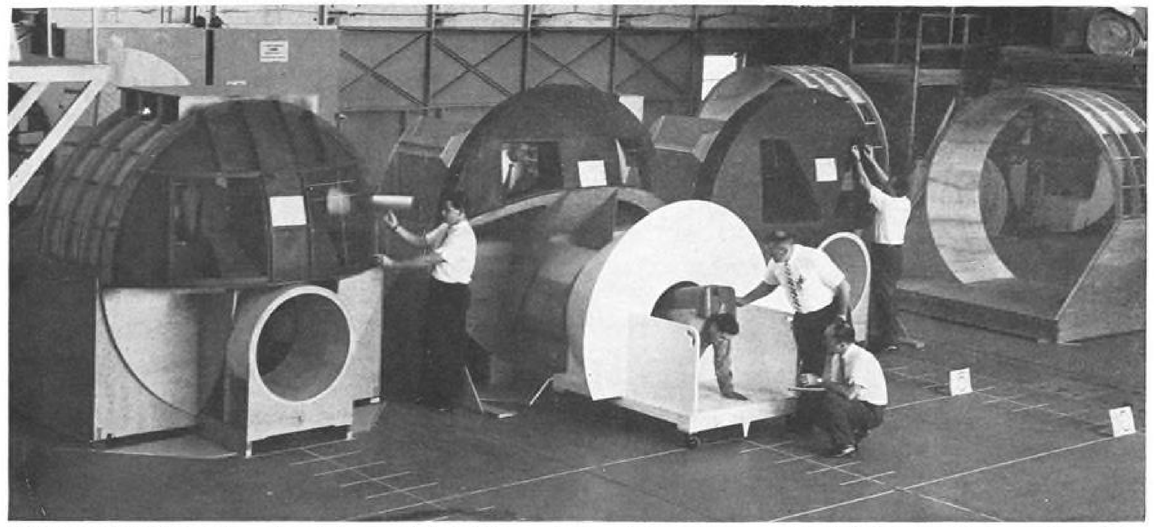
Jack Faulkner, who heads the Military Equipment Section of Alcoa's Cleveland Development Division, was one of the pioneers in working with stress relief by "squeezing." Today Jack offers Alcoa's customers years of experience in the complexities of this technique.

TIGHT TOLERANCES, MINIMUM WARPAGE—Compression stress-relieving makes hand and die forgings behave during subsequent machining operations. For instance, Alcoa recently made a hand forging in the form of a 90° arc of a 30-ft circle, with a cross section of 6 by 8 in. The customer had to do extensive machining, and assembly requirements called for a maximum departure from flatness and contour of .030 in. over its length of some 20-odd ft. Maximum warpage experienced during machining was .005 to .010 in.

Jack Faulkner is just one of hundreds of Alcoa's technical experts whose principal function is to help customers with metallurgical and fabricating problems. These "development men" are experienced engineers who have not only specialized in aluminum, but in specific industries. Jack, for instance, has worked almost exclusively with customers in the aerospace and military equipment industries for sixteen years. Have a problem that might involve aluminum? Just call your local Alcoa sales office. Or write Aluminum Company of America, 1868-U Alcoa Building, Pittsburgh 19, Pa.

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LEM MOCKUP NUMBER 1 consists of three cockpit shells for evaluating window placement and cockpit interiors. Center mockup window configuration, with 45 deg. slanted windows for downward visibility, is favored. Command module mockup is shown mated to forward tunnel to test docking interface. Latest LEM design probably will eliminate forward tunnel, however, in favor of single tunnel on top of vehicle. Lines on floor in foreground are used for field of vision measurements.

Preliminary Design Frozen on Lunar Bug

Bethpage, N. Y.—Preliminary design of Grumman Aircraft Engineering Corp.'s Apollo Lunar Excursion Module (LEM) has been frozen, paving the way for major subcontractors to begin designing subsystems.

Six major subcontractors have been chosen and seven more contracts are being definitized. Grumman is definitizing each subcontract in the same way the over-all LEM contract was negotiated with NASA (AW Dec. 10, p. 35).

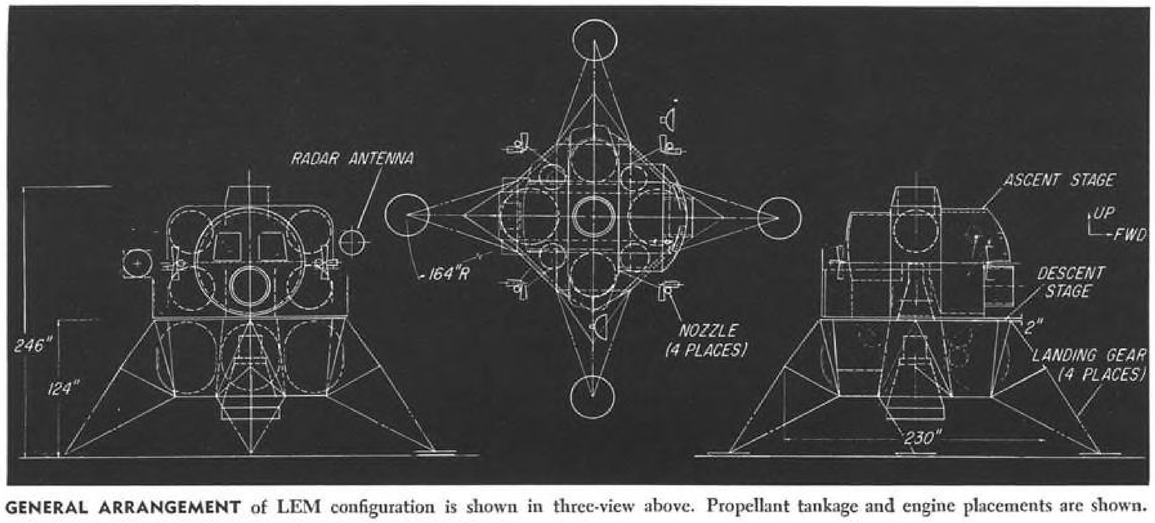
North American Aviation Inc.'s Rocketdyne Div. and Space Technology Laboratories have been chosen to pursue parallel descent engine development programs. Bell Aerospace Corp. will develop the ascent engine and Marquardt Corp. will develop the LEM's reaction control system.

United Aircraft Corp.'s Hamilton Standard Div. is developing the environmental control system. Radio Corp. of America will provide over-all systems engineering services for the LEM and also will develop the radar subsystems package (AW June 10, p. 36).

Contracts are yet to be awarded for the communications system, inflight testing, telemetry, recording systems, clocks, ground support systems, and the electric power generating system. The electric power competition has been completed, and contract winner is expected to be named shortly.

The LEM configuration has undergone basic changes since the first tentative design was revealed last fall (AW Nov. 26, p. 36). It now will stand 20.5 ft. high, including the descent stage and the four-legged landing gear, the latter having a radius of about 13.6 ft.

The ascent stage, which contains the cockpit, a docking tunnel and a major portion of the electronics and communications equipment, will be



GENERAL ARRANGEMENT of LEM configuration is shown in three-view above. Propellant tankage and engine placements are shown.





INTERIOR CLEARANCES OF LEM cockpit are tested with mockups above. Technician wearing Apollo backpack mockup (left) crawls through docking tunnel. Suspended from cable to simulate one-sixth gravity (right), technician tests mobility in the LEM cockpit.

about 10.2 ft. high and about 14 ft. wide. Maximum weight of the LEM will be 20-25,000 lb., with a full fuel load.

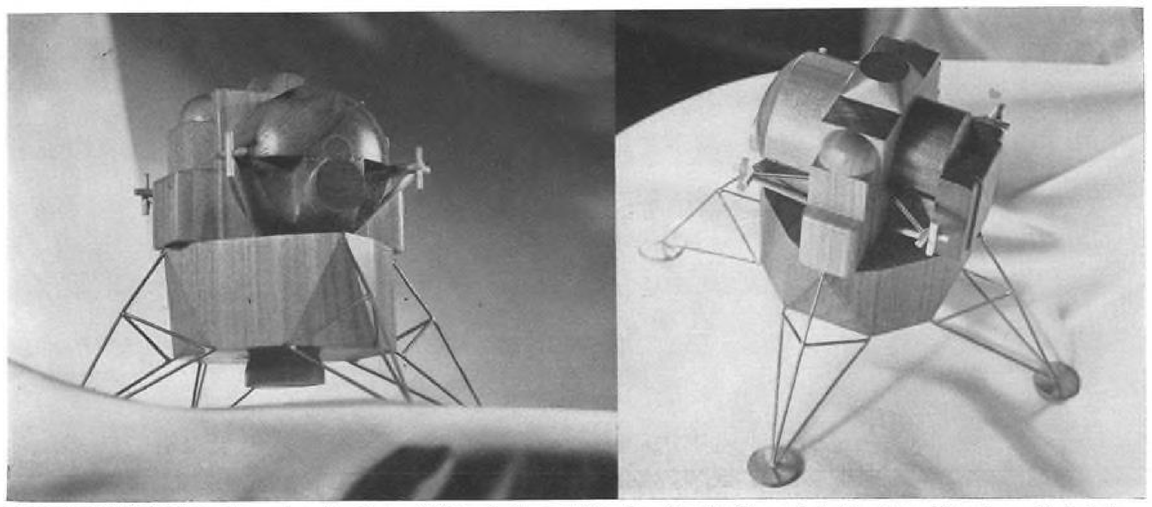
Anticipated lunar landing weight will be approximately 11,000 lb.

Nine test vehicles and 11 flight vehicles will be built for the first phase of National Aeronautics and Space Administration's Project Apollo effort to put two men on the moon for a brief period of exploration.

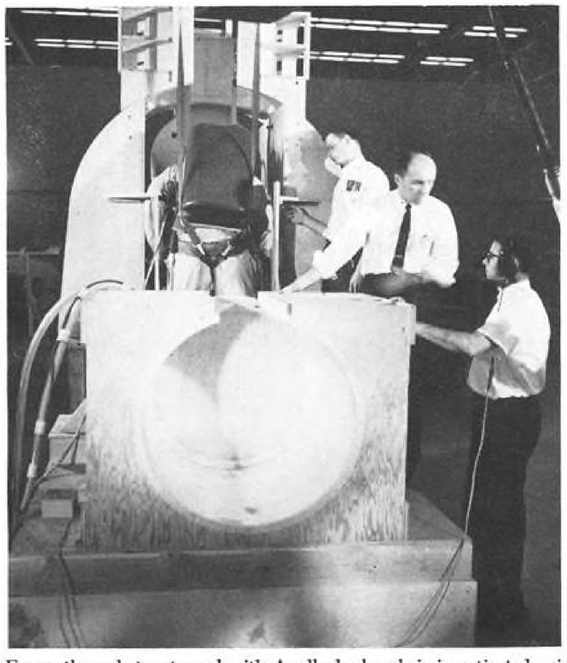
Grumman is building four wooden mockups and four test articles (TEMs) to test cabin layout, docking and stage interface characteristics and to further refine the configuration. Fifth and final mockup will be metal and will closely resemble the final vehicle. It is scheduled for completion early next year, when it will be used for the NASA design review.

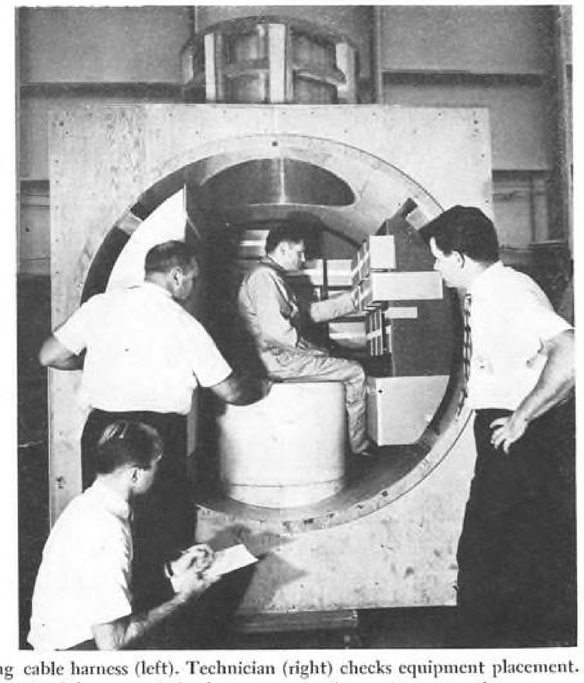
Basic LEM structure will consist of the four fixed landing legs, extending at about 45 deg. angles from the front, rear and sides of the vehicle. Final gear design has not been determined because so little is known about the lunar surface. The gear probably will consist of aluminum beam legs, each with a landing disc mounted on the lower end. Shock absorbers will be cylinders filled with crushable metal honeycomb.

Bottom stage of the vehicle will house the descent engine, which will control the LEM's approach to and landing on the lunar surface. Descent stage also will serve as the launching platform for the lunar takeoff and will house two oxidizer and two fuel tanks. They will be the same size, to help



WOODEN LEM MODEL photos show front view (left) and elevated side view (right). Forward docking tunnel has been eliminated.





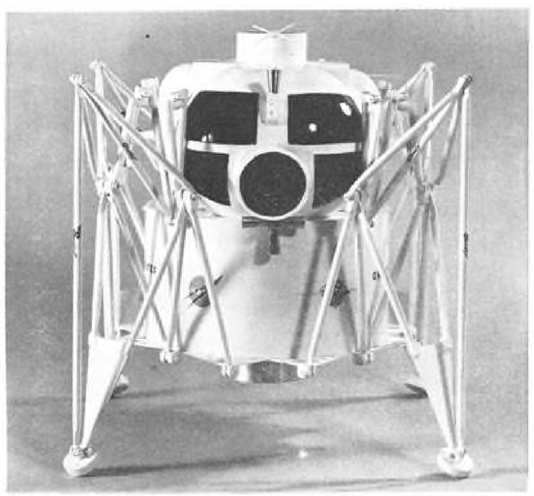
Egress through top tunnel with Apollo backpack is investigated using cable harness (left). Technician (right) checks equipment placement. The mockup in the center photos is referred to as the Peter Pan test stand because of the harness suspension system operation.

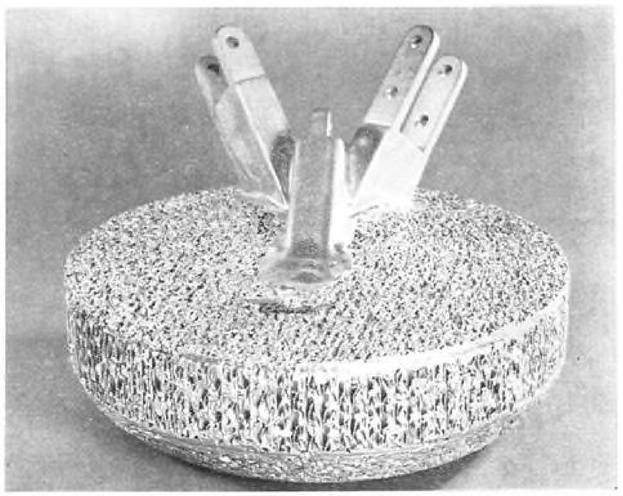
establish the center of gravity, and will be mounted between the main structural beams at the four landing gear attachment points. Oxidizer to fuel ratio will be 1:6.

Descent control instrumentation and scientific equipment not needed for the return trip from the moon will be housed in the lower stage to reduce the amount of fuel and engine thrust required in the ascent stage. Grumman studies have shown that six pounds of fuel are needed for every pound carried down to the lunar surface and returned. The ratio is four to one for every pound carried down but not returned. To save weight and to make as much fuel as possible available for the lunar takeoff, any equipment not essential for takeoff will be left behind on the moon.

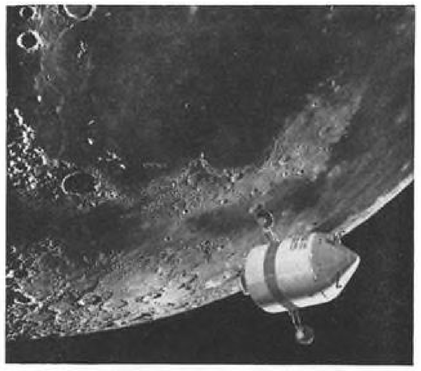
Mounted in the center of the bottom stage will be the descent engine. It will have a maximum thrust of 10,500 lb. and a throttlable ratio of 10 to 1. It also will have a 6 deg. gimballing capability to provide trim control during the hover and lateral flight modes called for in the lunar landing mission profile (see mission box on p. 161).

Rocketdyne's engine design employs an aeration injection technique and STL's will use a mechanically-controlled, variable-area injector with upstream vortex generators. The two designs will be evaluated after prototype firings next year and one will be chosen for the final system. Fuel for the propulsion system will be a 50-50 mixture of unsymmetrical dimethylhydrazine and hydrazine, with nitrogen tetroxide as the oxidizer. Propellants for the re-

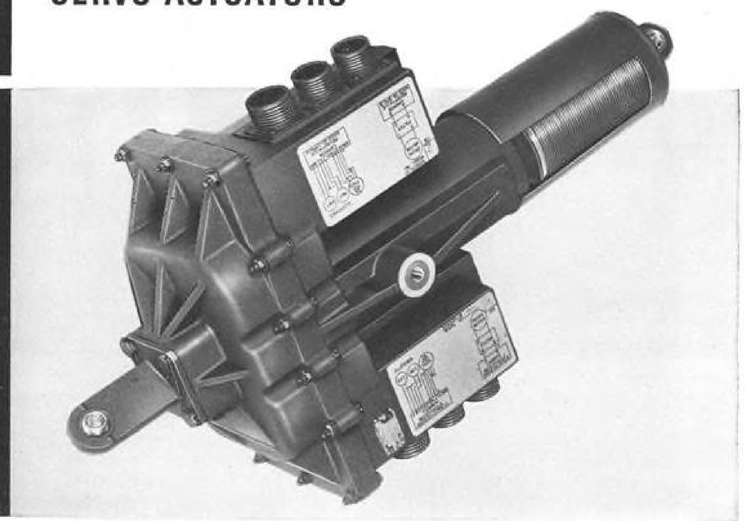


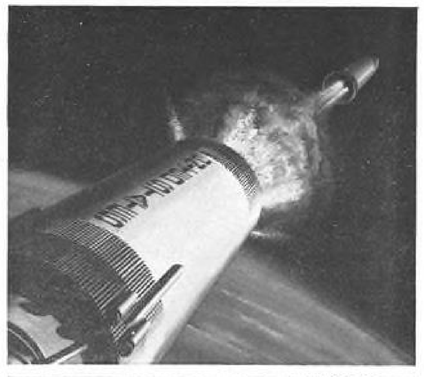


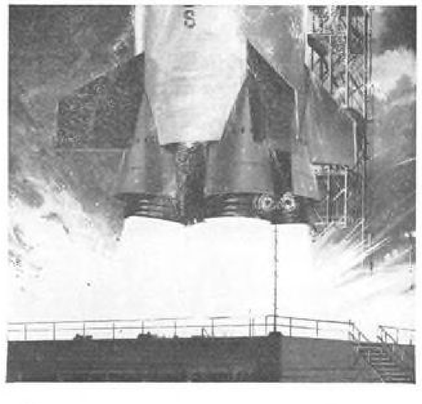
LEM GEAR DESIGN proposed to NASA by Bendix (left) is shown retracted. At right is aluminum honeycomb foot pad proposed by Bendix.



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LEM Flight Schedule Detailed

Mission assignments for the first 11 Apollo lunar excursion modules (LEMs) have been made. The first four will be unmanned and the rest manned. First LEM flight test will be either a Little Joe 2 booster ballistic shot or—if the Saturn 1B is ready—an earth-orbital test.

First excursion modules scheduled to be launched toward the moon are LEMs 8 and 9, and LEM 10 is to be the first lunar lander. Following is a summary of current mission assignments:

- LEM 1—If the Saturn 1B booster is not ready in time, this vehicle will be lofted into a 100 mi. high trajectory from the White Sands Missile Range by Little Joe 2. It will give designers a first opportunity to fire the vehicle's engines briefly in space.
- LEM 2—This vehicle is a backup. It could be used to repeat the trajectory shot or it could be flown as an orbital flight if the Saturn 1B is ready.
- LEM 3—The first orbital flight is scheduled for this vehicle. The unmanned bug will be launched from the Atlantic Missile Range on a Saturn 1B booster. The booster is scheduled to undergo flight test in 1965 and to begin manned Apollo launches in 1966, so LEM orbital flights will be conducted in late 1965 or early 1966. Purposes of this flight of several orbits will be to "space soak" the vehicle to determine if it will maintain a stable temperature, and evaluate subsystem performance after prolonged weightlessness.
- LEM 4—This will serve as a backup for LEM 3, but as with the previous backup vehicle a secondary mission will be assigned to it on successful completion of the LEM 3 mission.
- LEM 5—This vehicle will be joined with command and service modules for the first manned flight of the entire Apollo spacecraft. Booster for this flight, which will involve extended earth orbits, also will be the Saturn 1B. A small amount of fuel will be carried in each module to enable pilots to perform the LEM transfer maneuver, to practice crew transfer between modules and to test all engines in the spacecraft. Descent stage of the bug may be jettisoned to test the ascent engine.
- LEM 6—A second extended manned earth orbital flight will be performed with this bug and the command and service modules. Crew training will be continued, as will engine testing. Since the fuel supply will be limited, most of the engine testing might be done while the command and excursion modules are joined to prevent them from drifting beyond range of each other.
- LEM 7—This vehicle will serve as backup vehicle for the two previous flights, although secondary missions also are being considered for it.
- LEM 8—First manned flight to the vicinity of the moon will be made with this vehicle, which will be put into a circumlunar reconnaissance trajectory with the command and service modules. Booster for the flight will be the Saturn 5. Mission objectives will be to continue separation and docking training and to test mid-course correction techniques. Following circumlunar flight, during which extensive reconnaissance will be performed, the bug will be jettisoned and the crew will return to earth in the command and service modules, reentering in the command module alone.
- LEM 9—This vehicle will be used in the second Apollo spacecraft flight to the vicinity of the moon. LEM will be detached from the command and service modules while in a 100-mi. lunar orbit (see mission box, p. 161) and will be flown into the elliptical lunar approach orbit by two astronauts. Perilune of the orbit will be about 50,000 ft. and aplune, 100 mi. The elliptical path and orbital period will automatically bring the LEM back to a rendezvous position with the orbiting command and service modules every two hours. Number of lunar orbits LEM 9 will fly has not been determined. LEM 9 might be replaced with a specially designed reconnaissance module, which is now under study by Manned Spacecraft Center.
- LEM 10—This will be the first lunar landing vehicle. It will be launched on a Saturn 5 booster. Following the translunar transfer maneuver, it also will be injected into elliptical lunar orbit. At the 50,000 ft. perilune, the descent engine will be fired to brake it out of orbit. At 1,000 ft. it will hover and descend to landing.
- LEM 11—This vehicle will serve as the backup vehicle for LEMs 8, 9 and 10, and could be used for follow-on lunar missions.

action control system and the ascent stage engine will be the same.

The ascent stage will consist primarily of two pressurized cylinders—a 92-in.-dia. unit which will form the front of the vehicle and extend back through its center, and a 60-in.-dia. unit which will abut the rear of the larger cylinder and extend out as the vehicle's back.

The larger cylinder, which will house the cockpit, will have windows in the forward end. Window layout is still being explored.

Three forward capsule shells, grouped into Mockup Number One, have been built to study window placement for the cockpit. The final design probably will consist of two forward-visibility win-

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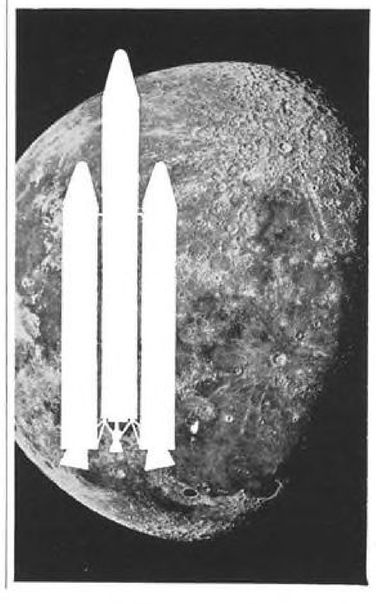
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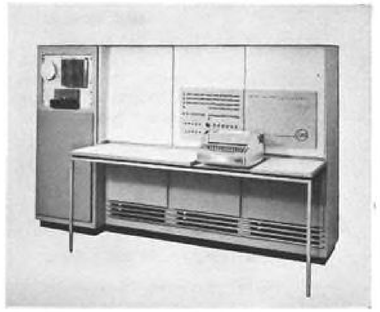


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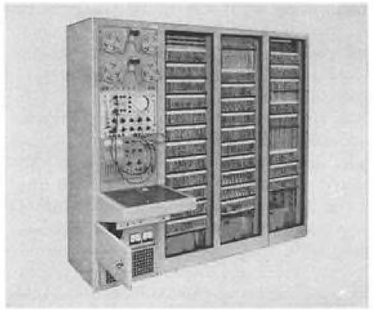
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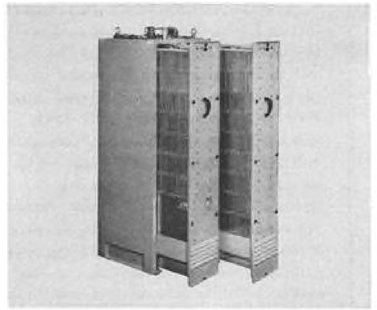
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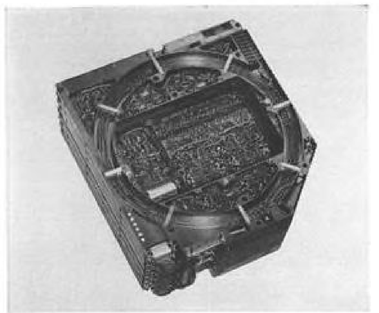
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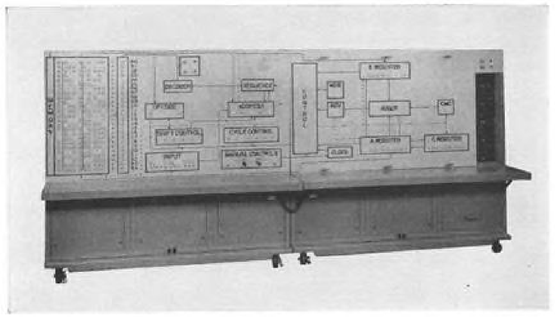
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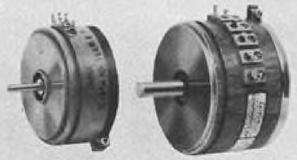
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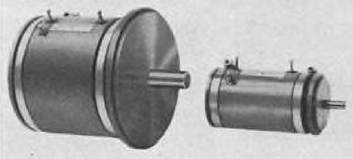
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dows, set at the eye level of the two astronauts, and two slanted in at 45 deg. angles near the floor for downward visibility during hover and vertical flight. Windows will be double paned.

Several window materials are being evaluated, ranging from plexiglass to new high-strength glasses such as the Chemcor silicon-based glass recently developed by Corning Glass Works. Weight will be a critical factor in their design.

Radiation Effects

Ultra-violet and infrared radiation also will be considered. Plexiglass becomes clouded when exposed to ultra-violet radiation, so protective coatings are being investigated. Ultra-violet radiation also can create a problem with the cockpit's environment, which will have a 100% oxygen atmosphere. Excessive ultra-violet radiation will form ozone, which could have deadly affects on the astronauts, so it will have to be filtered out.

Infrared radiation also will have to be filtered out to prevent excessive heat in the cockpit.

The cockpit environmental control system will draw on a liquid oxygen supply which will be shared with the electrical system's fuel cells. The oxygen will be used for crew breathing and also will be integrated into a cabin and electronic equipment cooling system. Electronic bays will be mounted on cold plates with a water and glycol mixture forming a heat transfer loop to the oxygen supply.

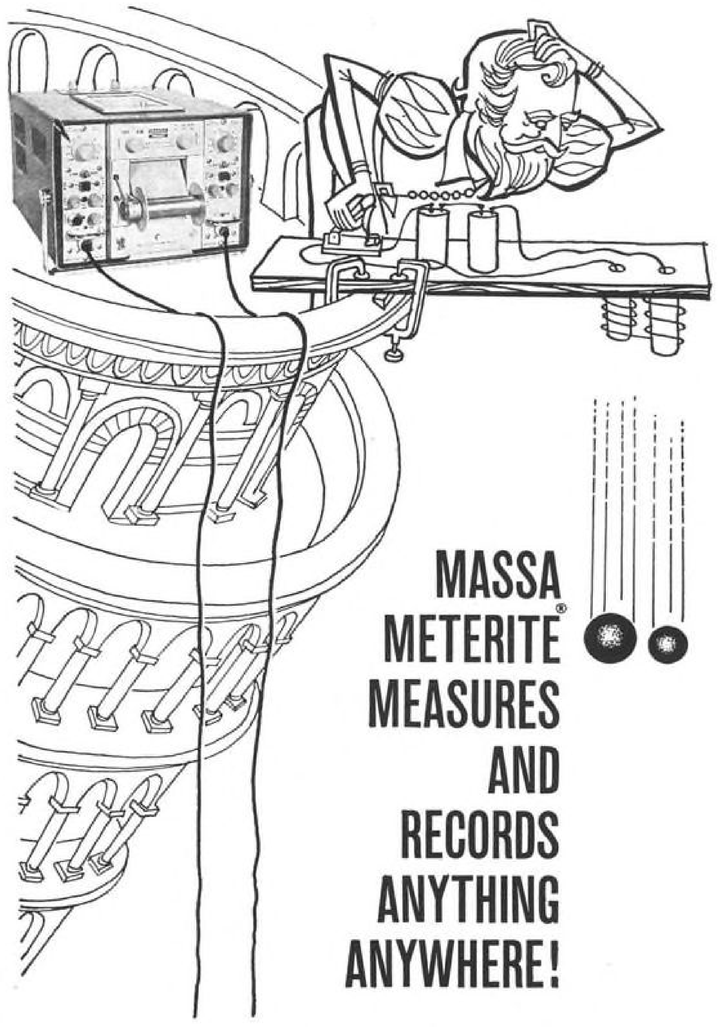
Cockpit Layout

Cockpit layout will resemble that of a conventional aircraft. The astronauts will be seated side by side, with the LEM commander on the left. Couches will not be required, since the LEM will not be occupied during high acceleration or deceleration. The LEM will encounter no atmospheric entry forces during the lunar approach and will be subjected to a maximum dynamic force of 4g in the landing.

LEM will be equipped with dual controls, which will consist of a small stick on the right for attitude control and a throttle on the left for thrust control, following basic aircraft control placement.

Instrumentation for attitude control, navigation and systems monitoring will be mounted on display panels in front of each astronaut and on overhead and side-wall panels. Projected mission profile calls for the vehicle commander to make the lunar landing, assisted by the other astronaut, who will act as an observer and perform other copilot duties.

The cabin will be pressurized at 5 psi., which will allow the astronauts to



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LEM Program to Include Nine Test Articles

Nine Apollo Lunar Excursion Module test articles (LTAs) will be built to work out subsystem placement and to qualify the vehicle's structural components and propulsion units. LTA 7 will have complete subsystems installed and will closely resemble the final vehicle.

LTA development sequence will be as follows:

- LTA 1—Electronics subsystems will be installed in this basic vehicle shell to work out equipment placement and line routings. LTA 1 also will be used for the first NASA ground checkouts of LEM subsystems.
- LTA 2—Stability drop test model for testing LEM landing gear structure. The descent stage and ascent stage will be represented with a mass equalling their design weights. Initial drop tests will be conducted at Grumman. Test vehicle then will be shipped to the Marshall Space Flight Center for further drop and shaker tests.
- LTA 3—For evaluation of LEM structural components and design characteristics through extensive drop and shaker tests. The LEM structure will be qualified with LTA 3.
- LTA 4—Prototype environmental control system will be installed for development testing in Grumman's environmental chamber. A simulation of internal heat loads will be included.
- LTA 5—For testing ascent and descent engines and the reaction control system as a prelude to propulsion system qualification tests. The vehicle will consist of a LEM shell with both engines, the reaction control system and limited tankage. Propulsion unit development will continue through 1964. By mid-1965 LTA 5 probably will be shipped to NASA's new Apollo test facility at the White Sands Missile Range in New Mexico for final propulsion qualification tests.
- LTA 6—Interface vehicle for North American Aviation's use in over-all Apollo spacecraft integration tests. North American, as prime contractor, is responsible for designing the docking mechanism and the fairing skirt which will enclose the LEM on the launch vehicle. NAA also will have to refine all systems interfaces between the LEM and the command module to ensure that electrical and communications connections are in line. NAA will then test the joined vehicles in a vacuum chamber.
- LTA 7—For qualification testing at Grumman of the environmental control and electrical systems. The finished system will then be sent to Manned Spacecraft Center to be tested in the new Clear Lake vacuum chamber. LTA 7 will be constructed to resemble the final flight vehicle as closely as possible.
- LTA 8—For use in a series of propulsion unit tests in the earth's atmosphere. Tethered tests will be conducted to evaluate the ability of astronauts to maneuver and hover by varying engine thrust. Calibration tests also will be run on equipment and instrumentation while the engines are firing.
- LTA 9—Full-scale power descent tests will be conducted with this final test vehicle, with the engines modified to operate in the atmosphere instead of a vacuum. Since the propulsion system will not be efficient in the atmosphere, the vehicle will have to be lifted off the ground by a crane or large helicopter. The descent engine then will be started, and the vehicle's hover and descent capabilities will be tested. The projected mission calls for manual descent from 1,000 ft. for the lunar landing, so the best simulation could be made by carrying the vehicle to that altitude under a helicopter. Grumman has held preliminary talks with the Sikorsky Div. of United Aircraft Corp. about using the S-64 helicopter for the tests.

open their faceplates. Astronauts will not fly the LEM in their "shirtsleeves," however, since they will be in it for a relatively short time and its cramped quarters would make removing and donning a space suit difficult.

The smaller cylinder will house flight guidance and communications subsystems. It also will be pressurized to protect sensitive equipment. The length of this cylinder will be dictated by the amount of equipment which requires pressurization. Location of the LEM center of gravity also could vary the length of the smaller cylinder. It may be lengthened to house equipment not requiring a pressurized environment if this would help establish the center of gravity where Grumman engineers want it—at the intersection of the vehicle's three axes.

Attached to the rear of the smaller cylinder will be a rectangular equipment bay to house electronics and communications gear that does not require pressurization, such as the fuel cells and fuel cell reactants. Liquid hydrogen will be used with the oxygen in the fuel cells to provide the primary source of electrical power. A peak-load battery will be included in the circuit and will be cut in automatically during periods of maximum power drain. This will permit a lighter weight power generating system geared to meet the lower average power demands.

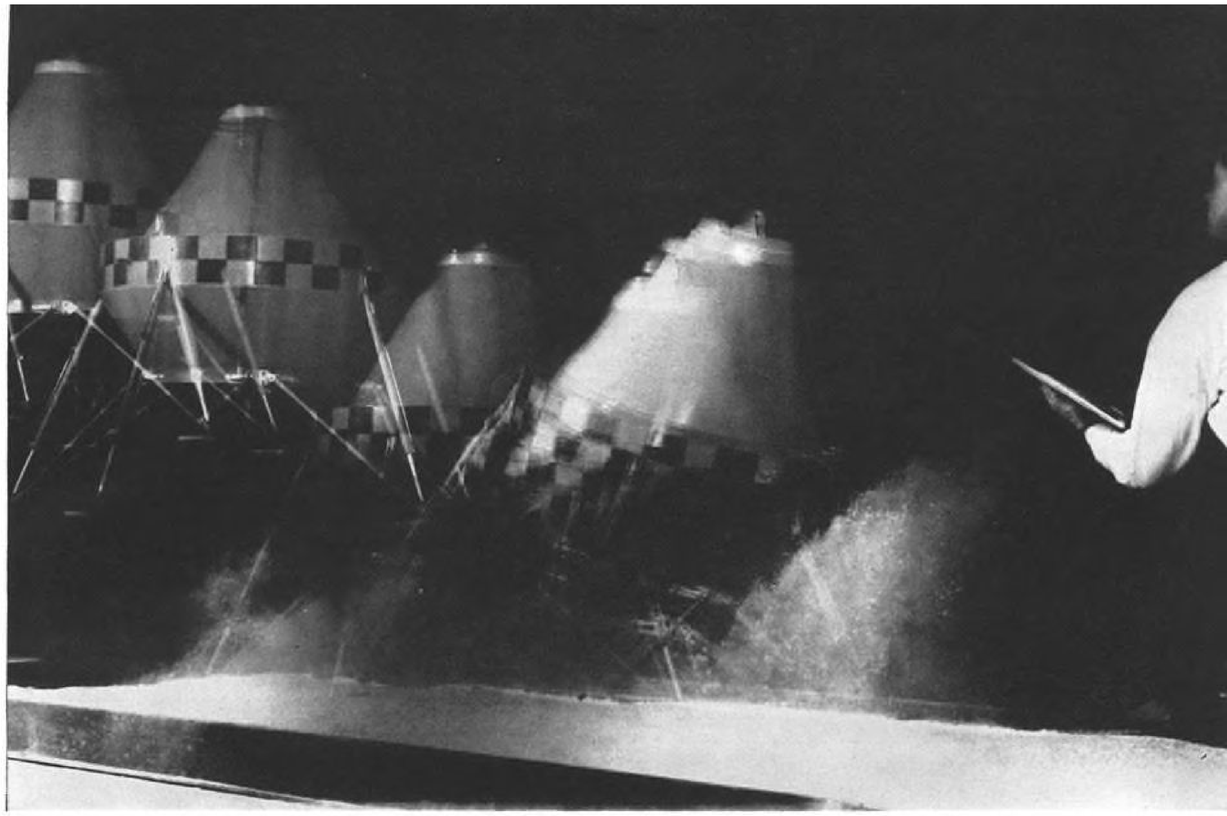
An oxygen and a fuel tank of equal size will be mounted vertically on the



Tests conducted by Republic Aviation Corp., Farmingdale, N.Y., under a contract awarded by International Latex Corp., developer of the suit for United Aircraft's Hamilton-Standard Division, NASA's prime contractor.

The other day, at Republic Aviation's Life Science Labs, where we are running the life-support and mobility tests on the Apollo Space Suit, somebody asked the guy in the suit how the tests are going, and he said:





ONE-SIXTH SCALE model of an Apollo Lunar Excursion Module simulates a lunar landing in a bed of pumice dust at Langley Research Center. Gear of this model used yielding-metal energy straps for impact attenuation.

side of the ascent stage cylinders, with the oxygen tanks set on top. Strapped to the outside of the fuel tanks will be saddlebag compartments containing oxidizer, fuel and pressurized helium tanks for the reaction control system. All tanks will be enclosed in squared-off fairings, giving the ascent stage the appearance of a rectangular structure with a large cylinder extending from the front face and a smaller one extending from the rear.

Fabrication Details

Skin material for both stages will be welded aluminum, 0.04 in. thick along the welded seams and chemically milled in between to save weight. Pressure cylinders will have double wall construction, with a 2-2½-in. layer of aluminum Mylar insulation in between. Aluminum channel beams will be welded lengthwise between the skin layers as structural members.

Some aluminum brazed or bonded honeycomb may be used in the LEM structure for micrometeoroid shielding and a limited use of titanium is being considered, especially in the cryogenic tanks. No use of magnesium or exotic metals is contemplated.

Micrometeoroid shielding will be wrapped around the descent stage, forming a skirt with a modified octagonal shape. Shielding also will protect the pressure cylinders, the propellant tanks and the rear equipment bay.

Aerodynamic qualities were not considered in the design, since the LEM will not fly in an atmosphere. Primary aim was to develop a practical design that embodied enough pressurized volume to protect the crew and all sensitive equipment and then to balance this with unpressurized compartments and fuel tanks in a way that put the vehicle's center of gravity at the intersection of its three axes. A completely pressurized vehicle would have exceeded the weight limitations of the LEM design.

The ascent stage engine is located at the vehicle's center of gravity and has its fuel lines and associated plumbing protruding up through the floor of the main pressurized chamber, just behind the crew positions. This puts vital engine components within easy reach for adjustment and repairs, both on the launch pad and on portions of the flight. When the two stages are together, the ascent engine nozzle is inaccessible in its compartment just above the descent engine.

Bell's ascent engine will produce 3,500 lb. thrust and will have a fixed-area injector. Varying propellant flow will produce a throttling ratio of about 3 to 1.

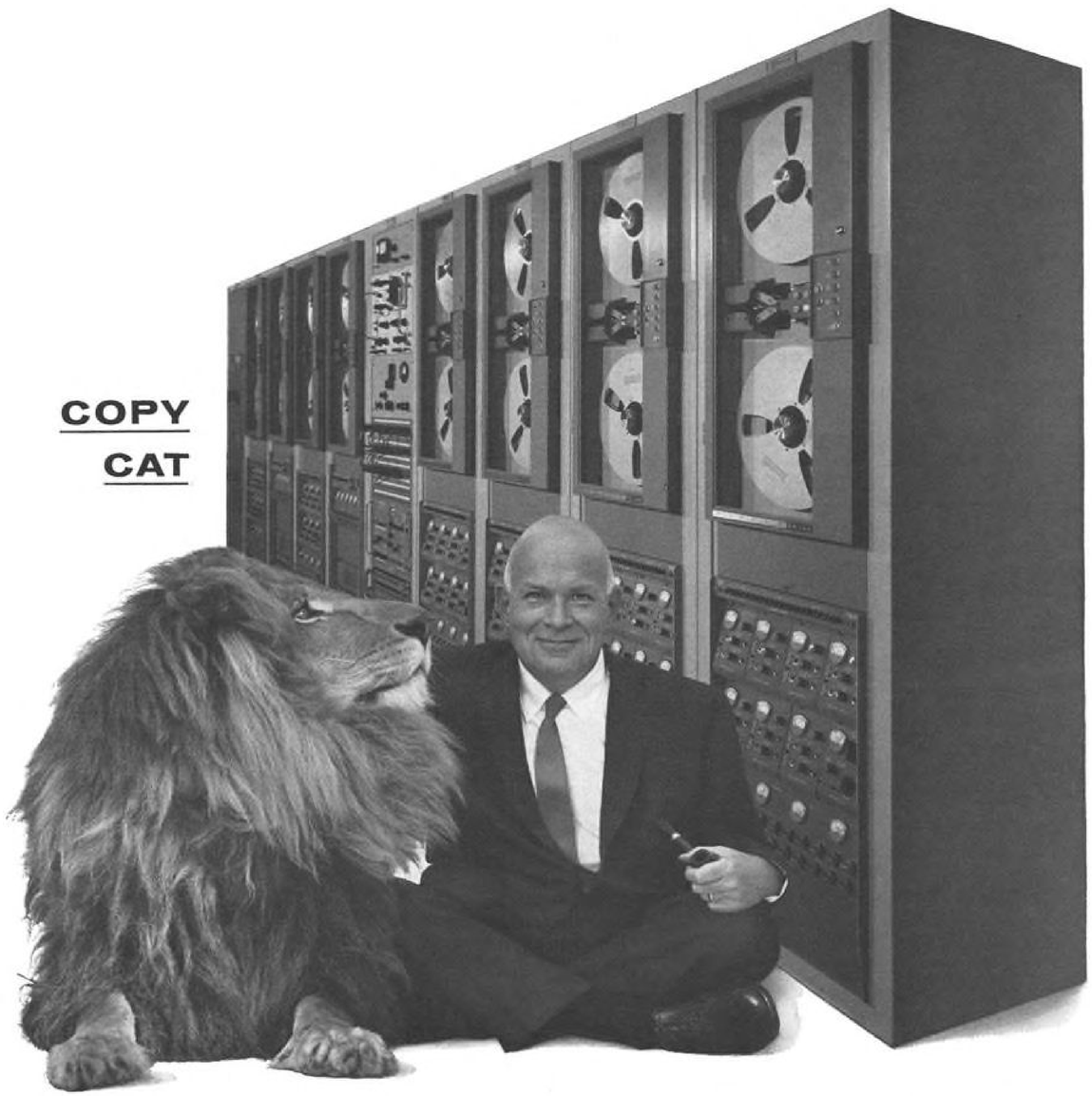
Since the two stages will be set together at the time of ascent stage lift-off, a potential "fire in the hole" problem was encountered. Clearance will be allowed around the descent engine to permit rocket blast from the ascent engine to pass through, but there is a possibility this opening could be plugged during a rough landing or a landing on a soft surface. The rocket blast in the plugged hole could pose serious heating problems.

Martin Co. Study

Martin Co. was given a contract to study the problem because of its experience with a similar situation on the Titan 2 ICBM. The Martin study concluded that since the rocket exhaust in a vacuum tends to flare out horizontally, the problem could be solved be providing an exhaust vent between the vehicle's two stages.

This may be accomplished by building the vehicle with a small gap between the two stages, or by running exhaust ducts from the ascent engine nozzle chamber out to the four corners of the vehicle.

Above the ascent engine compartment is a vertical, 32-in. dia. docking tunnel which extends up through the LEM's roof. This tunnel will be connected to the cockpit by an airlock, but will not pierce the pressure chamber. The docking tunnel will be used in the



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Six 1.5-mc Mincom CM-100 Recorder/Reproducers form the backbone of an extremely complex tape copy station recently delivered to the Atlantic Missile Range, through Defense Electronics, Inc., Rockville, Maryland. Set up at AMR last March, the station makes possible for the first time as many as five first-generation copies of prime data tapes in one operation. In addition to the six CM-100's, it also includes two 600-kc Mincom G-100's, two degaussers, and an advanced monitor alarm system policing forty-two 1.5-mc channels. The station is the result of Mincom's long experience with frequency responses of better than 1 mc—an outstanding reliability record since 1955.

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translunar transfer maneuver, during which the Apollo command and service modules will be rotated to attach the LEM to the nose of the command module. This will permit the two astronauts to enter the LEM for preliminary systems checkouts during translunar flight and later for the separation and descent from lunar orbit to the lunar surface.

A forward facing tunnel had been considered for docking following ascent from the moon, since it would permit the returning astronauts to fly straight into the docking maneuver with the command module. Forward tunnel now probably will be eliminated to simplify the design. Docking after ascent from the moon will be made with the top tunnel. Astronauts will use some form of an extendable telescope for visual reference.

In docking, the conical tip of the command module will fold back, exposing a smaller diameter tunnel section which will slip into the LEM's tunnel. Crewmen will then crawl through airlocks to move from one vehicle to the other. Devices to guide the tunnel sections together and to lock them are under development.

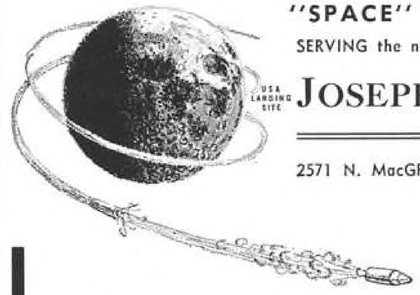
The ascent stage also will have equipment compartments under the equipment pressure chamber to house components that require little or no servicing. Accessibility has been a key consideration in the LEM design, with all components that will require maintenance, either on the launch pad or during flight, put within easy reach.

LEM attitude control will be provided by four reaction control quadrants set on pylons which extend at 45 deg. angles from the corners of the vehicle. This location keeps their jet blast away from the windows and the landing gear. Each pylon will have four nozzles, two set horizontally at right angles to each other and two vertically opposed.

This nozzle orientation puts two sets of eight reaction jets at the astronauts' command, providing sufficient redundancy to preclude total failure of the system. An entire thruster quadrant could be lost without affecting control. The thrusters will be identical to the ones Marquardt is building for the Apollo command module, as part of the effort to use as many common components in the Apollo vehicles as possible (AW Jan. 14, p. 39).

Since a common propellant mixture will be used in the engines and the reaction control system (RCS), provision will be made for one-way transfer of propellants from both main engine supplies to the RCS tanks. This will simplify the fuel system and extend the RCS capability, giving a variety of attitude and position control modes.

During rendezvous and docking after



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return from the lunar surface, for example, the LEM commander may want to rotate his vehicle and use the ascent engine for large position changes or rapid decelerations. He also may draw on the same fuel supply for repeated smaller changes in the RCS. Under the worst lunar landing abort conditions, rendezvous could take up to 17 hr., and the main fuel system would greatly extend the reaction control system's capability.

Design Frozen

With preliminary design work now frozen, Grumman's main effort now is focused on refining the configuration, definitizing the subcontracts and organizing the engineering and manufacturing team.

The LEM program will be fully projectized except at the lower supply and manufacturing levels, where the program will rely on basic corporate capabilities. The LEM project is located in Grumman's new Aerospace Engineering Center. Interface with the rest of the company is provided by Joseph Gavin, vice-president and head of the Programs Div., who monitors the program and coordinates its activities and needs with over-all Grumman corporate functions.

The LEM staff now numbers about 900—about 750 in management and engineering and 150 in manufacturing. Peak engineering staff will total about 1,200 and the manufacturing force ultimately will number more than 3,000 employes.

The LEM work is headed by Program Manager Robert Mullaney and his assistant, Frank Canning. Mullaney, who reports to Gavin, has five managers working for him. They are: William Rathke, engineering; Ted Moorman, test; John Snedeke, business; Joseph Kingfield, quality control; and William Bruning, manufacturing.

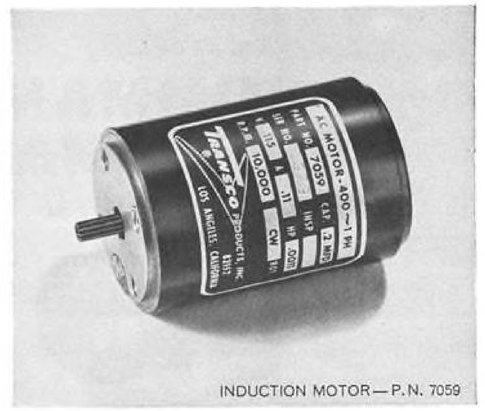
NASA Relationship

Interface between LEM program office and NASA is provided through an Apollo Spacecraft Project Office at Grumman. This resident office is headed by John W. Small, Jr., who coordinates the Grumman effort with the Apollo Spacecraft Project Office at NASA's Manned Spacecraft Center in Houston.

Small deals primarily with Gavin, Mullaney, and the five sub-managers, but interface lines are not sharply defined and the NASA team is free to deal directly with all levels. The NASA resident office now has a staff of about 25 but it may grow to 30 or 35 by the time the LEM production effort is fully underway.

First hardware to be produced will by the nine LEM test articles (LTAs). They will be used to determine final

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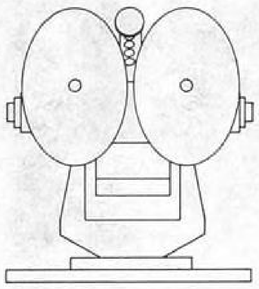
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Radio command guidance, developed for the U.S. Air Force Atlas Program, has again demonstrated outstanding performance—guiding Atlas 130D to insert NASA's *Faith 7* spacecraft precisely into the exact point in space for its 22 earth orbits.

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Successful in its command performance at every Mercury-Atlas launching, General Electric's radio guidance system has also been selected to control launch of the modified Titan II vehicle and its 2-man Gemini spacecraft. Such missions demonstrate the accuracy, reliability, and system flexibility achieved by a continuing *Accent on Value* at General Electric's Radio Guidance Operation, Syracuse, New York.

AEROSPACE AND DEFENSE GROUP GENERAL ELECTRIC

COMMAND PERFORMANCE



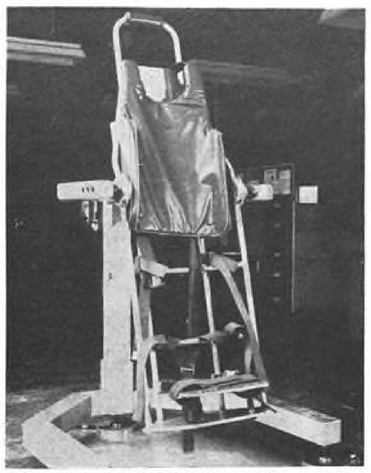
placement of subsystems, to qualify the LEM structure and to test the vehicle's propulsion units (see box on p. 151).

Flight testing of the LEM will be conducted in stages. First flight may be a ballistic shot using a Little Joe 2 booster, followed by prolonged earth orbital flights using the Saturn 1-B booster (see flight schedule box on p. 145). Earth-orbiting LEMs probably will be disposed of by letting their orbits decay until the vehicles burn up in the earth's atmosphere.

Manufacture of LEMs for use in the flight tests will be started during this fiscal year, but their development will be phased to take advantage of design information obtained with the test articles. Earth orbital flights will be made with LEMs 3 through 7. LEMs 8 and 9 will be flown to the vicinity of the moon, with LEM 9 possibly entering the 50,000 ft. lunar orbit—which will be the first step toward landing on the moon. LEM 10 will be the first lunar landing vehicle.

Since little is known about the lunar surface, a wide variety of landing conditions had to be taken into consideration. To design the landing gear and work out the landing approach and touchdown pattern, surface coefficients of friction ranging from zero to infinity had to be considered. Grumman engineers think the present gear design, the inherent stability of the LEM and the vertical approach to landing from 1,000 ft. will permit a safe landing, despite possible adverse surface conditions.

One problem, however, is the unknown size of small obstructions such as boulders or lunar surface features



FIVE-DEG.-OF-FREEDOM platform being built for NASA by Martin Co. will be used to simulate extra-vehicular activities. Platform floats on air cushion, and will be used to evaluate space suits, stability devices, etc., which might be operated.

PROBLEMATICAL RECREATIONS 180



The numbers one through seven are drawn from a hat without replacement. In how many ways will the sequence be alternately increasing and decreasing after the first choice, assuming a random selection? — *Contributed*

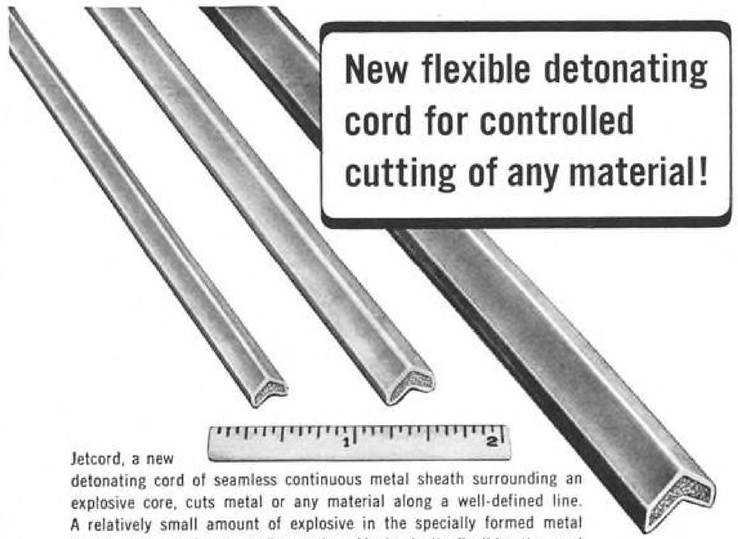
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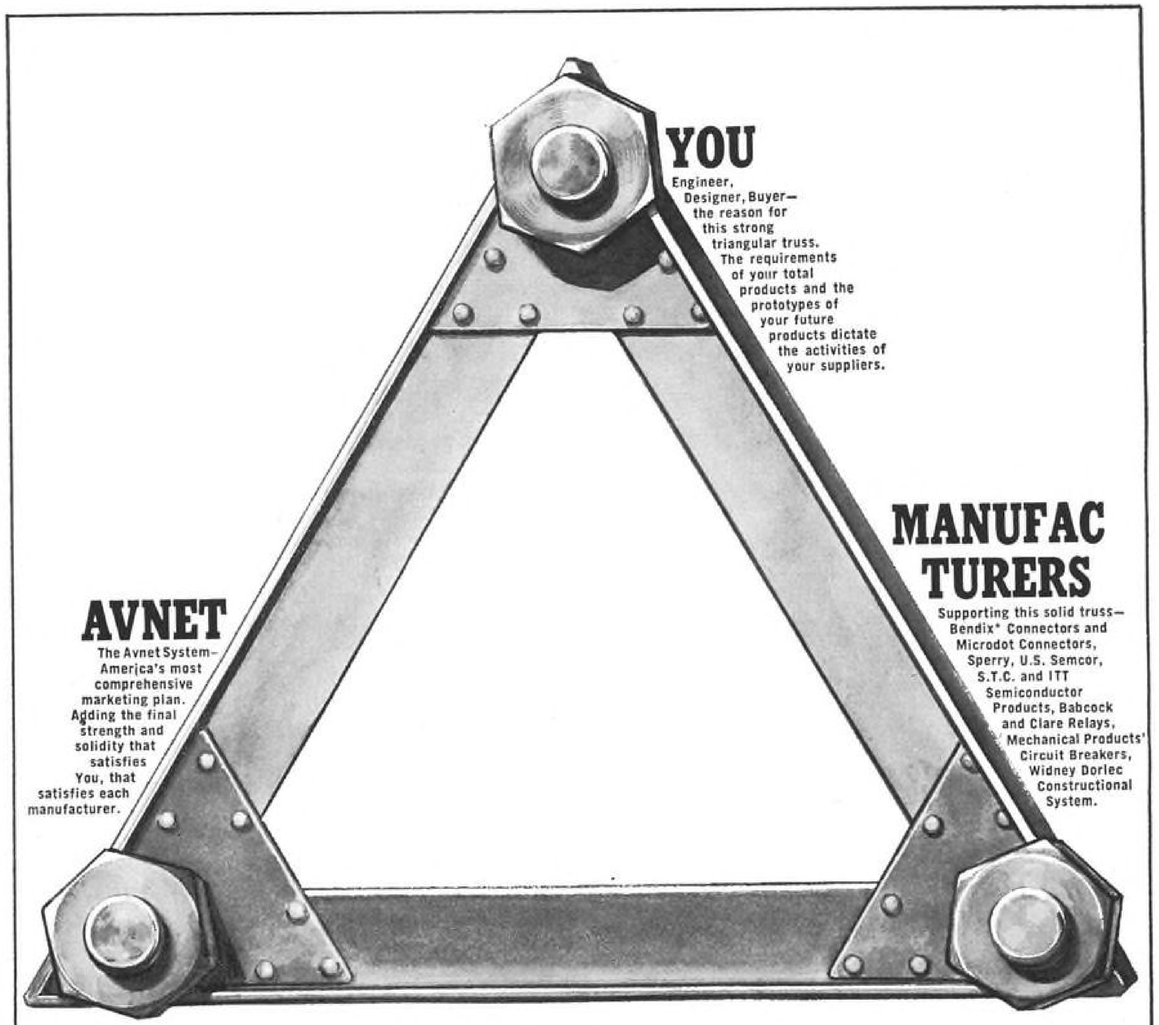
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which might not be detectable in reconnaissance flights. Grumman engineers expect some data to result from surface exploration programs such as Surveyor, which will put a roving vehicle on the moon.

This data probably will be limited, however, leaving final selection of the touchdown point up to the astronauts. This could be further complicated by the fact that touchdown will be made in a dust cloud raised by the rocket blast. A radar altimeter and autostabilization system will be used to control the touchdown, but surface obstructions still could pose a problem.

For this reason, the landing gear will be designed to permit landings with tilt angles of at least 15 deg. Using the reaction control system, takeoff from a tilted position probably could be accomplished with little difficulty.

Lunar Bug Mission Sequence Outlined

Apollo Lunar Excursion Module (LEM) will be carried beneath command and service modules during launch and in the earth parking orbit, and will be exposed shortly after the Saturn S-4B stage injects the Apollo into its translunar trajectory.

Portions of the adapter fairing will be shed, freeing the command and service modules from the LEM bug, which will remain attached to the S-4B stage. The command and service modules then will be rotated and the command module will dock with the top access tunnel on the bug. The S-4B stage will be jettisoned and two of three pilots in the command module will enter the LEM to begin preliminary systems checkout. Checkout will last about an hour and the pilots will then return to the command module for the remainder of the 72 hr. trip.

Mid-course corrections will be made with the 22,000-lb. thrust service module engine. It will be used a second time to slow the spacecraft and place it in a circular orbit about 100 mi. above the lunar surface. The two astronauts will re-enter the bug, separate it from the command module and roll it to an inverted position. The descent engine will propel the LEM down to about 15 mi. above the lunar surface, at which point it will be rotated upright again.

At an altitude of approximately 10 mi. the LEM will be injected into an elliptical orbit with a perilune of 50,000 ft. and an aplune that would bring it into rendezvous with the command and service modules every two hours. This will give LEM an automatic mission abort capability. If the astronauts experience difficulties at the 50,000 ft. point, they can rejoin the command module by letting the bug coast through to the high point of its orbit.

If the landing attempt is continued, the pilots will rotate the LEM at 50,000 ft. and use the descent engine to descend to a hover at about 1,000 ft. At this point the mission calls for zero forward speed. From the 1,000-ft. hover, the pilots will be able to fly the craft laterally 1,000 ft. in selecting the best landing spot. Descent from 50,000 to 1,000 ft. probably will be controlled automatically, since rapid fuel consumption of the descent engine will pose weight-to-thrust balancing problems.

Descent from 1,000 ft. to landing will be controlled manually, with one pilot flying the vehicle and the other acting as observer. At all times through hover, the command module will be overhead, so the astronauts could ascend to rendezvous in case of a landing abort.

Immediately after landing, the astronauts will run a pre-launch checkout on all systems. They will then perform a variety of scientific and exploratory tasks, which may call for both of them to be out of the bug at the same time. While exploring the moon, the men will be able to communicate with the command module and earth stations using their backpack or belt radios and a relay in the LEM.

After spending 24 to 45 hours on the moon, the astronauts will prepare to launch the ascent stage back to rendezvous with the command module. Liftoff will be vertical until all surface obstacles are cleared and then the ascent stage will be inclined and flown into an elliptical orbit.

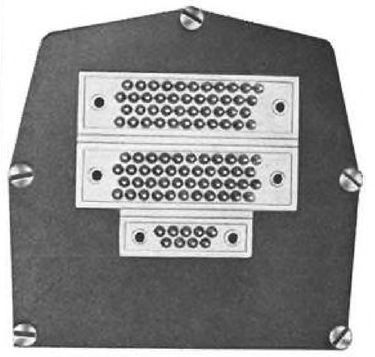
During the first half of the orbit, the ascent engine will be fired again, boosting the ascent stage to the 100 mile altitude of the command module. The launch profile calls for liftoff just as the command module appears over the horizon, with it passing overhead as the ascent stage approaches its altitude.

LEM will be flown into line below and behind the command module. Distance and speed differential between the two vehicles will be reduced until the bug is about 1,000 ft. from the command module and closing at about 10 fps.

Remainder of the docking maneuver will be controlled manually by the LEM crewmen, who will connect the tunnel to the command module tunnel. After the astronauts re-enter the command module, the LEM will be detached and the service module engine will be used to boost the command module out of lunar orbit and into an earth trajectory.

When the proper earth re-entry trajectory has been achieved, the service module will be jettisoned and the command module will be oriented for atmospheric re-entry. It will use a triple parachute system to lower it to an earth landing.

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Logistics Version of Lunar Bug Proposed to NASA by Grumman

Bethpage, N. Y.—Proposed configurations for a logistics version of the Lunar Excursion Module (LEM) and a development schedule designed to draw on the basic LEM program but not interfere with it, have been given to National Aeronautics and Space Administration by Grumman Aircraft Engineering Corp.

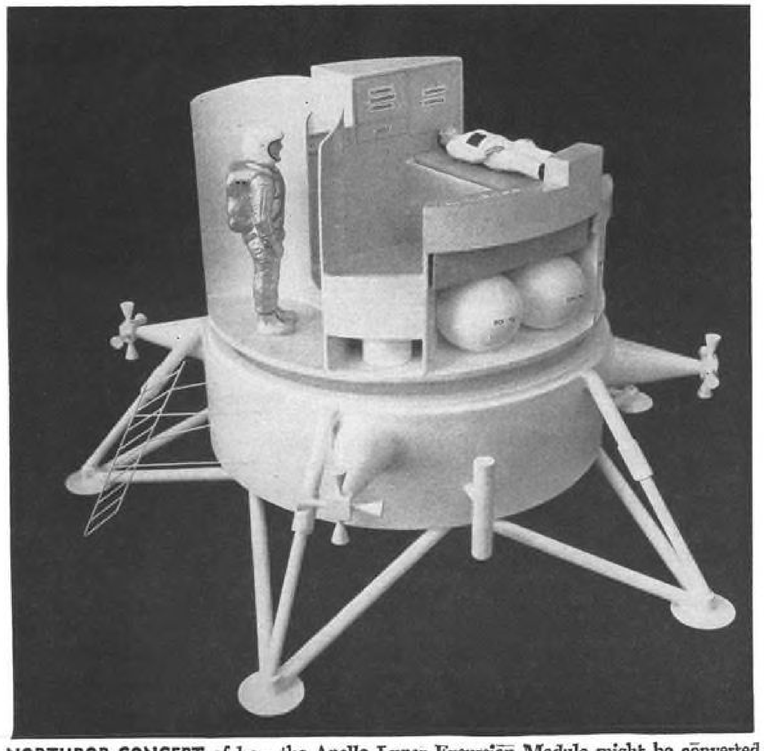
The LEM truck, which will consist of a slightly modified LEM descent stage with a 7,000- to 10,000-lb. capacity cargo compartment replacing the ascent stage (AW Feb. 11, p. 36), would be used to exploit NASA's Project Apollo by extending the astronauts' stay time on the moon from the present two-day limit to as long as two months.

Engineers in Grumman's Space Sciences Group have studied integration of a LEM truck project into the basic LEM program (see p. 141) to establish a schedule for development of the truck and to determine its manpower requirements.

The consensus is that if the LEM truck effort is funded and staffed to project size by 1964, a logistics vehicle could be available to support early Apollo lunar landings without disturbing development of the basic LEM vehicle.

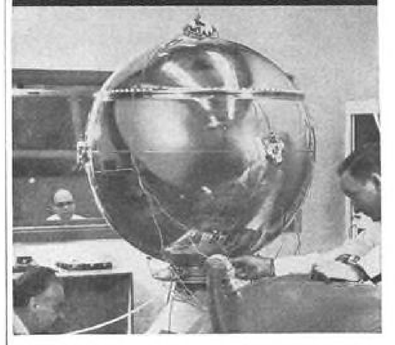
The LEM truck program evolved as an extension of Grumman's participation in a recent three-part, NASA-sponsored study on a totally new lunar bus logistics vehicle (AW Aug. 13, p. 30). Grumman estimates it will cost about $100 million to develop the vehicle. Cost of the lunar bus program, which would involve design and development of new hardware and possibly a new third stage for the Saturn 5 Apollo launch vehicle, has been estimated at about $750 million. Cargo capacity of the lunar bus would be 25-30,000 lb., as much as four times that of the truck.

Space Technology Laboratories developed the lunar bus vehicle design in one portion of the NASA study, while Grumman and Northrop Corp. conducted parallel payload studies. At the end of its portion of the study, Grumman was asked by NASA to look at



NORTHROP CONCEPT of how the Apollo Lunar Excursion Module might be converted into a shelter for extended exploration times on the moon is shown in this model.

SYSTEMS PROGRESS



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Two mass spectrometers, built by Consolidated Systems Corporation, were carried into orbit on April 3 on board Explorer XVII. Scientists at NASA Goddard Space Flight Center, responsible for the satellite, have reported that the data being telemetered to earth are providing the first actual measurements of the atomic and molecular particles making up the very thin gases in Explorer XVII's path through space.

The mass spectrometers are designed for a mass scale of 1 to 32 atomic mass units. The particle measurements depend upon detecting minute electrical currents as small as 5×10^{-16} amperes. Very small measurements—yes, but it is on the scientific base of thousands upon thousands of such painstaking measurements that the big, long-range program—Man In Space—depends for ultimate success. In other ways, too—measurements of radiation in the electromagnetic spectrum, commands to spacecraft, ground check-out of space experiments — CSC is contributing to the attainment of the space goals of the National Aeronautics and Space Administration.

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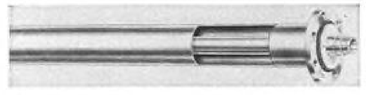
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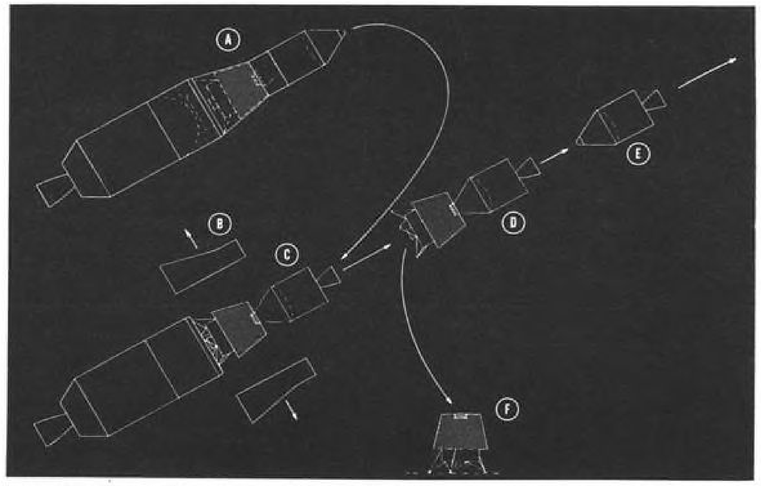
possible conversion of the LEM to a logistics vehicle.

NASA Headquarters has not yet made a decision on the LEM truck, but some officials feel it is a leading lunar logistics system contender. One spokesman said he felt there was a good possibility the LEM truck would be developed, because it would significantly extend the lunar mission time for a relatively small investment.

The discussion within NASA on development of a lunar logistics system revolves around three points: budgetary considerations; a question whether scientists would be satisfied with the limited exploration a LEM crew could perform without a logistics vehicle, and, at the other end of the scale, a feeling that a lunar base ultimately will be established, and all efforts should be geared toward developing the larger Saturn 5 lunar bus, not the LEM truck.

Grumman's proposal included shelter and lunar rover vehicle concepts it developed during the payload study, as well as proposed modifications for the LEM. The truck configuration includes:

- **Same descent stage** and descent engine as in the manned LEM.
- **Same landing gear,** with possible modification to carry different loads.
- **Repackaged ascent stage** electronics equipment needed for the landing and



LEM TRUCK mission sequence shows configuration after injection into lunar trajectory (A). Fairings are jettisoned (B) and command module reoriented (C). Spacecraft enters lunar orbit (D) and command module continues orbit (E) as LEM truck lands (F).

relocation of the packages in the descent stage.

- **Relocated reaction control** system, which is in the ascent stage in the manned LEM, to permit LEM truck attitude correction during landing.
- **Reprogramed automatic** landing system that would automate the command functions—performed manually in the manned LEM—and fully automate the rotation to hover and final touchdown.
- **Addition of four** attachment points around the circumference of the descent stage and two pressure points in the center of the structure.
- **Development of several payloads** designed to extend the astronauts' stay on the moon and improve their mo-

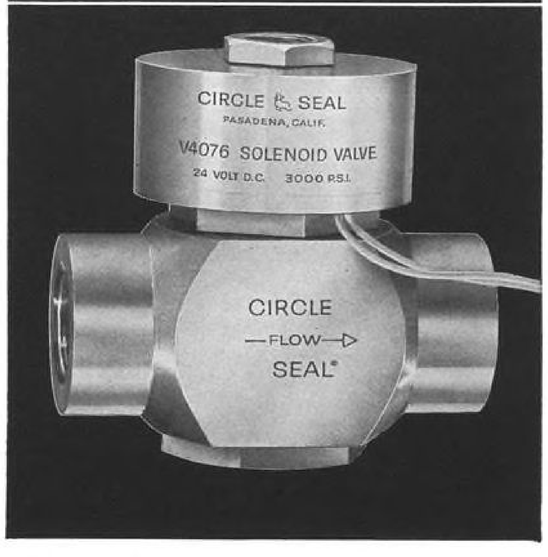
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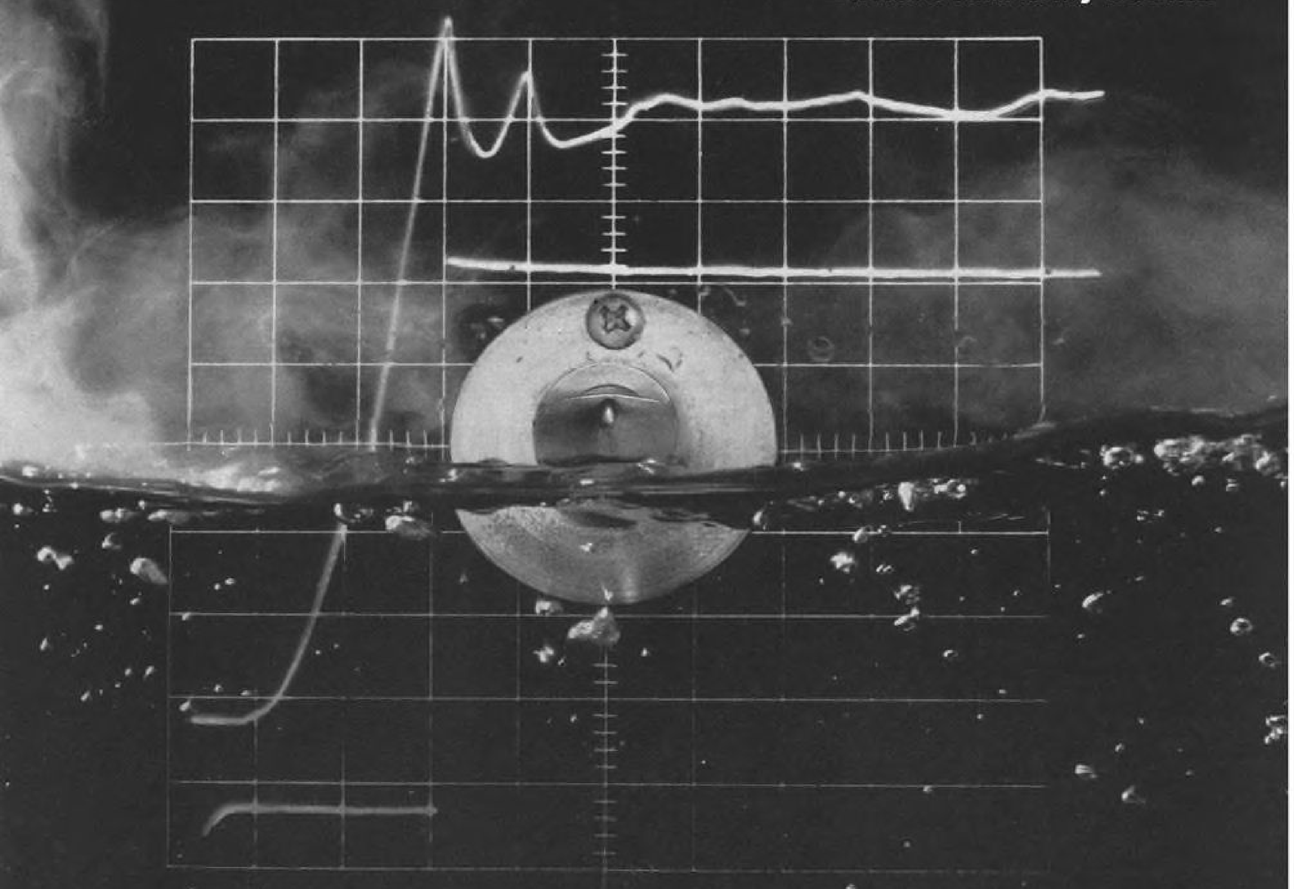
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bility. Payloads will be compatible for docking with the command and service modules of the Apollo spacecraft.

Typical lunar logistics mission would be launched with the same Saturn 5 class vehicle that will be used to boost the manned spacecraft to the moon. The LEM truck will be housed in the bottom of the Apollo spacecraft and transferred during translunar flight, the same as the manned LEM (see story, p. 141).

Same Landing Profile

Landing on the moon would follow the manned LEM mission profile, with the re-oriented spacecraft being flown into a 100-mi. high lunar orbit. The command module can carry either its full crew complement of three, or a reduced crew on the logistics flights. The unmanned LEM truck then will be launched into its elliptical lunar orbit—with a perilune of 50,000 ft. and a period equal to that of the command and service modules. After one or two orbits the descent engine will be fired, actuating the auto-land descent sequence.

Basic structure of the LEM descent stage would not have to be modified for the truck, since it is being designed for a maximum weight of 20-25,000 lb. The descent stage propulsion system also would not have to be modified.

Controls Relocated

The reaction control subsystem would be identical to that on the manned LEM, since the LEM truck payload mass and moment of inertia will not exceed that of the ascent stage. RCS plumbing will have to be rerouted, however, and located on the descent stage.

LEM's basic VHF communications system would be augmented and relocated in the descent stage. The UHF system would be eliminated.

Major components of the stabilization and control system would be retained and also relocated in the descent stage. Descent stage instrumentation would be retained with little modification, except for an added remote checkout equipment.

Fuel cells would be eliminated from the electrical power subsystem and replaced with batteries. Equipment cooling portion of the LEM environmental control subsystem, normally located in the ascent stage, would be relocated in the descent stage.

Major components of the guidance and navigation subsystem, also located in the ascent stage on the manned vehicle, would be retained and relocated in the descent stage. The system would be modified to provide a fully automatic descent and landing capability, plus several methods of remote alignment of components in lunar orbit.

Relocation of all the necessary components and subsystems can be accomplished without changing the basic descent stage structure or its tankage, Grumman said.

Payload stage of the LEM truck would vary in size and configuration depending on the cargo carried. If the cargo was basic provisioning, such as packaged life support supplies or communications equipment, the cargo container would be a simple aluminum shell designed to afford protection from micrometeoroids and the lunar environment. In the case of lunar shelters or roving vehicles, containers probably would not be needed, since the equipment will be designed to withstand the lunar environment.

Attachment of the payload to the descent stage also will vary depending on the cargo carried. Attachment fixtures may contain explosive bolts or may have hand-turned lock nuts. Roving vehicles also may be attached with racks which will slide over the edge of the descent stage and tip down to form drive-off ramps.

LEM truck development schedule worked out by Grumman calls for detailed studies of required LEM modi-

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fications to be performed this year. Preliminary studies already have been completed and Grumman is now waiting for a NASA decision on whether to begin development of the LEM truck vehicle.

If the project is funded, Grumman's LEM truck development schedule will be as follows:

• **Full staffing** of the LEM truck project by 1964, to produce final designs by 1965. Peak staffing of the LEM truck group would not occur until late 1964, after the development peak of the basic LEM program and at a time when Grumman engineering manpower requirements for this program are declining.

• **Development of two mockups,** one by the first quarter of 1965 for shipment to NASA's Manned Spacecraft Center in Houston where payload interface studies would be performed, and the other by about mid-1965 for use in final configuration studies.

• **Four test articles,** with development of the first being completed about mid-1965 and the others being completed during 1966. The test articles would be subassemblies for thermal-vacuum tests, a structural model to requalify the modified RCS, a structural model for static and drop tests and a qualification model for environmental testing of a complete vehicle.

• **First flight article** would be ready by mid-1967. It could be launched without the earth orbital flights required to prove the manned Apollo spacecraft.

Payload capability of the LEM truck using the descent stage as it is presently designed will be in the 7,000- to 7,500-lb. range. With advanced versions of the Saturn 5 launch vehicle, this capacity could increase to 10,000 lb. Increased performance also could be obtained in advanced LEM trucks, which would use cryogenic hydrogen and oxygen propellants. Cryogenic propellants would give the LEM engine a specific impulse of more than 400 sec., compared with 300 sec. which will be obtained with the storable propellants.

Payload configurations for the LEM truck were developed from data Grumman gathered in its earlier NASA study. First consideration was the effect of the length of lunar stay on the thickness of shelter skins and micrometeoroid shielding and hence, on the weight of the structure to be carried there.

Grumman human factors studies further reduced man's needs to a pounds-per-day basis and found that two men can live on 35 lb. of expendables (food, water, oxygen) per day under emergency conditions, but that 75 lb. per day is needed for normal operations.

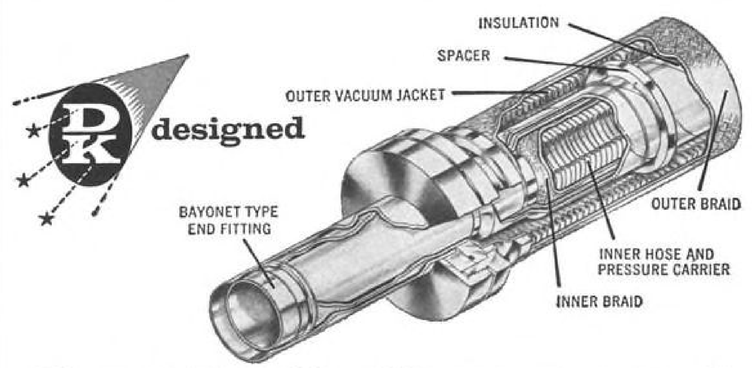
Added to this to form the full payload would be the weight of mission equipment—probably 750 to 1,000 lb. —the weight of lunar rover vehicles and the weight of personnel shelters.

Silo-shaped rigid structures with ellipsoidal tops were found to be the best shelters, according to Grumman studies. This shape fits the spacecraft configuration best and has strong pickup points. Spherical shelters are hard to handle and quonset-type shelters waste space in the launch vehicle.

Two- to four-man shelters designed by Grumman have inside diameters of about 10 ft. and are about 6 ft. high. They are double-walled, with the outside wall sections open on the top and held away from the inner wall with vertical "stand-off" frames. This leaves an open space surrounding the inner structure which the astronauts can fill with lunar soil to improve radiation protection.

These shelters would fit on the LEM truck, but shelters capable of holding more men would either have to be expandable or be launched by a larger vehicle. Grumman considered only rigid shelters, since they can be fully checked out prior to launch for increased reliability.

Weights of proposed shelters range from 400 lb. for a two-man, minimum-



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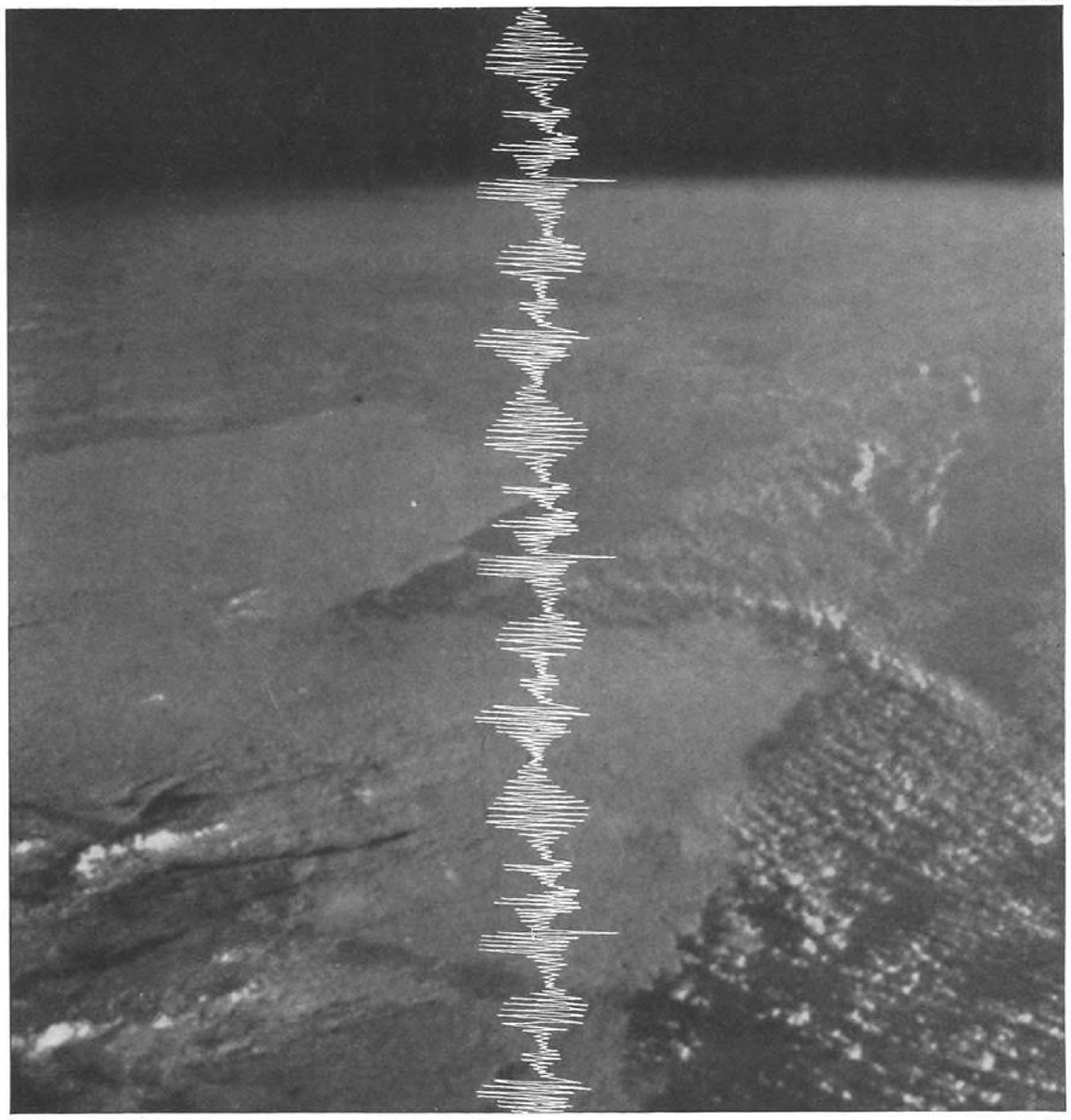
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energy structure to 1,100 lb. for a two-man, planned-stay shelter and 3,500 lb. for a six-man, planned-stay shelter. The minimum-energy shelter would be little more than a cocoon-shaped structure into which the astronauts would crawl to rest or to escape solar flare radiation.

The larger shelters would provide cramped but complete quarters with sleeping, eating and sanitary facilities, a fuel cell power system and stored consumables to replenish space suit consumables.

Also considered in the LEM truck payload studies was a variety of lunar roving vehicles. These could be modular units which could be used individually or joined into land trains.

Grumman Concept

One such vehicle envisioned by Grumman engineers would weigh 1,500 lb. and would have a range of 1,000 mi. unmanned (with the astronauts controlling it remotely) or 250 mi. with one or two astronauts on board. Electrical power would be generated by a centrally mounted fuel cell. Solar panels would be included as power system backup. Both the roving vehicle and a two-man shelter could be carried on one LEM truck, with enough expendables to last two men as long as two months.

The shelter would be mounted upside down on the truck, with a hinged power arm attached to an upper corner, and wheels folded against its sides. To set it up on the moon, the astronauts would extend the wheels and then use the powered arm to rotate the shelter off the LEM truck and onto its wheels.

The rover vehicle, which would be hinged in the middle for steering, would be folded in half on the truck bed. It would be unfolded and its wheels deployed and it would be driven off the truck on the tracked ramp. The shelter would then be hitched to the rover vehicle and the astronauts would have a mobile shelter.

Other Grumman designs include stationary shelters which would sit upright on the LEM truck bed. These would be pivoted away from the truck on one attachment point and lowered to the lunar surface.

Still other payloads include hinged land trains, which fold back on top of themselves to form small cargo packages. These would be used on scientific exploration trips, which probably will be conducted within the Apollo landing area of ± 10 deg. latitude of the lunar equator.

LEM truck payloads all will be designed to withstand the moon's environment for a year without serious deterioration. This will require additional micrometeoroid shielding, but it will permit stockpiling of supplies on the moon prior to manned missions.

After landing the LEM truck on the moon, the astronauts in the orbiting command module can complete several more swings around the moon on reconnaissance or training missions, before returning to the earth.

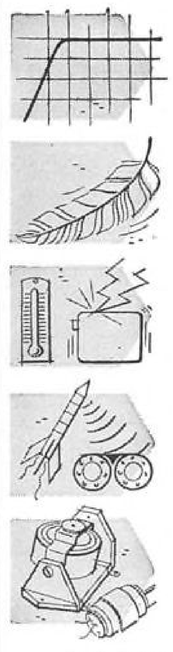
Countering arguments that the LEM truck concept will waste a command and service module every time a payload is placed on the moon, while the unmanned lunar bus will perform as a single, one-way vehicle, Grumman engineers say the manned modules provide an emergency method of returning home.

Thomas Barnes, who has headed LEM truck development within Grumman's Space Sciences Group, illustrated this with a description of a typical lunar supply mission:

Landing several payloads, which might include a spare ascent stage, would precede the landing of a scientific exploration party on the moon. Sufficient supplies to extend their stay for at least two weeks could be delivered by one LEM truck. Lunar orbit capability of the command module, presently limited to about a week, would be extended to two weeks, keeping a vehicle available should the astronauts want to return to earth earlier.

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Density, gm/cc	1.85 (.066 lb./in.³)
Elastic Modulus, psi	42,000,000
Ultimate Tensile Strength, psi	40,000 hot pressed 70,000 wrought
Yield Strength, psi	35,000 hot pressed 45,000 wrought
Elongation, % in 1 inch	1 min.—hot pressed 5 min.—wrought

■ BERYLCO field sales engineers and mill specialists have the experience, ability to provide technical advisory service.

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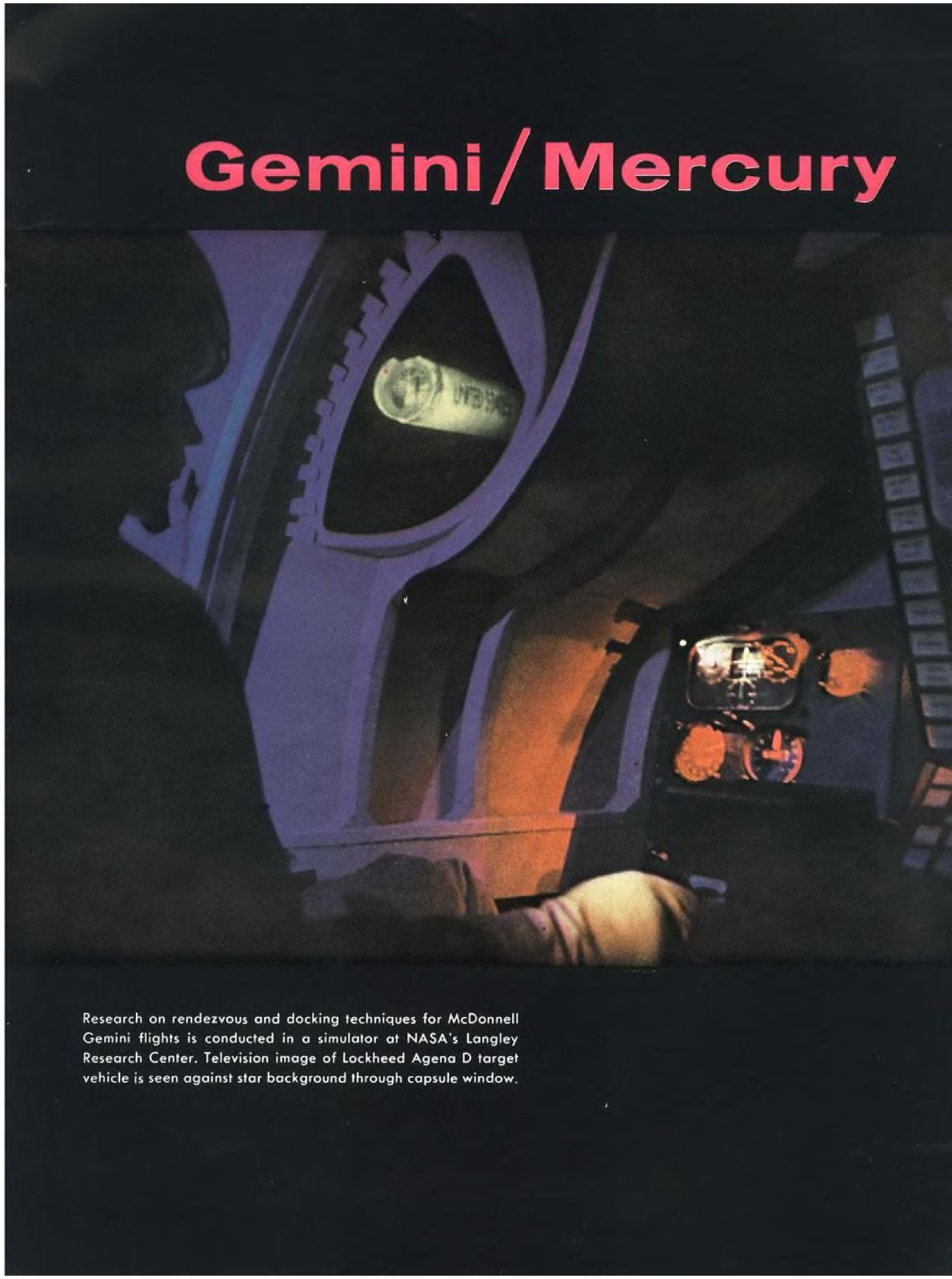
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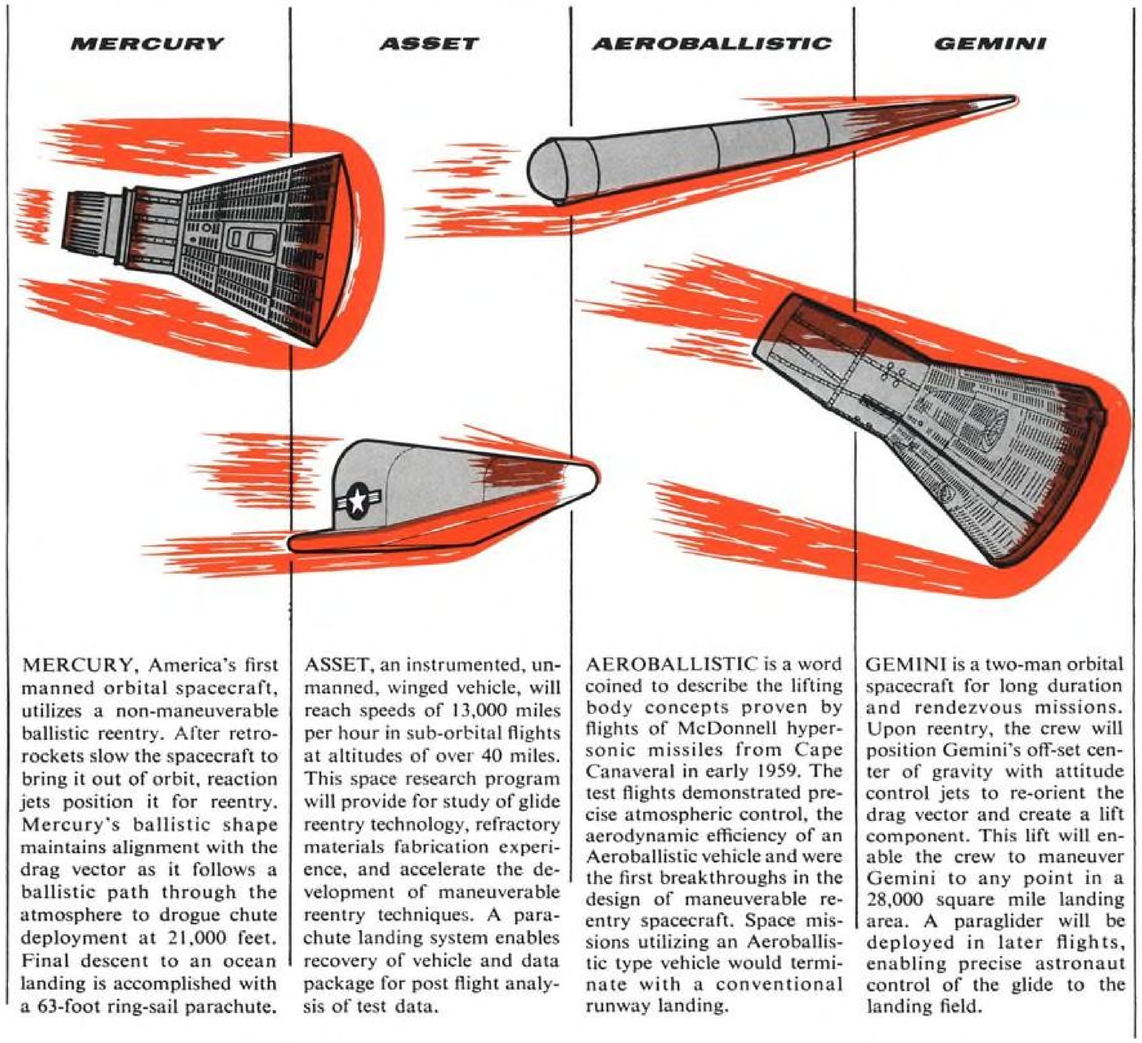
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Research on rendezvous and docking techniques for McDonnell Gemini flights is conducted in a simulator at NASA's Langley Research Center. Television image of Lockheed Agena D target vehicle is seen against star background through capsule window.

EARTH ORBITAL REENTRY

Four spacecraft programs, each engineered to explore
diverse techniques for earth orbital reentry, are underway at McDonnell.



MERCURY, America's first manned orbital spacecraft, utilizes a non-maneuverable ballistic reentry. After retro-rockets slow the spacecraft to bring it out of orbit, reaction jets position it for reentry. Mercury's ballistic shape maintains alignment with the drag vector as it follows a ballistic path through the atmosphere to drogue chute deployment at 21,000 feet. Final descent to an ocean landing is accomplished with a 63-foot ring-sail parachute.

ASSET, an instrumented, unmanned, winged vehicle, will reach speeds of 13,000 miles per hour in sub-orbital flights at altitudes of over 40 miles. This space research program will provide for study of glide reentry technology, refractory materials fabrication experience, and accelerate the development of maneuverable reentry techniques. A parachute landing system enables recovery of vehicle and data package for post flight analysis of test data.

AEROBALLISTIC is a word coined to describe the lifting body concepts proven by flights of McDonnell hypersonic missiles from Cape Canaveral in early 1959. The test flights demonstrated precise atmospheric control, the aerodynamic efficiency of an Aeroballistic vehicle and were the first breakthroughs in the design of maneuverable reentry spacecraft. Space missions utilizing an Aeroballistic type vehicle would terminate with a conventional runway landing.

GEMINI is a two-man orbital spacecraft for long duration and rendezvous missions. Upon reentry, the crew will position Gemini's off-set center of gravity with attitude control jets to re-orient the drag vector and create a lift component. This lift will enable the crew to maneuver Gemini to any point in a 28,000 square mile landing area. A paraglider will be deployed in later flights, enabling precise astronaut control of the glide to the landing field.

With MERCURY, ASSET, AEROBALLISTIC and GEMINI Spacecraft,
McDonnell is perfecting reentry techniques, shapes, materials and manufacturing processes
necessary for the achievement of U. S. leadership in space.

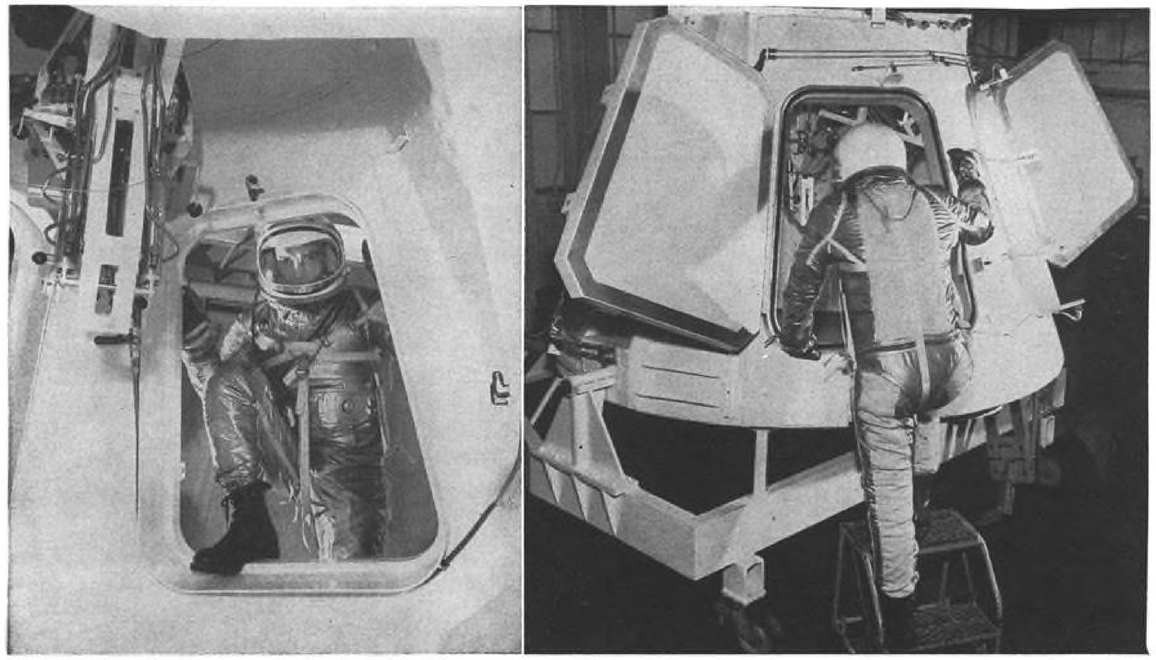
MCDONNELL

- *Mercury and Gemini are being designed and built by McDonnell for NASA under the technical direction of the Manned Spacecraft Center.*
- *Asset is being developed and built under the sponsorship of the Aeronautical Systems Division of the Air Force Systems Command.*
- *Aeroballistic vehicles were developed and tested under contract with the U.S.A.F.*



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TECHNICIAN ENTERS cabin of a simulated Gemini spacecraft at AiResearch in tests to determine ingress-egress characteristics of the configuration. During manned tests, a two-man crew will test the system under simulated orbital conditions. Gemini will be used to perfect rendezvous techniques and to provide data on the effect of prolonged weightlessness on humans.

Gemini Evolves Into Operational Program

Houston—Project Gemini has now evolved into an independent program that will give the U.S. its first operational equipment and experience for a wide variety of manned space missions, both civilian and military.

The two-man Gemini vehicle is both an extension of Mercury and a step toward the three-man Apollo lunar landing mission. In the past year, it has been made even more responsive to the needs of Apollo.

But National Aeronautics and Space Administration now sees the project's primary goals as the training of operational crews and the development of operational hardware and techniques that will form a broad enough base of space flight experience to make operations in space routine.

In the next several years, Gemini will be used to experiment with and perfect rendezvous techniques and to provide physiological data on the effects of prolonged zero-gravity flight on the human body.

Such missions as the transfer of men and cargo to an earth-orbital space station, assembly in orbit of elements of stations or launch vehicles or both, inspection and maintenance of faulty satellites, and one-man scientific expeditions are regarded by NASA planners as predictable future requirements. Depending on when these missions are incorporated into the national space program, Gemini is sure to pioneer some if not all of them.

Present NASA plans for the two-man spacecraft extend only through the next three years and Charles W. Mathews, director of the Gemini project office at NASA's Manned Spacecraft Center here, believes the program will achieve the major goals now set for it within five years after the spacecraft becomes operational in 1965. But because the predictable requirements listed above are expected to become firm goals, and because Gemini's capability is flexible enough to accommodate them, many engineers both here and at McDonnell Aircraft Corp., project prime contractor, believe Gemini will have a service lifetime of at least 10 years.

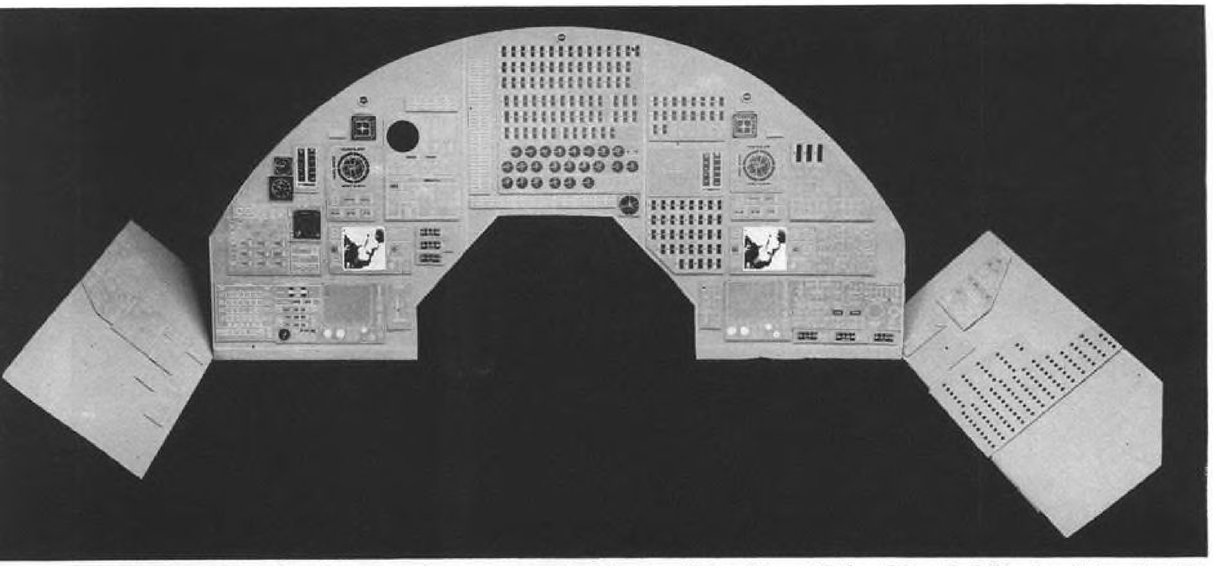
Major goals now assigned to Gemini are long-duration flight, crew flight-training and rendezvous. Crew flight-training is of particular importance. Unlike Mercury, where the capsule's orbital path was fixed at the time of insertion by its Atlas booster, both Gemini and Apollo will have the propulsive capability to alter their orbits.

A crew's ability to use this on-board propulsion to make mid-course corrections on the outbound and inbound legs of translunar flight, as well as insertion into and departure from lunar orbit, will be critical to the success of the Apollo program.

As in conventional atmospheric flight, proficiency is gained through experience, and the Gemini spacecraft will provide the orbital equivalent of a T-33 trainer for NASA pilots. To qualify for the pool of pilots from which NASA will select the first lunar landing crew, an astronaut will have had to make at least one rendezvous mission with a Lockheed Agena stage in a Gemini craft and one flight in a North American Apollo vehicle, according to present plans (see p. 195). Both flights will provide ample opportunity for pilots to exercise the on-board propulsion and rendezvous systems and for the spacecraft center to evaluate their individual abilities.

If the center can hold to its present schedule of a flight every three months, starting in 1965, the Gemini program could provide about 24 flight seats for pilot training, as well as other objectives.

But at least one, and possibly a



GEMINI CONTROL panel mockup shows instrument layout of the two pilot positions with the pilot on the left and copilot on the right.

second and a third, long-duration flight of 14 days for biomedical purposes is planned. These 14-day missions may not qualify the pilots for the first lunar landing crew because rendezvous with an Agena will not be involved. The crews will practice rendezvous with a transponder pod ejected from their spacecraft in orbit, but the absence of docking and maneuvering with a propulsive stage will limit the experience value of these missions.

First Gemini flight, scheduled for late this year, will be an unmanned orbital mission of indefinite duration. The spacecraft will be injected into orbit still attached to the second stage of its Martin Titan 2 launch vehicle and no attempt at recovery of the vehicle will be made.

Primary objectives of this flight will be the orbital performance of the guidance system, with data being telemetered back to ground stations; and compatibility of the spacecraft (AW May 13, p. 52) with the launch vehicle (AW Sept. 3, p. 38). This first spacecraft will carry almost none of its planned systems, and is being referred to as a "tin can."

Second Gemini flight, now set for mid-1964, also will be unmanned (AW May 6, p. 22), but will carry all operational systems with the exception of the North American Aviation, Inc., paraglider. Flight profile will be a ballistic trajectory down the Atlantic Missile Range, with recovery of the spacecraft at the end of the flight so that onboard systems may be examined.

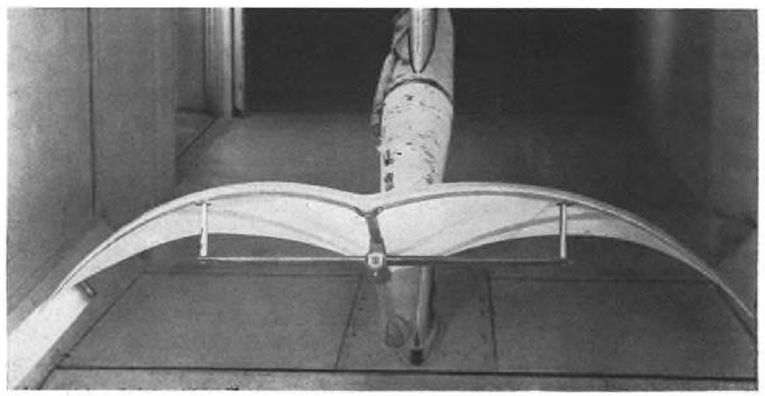
First manned orbital flight of Gemini now is scheduled for late 1964. Although plans are still tentative, the Manned Spacecraft Center is leaning toward a three-orbit flight as a spacecraft qualification mission. Landing would be made with an 84-ft. dia. parachute in the vicinity of the Atlantic Ocean off Bermuda where John Glenn, the first Mercury orbital pilot, landed.

After the first manned orbital flight —if it is successful—the center would like to proceed directly to a seven-day flight. There is concern among some NASA officials about the jump from a three-orbit flight to a seven-day flight and the decision on whether to go for it or for a flight of only three or four days probably will depend on the success of the first three flights. The jump, however, is indicative of the center's desire to make Gemini operational as soon as is technically possible.

Whatever the duration of the second manned orbital flight, it is fairly certain that the crew will practice rendezvous maneuvers with the 65-lb. Westinghouse-developed rendezvous exercise pod (AW May 13, p. 73), in preparation for rendezvous with a Lockheed Agena on the third manned mission.

First attempt to rendezvous with an Agena, now planned for the third manned orbital flight, probably will be kept as simple and straightforward as possible (AW May 13, p. 54). After docking with Agena, the Gemini crew might attempt some limited maneuvers with the stage's propulsion system. Duration of this mission is not expected to exceed two or three days.

Maximum duration flight now is being considered for the fourth manned mission. Tasks for this 336 hr. flight still are being evolved, but the spacecraft might be placed in an orbit whose plane was more highly inclined to the equator than Mercury flights (about 30 deg.), so that the crew would fly over a greater area of the earth. Besides practicing rendezvous with the



SCALE VERSION of Gemini paraglider is set for tests in Langley's transonic wind tunnel.

Gemini Slippage Due to Variety of Causes

Houston—One-year slippage in the Gemini program has resulted from an under-estimation of the technology required, lack of vital design data and a personnel shortage during the project's formative phases early in 1962.

The original flight schedule called for an unmanned ballistic flight down the Atlantic Missile Range in August or September of this year and a manned orbital flight by December. Now the first unmanned flight, which will be orbital (see p. 175), is set for December and the first manned orbital flight is scheduled for the last quarter of 1964. A second unmanned flight—a ballistic lob down the Atlantic range—has been inserted between these two missions.

"There was a feeling," Gemini Project Office Director Charles W. Mathews said of the program's early stages, "that Gemini technology would not be as far advanced beyond Mercury as it has since proved to be."

Mathews also said it took longer to freeze the two-man spacecraft's design than expected because vital data was not available when it should have been. As examples, he cited the paraglider and the thrusters in the on-board propulsion system, the former being developed by the Space and Information Div. and the latter by the Rocketdyne Div. of North American Aviation, Inc.

The paraglider, which is being developed under a separate Manned Spacecraft Center contract for delivery to McDonnell Aircraft Corp., the spacecraft manufacturer, as government-furnished equipment, has had development troubles (AW Jan. 28, p. 55).

In deploying, the paraglider imposes concentrated loads on the spacecraft and this loading data—to have been gathered by a series of tests at Edwards AFB, Calif.—was critical to the final design and location of load-bearing members in the Gemini vehicle.

Although the Edwards tests have not produced the expected data, they have provided guidelines and the cabin has been built to strength levels which are expected to be adequate.

Testing of the on-board propulsion system, called Orbital Attitude and Maneuvering System (OAMS), has revealed that pulsed firing of the thrusters results in more ablation loss of material lining the chambers than steady firing does. Rocketdyne is conducting research into this problem, which adversely affects the required duty-cycle life of the thrusters.

Technical problems have arisen with other systems, Mathews said, and some could have caused slippage if they had occurred earlier.

Shortage of personnel has also contributed to the slip. When the program began late in 1961, about 80 people were working part-time on Gemini. Their full-time job in the engineering division of the Space Task Group at Langley Field, Va., the forerunner of the center, was the Mercury program, so their part-time work was equal to that of about 12 full-time engineers.

Consequently, the Gemini work statement—under which contracts were written and specifications set—was not very detailed, according to James A. Chamberlin, who was the first Gemini project office director and is now senior engineering adviser to Center Director Robert Gilruth.

In the spring of 1962, when the manned flight programs moved to Houston, Chamberlin built up a project office of about 80 full-time men.

Some of these engineers and managers were assigned to Gemini from the Mercury project office and some came from industry. With experienced personnel able to devote more effort to the project, a review of the design of systems already contracted for was begun.

By late spring or early summer of last year, project personnel had found many areas in which reliability or performance could be increased and operations simplified.

An example, according to Duncan R. Collins, chief of the project office spacecraft division, and Scott Simpkinson, technical assistant to Mathews, was the switch from standard flared fittings to brazed fittings on all propellant lines in the on-board propulsion system. The change was based on Mercury experience.

Very few systems escaped the general tightening of specifications. Where a firm had had prior experience with Mercury —such as Collins Radio Co. or AiResearch Div. of the Garrett Corp.—the revisions usually were not extensive.

But many changes had to be made in many systems. Consequently, subcontractors revised both delivery dates and cost estimates. By last fall it had become apparent that NASA was buying a better spacecraft but with higher costs and longer development times. Project personnel say supplemental funding might have helped slightly, but probably would not have been available in time to have been worth the effort. "The problems that have constrained the program," Mathews said, "have required brainpower—rather than just sheer manpower."

There have been other factors in the program's delay. Mathews believes the present flight schedule is more logical than an earlier schedule (AW Oct. 29, p. 23), which envisioned an 18-orbit flight as the second mission and 14-day flights as the third and fourth flights.

Mathews emphasizes that schedules are predicated upon fairly high rates of assumed success—around 95%—in the development of systems, but with an awareness that problems will arise and that some slippage is inevitable. Schedules must be laid out this way, he believes, as a stimulus to performance. He feels that the one-year delay so far is not as bad as it might appear—that a slippage of several months probably was inevitable.

Mathews and other project personnel feel that Gemini is progressing as well as, or better than, Mercury was at a comparable time. Nearly three years passed between Mercury's inception and the first unmanned orbital flight. If Gemini can meet its present schedule, only two years will have elapsed between these two milestones. It was three and one-half years from the beginning of Mercury until the first manned orbital flight.

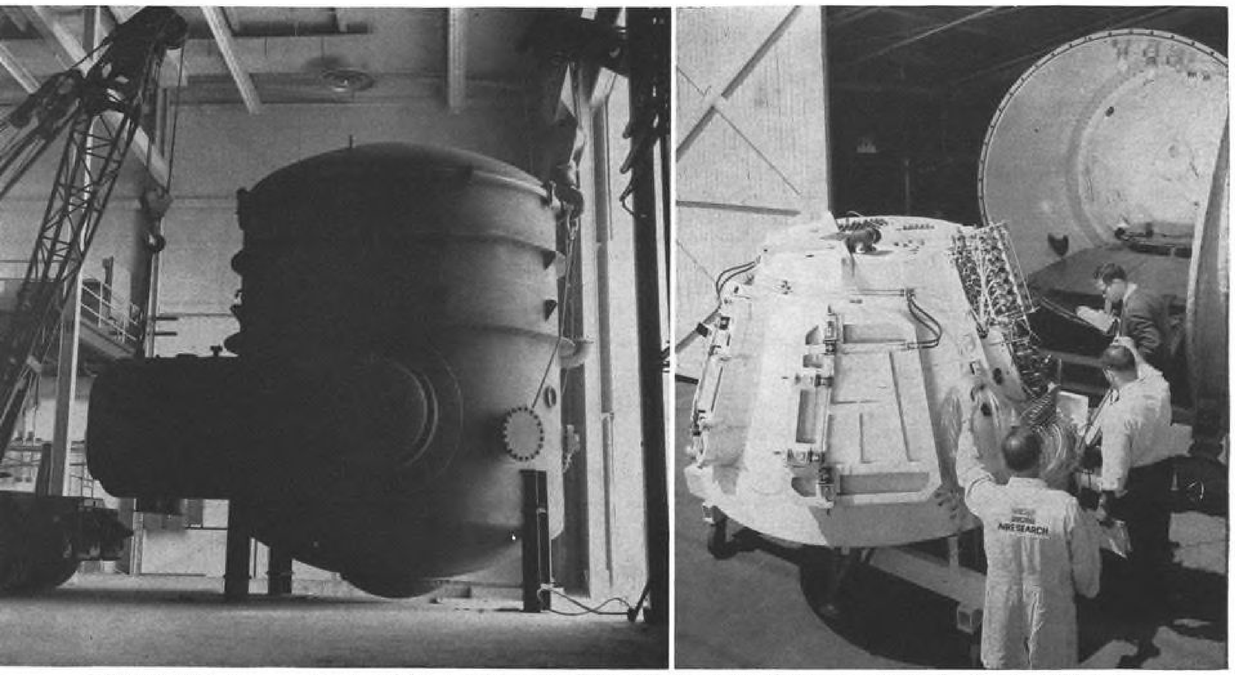
Gemini will be almost three years old before its first manned orbital flight late in 1964.

Manufacturing tooling at the McDonnell plant in St. Louis was more complex that that used for Mercury capsules, according to Mathews, and this too cost time.

But this has had the advantage of "a higher quality spacecraft, a better-made spacecraft than we would have had otherwise," Mathews said.

Most project personnel believe it is better to pay the penalty of a longer development cycle for the benefit of a trouble-free, operational spacecraft.

They would like to avoid the hazards of the Mercury program, where development proceeded concurrently with operations, requiring modifications upon modifications in one capsule after another.



NEW 240,000 ft. space chamber (left) at AiResearch. Boilerplate Gemini (right) is moved into chamber for ECS tests.

transponder pod, a task lasting only several orbits, and exercising the on-board propulsion system, the crew probably would make extensive observations and photographs of the earth and its atmosphere.

Inserting the 14-day mission into the flight schedule at that point would allow six months for analyzing the results of the first Agena rendezvous flight before another Agena rendezvous was attempted. This period also would permit the testing of any hardware modifications that might result from the analysis.

Fifth manned orbital flight and all subsequent missions are now expected to be Agena rendezvous flights unless the 14-day mission uncovers physiological anomalies which have to be explored further. If this should happen, the earliest a second long-duration flight would be scheduled would be the sixth or seventh flight, to allow at least six months for study of the problems.

Some tasks that might be programmed for rendezvous flights to support Apollo include:

• **Highly elliptical earth orbits.** Using the propulsion system of the Agena after rendezvousing and docking with it, the Gemini crew might fly from a circular orbit into an elongated ellipse with an apogee of about 2,000 mi. and a perigee of about 160 mi. Flight profile on the descent from apogee to perigee could be made to simulate the earth-return leg of an Apollo lunar flight and data could be gathered on re-entry heating. Gemini's heat shield, according to one NASA source, has a greater potential than required for earth-orbital operations. Sensors of the Apollo guidance system could be exercised to evaluate their ability to discriminate between a true earth horizon and the haze layer which surrounds the earth at an altitude of about 55 to 75 mi. Sensor output will be vital to the correct alignment of a returning Apollo spacecraft with the narrow 40-mi. re-entry corridor in the earth's atmosphere.

• **Systems testbed.** Some Apollo systems and components, such as the inertial platform and star-tracker of the guidance system, can be realistically tested only in orbital flight and Gemini probably will carry a number of these on different flights to provide performance data. Other Apollo systems which might be flight-tested aboard Gemini include the life support system, communications and personnel suits. Apollo suit may first be exposed to the space environment by a Gemini crewman during an extra-vehicular excursion.

• **Simulation of lunar orbit rendezvous.** Pilots will practice the terminal phases of lunar orbit rendezvous, the mode selected by NASA for the manned lunar landing, possibly in 1966. A narrower form of rendezvous than that which NASA would like to develop for earth-orbital operations, lunar rendezvous involves little or no plane differences between the orbiting command module and the ascending lunar excursion module. Launch window will be determined by phase differences between the two Apollo modules. After having rendezvoused and docked with an Agena, the composite Gemini-Agena vehicle would simulate the Lunar Excursion Module and the orbiting command module would be simulated by a transponder package jettisoned from the Agena. Gemini crew then would fly simulated ascent and descent aborts, using the Agena's propulsion, as well as nominal rendezvous.



WORKMEN INSPECT parawing after Gemini test. Development problems will delay use.

The Gemini project office now is deeply involved in working out a coherent series of missions other than the clearly identifiable tasks to support Apollo.

Extra-vehicular maneuverability—the ability of a crew member to leave his craft and function usefully in space—is coming to be considered as essential to future space operations as rendezvous itself. The first U. S. extra-vehicular excursion will be conducted with Gemini —perhaps as early as the second manned mission.

The technique is expected to develop along this graduated line of complexity:

• **Survivability.** The first attempt to operate outside the sheltered environment of a spacecraft probably will do little more than prove that the concept is feasible. Later flights might include testing of new suit designs, such as Apollo's.

• **Locomotion.** The next logical step after proving that a man can survive outside his craft is expected to be a search for the most effective way to move him about. Both propulsive devices and mechanical links—such as a tethered line—will be studied, but the higher reliability of a physical connection is sure to guarantee its presence on early flights, if only for safety. Rocket belts are the most likely propulsive devices to be tested early.

• **Inspection and maintenance.** The first practical task is likely to be an attempt to repair or replace malfunctioning equipment the spacecraft. Next might come rendezvousing and docking with an Agena stage and repairing it. Then attempts might be made to rendezvous with satellites such as Telstar, Tiros or one of the Explorers. It also is possible that the Gemini crew might retrieve a portion of skin or a solar paddle from a U. S. satellite and return it to earth for study of the effects of long exposure.

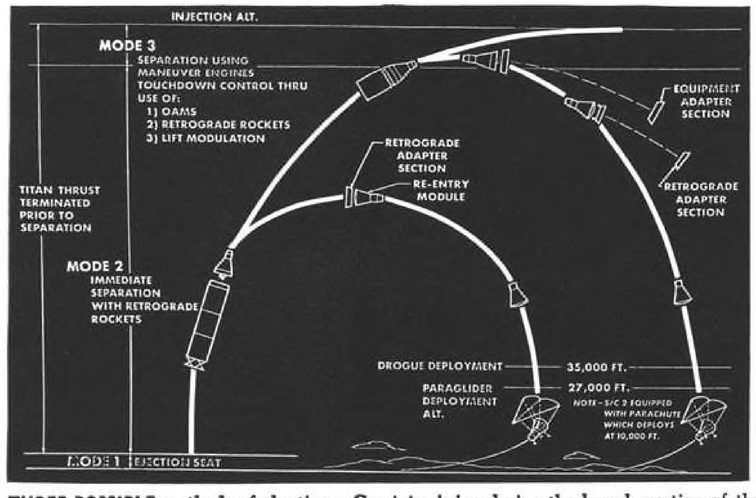
• **Structural assembly.** Foreseen as an advanced application of extra-vehicular maneuverability, this technique could be useful in the construction of modules into space stations or of launch vehicles in orbit.

• **Emergency transfer.** Also considered as an advanced application, this probably will become a mandatory requirement in future years, when more men are operating for greater lengths of time in space and the possibilities of illness or injury increase.

Other future missions for Gemini might include manned excursions into the Van Allen radiation belts, one-man scientific expeditions, use as a personnel ferry and logistic supply for manned orbital laboratories (see p. 77 and 214) and the near-simultaneous launch of two vehicles.

Manned excursions into the Van Allen belts would be made with adequate shielding for the pilots and would attempt to determine exact radiation levels and evaluation of different methods and materials for shielding. One-man flights are fairly firm in Gemini future planning, with the second seat given over to such bulky equipment as an ultra-violet astronomical telescope, an infrared spectrometer or an experiment that might call for visual observation and periodic manual adjustment.

If the U. S. decides to develop a



THREE POSSIBLE methods of aborting a Gemini mission during the launch portion of the flight are shown in the diagram above. Early flights will use parachutes and will land on water. Later flights will use paraglider to come down on land.

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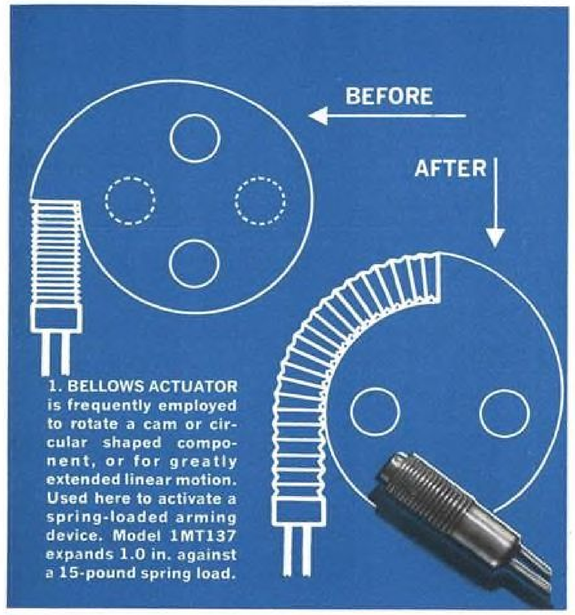
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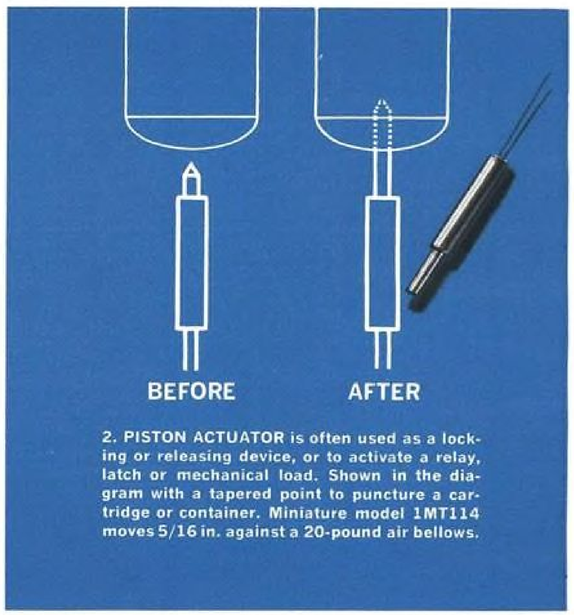
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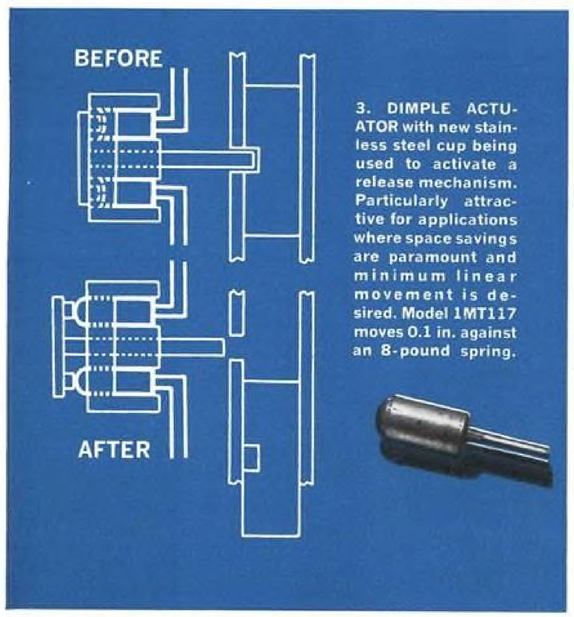
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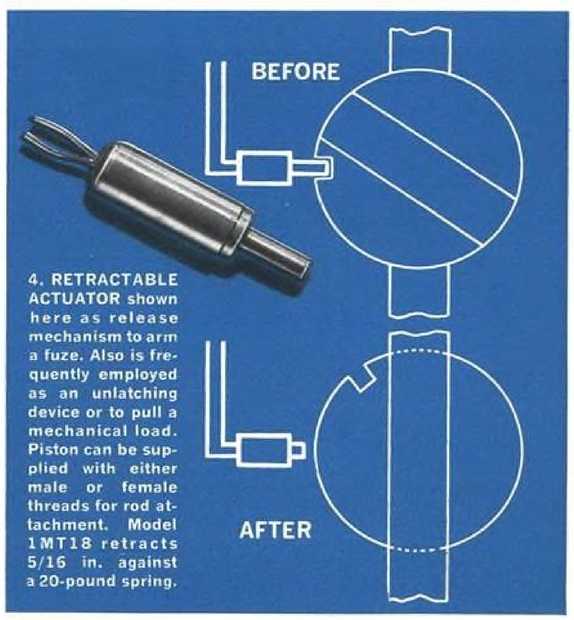
1. BELLOWS ACTUATOR is frequently employed to rotate a cam or circular shaped component, or for greatly extended linear motion. Used here to activate a spring-loaded arming device. Model 1MT137 expands 1.0 in. against a 15-pound spring load.



2. PISTON ACTUATOR is often used as a locking or releasing device, or to activate a relay, latch or mechanical load. Shown in the diagram with a tapered point to puncture a cartridge or container. Miniature model 1MT114 moves 5/16 in. against a 20-pound air bellows.



3. DIMPLE ACTUATOR with new stainless steel cup being used to activate a release mechanism. Particularly attractive for applications where space savings are paramount and minimum linear movement is desired. Model 1MT117 moves 0.1 in. against an 8-pound spring.



4. RETRACTABLE ACTUATOR shown here as release mechanism to arm a fuze. Also is frequently employed as an unlatching device or to pull a mechanical load. Piston can be supplied with either male or female threads for rod attachment. Model 1MT18 retracts 5/16 in. against a 20-pound spring.

manned earth-orbital space station, Gemini and Agena probably will be used to demonstrate the feasibility of both personnel ferries and un-manned logistic supply vehicles, and Gemini may serve as the early operational ferry. The manned spacecraft would attempt to hit an imaginary cube in space simulating a station and, after riding along in this cube for a while to simulate docking, would then attempt various maneuvers such as recovery or rendezvous with a malfunctioning satellite.

In a variation on this theme, the Gemini would simulate a station and the Agena an un-manned cargo supply vehicle. Both ground stations and the Gemini crew would attempt to bring the Agena to the manned spacecraft, although it is unlikely that the stage would ever play the active role in docking. The stage would simply be brought in close proximity to the spacecraft.

Perhaps the most ambitious future Gemini mission is the tentative plan to launch a manned Gemini and an unmanned stage within minutes of each other and then attempt a rendezvous and docking maneuver immediately after orbital insertion.

Although this would be programed as a feasibility demonstration, it might open the door for space operations with a proved and flight-tested upper stage placed in orbit by an unproved booster.

For example, the Saturn S-4B upper stage will have been flown perhaps as many as four to six times aboard the Saturn S-1 first stage before it flies as the third stage of the advanced Saturn 5 launch vehicle. If these early flights are successful, NASA should have a fairly high degree of confidence in the S-4B's performance by that time.

As a way of accomplishing the first manned lunar landing before the complete three-stage Saturn 5 is man-rated, NASA might use a combination of the advanced—but not man-rated—Saturn 5 and the smaller payload-capacity—but man-rated—Saturn S-1B. The Saturn 5 would carry as its payload a fully-fueled S-4B stage, the Apollo service module and perhaps the Lunar Excursion Module. The Saturn S-1B would carry the manned command module.

At some point during the Saturn 5's trajectory—perhaps at burnout of the S-2 second stage—when it would appear that this payload had been successfully injected into orbit, the Saturn 1-B would be launched into orbit. The manned Apollo command module then would rendezvous with the service and lunar excursion modules sometime within the first orbit and, after docking, proceed to translunar flight.

Whether this technique would be used probably would depend on the feasibility demonstration of a Gemini rendezvous with an Agena or a Centaur stage immediately after orbital insertion, and on whether the technique would offer enough time savings to warrant its greater technical complexity.

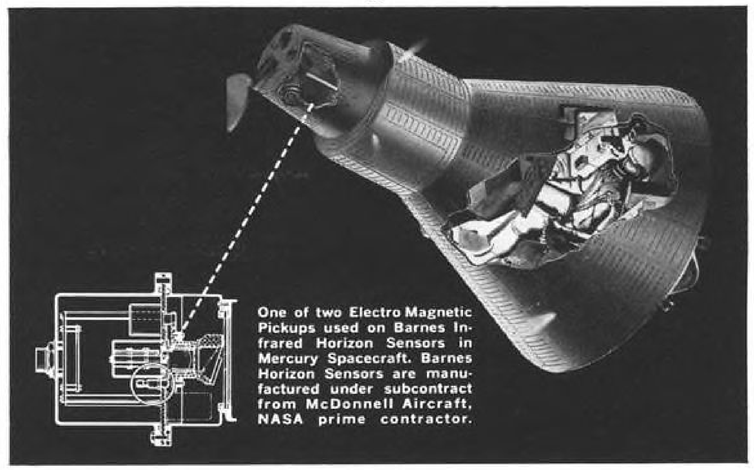
Hors de Combat Badge

When Rep. Daniel J. Flood (D.-Pa.) learned in recent House hearings that the Air Force will play a very minor role in National Aeronautics and Space Administration's Project Gemini, he told Brockway McMillan, then USAF assistant secretary for research and development, that he hoped USAF would not supply "money to an overfunded agency" (NASA) for the project. McMillan replied: "Not if I can help it." Then the following exchange took place:

- Rep. Flood: I would suggest you have your experts in the Air Force design a combat badge, a new one. You ought to design a new one and put it on the new boys who will be in this mission and design it as the tail of NASA's kite.
- McMillan: I think a dollar bill should play a prominent role in that heraldic device.
- Rep. Flood: As of now, you are the tail of a NASA kite and they have got a lot of kite.
- McMillan: Mr. Flood, I do not think it is quite that dramatic. . . .

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(b)

(c)

(d)

(e)

(a)

Gemini Rendezvous Mission

Steps in the Gemini – Agena D rendezvous sequence begin at (a) with launch of Gemini by Titan 2. On the previous day, Agena (b) will have been launched by an Atlas. After docking (c) and maneuvering in space, Gemini will break away from Agena (d), turn around and jettison its adapter sections (e). First missions will use parachute recovery (f). Normal rendezvous flight time will be two days.

(f)

-L. J. HERB-

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Man's Capabilities Affect Design, Mission of Gemini

Houston—Conviction that man is the best controller is the foundation for design, manufacture and mission philosophy of the two-man Gemini spacecraft, and it has had a significant effect on the reliability and simplicity of the hardware in this program.

This belief stems directly from the experience gained by the National Aeronautics and Space Administration and McDonnell Aircraft Corp., prime contractor, from the Mercury project. Extensive automation in the one-man spacecraft made it an unwieldy vehicle to design, build and use. "The sequential circuitry [in Mercury]," said one NASA official, "was a real nightmare with all its redundant and parallel circuits."

Mercury design was frozen at a time when it was totally unknown how and if man could function in a weightless environment, and it was essentially a completely automatic system. Nevertheless, automatic control of capsule systems in Mercury had been carried to a point where, according to this source, it tended to have a negative value. He cited the Mercury-Atlas 9 flight of USAF Maj. Gordon Cooper as an example: "We had to make a considerable effort toward the end of the flight to figure out a way of getting around" the malfunctioning automatic sequencer which controlled re-entry.

The fact that Cooper overcame this problem, manually controlled his craft during re-entry and landed precisely where the automatic system would have dropped him, only confirmed NASA's belief that man could perform a great many tasks, which—at least at the start of the Mercury program—had been thought better to be entrusted to automatic circuitry. As a result of the manned Mercury flights, NASA's confidence increased in man's ability to cope with his situation in space and, today, control of practically all Gemini systems rests in the hands of the crew.

Although Gemini has retained Mercury's basic aerodynamic configuration, the two-man spacecraft actually has a much different structure than its one-man predecessor. In Mercury, structure and system were intricately entwined in a monolithic capsule. With all systems inside the pressure vessel fabrication was not easy; at the most, two men could work inside a spacecraft with the heat shield off. With the shield on, only one man could work inside the craft, and not too comfortably. Further, systems were piled layer cake-fashion on top of systems and the removal of one frequently involved the removal of others. Finally, checkout was an admittedly dismal chore, since flight electrical connections had to be broken to accommodate test equipment.

This experience led NASA and McDonnell to make several fundamental changes concerning Gemini. First, spacecraft and systems would be built as separate and independent modular units. Second, systems would be located on the outside of the pressure structure and would be packaged as easily-removable units. Finally, attention would be paid during the design phase to the location of built-in test points in parallel with the circuit and system being tested.

The spacecraft structure was broken into four modules: rendezvous and radar; re-entry control; cabin, including the manned pressure vessel; and adapter, which consists of two parts, retrograde and equipment.

NASA found that modular construction has several advantages: it allows a greater concentration of manpower to be used on more parts of the spacecraft, thus shortening manufacturing time; and it tends to isolate the impact of modifications to the module involved. This was not true for Mercury, where only a few men could work on the capsule at any given time and where changes—even of a minor nature—generally were felt up and down the line.

At the McDonnell plant in St. Louis, Mo., modules are manufactured as structural assemblies on separate production lines on the factory floor. They then move into the environment-controlled "white" room at the end of the floor and there each module, still following its own separate path, is fitted with systems. There also, each module is tested individually and as part of the complete spacecraft, with electronic simulators acting as the balance of the two-man vehicle for the latter tests.

Modules then flow together to form a complete spacecraft, after an approximate seven-month manufacturing process, and each complete Gemini then is subjected to about an additional 10 weeks of vibration, pressure and firing tests. At the end of this 10-week test period, the spacecraft is ready for delivery to NASA.

Gemini manufacturing sequence, although similar to that of Mercury, is arranged in more logical sets of tasks and permits both concurrent and parallel manufacturing and testing of individual spacecraft components.

All Gemini systems have been packaged in modular form also and are mounted in external bays on the spacecraft structure. Because of difficulties encountered during the Mercury program with the stack-upon-stack arrangement of systems, system modules in Gemini are only one layer deep and replacement of one does not necessarily disturb adjacent packages.

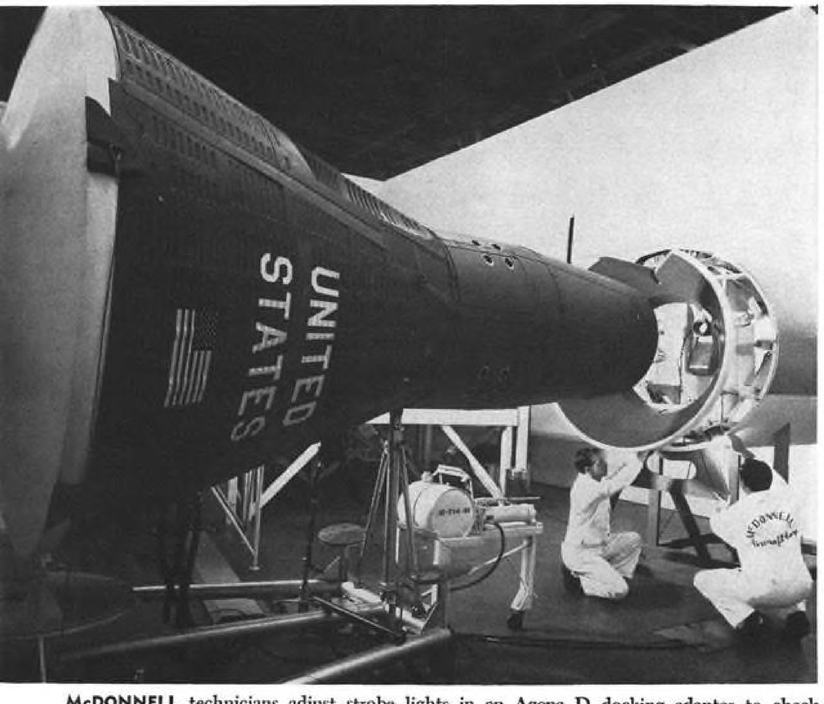
These packaged systems are accessible for inspection and maintenance through 35 access hatches on the spacecraft—three on the rendezvous module, eight on the re-entry control unit, 13 on the cabin—including the two pilot ingress/egress hatches, and 11 on the adapter module. In addition, there are three umbilical access hatches. Roughly 75% of the cabin spaceframe consists of hatches.

Hatches provide ready access to systems for inspection, repair and replacement. Replacement of a faulty system with a flight-certified spare is likely to be the most common form of maintenance on Gemini and could well be accomplished in a matter of minutes by two or more technicians working side by side.

For initial Gemini flight countdowns, NASA expects to proceed cautiously in examining each faulty system—to determine the precise cause of malfunction and whether the problem is unique or generic to that system—before replacing it and proceeding with the count-down. This may result in delays of several hours and postponements of one or two days, as was common with Mercury flights.

But as experience with systems performance accumulates and confidence rises in their reliability, it is likely that NASA will take full advantage of the quick-replacement capability afforded by the Gemini design and attempt to meet launch windows despite system failures. Not all modules possess this capability to an equal degree, however. Systems in the adapter module are not as accessible as those around the cabin. The adapter's external spaceframe also serves as a radiator to dissipate heat generated by electronic systems. This surface, therefore, cannot be compartmentalized without incurring a major problem in joining and sealing the radiator tubing which runs along the backside of the adapter skin. Further, the size of the systems in the adapter module makes it impractical to pull them through a hatch.

Should replacement of a bulky system—such as the fuel cell or propellant tankage for the on-board propulsion system—become necessary, the entire space-



McDONNELL technicians adjust strobe lights in an Agena D docking adapter to check tolerances. Gemini pilots will use flashing light as a visual rendezvous reference.



TITAN 2 Gemini launch vehicle is assembled for test at Martin Baltimore. The 100,000-lb. thrust second stage is hoisted to its position. Vehicle is 110 ft. high.



craft would have to be de-mated from its Titan 2 booster and returned to the hangar so that technicians could get at the faulty unit through the open back end of the adapter.

Major Gemini systems include the onboard propulsion system, called OAMS for Orbital Attitude and Maneuvering System; recovery and landing gear; electrical power; environmental control; rendezvous radar; communications, and guidance.

Rocketdyne Div. of North American Aviation, Inc., is developing the onboard OAMS propulsion system which will give Gemini a total velocity capability of about 700 ft./sec. or the ability to make a plane change of about 0.5 deg.

The propulsion system consists of two separate sub-systems—one for re-entry control only and the other, which also is the larger of the two, for attitude control and velocity changes during orbital flight. The re-entry control unit is composed of two separate and independent rings of eight 25-lb. thrusters, each pressure-fed from separate tankage in the same module. Either ring, both located in the re-entry control module, can control Gemini during re-entry.

The larger propulsion sub-system consists of eight 25-lb. thrust engines for orbital attitude control, two 100-lb. thrusters for acceleration, two 85 lb. units for deceleration and four 100-lb. thrust units—whose thrust vector lines are perpendicular to the spacecraft's centerline—for vertical or horizontal displacement.

Thrusters burn a hypergolic mixture of nitrogen tetroxide and monomethyl hydrazine propellants. Specific impulse of this propellant combination is about 290 lb.-sec./lb., compared with the approximate 155 lb.-sec./lb. of the monopropellant hydrogen peroxide used by Mercury for attitude control. Jerome B. Hammack, of the Gemini project office at NASA's Manned Spacecraft Center, recently estimated that the choice of this hypergolic combination, rather than a comparable peroxide system, saved about 700 lb. of payload for Gemini.

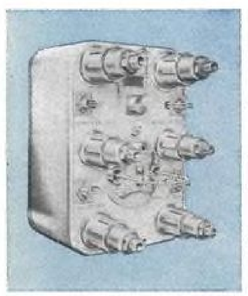
Thrusters are cooled by pyrolysis, or charring of the material lining the thrust chambers. In development testing of this system, Rocketdyne discovered that a higher char rate occurs with firing durations between 10 and 30 sec. Above and below this band, the char front progresses in accordance with predicted values.

Char was found to run deeper in that region of the chamber near the nozzle throat. Rocketdyne and NASA made analytical studies of various mission profiles along with duty cycles, pulse frequencies and pulse durations required of the thrusters with each profile. From this computer-derived data and with the empirical data already obtained on char progression, Rocketdyne was able to determine an optimum design for distribution of material in the chambers.

Rocketdyne could not simply add more material to the chambers. To do so would change the ratio between chamber length and volume to exit throat diameter of the thrusters and, consequently, performance. Added ma-



TITAN, Gemini launch vehicle, is aligned for testing at Martin Co. facility.



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GEMINI engineering mockup with an Agena docking collar simulator at the far left. McDonnell employe in pressure suit stands with his hand just behind one of the two hard points to be used to lock the Agena target stage onto the Gemini spacecraft.



INTERIOR VIEW of the two-man Gemini cockpit mockup shows seating arrangement and the multitude of crew displays. Portion of the spaceframe immediately forward of the cockpit is scalloped for better vision. Reaction control orifice is at upper right.

terial also would increase the total weight of a spacecraft already approaching the 8,000 lb. payload capacity of the Titan 2 booster. One extra pound of payload has been estimated to require another 70 to 100 lb. of thrust from the launch vehicle. Instead of adding material, therefore, Rocketdyne re-distributed the amount of material originally lining the chambers, adding to the section where char is heaviest and thinning the region where char is lightest, at the top of the chamber near the injector.

For long-duration flights—between 7-14 days—the on-board propulsion system consists of only a single set of tanks for fuel, oxidizer and gas pressurization. For rendezvous missions, which are shorter in duration but which require more maneuverability, a duplicate set of tanks are added to Gemini's adapter. Second set of tankage partially explains the heavier weight of a Gemini configured for rendezvous—at 7,800 lb. —than one intended for long-duration flight—at 6,800 lb.

On-board propulsion system, plus the variable launch azimuth capability of the Titan 2 launch vehicle and the additional propulsion of the Agena stage, all have been combined to give Gemini the capability of flying in almost any orbital plane. The logical extension of this maneuverability was to add the capability of controlled re-entry and surface landing.

To this end, NASA and McDonnell designed Gemini with a center of gravity offset by about 1.5-in. from the spacecraft's geometric center, giving the vehicle a positive lift vector during re-entry. With the CG aligned with the flight path and above the spacecraft's geometric center, oriented toward space, the lift vector is greatest and Gemini trims out at an angle of 16 deg. above a local horizontal. Rolling the CG back and forth across the 180 deg. arc on the space-oriented side of the trajectory causes the spacecraft to bank proportionately to the amount of roll. Maintaining a constant roll rate nulls out the lift vector and causes the vehicle to fly a zero-lift trajectory.

By modulating the lift vector, the Gemini crew can extend—but not shorten—the re-entry trajectory or correct minor plane misalignments between re-entry plane and the plane of their chosen landing field.

Coupled with this positive lift capability during re-entry is the paraglider landing system, which would enable Gemini to make an aircraft-type landing on any smooth surface. At the beginning of the Gemini program, it was obvious to NASA that there had to be a better way of landing and recovering a spacecraft than deploying large forces of the U. S. Navy and Air Force throughout the world. For this reason, and also for the re-use of spacecraft, NASA decided on an inflatable wing and a tricycle skid gear as the primary landing system for Gemini.

Manned Spacecraft Center selected the Space and Information Systems Div. of North American Aviation, Inc., to develop the paraglider under separate contract. The wing is to be delivered to McDonnell as government-furnished equipment. Six paragliders have been ordered, although a production contract has yet to be signed. McDonnell is building the skid gear as part of the spacecraft.

Paraglider has had development problems (AW Jan. 28, p. 55) and is far behind schedule. It will be replaced by a single 84-ft. dia. parachute system, similar to that developed for Mercury by Northrop Ventura, on initial flights. The wing might be qualified in time for the fourth Gemini mission, according to one NASA official, but it is more likely that it will not be ready until the sixth mission. If it encounters further development troubles, it might not be flown until the seventh or eighth mission. NASA officials are admittedly disappointed in the wing's development to date, as it necessarily means that initial Gemini flights will terminate with water landings and that Defense Dept. recovery forces again will have to be deployed.

NASA had hoped to avoid water landings because of the salt water corrosion problem. This corrosion might make impossible attempts to re-use Gemini spacecraft which have landed in the ocean; at the least, it will make refurbishment a more difficult and expensive operation. NASA also had hoped that it could reduce drastically the amount of support required for recovery operations by Defense Dept., since this involves scheduling problems and additional cost to NASA.

Recently, a number of modifications have been made to the paraglider. Billow of the sail material between the wing booms has been flattened slightly by narrowing the apex angle of the triangular Fortrel cloth segments from 55 deg. to 52.5 deg. This has increased the lift/drag ratio from 2.8 to 3.8.

L/D ratio was increased to give the pilot more control over his descent rate, especially for the flare maneuver. This maneuver, made just prior to touchdown, is critical with respect to altitude —it is expected to be made 60 to 70 ft. above the ground. Fearing that a pilot might be fatigued at this point, after a long flight in space, and that he might not respond promptly when the time came for this maneuver, NASA ordered the L/D increased so that the pilot will not stall if he flares too early or fly his craft into the ground if he flares too late.

This modification has resulted in a small vertical velocity component of 5-6 fps. being added to touchdown, but the horizontal velocity is expected to remain about 76 fps.

In one other change to the paraglider, NASA has reduced the pay-out length of the nose cable—one of several which join the wing and spacecraft—so that the maximum wing setting now is 38 deg., compared with an earlier maximum of 45 deg. Manned Spacecraft Center feels that the new angle is sufficient for the flare maneuver, given the new L/D ratio and an improved minimum lift coefficient. Normal glide position of the paraglider is 25 deg. above the line of flight.

Electrical power for the two-man craft will be provided primarily by a fuel cell, developed by General Electric's Direct Energy Conversion Operations, Lynn, Mass., and secondarily by a group of silver-zinc batteries. A fuel cell was selected for the primary system over conventional batteries because of

Major Gemini System Contractors

Company	System	Value (Millions*)
McDonnell Aircraft Corp. St. Louis, Mo.	Prime Spacecraft	$456.6
Rocketdyne Canoga Park, Calif.	Reaction control and orbit attitude maneuvering	30.8
Honeywell St. Petersburg, Minneapolis	Inertial measuring unit and attitude control, maneuver electronics	25.3
International Business Machines Owego, N. Y.	Inertial guidance system and integration	24.9
AiResearch Mfg. Co Los Angeles	Environmental control and reactant supply	19.8
Electromechanical Research Sarasota, Fla.	Data transmission	14.8
Westinghouse Electric Baltimore, Md.	Rendezvous radar, transponder	8.6
General Electric Pittsfield, Mass.	Fuel cell	8.4
Weber Aircraft Burbank, Calif.	Ejection seats	4.4
Motorola Scottsdale, Ariz.	Digital command	3.9
Advanced Technology Laboratories Mountain View, Calif.	Horizon sensors	3.1
Northrop Ventura Newbury Park, Calif.	Recovery system	2.0
Collins Radio Cedar Rapids, Iowa	Communications	1.7
Thiokol Chemical Elkton, Md.	Retrograde rockets	1.6
Link Binghamton, N. Y.	Computer	1.3
American Car & Foundry Paramus, N. J.	C&S band beacon	1.1
Hamilton Standard Windsor Locks, Conn.	Ground servicing units	1.0
Lear Siegler Grand Rapids, Mich.	Attitude display	1.0

* As of July 1, 1963.

its better power-to-weight ratio for time periods above several days and because its reactant product is potable water. Cell system delivers 2,100 watts.

Four silver-zinc batteries, each rated at 40 amp.-hr., provide power to the spacecraft during retrograde, re-entry and post-landing periods because the adapter module in which the cell is located is jettisoned prior to re-entry. The batteries also provide emergency power for at least one full orbit in the event of fuel cell failure during flight. Three smaller silver-zinc batteries provide power to actuate pyrotechnic devices, control relays and solenoids on isolated circuits.

This power system will preclude voltage spikes, which proved troublesome to Mercury.

Also as a result of Mercury experience, individual inverters will be used for each of the a.c.-powered units such as the environment control system electronics, suit and cabin fans, coolant pumps and the inertial guidance system.

The fuel cell and its propellants—cryogenic hydrogen and oxygen—are stored in the adapter module. Location of systems such as the cell in the adapter and in bays surrounding the manned cabin has solved the problem of accessibility and maintenance, but in so doing has raised the problem of heat dissipation.

In Mercury, systems inside the spacecraft were cooled by the gaseous oxygen that was circulated through the cabin. Gemini's design rules out convective cooling.

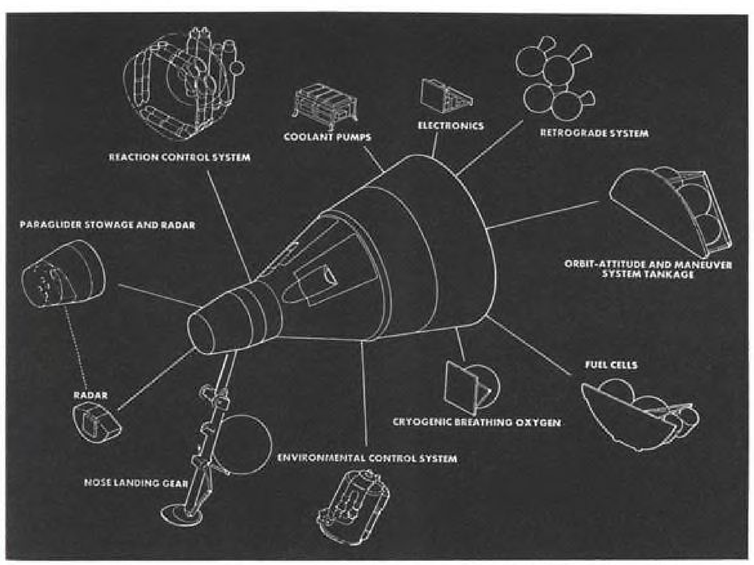
Solution was to mount all heat-generating systems on hollow aluminum cold plates, and circulate a silicon ester fluid through the sandwich-type units. The fluid, developed by Monsanto Chemical Corp., picks up heat and is pumped back to the adapter module through tubing.

Tubing, in the form of T-shaped extruded magnesium alloy, serves both as a fluid conductor and as a structural stringer. A tube bulb, 0.25-in. dia., extends off the bottom of the approximately 0.5-in. long shank of the "T" and thereby derives some protection against meteorite puncture simply by being away from the external skin of the module.

Heat soaks through the bulb and the "T" leg to the magnesium alloy skin of the adapter module and there is dumped by radiation. Surface of the adapter is about 190 sq. ft. and provides a fairly large radiator area. During the boost phase of flight, aerodynamic heating raises the temperature of the adapter's surface beyond its effective level.

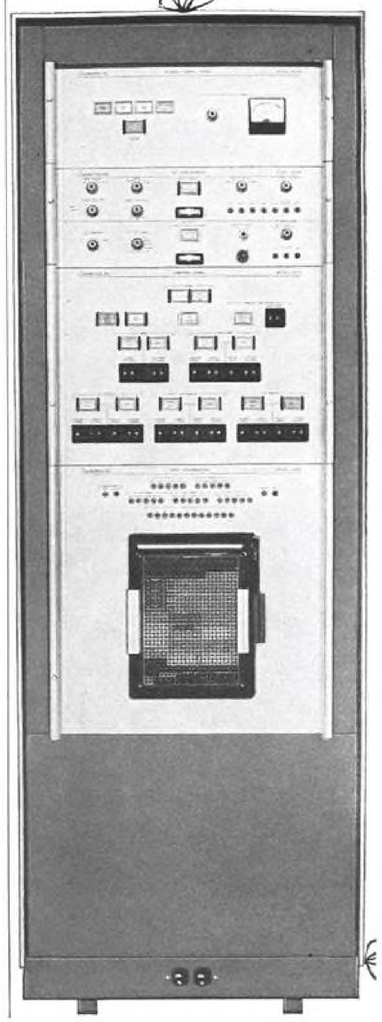
A water boiler is therefore substituted for the two independent Monsanto loops during this leg of the flight. In orbit, the radiator requires about 30 min. to cool off before it can become effective.

Guidance and control system consists of a four-gimbal gyro-stabilized platform, originally developed by Honeywell for the Centaur upper stage (AW Dec. 26, 1960, p. 65), a digital computer developed by International Business Machines Corp. (AW July 15, p. 58), a logic circuit, also developed by Honeywell and the rendezvous radar, developed by Westinghouse Electric Corp. Infrared horizon sensors are provided



LINE DRAWING SHOWS the two-man Gemini spacecraft surrounded by its major systems. Nose landing gear will be a part of the system only in a paraglider recovery.

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COMPACT AND FLEXIBLE:
The basic Telemetrics 620 System mounts easily in a 6-foot standard 19-inch relay rack, with space available for add-ons.

ALL CONTEMPORARY FORMATS:
The Telemetrics 620 System accepts PCM data in practically any format from receivers, tape recorders, and simulators; and produces decommutated outputs to tape recorders, computers, and analog and digital recording devices. Regenerated data outputs are made available for serial tape recordings. A pre-programmed patchboard is available for each of today's formats.

COMPLETE BIT-RATE RANGE WITHOUT PLUG-INS:
Operator selectable from fractions of 1 pps to 1,200,000 pps.

SUPERIOR SIGNAL-TO-NOISE PERFORMANCE:
Every production unit performs within 1 db of theoretical best.

INCREASED RELIABILITY FACTORS:
Advanced cooling system maintains internal temperature within a few degrees of ambient. Gold-to-gold taper-pin connections eliminate solder-joint troubles. Severe component derating reduces random failure. Reduction of front-panel adjustments lessens operator-error.

SIMPLIFIED OPERATION:
The Telemetrics 620 System is easily operated by general data processing personnel as well as telemetry specialists.

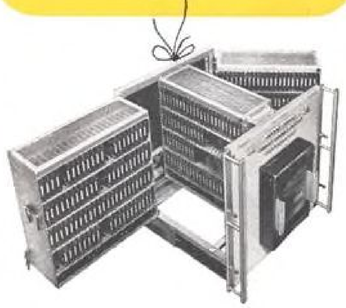
MAINTENANCE SIMPLICITY:
Units glide forward on ball-bearing slides. Automatic retractors handle cable slack. Quick and accurate testing of plug-in circuit operations accomplished with Model 110 Plug-in Tester (optional).

Bit Synchronizer *features operational simplicity and extremely low error-rate. All phases of synchronizer performance displayed on front panel. Makes less than one error in 10,000,000 bits with S/N = 14 db, and true bit sync easily maintained even when noise increases above signal to: S/N = —3.6 db.*
Options *to bit synchronizer include: crystals for any frequency, second input conditioner for dual channel tape operation, switch for selecting additional receiver or tape inputs, automatic bit rate selection, and special connectors.*



'63, 4, 5, 6, 7, ∞

Data Synchronizer—*Combining all circuits into one unit reduces wire length. Point to point wiring reduces cross-talk. Swing out chassis have self-contained blowers to provide cooling during maintenance. Gold-to-gold taper pin connections eliminate solder joints as a source of trouble. Spare plug-in locations allow for addition of options. Front panel indicators display system status.*





PCM Decommutation System Model 620-2 (Boeing)
designed for X-20 (DynaSoar), Gemini, Minuteman, and Saturn formats. Accepts parallel tape, receiver, or simulator inputs; produces parallel outputs (each channel ID coded) for tape recorder and computer.

'63, 4, 5, 6, 7, 8

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by Advanced Technology Laboratories and displays by Lear-Siegler.

This guidance system, which some Gemini project personnel view as the forerunner of future deep-space navigation systems, is used in a number of different ways:

• **Back-up during launch.** Primary guidance for the Martin Co. Titan 2 launch vehicle will be provided by the General Electric-Burroughs Corp. radio-command system adapted from the Atlas and Mercury-Atlas programs, but the IBM-Honeywell inertial system will be capable of steering the Gemini-Titan 2 into orbit in the event of a primary system failure.

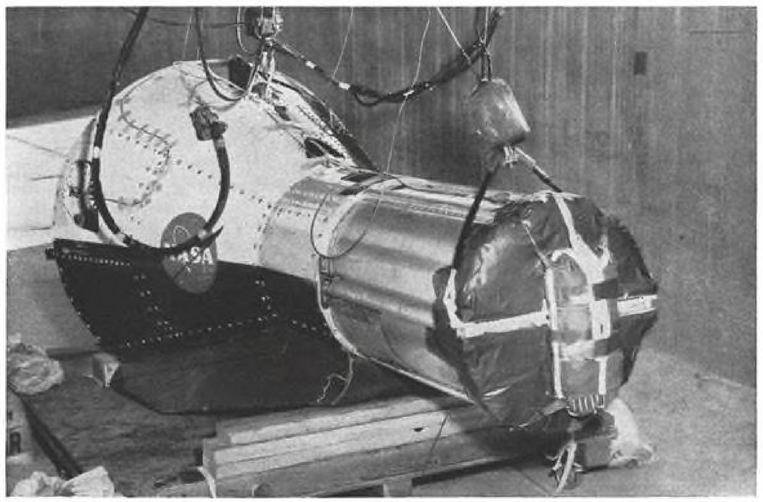
• **Orbit navigation.** In orbit, the computer constantly determines the position of Gemini relative to earth longitude and latitude. It predicts future plots so that by looking at charts, the crew can tell which landing sites are available to them on future orbits. Should the crew be interested in a particular field or in flying over a specific area of interest, they would enter the coordinates of that site into the IBM computer. The computer then would display the directions and magnitudes of the velocity vectors required to reach that site, and if it is a landing field, time for retrofire.

• **Rendezvous.** Interferometer-type radar developed by Westinghouse (AW Oct. 22, p. 72) provides range, range rates and elevation data on the Agena

Titan 2 Vibrations

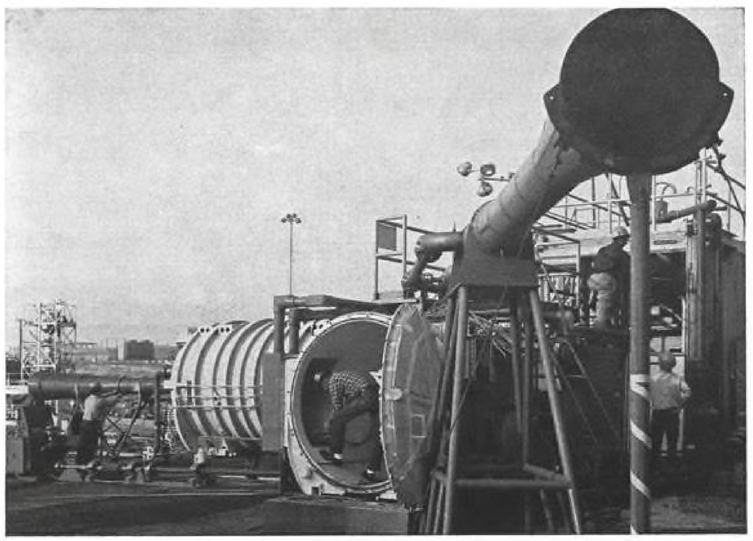
Vibration problem continues in the first stage of the Titan 2 Gemini launch vehicle, but modifications to the propellant feed system are reducing the forces of the oscillations. Ullage pressure has been increased, a surge chamber and mechanical damper have been added and the aluminum propellant lines have been substituted for steel in attempts to reduce the longitudinal force of 1g, which oscillates back and forth like an accordian with a frequency of 11 cps.

The condition lasts about 20 sec. and reaches its peak about 90 sec. after lift-off. Medical studies have shown that the eyes and some internal organs come to resonance at a frequency range of 5-14 cps., resulting in a wide range of reactions by the pilot, "most of them unpleasant," according to Willis B. Mitchell of Manned Spacecraft Center's Gemini Project Office. Series of tests is to start this month at Ames Research Center using a gondola in which a pilot will be subjected to varying gravity-frequency combinations to determine the limits of effectiveness under these forces.



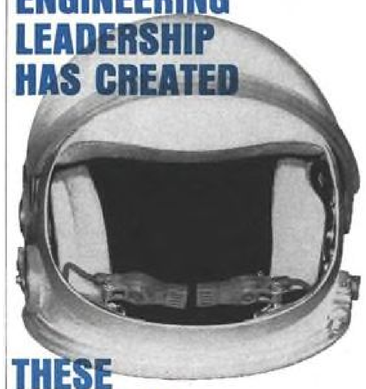
BOILERPLATE GEMINI spacecraft is being readied for a paraglider drop test by North American Aviation. The dummy vehicle is carried under a helicopter for these tests.



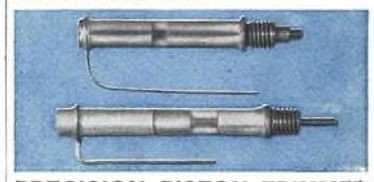


GEMINI LAUNCH vehicle (Titan 2) second stage, above, is moved from assembly to test by Martin Co. Below is Rocketdyne chamber for testing Gemini maneuvering engine.

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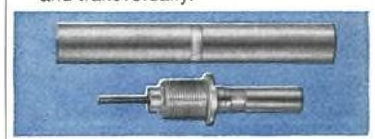


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target stage relative to the Gemini spacecraft.

The computer uses this data to determine the optimum intercept course to be flown by the manned vehicle to rendezvous with Agena.

• **Re-entry.** With data inputs from ground tracking stations and from the Honeywell platform, the computer continuously compares the actual trajectory being flown by the re-entering craft against the ideal trajectory to be flown to the landing site.

The difference between the two trajectories is an error signal sent by the computer through a logic circuit to the appropriate thrusters of the re-entry control system; the spacecraft then is rolled, pitched or yawed to the correct heading.

Communications and environment control systems, the former built by Collins and the latter by AiResearch, are similar to those in the Mercury capsule. Major difference between Gemini and Mercury environment systems is that the pilot's suit in the two-man craft now is the primary life support system; the capsule was primary and the suit secondary in Mercury. Also, primary breathing oxygen for Gemini will be in super-critical form rather than gaseous as in Mercury; this 104-lb. sphere will be located in the adapter module and will be used for long-duration flights of the Gemini spacecraft.

Secondary oxygen system consists of two 7.5-lb. spheres of gaseous oxygen at 5,000 psi.

These bottles are located in the environment control package in the pressurized section of the cabin module and are the primary suppliers during the short-duration rendezvous missions, as well as the orbital emergency, normal re-entry and post-landing reservoirs.

Heat Exchangers

Heat exchangers in Gemini, which cool recycled gas, are finned and use the Monsanto silicon ester-fluid loops to draw off metabolic heat from the life support system. Mercury used a water boiler.

Gemini communications consist of redundant ultra-high-frequency (UHF) and high-frequency (HF) transmitters and receivers, the former the primary and the latter the secondary link.

Another significant change in Gemini from Mercury is substitution of a pulse-code-modulated (PCM) telemetry system for the frequency-modulated (FM/FM) system.

Greater mission complexity and the addition of a second crew member dictated a higher-capacity, faster read-out telemetry system and so NASA elected to use a PCM system. It is being developed by Electro-Mechanical Research.

Tracking Stations

Six existing Mercury tracking stations and one new one will be used for this PCM telemetry system, through a new acquisition aid antenna, additional telemetry receivers, high-speed data processors, more digital command transmitters and modifications to FPS-16 radars to permit better discrimination between Gemini and Agena, at each site.

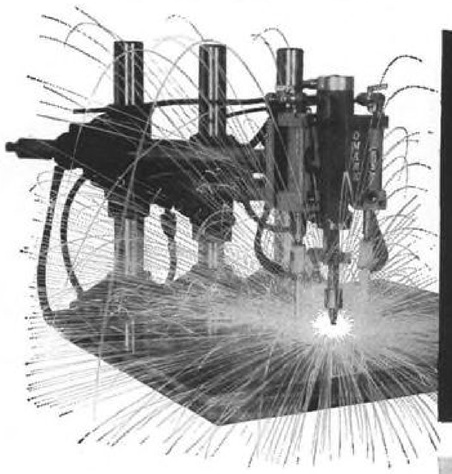
Target and seeker will be transmitting on very close frequencies. New station will be Carnarvon, Australia; existing stations to be modified include Honolulu, Guaymas, Corpus Christi, Cape Canaveral, Bermuda and the Canaries.

One of two tracking ships—either the Rose Knot or the Coastal Sentry—will be equipped with the augmentation kit.

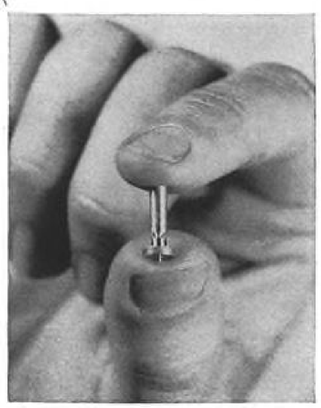
A decision has yet to be made whether to similarly equip the second ship or to build a new station on an island in the far western Pacific Ocean, such as Okinawa or Japan.

Mercury stations not equipped with the kits will be able to maintain voice communications with Gemini spacecraft, but will not be able to receive PCM telemetry data nor send the variety of commands possible at the newly-modified stations.

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Gemini to Be Rendezvous Proving Ground

Gemini rendezvous program is being designed as the proving ground for techniques and experience that a variety of advanced programs will need for the most economical attainment of their goals.

Lunar orbit rendezvous, the technique selected by National Aeronautics and Space Administration for the Apollo manned lunar landing mission, is but one type of rendezvous and cannot provide the broad foundation of rendezvous procedures and doctrine upon which NASA plans to base many of its future programs. Gemini, therefore, has emerged as a vital program in its own right in addition to maintaining its critical Apollo support role.

Equipment to be used in this comprehensive exploration of rendezvous includes the two-man McDonnell Gemini spacecraft, the Lockheed Agena D upper stage and the Martin Titan 2 launch vehicle. Agena was selected for this program because of its experience—various configurations have been flown more than 100 times in the past four-and-one-half years. In addition, it has demonstrated reliability in these flights, and its propulsion system has a multiple re-startable capability. Titan 2 capability extends beyond injecting a heavy payload into orbit; it can be maneuvered during boost to optimize the terminal leg of rendezvous for the spacecraft.

Role Interchange

Because performance and accuracy of these vehicles in consort exists only on paper until actual flight experience is obtained, NASA's Manned Spacecraft Center decided at the start of the program that both spacecraft and stage should be able to swap the roles of seeker and target to increase chances of success.

At the same time, the center sifted its future plans—lunar operations, earth-orbital operations leading to deep-space manned probes, earth-orbiting space stations and related tasks—to see which elements of rendezvous are common to all. Starting with the assumption that operations should be simplified for reliability and economy, NASA found that:

• **Target vehicle and seeker** normally should be unmanned and manned, respectively, and target vehicle should be placed in orbit first. With this sequence, the mission does not commit the manned vehicle to flight until after the target has been successfully orbited and its proper functioning ascertained.

• **Fixed orbit** should be flown by one of the two vehicles—normally the target—unless the mission could not be made without assistance from the fixed-orbiting vehicle. There should be a reasonable difference between the orbital periods of target and seeker so that phase differences between the two can be resolved.

• **Confidence level** in the launch vehicle and the spacecraft should be high enough to take full advantage of the best launch windows.

• **Launch vehicles** should have the capability of correcting out-of-plane errors between seeker and target. Guidance system should be capable of correcting errors which have accrued during boost and mid-course flight so that the terminal leg of rendezvous is able to concentrate on docking.

Flexible design of Gemini and Agena will permit each of these areas to be explored in depth. Although both spacecraft and stage will be configured with their full design capabilities from the start, the tasks planned for each successive mission will graduate to increasing complexity. Each rendezvous mission will contain minimum objectives, and if these are realized early in the flight, there will be the option of attempting other tasks or repeating those accomplished.

The large number of variables of vehicle performances and assumed conditions make it impossible at this stage to describe a typical mission. Generally, an Atlas will lift a fueled Agena into a circular 190-mi. orbit, with an angle of inclination of 28.87 deg. and a period of 91.4 min. This angle was selected because it traces out the largest possible number of orbital plots which pass through or near Cape Canaveral. With many Agena overhead passes in close to the spacecraft launch site, plane differences between the two can be held to a minimum. In Gemini rendezvous missions, plane differences are not considered as critical as phase differences.

The day after Agena has been orbited and its ephemeris calculated, the two-man spacecraft will be launched. Minor plane differences between target and seeker will be corrected during boost flight by the Titan 2. This converted USAF ballistic missile can be rolled as much as 20 deg. clockwise or counterclockwise to take up any flight azimuth in this 40 deg. spread. Tracking limitations of the Atlantic Missile Range restrict this azimuth band to between 82 and 105 deg., or to 23 deg.

Agena Maneuverability

The Lockheed Agena D target vehicle in the Gemini rendezvous mission will have the capability of changing its plane by as much as 12 deg. in maneuvering toward the Gemini target. Depending on how much velocity capability is used to attain the proper orbit, it is now estimated that the stage will have between 5,400 and 4,100 fps. potential velocity change remaining after it reaches orbit. This corresponds to plane change capabilities of 12 deg. to 9.5 deg.

After the docking maneuver is completed, Agena is expected to have a potential velocity increment of 2,300 fps. remaining.

This will allow the stage to change its plane by 6 deg.

Variable-Azimuth Launch

This variable-azimuth launch capability can be used in two ways: parallel launch or yaw steering. In the first method, Gemini is launched when the plane of the orbiting Agena and the plane of the Gemini-Titan 2 combination come within 0.6 deg. of each other at the point of launch. This will provide a total plane window of about 135 min., with two optimum planes of 37 min. each. The first occurs as Agena passes the Cape on an ascending arc to its northernmost latitude and the second as it descends from this point.

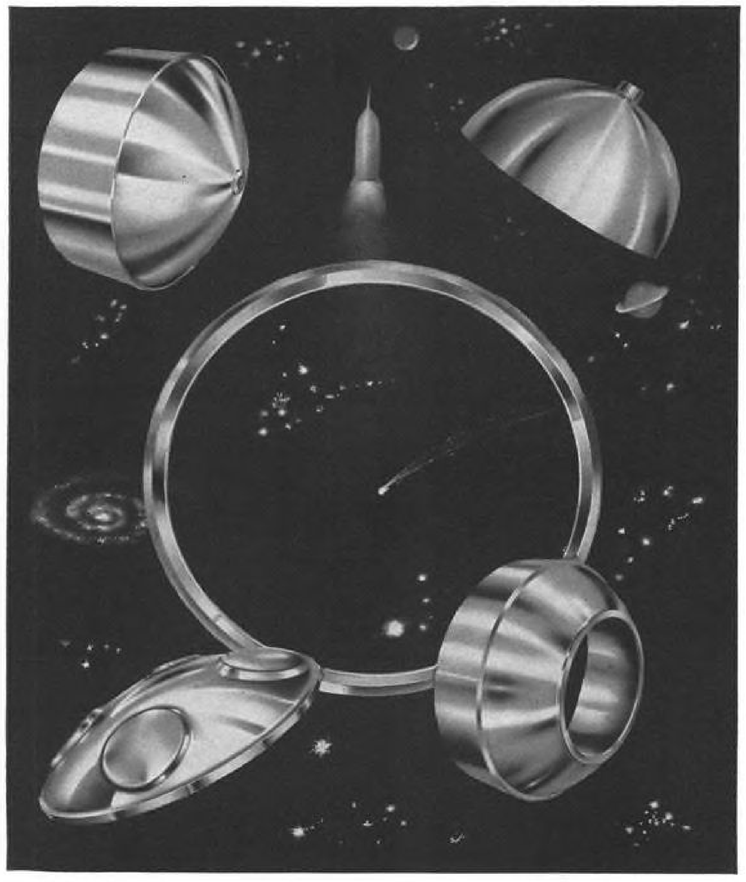
By launching into a plane nearly parallel with that of Agena, the plane of the seeker should intersect that of the target about 90 deg. from the launch site.

If the phase relationship of the two vehicles was optimum at the time of Gemini launch, then the mission will proceed directly from boost-flight to the terminal phase. This is called an immediate rendezvous.

Elliptical Orbit

If the spacecraft is launched at any other time when phase is not optimum, the spacecraft will be placed in an elliptical orbit, 190 mi. at apogee, 104 mi. at perigee, with a period of 90 min. and an inclined angle no more than 0.53 deg. different than that of Agena's. Difference in orbital periods is equal to 5.6 deg. of travel each revolution and this is the catch-up rate for the lower-altitude, slower-moving Gemini.

If rendezvous is to be achieved by orbital mechanics only, there is a limit to the amount of phase difference that can be tolerated between Agena and Gemini at the time of the second launch. If rendezvous must be accomplished within one day after orbital injection of Gemini, the two vehicles can be no more than about 90 deg. out



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of phase since 16 orbits in a 24-hr. period times 5.6 deg. catch-up per orbit equals 89.6 deg. If NASA is willing to let the manned spacecraft circle the earth four days before initiating the mid-course propulsion maneuver of rendezvous, then the allowable phase difference between seeker and target would expand almost to 360 deg.

Present NASA plans view 29 orbits as the maximum time spent by the manned vehicle in catching up to Agena; this translates into a maximum of 160 deg. allowable phase difference between the two, and corresponds to a phase launch window of 43 min. At least for the first mission, the upper limit of phase difference probably will be held to 70 deg., or a catch-up limit of 12 or 13 orbits.

In yaw steering, the first part of boost flight would be similar to that of the parallel-launch, with the Titan 2 flying along an optimum azimuth to intercept the orbital plane of Agena. During second stage burning, as the two planes crossed, Titan 2 would be yawed to place Gemini in a co-planar orbit with Agena. Second method is expensive in terms of fuel expenditure, but allows for correction of greater out-of-plane errors and uses Titan 2 as the primary propelling agent.

Variables in the mission are infinite. After Agena's orbital parameters have been calculated by a computer and determined to be slightly different than expected, the computer might also predict that the optimum plane and phase windows will occur four days later—near the end of the stage's five-day capability. Should the launch of the manned vehicle be postponed until then or should it be launched immediately, with phase and plane differences resolved by re-starting the Agena and placing it in a new—and hopefully correct—orbit? If Gemini is injected into a slightly higher than expected orbit, so that the difference in orbital periods is only about 40-45 sec. and the catch-up rate is about 2 deg. per revolution, would it be better to kick Agena out on a long ellipse to increase the catch-up rate, or would it be better to use some of the manned spacecraft's on-board propellant to drive the vehicle into a lower orbit? If troubles have been cropping up on the day of launch of the manned spacecraft and a one-day postponement appears likely if the vehicle is not launched during the next 43-min. phase window, might it not be better to pass up that last chance today if the computer shows that re-cycling after that window will insure missing the ideal plane and phase windows?

These are but a few of the many variations and contingencies which can and probably will confront mission operations and control personnel.



SEVEN MERCURY ASTRONAUTS, lined up by an Air Force-Convair F-106B in which they maintained flight proficiency, are (l. to r.) Malcolm Scott Carpenter, Leroy Gordon Cooper, Jr., John H. Glenn, Jr., Virgil I. Grissom, Walter M. Schirra, Jr., Alan B. Shepard, Jr., and Donald K. Slayton. Glenn, Carpenter, Schirra and Cooper flew orbital missions. Shepard and Grissom flew suborbital flights.

Mercury Showed Value of Pilot in Space

Decision to end Project Mercury with the fourth manned orbital flight last May 15 has closed the first chapter in the U. S. program to probe the fringes of space by experimenting with man as a functioning part of the satellite system.

In its brief lifetime, Mercury proved to be the vital element in providing this nation with the confidence, experience and fundamental knowledge necessary to fully utilize man and his abilities in complex space missions of the future.

When the Mercury program was born in October, 1958, it was given two fundamental objectives: determine man's capabilities in space, and develop the foundation for manned space flight technology.

As the program evolved, it became obvious that Mercury was contributing not only to the technical and engineering advancement of the U. S., but also to its political and international maturity.

The manner in which Mercury flights have been conducted became a symbol of the open society, a factor which has been heavily exploited by the Kennedy Administration.

Any summary of Mercury, even by its detractors, would have to state that the project effectively met its objectives. Gemini and Apollo spacecraft and missions—based on Mercury experience—are being designed with the pilot as a primary, integral system whose judgment, reasoning and discrimination are not only desired but are critical to mission success. And these future missions will be conducted on the patterns which Mercury established.

The major difficulties experienced in Mercury flights, according to Christopher C. Kraft, Jr., director of flight operations, stemmed from an inability to design the first spacecraft system around the man.

"The reason we got in a box with Mercury," he said, "was because we didn't know what man could do. We didn't know if he could react in the 10 sec. time period in an off-the-pad abort. We didn't know how he would adapt in a zero gravity environment."

As a result of these basic unknowns, Mercury was designed as an automatic system in which the astronaut was considered a passenger rather than a pilot or controller.

Without the astronaut, however, only Cdr. Walter M. Schirra's Mercury Atlas-8 mission would have been completed successfully of the four orbital manned Mercury flights. Both Lt. Col. John H. Glenn and Lt. Cdr. Scott Carpenter, because of fuel depletion, would have had to come down after two orbits if they had not manually controlled their capsules. Maj. Gordon Cooper could not have re-entered the atmosphere automatically because his sequencer became inoperative at the end of the 19th orbit. He was able to suc-

Mercury Funding

Washington — United States spent $411.8 million to conduct the Mercury program through six manned space flights. Of this, $358.6 million was spent for research, development, operations, launch vehicles and range operation and $53.2 million was spent for construction and equipment.

In its Fiscal 1961 budget request in January, 1960, National Aeronautics and Space Administration estimated completion cost of Mercury at $393 million. Fiscal 1961, the third funding year for the program, was the peak year—$109.5 million was spent for research and development and $15 million for construction.

The Mercury flight program ended last May 16 when Maj. Gordon Cooper completed 22 orbits in the Mercury Atlas-9 spacecraft. Maj. Cooper's flight was the most expensive, costing $29.8 million.

cessfully complete his programed 22 orbits by piloting the capsule.

Most obvious measure of the success of Project Mercury is reflected in the flight program (see chart, p. 199), which consisted of 25 rocket-boosted launches and a beach abort test.

While these flights demonstrated the validity of concepts and theory, it is less obvious that they were possible only through the successful solution of hundreds of new problems and challenges which had never had to be solved before, at least in the same degree. Among them:

• **Spacecraft development.** This involved conceiving, designing, developing and manufacturing the most reliable systems and subsystems to control environment, maintain orientation, assure worldwide communications, validate the ability to survive under unprecedented heating loads, and assure safe re-entry.

In the development of the Mercury system, according to Robert R. Gilruth, director of Manned Spacecraft Center, the capsule was designed first for good re-entry performance and its compact, symmetrical shape was readily adaptable to the Redstone and Atlas booster geometry. Its upper structure was arranged to contain the parachutes and support their loads.

The landing bag was included to attenuate landing shock and to stabilize the capsule in water.

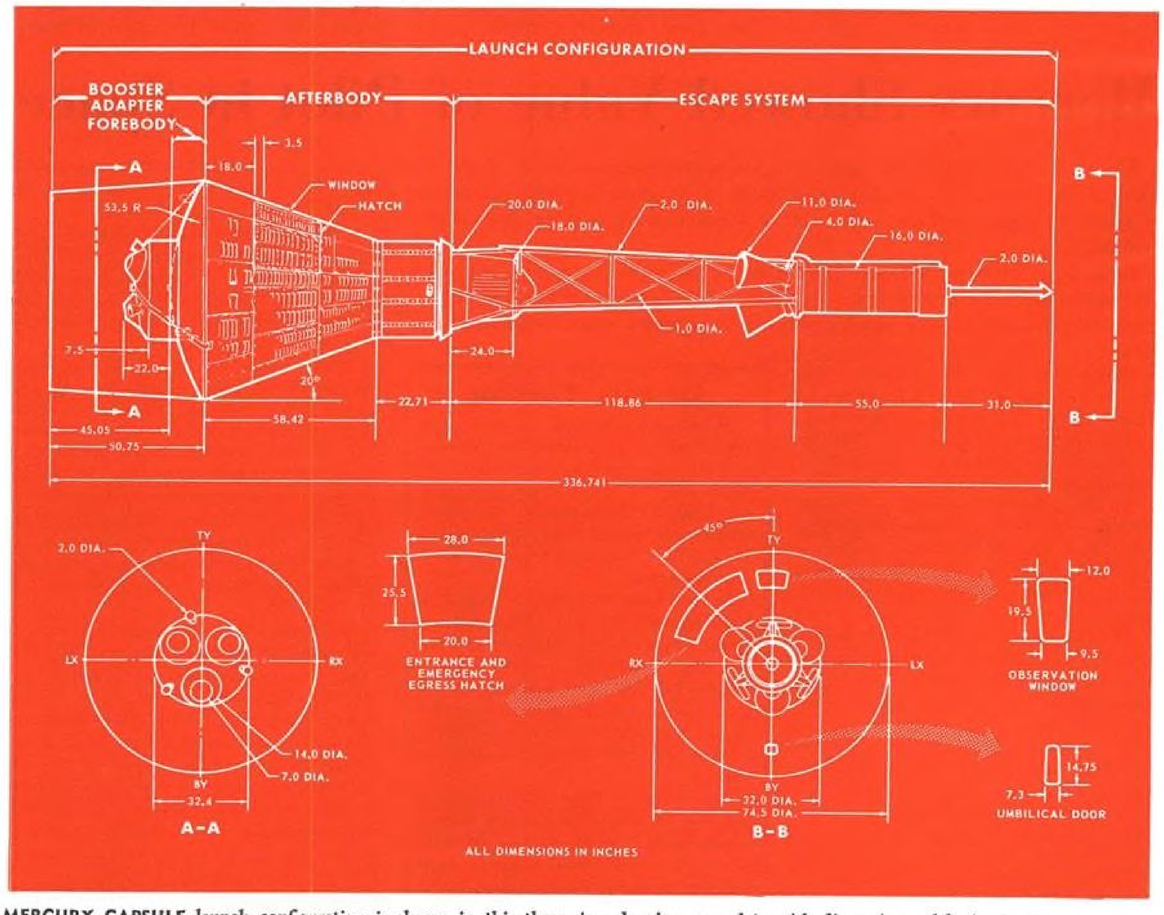
"The problems of providing all these capabilities, together with a launch escape method, separation motors, retrorockets, life support equipment, stabilization and control systems, communications gear and other crew requirements within the allowable weight limits was extremely challenging," Gilruth said. If Mercury had been redesigned as much as three years after the designs were frozen, there would be "very little in its basic concepts that we would or could change," he said.

As the program developed, however, it became obvious that the capabilities of the astronaut went well beyond mere survivability, and that some method would have to be devised to allow him to overcome the "single point of failure" problem in automatic systems.

This problem develops when the



ASTRONAUTS Cooper (right) and Glenn examine helmet and gloves Cooper wore on the MA-9 mission.



MERCURY CAPSULE launch configuration is shown in this three-view drawing, complete with dimensions of basic structures.

Project Mercury Flight Program History

Mission Name	Date	Objective	Pilot/Passenger	Apogee and Perigee (mi)	Remarks
Little Joe	8/21/59	Booster Test	None	Suborbital	Failure. Escape rocket fired on pad.
Big Joe	9/ 9/59	Re-entry Test	None	Suborbital	Success.
Little Joe 1	10/ 4/59	Booster Test	None	Suborbital	Success.
Little Joe 2	11/ 4/59	Max "q" abort	None	Suborbital	Escape rocket fired early.
Little Joe 3	12/ 4/59	High altitude abort	Monkey (Sam)	Suborbital	Success.
Little Joe 4	1/21/60	Max "q" abort	Monkey (Miss Sam)	Suborbital	Success.
Beach abort	5/ 9/60	Pad abort	None	Suborbital	Success, production capsule.
Mercury Atlas-1	7/29/60	Re-entry Test	None	Suborbital	Failure, booster exploded.
Little Joe 5	11/ 8/60	Max "q" abort	None	Suborbital	Failure, escape rocket ignited early.
Mercury Redstone-1	11/21/60	Test capsule structure	None	Suborbital	Failure. Early booster cutoff.
Mercury Redstone-1A	12/19/60	Test capsule structure	None	Suborbital	Success.
Mercury Redstone-2	1/31/61	Systems Test	Chimp (Ham)	Suborbital	Success.
Mercury Atlas-2	2/21/61	Re-entry Heating	None	Suborbital	Success.
Little Joe 5A	3/18/61	Max "q" abort	None	Suborbital	Escape rocket fired early.
Mercury Redstone Booster Development	3/24/61	Man-rate Redstone	None	Suborbital	Success.
Mercury Atlas-3	4/25/61	Capsule orbital test	None	.....	Failure, booster destroyed.
Little Joe 5B	4/28/61	Max "q" abort	None	Suborbital	Success.
Mercury Redstone-3 (Freedom 7)	5/ 5/61	Manned Flight	Cdr. A. B. Shepard	Suborbital	Success. First U. S. manned space flight.
Mercury Redstone-4 (Liberty Bell 7)	7/21/61	Manned Flight	Maj. V. I. Grissom	Suborbital	Success. Capsule sunk.
Mercury Atlas-4	9/13/61	Capsule Orbital Test	None	158.6–100	Success. One orbit
Mercury Scout-1	11/ 1/61	Check Network	None	.....	Failure. Booster destroyed.
Mercury Atlas-5	11/29/61	Capsule, Systems Test	Chimp (Enos)	146–99	Success. Ended after 2 orbits because of fuel depletion. 3 orbits planned.
Mercury Atlas-6 (Friendship-7)	2/20/62	Manned Orbital Flight	Lt. Col. J. H. Glenn	162.7–100	Success. 3 orbits. First U. S. manned orbital flight.
Mercury Atlas-7 (Aurora-7)	5/24/62	Manned Orbital Flight	Lt. Cdr. Scott Carpenter	166–100	Success. 3 orbits.
Mercury Atlas-8 (Sigma-7)	10/ 3/62	Manned Orbital Flight	Cdr. W. M. Schirra	176–100	Success. 6 orbits.
Mercury Atlas-9 (Faith 7)	5/15/63	Manned Orbital Flight	Maj. Gordon Cooper	166–100	Success. 22 orbits. Final Mercury Flight.

pilot is unable, because of a system's design peculiarities, to over-ride or correct a failure in an automatic system. Instances of this occurred in the Glenn, Carpenter and Cooper flights.

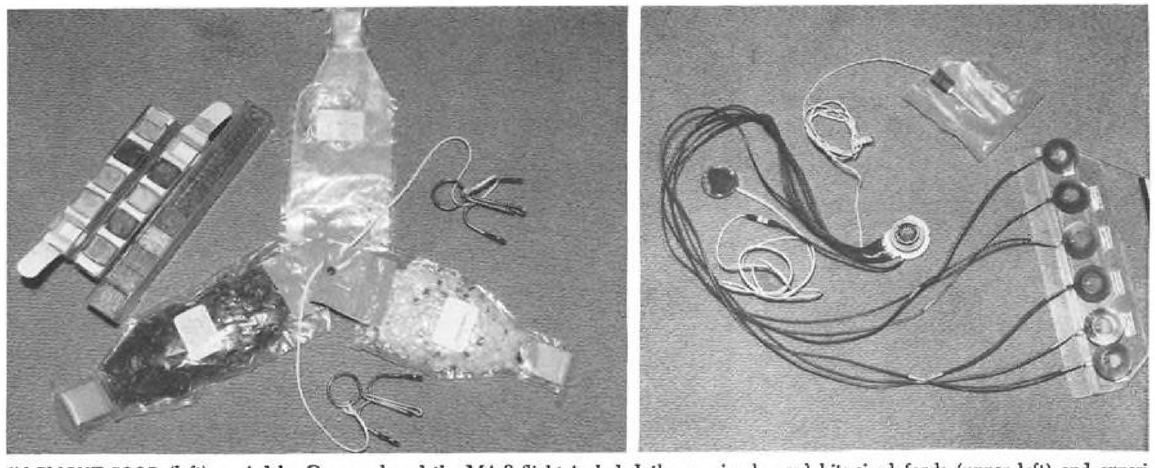
Kraft said there are many cases "where we have to have an automatic system. But when man can do it, don't make it [the system] so that he can't correct it."

Another basic spacecraft design learned early in Mercury, which will be reflected in Gemini and Apollo, was that the layer-cake scheme of piling system on top of system inside the pressure vessel is the complicated way. In a number of instances, it was necessary to virtually tear the pressure vessel down when a minor component failed in checkout.

As a result, easy access to subsystems and components is a key element of Gemini and Apollo design.

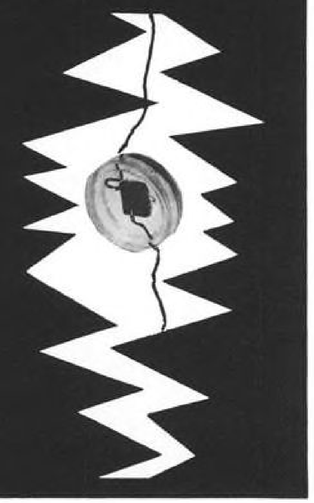
• **Pilot selection and training.** Despite heavy pressure on National Aeronautics and Space Administration to relax its stringent criteria for astronauts, the agency remains convinced that space pilots should be both engineers and test pilots. Officials point to the piloting skills and energy management experience required on all Mercury orbital flights.

Primary agitation to relax astronaut selection qualification criteria comes from the scientific community, whose spokesmen feel a scientist should be in the Apollo lunar landing crew, and from feminists, who were given new



IN-FLIGHT FOOD (left) carried by Cooper aboard the MA-9 flight included the previously used bite-sized foods (upper left) and experimental dehydrated food tested for the Gemini program. Packaged in three plastic bags, it is mixed with water for consumption. Bio-sensors (right) worn by Cooper included oral thermometer (top center) and heart and respiration rate monitors.

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hope when Soviet female Cosmonaut Valentina Tereshkova flew successfully in Vostok 6 last month (see p. 315).

The seven original Mercury astronauts were selected from among 22 engineering test pilots who qualified both physically and mentally. Degree of motivation was the final selection basis for them. Several of the remaining 15 from the original 22 are among the second group selected by NASA.

The agency's pilot pool will have to be substantially increased during the next two years because NASA feels an astronaut should be in training a minimum of two years, and assigned to a specific flight for a minimum of six months before the scheduled launch date.

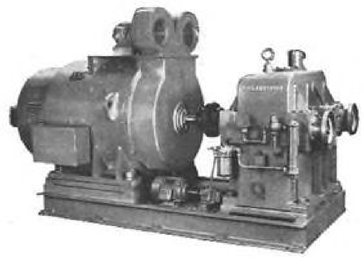
Because Gemini and Apollo flights will be conducted simultaneously, and each flight has a primary and backup crew, it is possible that in the course of a year, with four Gemini and three Apollo flights on the schedule, 34 pilots would have primary or backup assignments.

In the area of training, Walter C. Williams, associate director of Manned Spacecraft Center, and Kraft feel that



LITTLE JOE booster, first launch vehicle to test Mercury spacecraft, is checked on its pad at Wallops Island, Va. Capsule was fired on a suborbital trajectory.

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ASTRONAUT Cooper, carrying portable air conditioner, leaves Hangar S after a day of simulated flight. Below, Cooper (left) examines engines of Atlas booster 130D.



CLOUD FORMATIONS over India (below) were photographed from the Mercury capsule by Astronaut Cooper during the 8th orbit of his MA-9 flight. The camera used was a modified Hasselblad with an 80 mm., f:2.8 lens. Film was Anscocolor ASA 160.



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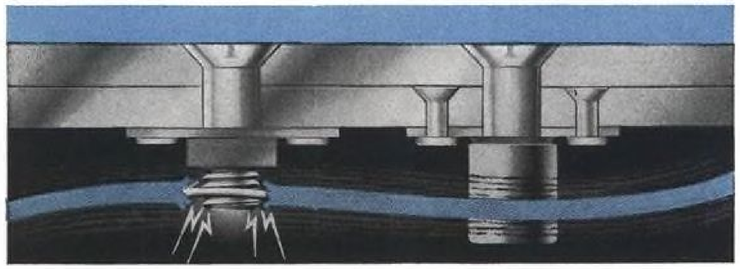
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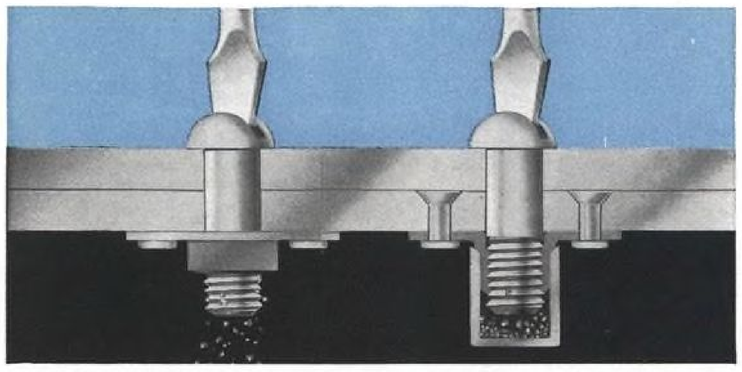
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Lessons of Mercury

George M. Low, assistant director of Manned Space Flight and the NASA official who justified Project Mercury funding before Congress throughout the program's lifetime, feels that Mercury has taught lessons in two fundamental areas—development and operations.

"There was no unexplained failure in Mercury," Low said, "and there will be none in Gemini or Apollo." He attributes this to a new understanding on all levels of the importance of quality and specific attention to detail, not only among the management executives but also to workmen on the production line.

One way of assuring this attention to detail has been visits by the astronauts to manufacturing plants. This was found to be an effective way to make workmen realize their importance to the national program.

In the operational area, Low said: "We have built a team of real professionals. It is amazing to see how they have developed in four years where now they have the confidence and guts to say 'let's go.'"

Mercury effectively demonstrated the value of mission simulators. Mission simulation, consequently, will be a continuing and critical part of Gemini and Apollo programs for both flight and ground crews.

• **Bioastronautics.** This area holds the greatest vacuum in substantial information (see p. 83) because the effects of long periods of zero-gravity are still unknown and cannot be duplicated on earth. While NASA is convinced that space flight will impose no long-term deleterious effects on the ability of the pilot to perform complicated tasks, there have been a number of diagnoses of physiological changes in pilots. During his flight, Soviet Lt. Col. Gherman Titov suffered from motion sickness. In post-flight physical examinations, both Schirra and Cooper had lowered blood pressures and blood pooling, and Maj. Andrian Nikolayev had increased calcium deposits in his urine.

Nevertheless, Mercury provided the U. S. with much new knowledge and marked the first steps toward life support systems able to sustain life in space and instrumentation capable of measuring vital signs.

• **Launch vehicle qualification.** Mercury provided an abort sensing system which allowed NASA to use the Atlas launch vehicle—intended as an intercontinental ballistic missile and not for manned flight—to boost the Mercury capsule into orbit. The same concept is being incorporated into the Titan 2 Gemini launch vehicle's malfunction detection system, and for sensing probable abort conditions in the Saturn vehicle family that will launch Apollo.

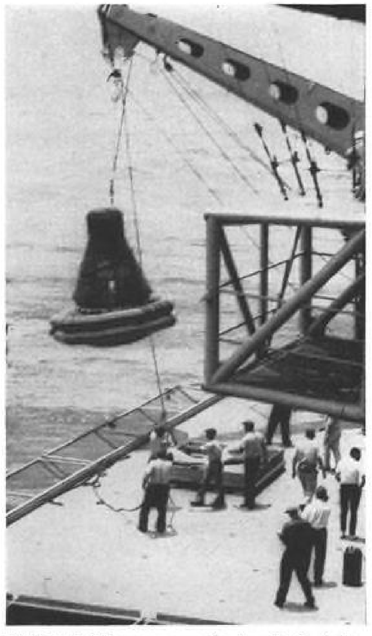
• **Network design** for worldwide control. The Mercury network is being expanded to handle both Gemini and Apollo earth-orbital missions. Mercury gave the U. S. its first opportunity to conduct large-scale flight operations on a real-time, or immediate response, basis.

The network was able to maintain near-constant communications with the pilot and establish the framework for a central control facility for lunar landing and planetary exploration missions.

• **Recovery and recovery control.** Mercury recovery was perhaps the most difficult recovery challenge the U. S. will have to face in manned spacecraft because the Mercury capsule traveled on a true ballistic trajectory after the retrorockets fired. Gemini and Apollo, although they retain the same basically ballistic configuration as Mercury, will be maneuverable because of offset centers of gravity.

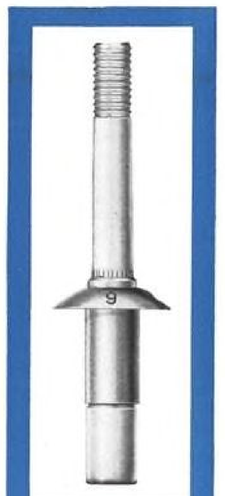
The important point, however, is that Mercury taught ground controllers how to pinpoint the spacecraft landing point so recovery forces could retrieve capsule and pilot quickly.

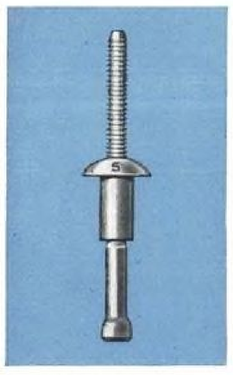
Mercury, then, set the pattern not only in these general areas but also by demonstrating that man himself can

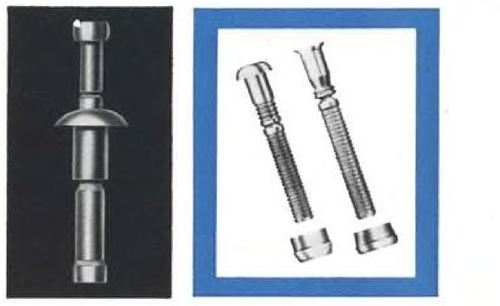


FAITH 7 Mercury capsule in which Astronaut Cooper completed 22 orbits on his MA-9 flight is shown being winched aboard an elevator deck on the carrier Kearsarge southwest of Midway Island in the Pacific after 34 hr. 20 min. in space.

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Williams, who said Mercury wrote the "cook book" for the entire manned space flight program, characterized the project as quite similar in scope to the X-series of experimental aircraft. The distinctions are that the front runners in space are measured in distance and time; in aircraft they are measured in speed and altitude.

From a scientific standpoint, Mercury demonstrated a potential for man as an experimenter, rather than establishing a record of new scientific findings. Both Glenn and Carpenter had flight programs which probably were too heavily loaded with required tasks. By the time Schirra flew in MA-8, it had been decided that an engineering mission was required in order to establish confidence in the spacecraft and systems for the 22-orbit mission.

Even with these limitations, the stage has been set for man to be a versatile experimenter and explorer in the Gemini and Apollo missions.



LIFE VEST, normally stowed in lower left leg of Cooper's space suit is checked prior to the MA-9 flight. During debriefing on the carrier Kearsarge after flight, Cooper (below) is checked by NASA physician.



Mercury Taught Space Pilot Techniques

Houston, Tex.—Fuel management, critically important to manned spacecraft to insure positive control capability during retrofire and re-entry maneuvers, was the major piloting consideration in Project Mercury. It is considered just as critical in future missions because of a wider scope of control, requiring increased fuel usage for rendezvous, orbital change and lunar landing maneuvers.

Mercury flight plans were organized to minimize fuel consumption maneuvers, because the Mercury spacecraft in orbital flight is an undamped vehicle. If a roll, pitch or yaw were initiated, the vehicle would continue the maneuver until it was checked by an opposite reaction, expending additional fuel. Therefore, the technique was aimed at keeping control thrust movements low—it was considered wasteful of fuel to develop vehicle rotation greater than one degree per second.

Use of the hand-controller required considerable training in ground simulators. The inherent thrust reaction cross-coupling effect of the spacecraft thrusters not being aligned at the vehicle's center of gravity was aggravated by all three control axes being on a single hand controller. This phenomena generated the possibility of going to a two-axis controller and rudder pedals on a future spacecraft. First Gemini design included pedals, but they were removed soon after the engineering mockup review last August.

The hand controller used high stick break-out forces to insure that it would remain neutral during high accelerations in launch and re-entry, and to provide sufficient resistance so the pilot would be aware of any inadvertent manual movement of the control, particularly if his movements were stiffened by a pressurized suit. Control force gradients—pounds of force vs. stick deflection after breakout—were similar to those on aircraft.

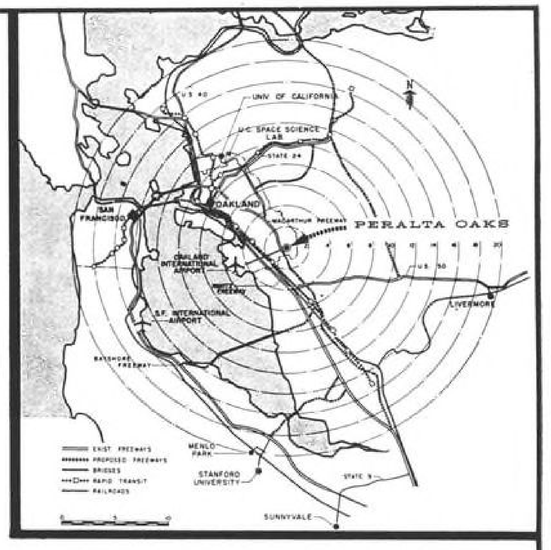
Orbital experience developed that the spacecraft pilot relies more on visual cues for orientation than in aircraft, where he has gravity cues. Adequate dayside determination of yaw and roll was found possible by pitching the small cylindrical end of the spacecraft downwards to get a vertical view of the earth, since a sharp angle appeared to give the terrain more motion than a normal zero orbital attitude. Angles of pitch-down to obtain these cues varied among Mercury pilots.

The spacecraft is aligned for retrofire by the automatic stabilization control system to normal orbital flight attitude of zero degrees roll, zero degrees yaw and —34 deg. The pilot also chooses a manual control system as a backup to ASCS to ensure proper attitude during retrofire and re-entry and, if necessary, to assist in damping out spacecraft oscillations which come in as dynamic pressure builds up.

Prior to re-entry, the control system establishes a steady roll rate of approximately 10 deg. per sec., stabilizing the vehicle in event it has developed a center of gravity shift along its axis which would feed in a lift vector on re-entry. The stabilizing roll in effect would cancel out such a lift effect and minimize trajectory dispersal.

The pilot attempts to damp out pitch and yaw oscillations which attain approximately one cycle per second frequency, introducing an environment considered similar to that experienced in an aircraft in strong turbulence at low altitude, or during pilot-induced oscillations. Re-entry damping can usually be satisfactorily maintained if control fuel holds out until drogue chute deployment.

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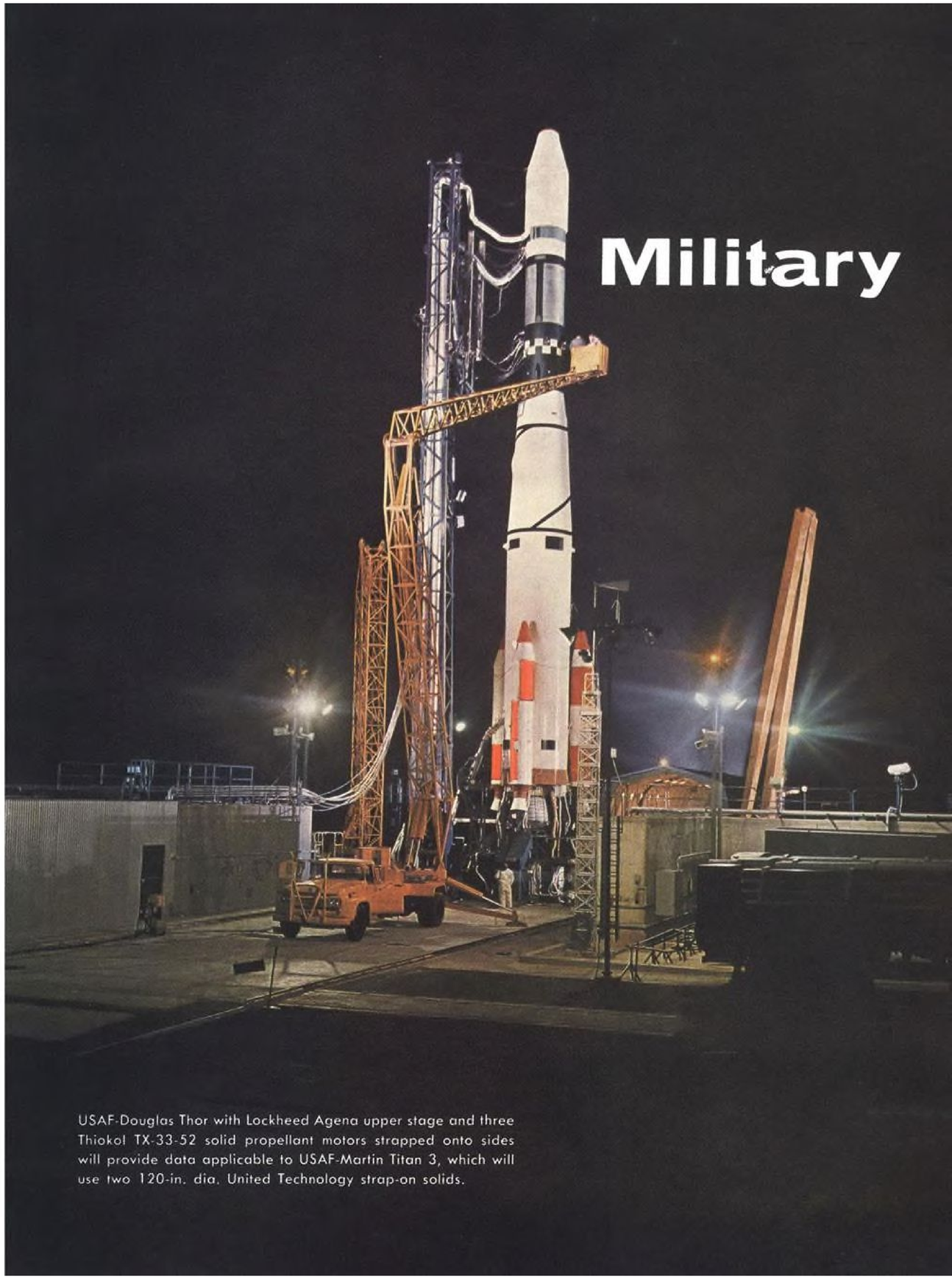
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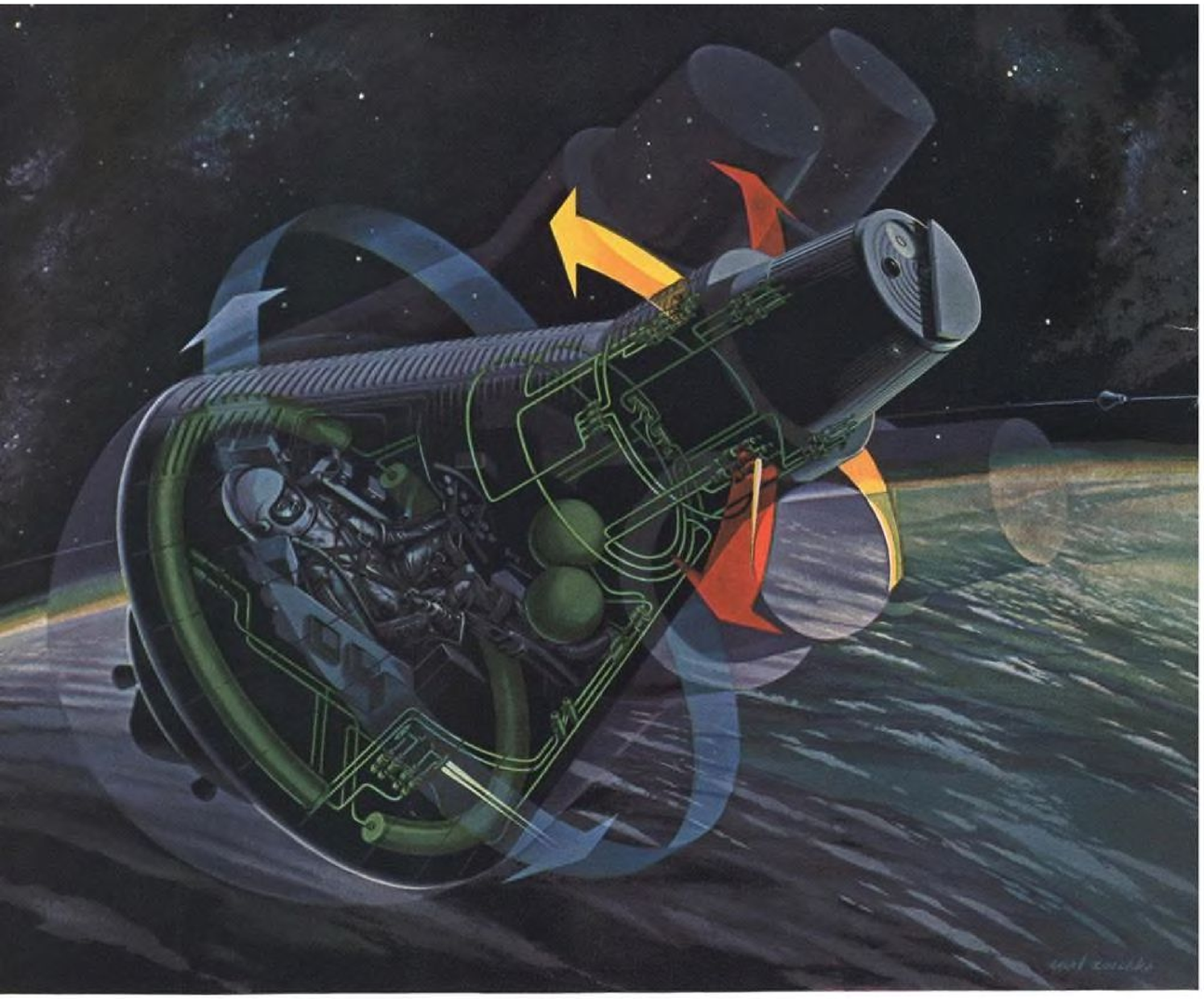
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Thinking Matures on Military's Space Role

Washington—National thinking on the role of military man in space is rapidly reaching a point of maturity after almost six years of argument and debate.

The period since the launching of Sputnik 1 has been one in which the vacuum of clear military requirements for man in space was a greater challenge than the vacuum of the space environment itself.

Contestants have ranged from those who saw no need for man to leave the earth in order to protect it to those who saw the military space theater limited only by the physical laws of the universe.

But there is evidence now that the battle is being won by those who insist that military man must at least go into space and find out whether he can perform military tasks that cannot be done by machines alone, or can be done better by man.

Mercury, Vostok Evidence

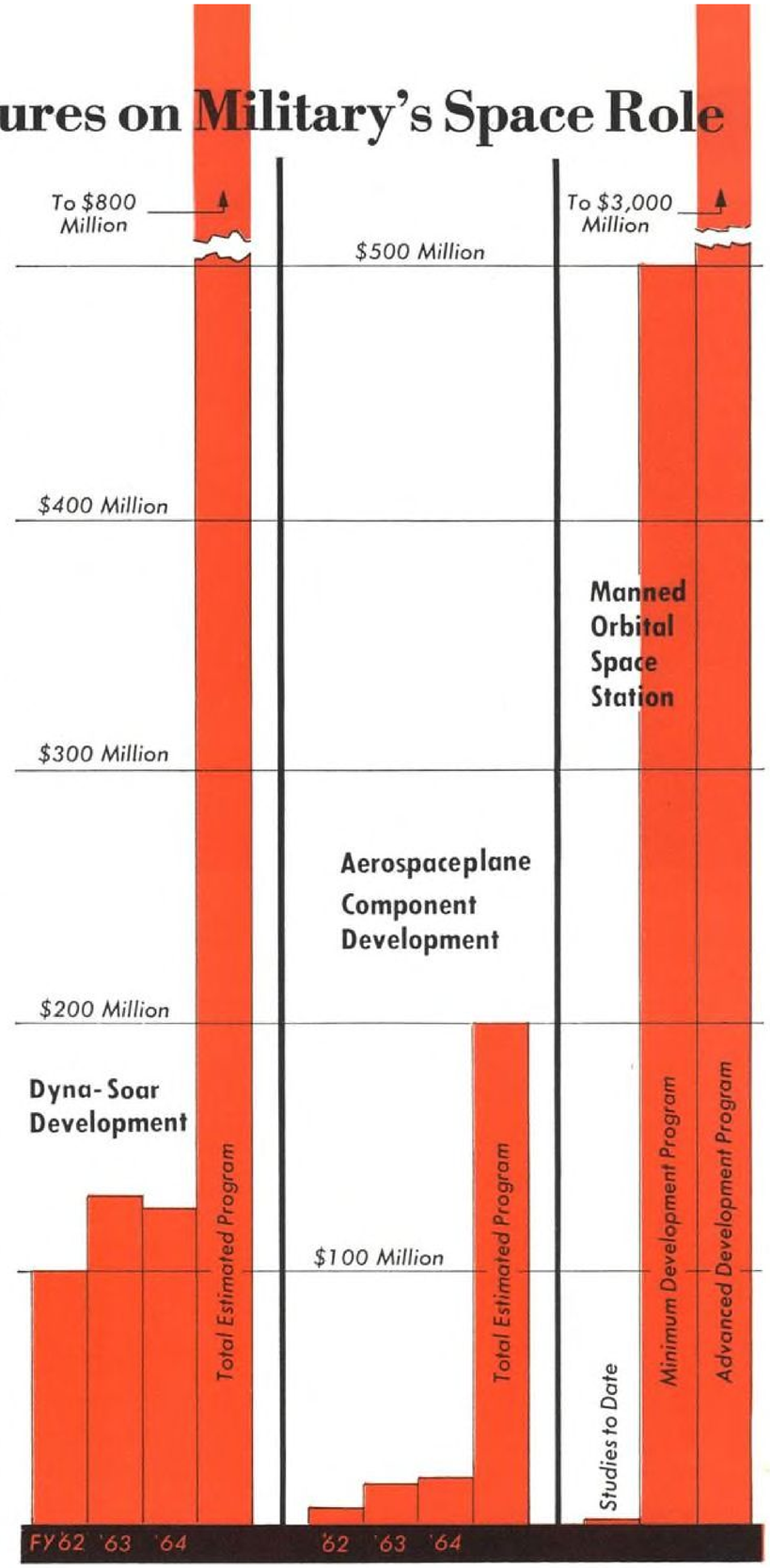
The evolution of this attitude has been affected by a number of things that were not on the record a few years ago. Project Mercury and the Soviet Union's Vostoks have demonstrated that man not only can survive in space but also can contribute to the performance of the mission. Progress in missile and space weaponry has convinced some that the next area in which one side or the other will gain a great technological advantage is space—and that if it has the potential as a theater of war, man eventually will fight there.

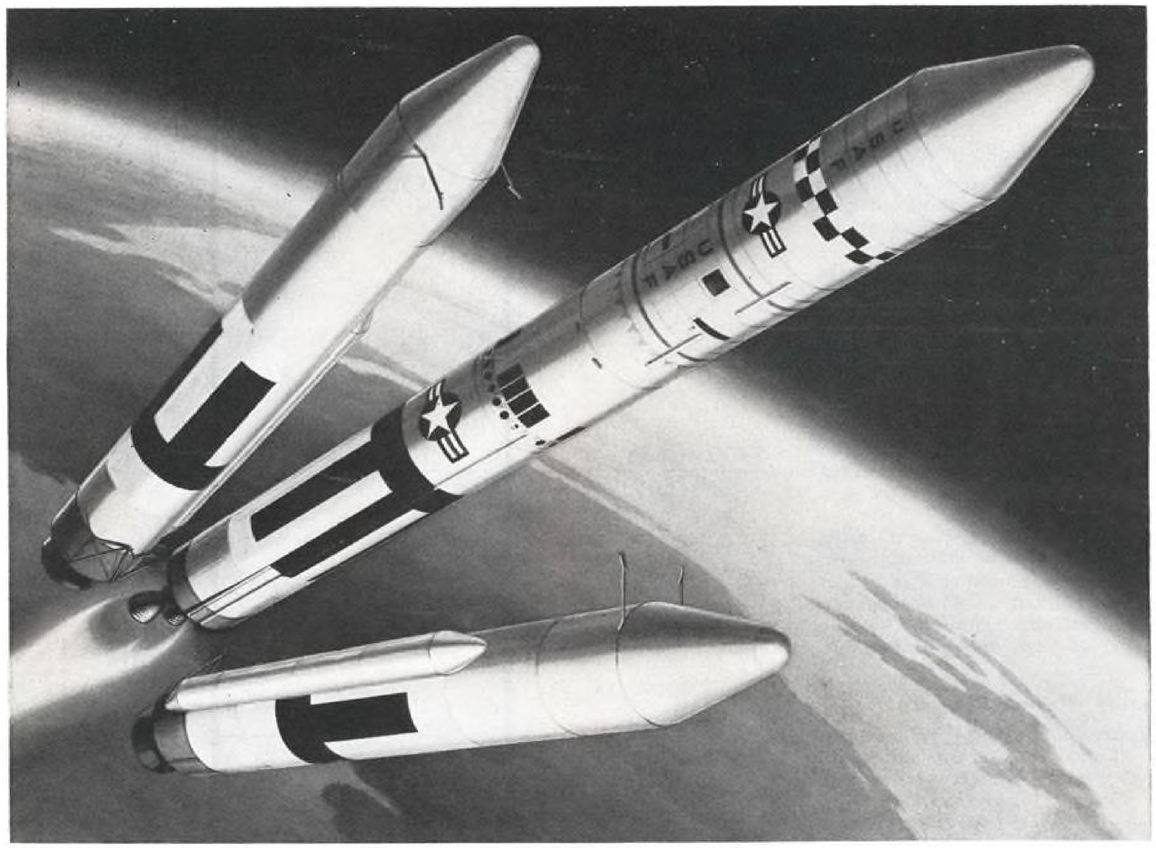
This increased conviction that the potential of military man in space can no longer be allowed to go unexplored is accompanied by a growing realization that the civilian space program cannot by itself answer all the military questions.

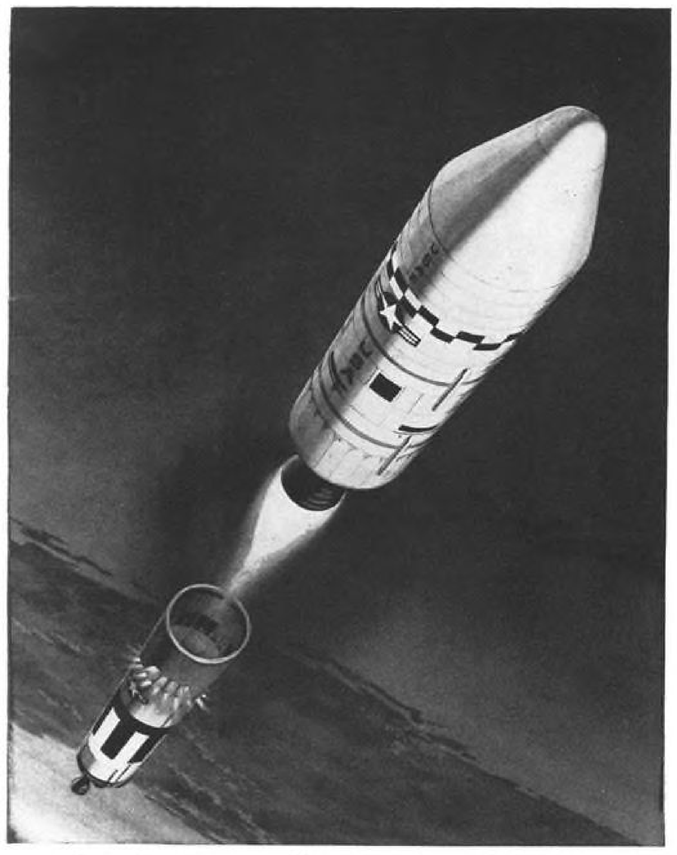
Two Conclusions

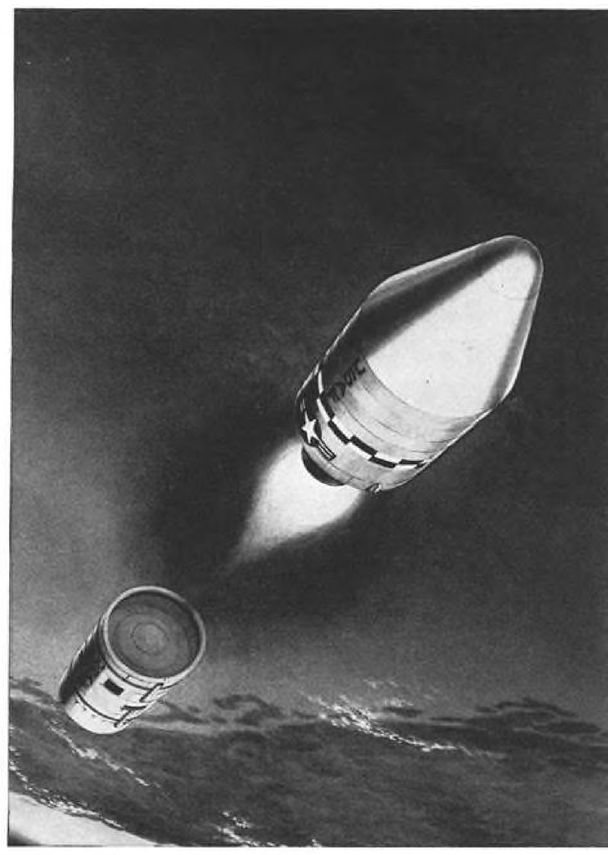
In recent months this realization has led the Defense Dept.—which has taken an extremely cautious approach to the military space question—to reach two basic conclusions:

• **One way or another,** it will let its principal space agent, the Air Force, put pilots and components of military weaponry into space to see what man adds to the system. This will be done first either with the Dyna-Soar boost glider, if it can survive a current comparison with National Aeronautics and Space Administration's two-man Gemini spacecraft, or with a more closely integrated NASA-USAF Gemini pro-









ARTIST'S CONCEPT shows United Technology 120-in. solid boosters separating from USAF-Martin Titan 3 core. Vehicle will be used for Boeing Dyna-Soar boost glider, other military payloads. Above, separation of second stage and then of transtage.

gram than is now planned—or possibly with both.

• **There will be no more** major manned space flight undertakings by either NASA or Defense Dept. that do not fully consider the other agency's needs. The cost in national resources of manned space projects—particularly a project the size of manned orbital space station—is one of the principal reasons for this new approach. But another is the disappointing result of the attempt to make Gemini a joint NASA-DOD program (see p. 225).

Once the Office of the Secretary of Defense had agreed that Air Force should play some role in Gemini, a joint board examined the possibilities for military participation and found them much smaller than expected. This has convinced the Air Force—and some Air Force officers believe it has convinced Defense Secretary Robert S. McNamara—that no NASA program will satisfy the Defense Dept.'s needs unless it is planned that way from the beginning, and that even then this approach is less satisfactory than for Defense to have its own programs.

Even the NASA-DOD agreement which created the Gemini planning board included a provision that neither agency would undertake a major manned program without the other's input, but the Gemini experience probably has done two things—reinforced Defense Dept.'s determination to play a major role in a manned orbital space station project rather than to ride "piggyback" on a NASA project; and reinforced Air Force's chances of keeping the Dyna-Soar project, for which funding and control rest clearly within the Defense Dept. itself.

The growing conviction that the nation must protect itself in the manned military space area is shared by most top NASA officials. Few of them will argue that NASA programs are producing all the specific information military men need to assess their usefulness in space, even though the NASA programs clearly are producing technology that will be applicable to both civilian and military missions.

The following comments by several top officials of NASA's manned space flight programs show their awareness of national defense aspects of space:

• **"I don't think NASA** should do things because of their military value, but anyone in the world who does these things will be building the technology. You can't be much of a defender unless you have the technology. The deadlock of ballistic missiles will be broken, probably by space."

• **"A very large element** of this [Apollo program] is competing with Russia. It is sufficiently ambitious that it requires Russia to make major developments if she wants to stay ahead of us . . . [We] will wind up with several operational elements—spacecraft, service module with maneuvering capability, a class of launch vehicles—and an industry well trained in designing for space. This may be the single most important reason for doing it."

• **"You can't divorce thinking** from applications, peaceful or military. National Advisory Committee for Aeronautics never did. NASA has lost a little of what NACA had, but we're bringing it back. We need better liaison. Then both the technology and the information are available for anyone. We can't afford to be so decoupled as to force [Defense Dept.] into parallel programs. It is implicit that we should develop a national capability, without the nation prejudging whether it is peaceful or not."

In spite of this feeling by NASA officials that hardware and techniques developed in peaceful exploration can be adapted later to military uses, adaptation costs money — and time, which might become even more critical than money. And adaptation is not enough, according to the military view, since what is really needed is expansion of hardware capabilities, extension and specialization of techniques and development of specific components peculiar to military missions.

As the service that handles more than three-quarters of Defense Dept.'s billion and a half dollars or more a year in space funds, Air Force has in the past year unified its own space thinking.

It now considers a manned orbiting space station not only as a necessity for determining military man's future in space, but a focus for the service's space activities as well. Such a focus, according to Lt. Gen. James G. Ferguson, deputy chief of staff for research and development, "is not absolutely mandatory but it helps us reason, think, justify."

Current Air Force plans for space programs, many of them approved by the Defense Dept. but some still only proposed, are a distillation of what at times have been more ambitious ideas.

This distillation is a result of two things—a maturing of Air Force's own thinking and planning as the space age progressed and possibilities became easier to separate from impossibilities; and a narrowing down of goals forced by the cost-conscious, management-conscious and balanced forces-conscious Defense Dept. administration.

The service's first general operational requirements in space were written early in 1958, shortly after Sputnik, when there was some missile hardware and some re-entry technology available but no real experience with space flight.

In 1960, when space flight was less than two years old and no manned flights had yet been made, Air Force undertook to write a crude 10-year plan.

In June of last year, Defense Dept. asked Air Force to translate this into a

Index of Progress

Air Force Secretary Eugene M. Zuckert quoted the following statement from a Rand Corp. report in his speech before a recent symposium on the exploration of Mars:

"Since mastery of the elements is a reliable index of material progress, the nation which first makes significant achievements in space travel will be acknowledged as the world leader in both military and scientific techniques. To visualize the impact on the world, one can imagine the consternation and admiration that would be felt here if the U. S. were to discover suddenly that some other nation had already put up a successful satellite."

The statement was written early in 1946, 11½ years before the lanching of Sputnik 1.

USAF Space Programs

Washington—Air Force now considers four major space programs to be of primary importance, Brockway McMillan, then assistant secretary for research and development and now Air Force under secretary, told the House Defense Appropriations Subcommittee.

These are Dyna-Soar, Titan 3, space based early warning and a manned orbital development station, he said. All but the last are DOD-approved.

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Hydrofoils and Cavitation	Unsteady EM-Plasma Interaction	Wind and Shock Tunnels	Electronic Circuit Development
Materials and Fatigue	Missile Trajectories & Orbit	Analog Computers	Education & Training
Mathematics & Numerical Computation	High Speed Flows & Shock Waves	Digital Computers	Training & Training Devices
Shell Theory	Combustion Processes	Internal Flow	Experimental Techniques
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Thermal Stress	Instruments (Aerodynamic)	Instruments (Elec. & Struc.)	Non-Linear Vibrations
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five-year program that included specific projects and specific costs in dollars. This plan was completed in September and submitted in November.

"We had to be highly selective," Gen. Ferguson said. "We had to be responsive to the demand that we select only high priority items that were in the national interest, and we had to be continually examining the balance between investment in these important undertakings and in aircraft and missiles—which are also part of our responsibility."

The program that resulted included some 70 line items, ranging from such technological building blocks as advanced guidance systems to a manned orbital space station.

It attempts to let the Air Force do two things, according to Gen. Ferguson:

- "**Augment**, by use of space systems, the existing military capabilities of U.S. terrestrial forces." This means finding better ways to do current missions such as surveillance and early warning, and finding out what new missions there may be.
- "**Develop** a military patrol capability for the protection of U.S. interests in space." This is the ability to watch events in space and cope with any military problems they may present.

For the time being, Air Force's interest in manned space flight is limited to the area beneath the Van Allen belts and its general interests are limited to some 2,000 mi. for early warning and to 22,000 mi. for synchronous orbit communication satellites.

Although the Manned Orbital Development Station—or National Orbital Space Station if it becomes that—is not yet an approved program, Air Force considers this to be its number one priority need in the manned space flight area.

Defending Space Flank

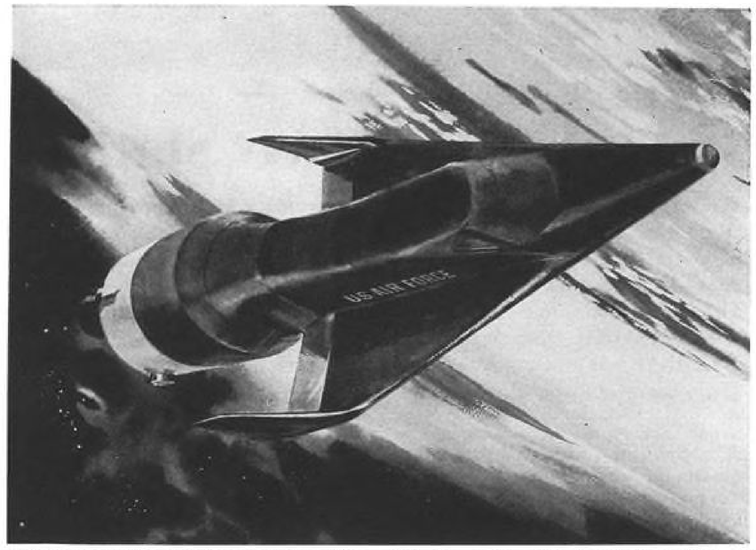
"The Soviet Union is faced with the formidable free world defenses relative to the mediums of air, sea and land. But in space, this new medium, they see no evident and applicable Western world defenses.

"In this new medium the Soviet strategist may well hope to attain strategic ascendancy. But he can only entertain that hope if we fail to achieve the timely developments of military capabilities for space.

"Both we and the Soviets know that the advent of human space activity exposes an open flank, even though the precise dimensions of this flank are not yet clearly perceived. Obviously, we cannot afford to ignore such a flank, nor do we propose to do so."—Lt. Gen. James G. Ferguson, USAF deputy chief of staff for research and development, before the House Committee on Science and Astronautics.



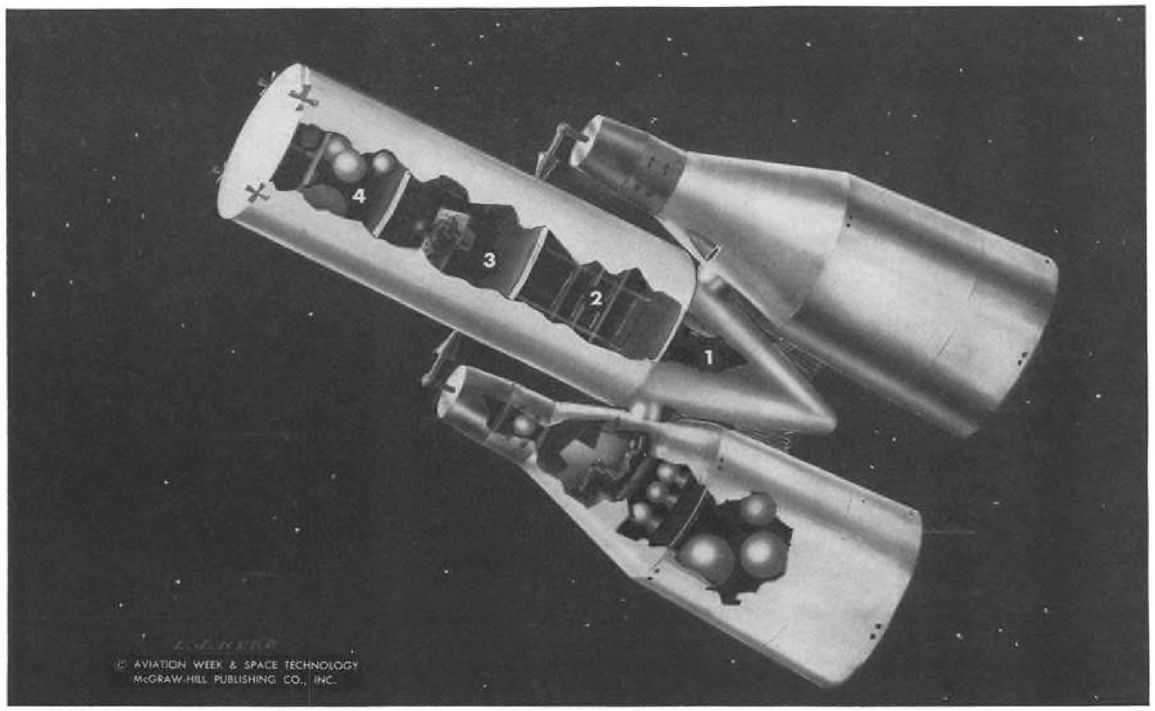
AEROSPACE MEDICAL Research Laboratories personnel explore problems of space maintenance, working on Pratt & Whitney RL-10 liquid hydrogen rocket engine during weightless trajectory in Boeing KC-135, as part of a joint USAF-NASA project.



BOEING DYNA-SOAR boost glide vehicle orbits the earth with transition section and powered transtage attached. Transtage is used for orientation as well as boost.

The service is well on the way toward developing most of the needed technology through projects that are approved —the Titan 3 booster (see p. 221) and the Dyna-Soar (see p. 230) and/or Gemini (see p. 225) for early ferry vehicles, and manned hypersonic vehicles for use with later generation stations (see p. 245). Studies by Air Force and industry have indicated a small laboratory module capable of supporting three or four people for 30 to 90 days may be the most likely initial station, but both Air Force and NASA are in the process of contracting for final, definitive studies that are expected to lead to development.

Each agency will have its contractors concentrate primarily on the agency's own needs, but NASA and USAF will swap requirements and information. There undoubtedly will be some struggling to see who dominates any joint program that results, but there is little doubt that it will indeed be a joint program.



AIR FORCE SPACE STATION concept uses Gemini as the ferry vehicle, a canister as the station, and the Titan 3 launcher.

USAF Gives Space Station Top Priority

Washington—Air Force has firmly decided to focus its manned space flight goals on a space station program and is speaking with one voice on this issue. This follows three years of being unable to make a persuasive case with the Defense Dept. for its military man in space plans.

The climate today in both the White House and Defense Dept. is considered more receptive than ever for a military manned space program, largely because there is a growing realization of the Soviet military space potential.

Civilian leaders in the Pentagon appear to be accepting the belief that national security requires, at the very least, a program which can determine what can be done only by man in space, and what he can do better than sensors alone.

The space station is generally seen as a program into which the service can wrap its needs and goals as a logical package that can be rationalized and justified to its proponents and its critics.

Wisdom of having a central focus has been demonstrated by the National Aeronautics and Space Administration in its Apollo lunar landing program. By adopting the same philosophy, Air Force feels it will be able to advance space technology through a system of launch vehicles and manned spacecraft with the fundamental characteristic of being expandable into a combat space system.

To make the space station the same sort of focus that Apollo now is, it may even be necessary for the President to identify the station as a national goal—as he did the manned lunar landing.

Both NASA and Air Force frankly admit that there cannot be two space station programs—one civilian and the other military. The questions that arise are who will manage the national program, and how will money and technical resources be pooled. Now that the NASA-DOD Gemini agreement is six months old and there has been an opportunity to examine its implications, neither USAF nor Defense Dept. is completely happy with the role Air Force has in this program.

As a result, Defense Dept. feels it must have the management role in the space station program.

Air Force feels that Gemini demonstrates that scientific investigation can be carried out in a military vehicle, but that the opposite is not necessarily true.

At this point, Air Force appears to have the edge as the agency most likely to manage space station development—if it is made a national program within the next 18-24 months. Air Force has become more articulate in expressing its need for the station, but that is not the only reason for the conclusion.

The main reason is that USAF considers space station its top priority program; space station is not a part of NASA's "hard core" program, and the civilian agency foresees no way to justify an expensive new program until the funding peaks have been passed in Gemini and Apollo.

NASA's hard core program consists of projects that contribute directly to the manned lunar landing mission—and there are several other concepts, now unfunded, that could reach hard core status and further delay chances of a heavily-funded NASA space station program. Among them are a lunar logistics system, which would cost $500 million, and a lunar reconnaissance vehicle that would cost another $100 million.

Funding is the most immediate measure of resources, but it does not tell the entire story. Available management is another factor working in Air Force's favor. NASA bumped squarely into the management resources problem in considering another Mercury mission. Key reason for ending Mercury with Maj. Gordon Cooper's 22-orbit flight, according to NASA Administrator James E. Webb, was the agency's desire to relieve its manned space flight management of that program so they could concentrate on Apollo and Gemini.

There are a number of factors working in NASA's favor for management of the program, if it is made a national program after the peak funding years for Gemini and Apollo—1964 through 1966—are passed. But NASA's reasons for wanting a space station—as a laboratory and as a planetary exploration testbed—mean that it is not now a top-priority item.

NASA Budget

Whether it is the nation as a whole or only the NASA budget that cannot afford another multi-billion dollar space program now is a question that will be decided ultimately by the President. Dr. Lawrence L. Kavanau, special assistant for space to the director of defense research and engineering, feels that a limited space station project "need not represent a national commitment as far-reaching as the manned lunar landing program."

Kavanau, who two months ago became the first top Pentagon civilian to publicly support a military manned space station, said the program should be national rather than single-agency. "There is no question," he said, "that if a decision is made to proceed, the Defense Dept. should be made a full partner in this enterprise all the way, and may even qualify for management of the national project to satisfy both NASA and DOD needs.

"We are finding that, although there are many important and worthwhile things that can be done with Gemini, due to the late stage of development, no significant DOD input can be made to the Gemini design. Gemini, while highly useful, could have been made even more so by joint participation earlier in the game," Kavanau said.

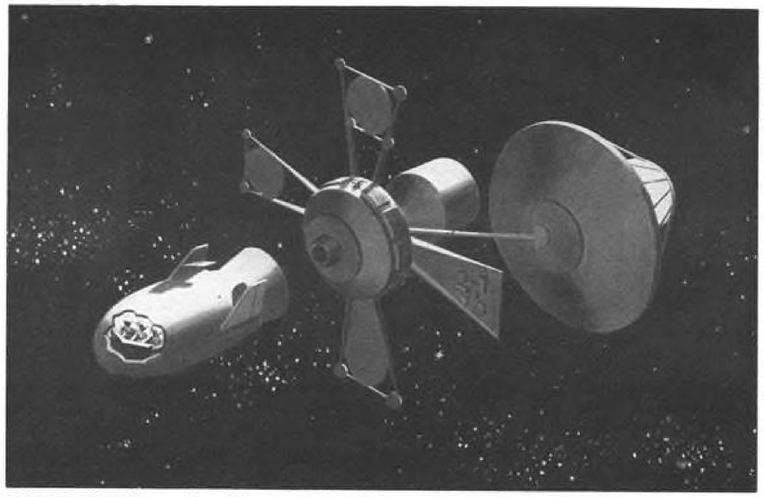
Monitoring Needed

"Applying this experience to our space station activities clearly indicates the desirability of undertaking such a program, from its conceptual stage forward, in a manner which, at all stages, considers the requirements of both agencies. It is essential therefore, that studies of future possibilities, whether sponsored by NASA or DOD, be fully coordinated in advance and carefully monitored as they proceed from concept to hardware in order to produce a mutually acceptable end product."

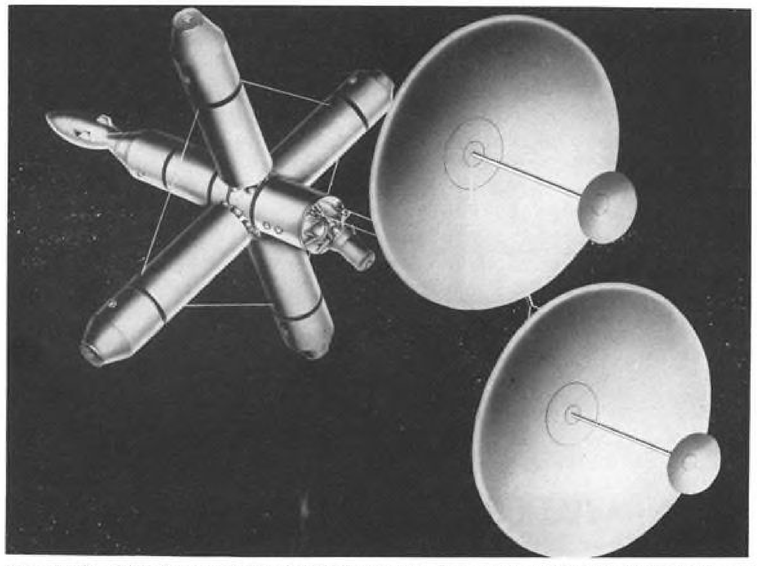
Air Force Secretary Eugene M. Zuckert has labeled the space station an "absolutely critical" stepping stone in building an operational space defense system, and said the station should be put in operation by 1968. Zuckert also anticipates a cooperative program with NASA.

NASA's conceptual studies, which recently went out to industry, did not benefit from any military inputs at the working level on which the specifications were written, and the mechanics of a coordinated program obviously have yet to be spelled out. NASA and Defense Dept. agreed in January that neither will institute the development of a manned space flight system without the concurrence of the other, and it is probable that the phase two design study effort will include mutual requirements.

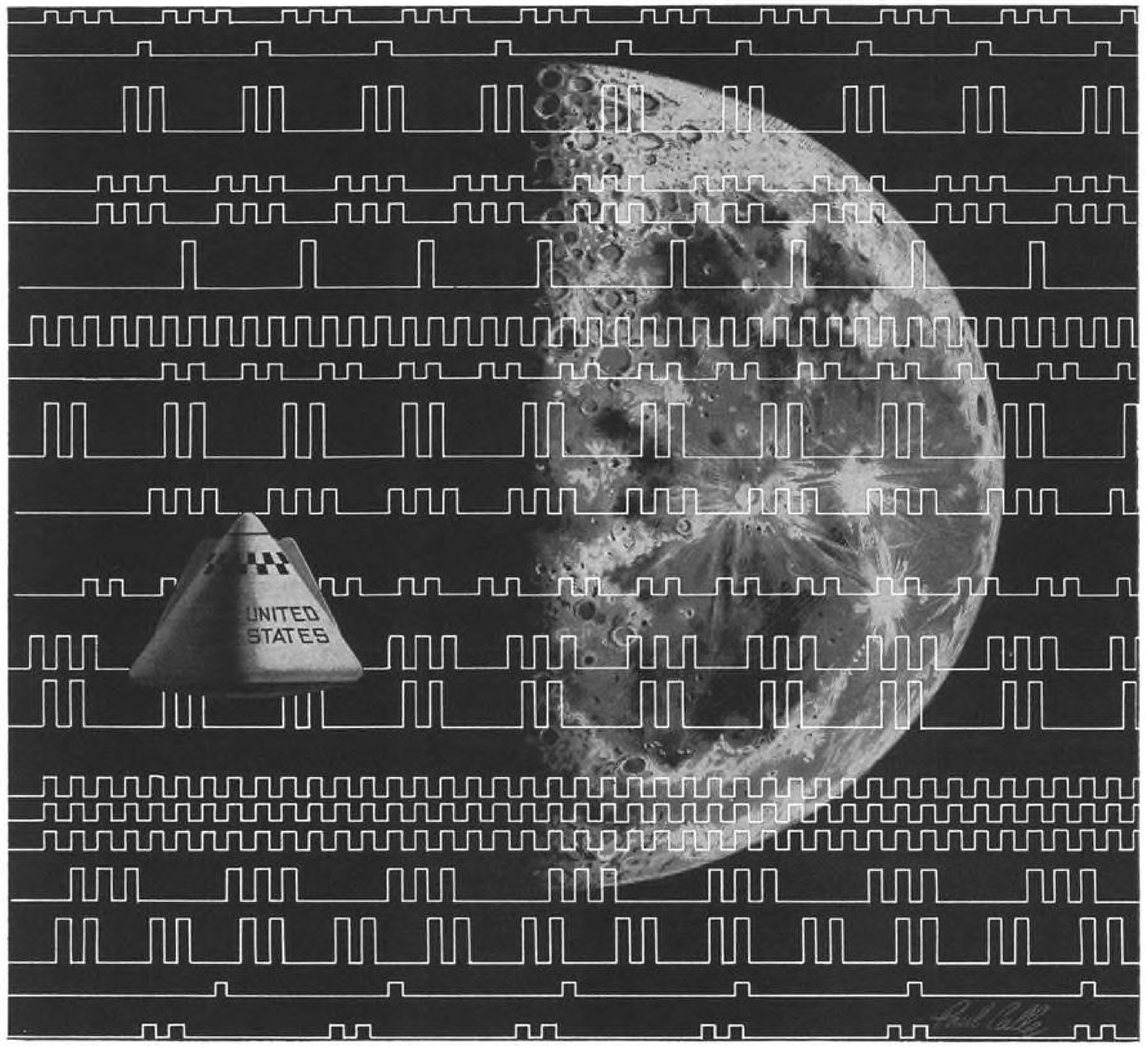
The Air Force space station, which currently has the unofficial name of Mods (for military orbital development station) already has a fairly long study history. Concepts of what a space station could be like and could do began being generated soon after Sputnik 1 was launched in 1957. In the succeeding six years, between $4 and $5 million



SMART STUDY completed by a number of companies in 1961 through both funded and unfunded efforts resulted in this General Electric concept. Idea was to determine trade-offs between sending a crew to repair satellites or to replace them.



MILITARY TEST Space Station (MTSS) was the first space station concept which was studied with Defense Dept. funds. In this General Electric drawing, expended vehicle stages form the structure. Large antennas are used as solar collectors.



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has been spent in-house and with industry to develop these concepts on paper.

The current concept is quite similar in configuration to the one being emphasized by NASA. History of programs that have contributed to the current Air Force concept includes:

- **Slomar** (for satellite logistics maintenance and repair). Studies were conducted in 1960 and 1961 by Lockheed, General Dynamics/Convair, Martin, Douglas and Norair. These companies shared $600,000 in funding.
- **MTSS** (for military test space station). A total of $700,000 in study contracts was shared by Lockheed, General Electric, McDonnell, General Dynamics/Convair and Martin. They were conducted in 1960 and 1961.
- **Smart** (for satellite maintenance and repair techniques). Largely an in-house Space Systems Div. study in 1961, with support from General Electric and Lockheed.

Industry Studies

In addition to these funded studies, a number of aerospace firms financed their own parallel studies.

With space station now about ready for the program definition phase, Air Force is faced with a series of fundamental questions it must answer for itself and others. Among them: What can a space station do that an unmanned space vehicle can't do? How much will a space station cost? Of what will it consist?

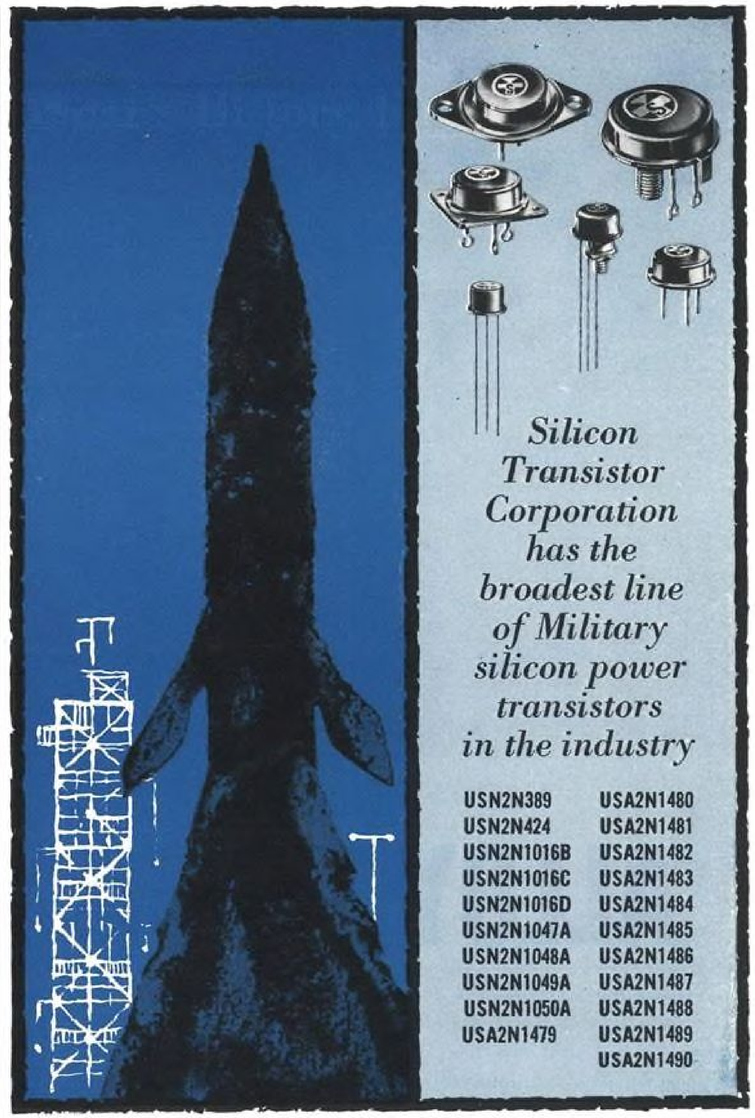
In the six years that the station has been under formal study, some of the answers have evolved. The drawing (p. 214) is an indication of what an early military space station probably would look like. It would make wide use of existing or funded hardware and have the ability to become larger and more advanced without affecting the time schedule.

First space station system would essentially consist of a booster, a station

USAF Space Station

Air Force Space Systems Div. will award four-month parallel contracts next month to three companies to define a conceptual military space station system configuration, which has been given the name OSSS, for orbital space station system.

If Air Force receives approval for a space station program, the first substantial funding will be in over-all program definition, which could begin this fall. Air Force feels it should be prepared to begin preliminary design of the system by next spring in order to meet the 1967-68 target date Air Force wants to have it in operation.



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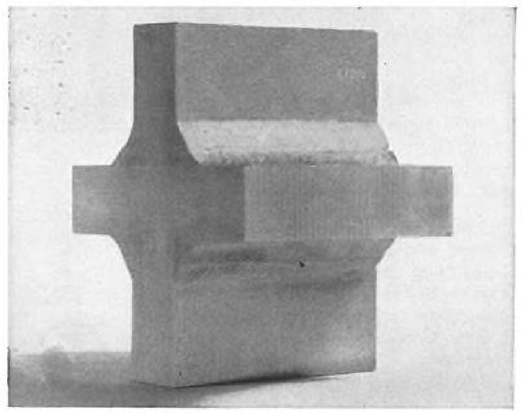


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Cruciform weld test for restrained weldments demonstrates Alloy 7039 advantages in weld ductility and weld crack resistance. Results are superior to every other heat-treatable alloy with no requirement for post-weld heat treating.

REPRESENTATIVE TENSILE PROPERTIES—PLATE (at Room Temperature)

	Test Direction	7039** -T6(1)	2014 -T6	2219 T-87	5083 -H113
TENSILE STRENGTH, KPSI	Long.	65	—	68	46
	Trans.	65	70	69	—
YIELD STRENGTH, KPSI	Long.	55	—	57	33
	Trans.	55	60	57	—
ELONG.— % IN 2"	Long.	13	—	10	16
	Trans.	13	13	10	—
COMPRESSIVE YIELD, KPSI	Long.	58	—	57	32
	Trans.	60	—	60	35
BRINELL HARDNESS		133	135	128	—
NOTCHED TS, KPSI		98	65	—	60
NTS/UNTS		1.35-1.5	0.93	—	1.26

(1) 0.25 to 2.0-inch gauges.
**An experimental temper not yet available commercially shows tensile properties 5 to 10% higher than the -T6 temper.

7039 CHEMICAL COMPOSITION (as registered with the Aluminum Association)

	% by Weight
SILICON	0.30 Max.
IRON	0.40 Max.
COPPER	0.10 Max.
MANGANESE	0.10-0.40
MAGNESIUM	2.3 -3.3
CHROMIUM	0.15-0.25
ZINC	3.5 -4.5
TITANIUM	0.10 Max.
OTHERS, EACH	0.05 Max.
OTHERS, TOTAL	0.15 Max.

REPRESENTATIVE AS WELDED TENSILE PROPERTIES OF BUTT WELDS IN PLATE*

	7039-T6/ X 5039**	2219/ 2319**	2014/ 5356**	5083/ 5183**
TENSILE STRENGTH, KPSI	54	37	40	43
APPARENT YIELD STRENGTH, KPSI	32	19.5	28	21
ELONGATION % IN 2"	11	4.3	3.2	16

*These properties have been obtained in weldments tested with bead removed. **Weld Filler.

PHYSICAL PROPERTIES

	7039	2014	2219	5083
SPECIFIC GRAVITY	2.74	2.80	2.83	2.66
DENSITY, LBS. PER CU. IN.	0.0988	0.101	0.102	0.096
ELECTRICAL CONDUCTIVITY, % IACS	35	50	44	29

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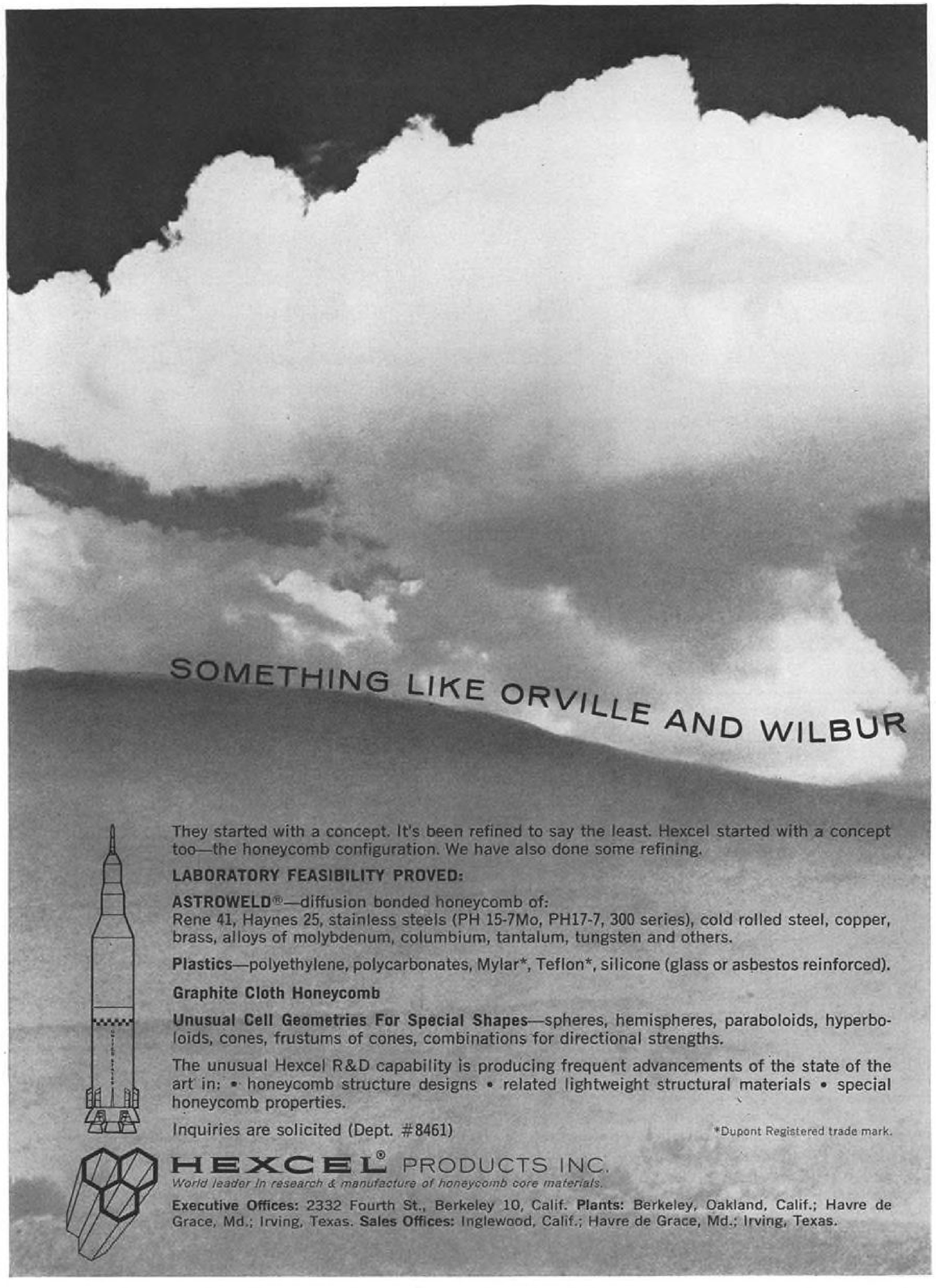
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module and a ferry vehicle. The booster would be a USAF-Martin Titan 3, the station a canister, and the ferry might be a McDonnell Gemini spacecraft.

Depending on how much or how little this station system will be called on to accomplish, it could cost as little as $500 million or as much as $3 billion. And Air Force wants it in orbit by 1967 or early 1968.

These cost and schedule projections are consistent with NASA's estimates for its manned orbiting research laboratory (MORL) program.

The station module in the Air Force system, 10 ft. in dia. for compatibility with Titan 3 and about 17 ft. long, would be divided into three compartments—an experiment area, a living area and a power room.

The operating concept is as straightforward as the hardware. The canister would be launched into a 300-mi. orbit by Titan 3. Then another Titan 3 would launch a combination personnel-equipment payload into a rendezvous trajectory.

Equipment module could be an elongated Gemini adapter section, attached to the personnel shuttle, which would be a standard Gemini vehicle. If only the personnel module is to be launched, Titan 2 would be used as the booster.

Growth potential could come into the picture with the launch of one or more additional station modules, which would simply be secured to the central hub. Maneuverable shuttle, which remains a critical USAF goal to permit emergency return to earth without waiting for the station to be over a precise de-orbit point, could be added to the station system without requiring radical re-design.

Air Force is seriously considering the Boeing Dyna-Soar (X-20) and Aerospaceplane as leading candidates for the maneuverable shuttle mission. On a short mission, four passengers and the pilot could be carried in X-20. Initially, however, station hardware and techniques would rely largely on systems and procedures developed in Gemini programs.

Gemini will develop fundamental rendezvous procedures for future manned space flights, both civilian and military. This program also will determine whether artificial gravity and a two-gas environmental system are needed. The Apollo lunar landing project will advance knowledge in these areas, even in its earth-orbiting missions.

For the space station program, Apollo will determine requirements for crew transfer and will extend the 14-day weightless flight experience to as much as 90 days in earth orbit. Military space station is envisioned as a 90-day system.

Air Force feels this space station system would put it into a position to determine clearly what man's contributions can be in a military satellite system, and at the same time provide the means to:

• **Extend existing** military capabilities in surveillance, reconnaissance and communications by having a man on board who is able to interpret data from and repair and maintain sensors.

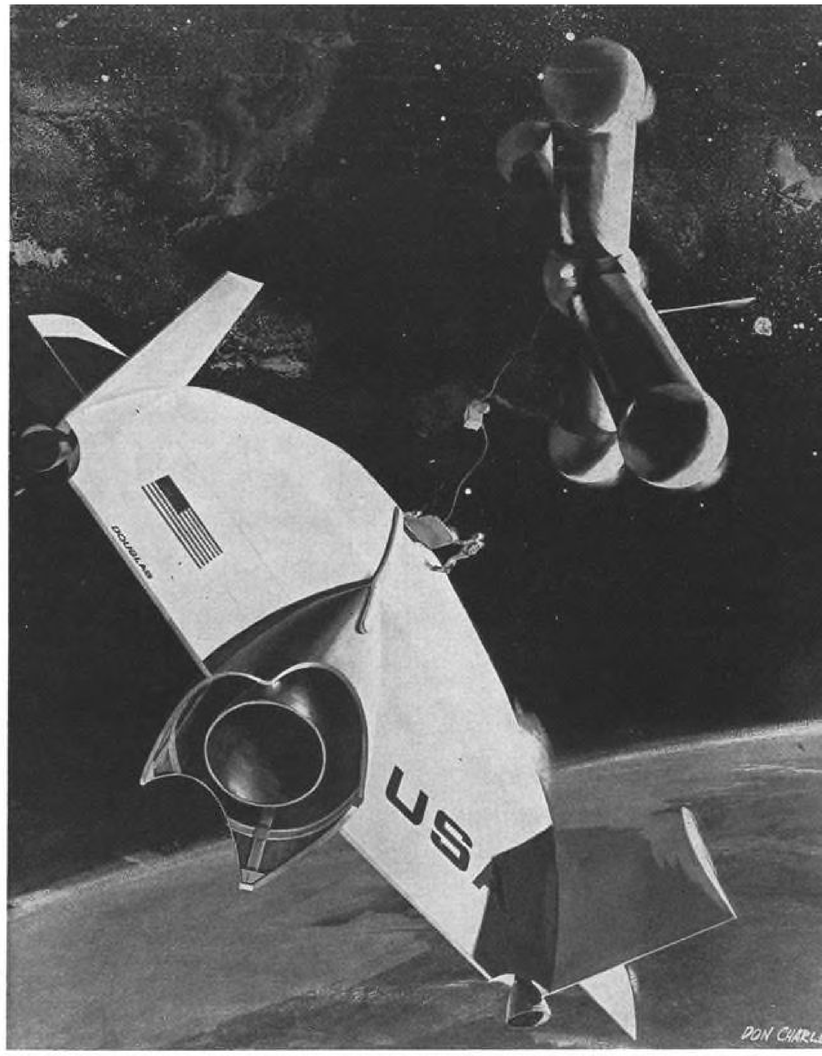
• **Determine** the requirements and procedures for a space patrol, which one official described as having precisely the

Titan 3 Capability

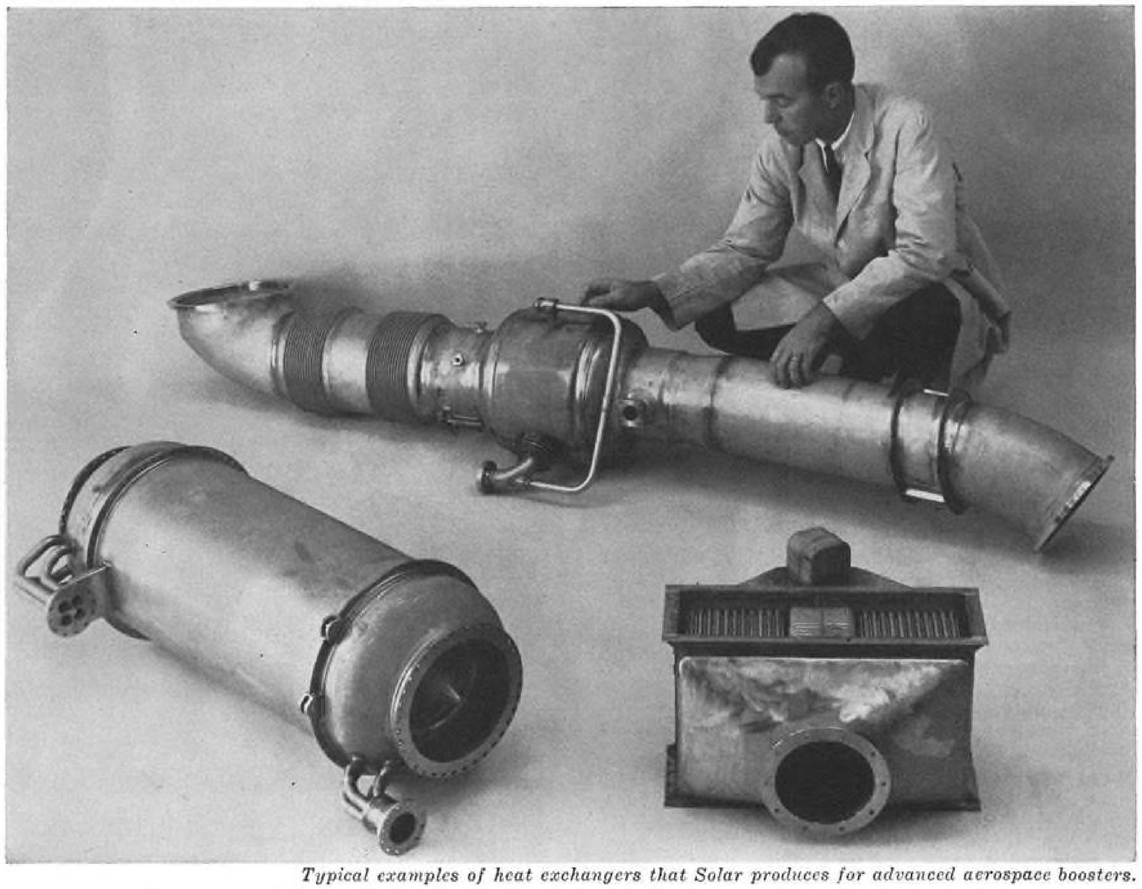
Air Force has decided to bank on the Titan 3C launch vehicle as an integral part of its Military Orbital Development Station (Mods) program (see story), rather than rely on the Saturn vehicle, because of what it considers the flexibility, availability and economy of Titan as compared with Saturn. Development program for Titan 3 is estimated to cost $808.3 million, and is scheduled to consist of 17 launches—five of the core and 12 of the core plus transtage and 120-in.-dia. strap-on solid-propellant motors.

Titan 3C will be capable of launching 25,100 lb. into a 100-mi. orbit; 13,000 lb. into a 2,000-mi. orbit; 5,100 lb. into an escape trajectory, and 2,140 lb. into a synchronous orbit, according to Defense Dept. testimony before Congress. Basic space station module will weigh 15,000 to 20,000 lb.

Defense Dept. estimates that in a five-year launch program of 25 launches per year, the unit cost of Titan 3C on the pad and ready for firing could be as low as $9 million.



FERRY VEHICLE passes supplies to a rotating space station in this Douglas concept. The ferry, called Astro, is powered by a Rocketdyne J-2 main engine, with two Pratt & Whitney RL10 engines outboard. The station would be assembled with parts delivered to orbit by Saturn 5, using spent S-4B stages as part of the structure.



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Potential Uses

These immediately-identifiable potential uses for a military space station are expected to be the heart of the arguments with which Air Force will translate its concepts into a definition of requirements and then into a program.

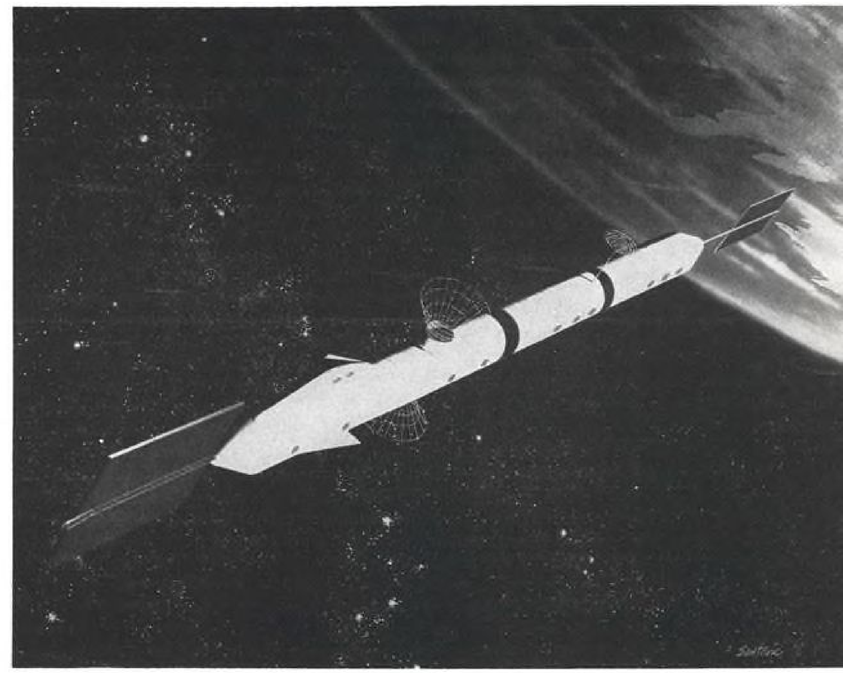
Initially, the station would be considered a testing base where sensors and equipment could operate in conjunction with a crew.

The first experiments would use a four-man crew which would stay up for as long as 90 days.

Critical Element

Critical element for an expanded system is power—both propulsive power for maneuvering to inspect, adjust orbit, etc., and electrical power for internal systems.

For this reason, Air Force planners expect to continue to be heavily involved in nuclear auxiliary power development through such programs as Snap (systems for nuclear auxiliary power), and Spur (space power unit reactor), and in non-nuclear power programs.



PERMANENT SPACE STATION, called Outpost III, was conceived by General Dynamics/Astronautics' Krafft A. Ehricke as a training base for as many as 10 astronauts. The station, first proposed by the company early last year, would use both solar and nuclear power sources. About 210 ft. long and weighing 50,000 lb., the training facility would be launched in sections and assembled while in a low earth orbit.



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Air Force Will Have Small Role in Gemini

Air Force's part in the early years of Project Gemini will be much less than the service had originally hoped for, and even its ultimate role will not be determined for some time.

Usefulness of Gemini in Air Force's plans depends partly on the fate of the X-20 (Dyna-Soar) boost glider and partly on national decisions affecting a joint National Aeronautics and Space Administration-Defense Dept. manned space station. In any case, the Air Force probably will not be able to buy and fly its own Gemini capsules until some time after NASA has flown the first 12.

Air Force may eventually use Gemini as a manned satellite inspector or interceptor or a space station ferry, and might even use the capsule with a larger adapter section as an interim manned laboratory. It may go to larger versions of the capsule and adapter, scaled for use on the Titan 3.

But until the project is farther down the road and other considerations become clearer, the program will in fact be a NASA program with only limited Air Force participation.

Support Functions

As it did in Project Mercury, Air Force will supply boosters, launch assistance, some pilots—through the NASA astronaut pool—and some recovery forces. It also will supply boosters and target vehicles for rendezvous experiments, assign some personnel to work directly in the Gemini program at NASA's Manned Spacecraft Center, and have experiments aboard a number of NASA flights.

But under present plans, Air Force will not add significant funding to the project, buy its own boosters and capsules or supply pilots from its own astronaut pool for the flights covering the first two years or so.

The joint NASA-DOD Gemini Program Planning Board, created under an agreement of last Jan. 21 between Defense Secretary Robert S. McNamara and NASA Administrator James E. Webb, decided on this limited USAF participation for what most Air Force officers consider valid reasons.

The board at that time had as co-chairmen Robert C. Seamans, Jr., NASA associate administrator, and Brockway McMillan, then assistant USAF secretary for research and development and now USAF under secretary. Other members were Brainerd Holmes, then deputy associate administrator of NASA and director of its office of manned space flight; Adm. W. F. Boone (ret.), deputy associate administrator of NASA for defense affairs; Lawrence L. Kavanau, special assistant to the director of defense research and engineering, and Gen. Bernard A. Schriever, commander of the Air Force Systems Command.

Many Air Force officers believe that the board, in arriving at its decision, also proved a vital point—that military needs cannot be satisfied adequately in any program that was not laid out from the beginning with the military needs in mind.

"If you're going to build military capability," one USAF officer said, "you can't go piggy-back."

In finding this out for itself, the board may have helped the Air Force lose a skirmish and win a war. McNamara has shown increasing interest in letting military man explore what his usefulness in space may be, without waiting for hard military manned space requirements.

Now the Gemini board's review is helping convince McNamara that Defense Dept. must have its own manned space flight programs or have a much stronger voice in joint civil-military programs if it is to get the answers it needs, some USAF observers believe.

Agreement Provision

Part of the Gemini agreement was that neither agency would begin major new manned space flight programs without the concurrence of the other. This was done partly because manned space programs have become so expensive that there is high-level recognition that the country cannot afford dual efforts.

But the Gemini experience has added another reason—that a program planned by one agency and joined later by another cannot serve both equally well.

Purpose of the Gemini board was to "assure that the Gemini program is planned, executed and utilized in the over-all national interest . . . so as to avoid duplication of effort in the field of manned space flight and to insure maximum attainment of objectives of value to both the NASA and the DOD."

This proved easier to agree upon in principle than to execute. Gemini began as a next step beyond Mercury, but it has become a vital support and training vehicle for the techniques and some of the hardware of the space agency's three-man Project Apollo lunar landing program.

Apollo is a program with a high national priority—whereas what the Air Force wants to do with Gemini is simply to explore what military man's role might be in space. In essence, the board concluded that Air Force should do nothing that would interfere with the achievement of the Project Apollo goal.

USAF Problem

Air Force could, according to one NASA manned space flight official, "get a billion dollars worth of space flight experience for a couple of hundred million dollars." But Air Force found that Gemini planning and commitments were far enough along that it could not get into the program fully until well downstream unless it wanted to sacrifice the funds for some existing requirement—such as bombers or missiles—and set up a second production source and also a second launching complex.

Air Force will have experiments aboard early capsules—possibly even the first manned flight. But a NASA official put it this way: "Over the past months we have had very detailed discussions with the Air Force on how they can participate. There is no question about it, NASA would welcome and the Air Force would like more participation . . .

"If DOD and the Air Force want in, they can get in, but they have to get in line. That is one of the constraints. Gemini is tied very closely to Apollo and a lot of experiments are tied to that. Others are for general knowledge, and the Air Force experiments would have priority equal to those," the NASA official added.

Some groups within the Air Force were prepared to argue that the service should give up Dyna-Soar if it could gain real control of the Gemini program. Even though McNamara approved the full funding of Dyna-Soar for Fiscal 1964, he has asked that both Gemini and Dyna-Soar be reviewed to see how they might lead toward military missions—and there is some feel-

USAF Gemini Funds

Air Force has proposed to spend $27 million as its contribution to Project Gemini during Fiscal 1964, with most of the funds allocated to Titan 2 launch vehicle support, and the remainder for development of Air Force experiments to be carried on National Aeronautics and Space Administration's Gemini spacecraft.



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ing that McNamara might kill Dyna-Soar before Fiscal 1964 ends. If Dyna-Soar were killed, USAF's future involvement in Gemini might be increased considerably.

In spite of its minor role in Gemini, Air Force hopes to gain experience and knowledge on launch reaction time, rendezvous—including changes in ellipticity and plane of orbit—docking, the firing of large engines in space, maneuvering at hypersonic speeds, controlled landings on water and land, etc.

A great many questions about man's usefulness in space will be answered in the long duration flights and in extra-vehicular operations that could contribute to such probable military missions as inspection, maintenance and repair, assembly, and rescue.

Even though Apollo experiments may enjoy a higher priority, USAF also hopes to test some sensors on NASA flights that would provide some knowledge in the areas of reconnaissance and inspection.

Air Force studies and the reviews by the Gemini planning board indicate that there are three types of things can be done with Gemini:

• **Category 1.** Experiments that have both civilian and military value, such as what the astronaut can see in space generally, what he can see against a star background, what he can see on the ground in day and night and under varying conditions, how much he can judge during a rendezvous (or rendezvous-inspection), what he can see when the vehicle is stabilized and whether he can compensate when it is not, etc.

• **Category 2.** Experiments that would produce information applicable only to military missions. These might include experiments designed to tell how much on-board power is required by military systems, how much maneuverability is required for military missions and for landing under unfavorable conditions, requirements for rendezvousing and inspecting non-cooperative or hostile satellites, etc.

• **Category 3.** Actual use of Gemini for operational missions. Air Force is likely to do this eventually, regardless of the size of its role in the experimental program. NASA officials see Gemini evolving into an operational spacecraft, following the experimental Mercury spacecraft as operational aircraft followed the X-aircraft series.

For the time being, however, the demands of the Apollo program, the lack of firm requirements, the high cost of space experimentation and the late start at trying to make Gemini a truly joint program have limited Air Force to Category 1. The board will continue to watch the program with an eye toward allowing greater participation later in Categories 2 and 3.



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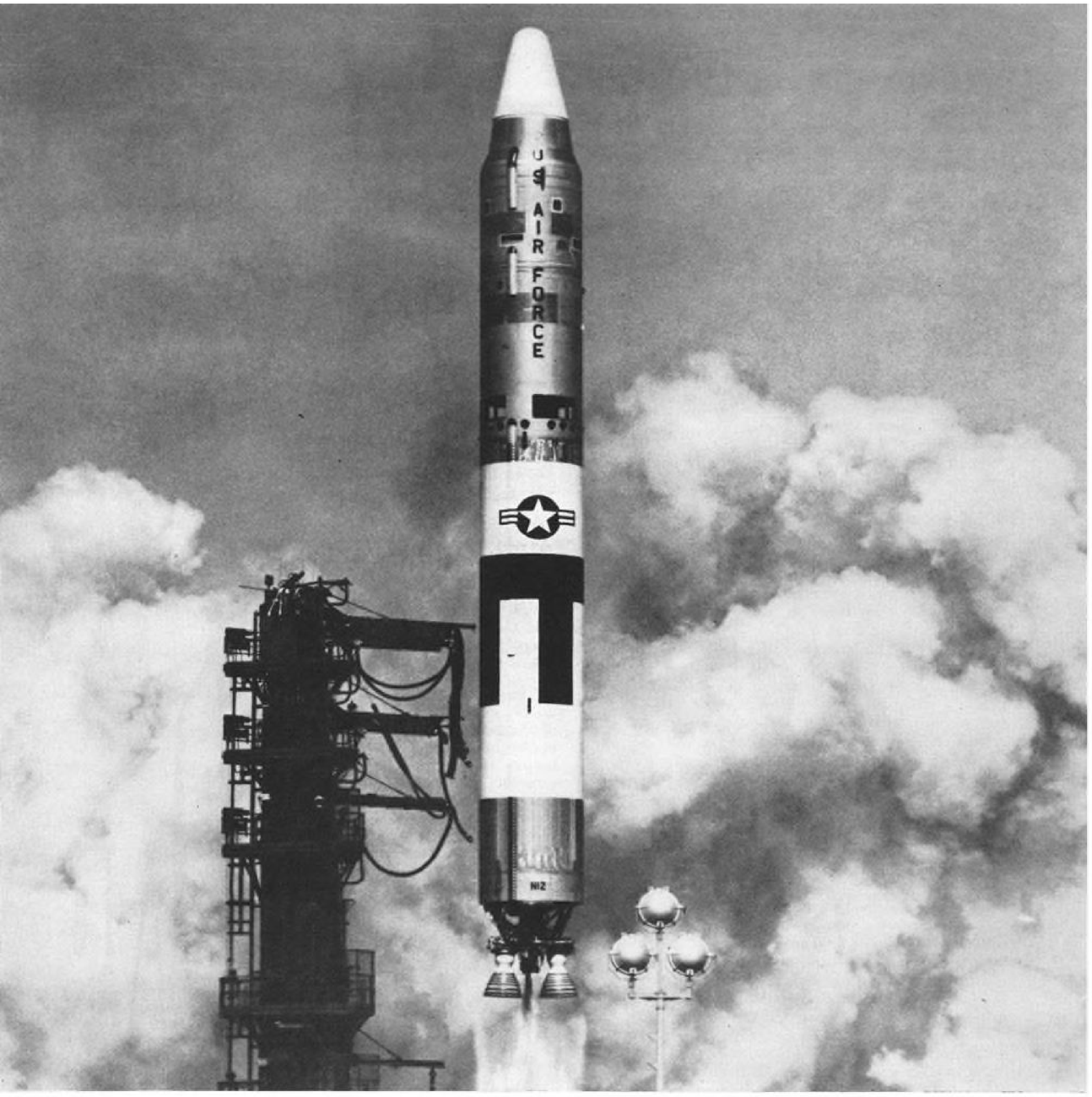


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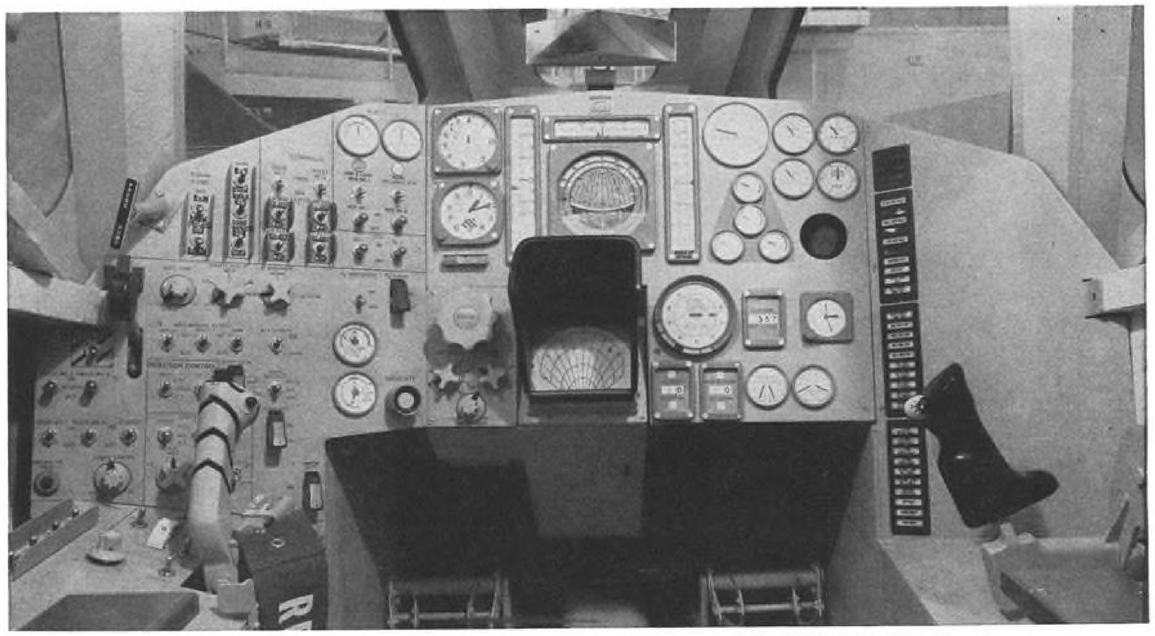
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DYNA-SOAR cockpit layout and details are shown in this mockup. Front windows will be shielded in flight through entry.

X-20 Will Probe Piloted Lifting Re-Entry

Dayton—Boeing X-20 (Dyna-Soar) boost glider, a second generation space vehicle intended to explore piloted lifting re-entry, is expected to begin laying the scientific, technical and industrial groundwork that would enable the Air Force to counter any future military challenge in space.

Although X-20 is a research vehicle rather than a prototype military system, its design is flexible enough that it could be used for a variety of potential military missions such as ferrying men and materials in space, surveillance, rendezvous and interdiction.

Dyna-Soar also is looked upon as a building block which could lead to more sophisticated operational military vehicles. If a vehicle were designed specifically as a military space interceptor, for example, it probably would differ from X-20, according to Jack Trenholm, deputy director of the X-20 program, at Air Force Systems Command's Aeronautical Systems Div. Even so, Dyna-Soar might be able to do the job, he admitted.

Main objectives of the Dyna-Soar program now are to:

- **Demonstrate controlled** lifting re-entry from orbital flight and gather useful scientific and technical data for the design of better lifting re-entry vehicles.
- **Investigate a pilot's** ability to perform useful functions in space.
- **Explore piloted, maneuverable** re-entry and achieve conventional landing at pre-selected sites.

The pilot plays a key role in the Dyna-Soar concept, as he does in operational military aircraft, and is not simply an overseer of automatic systems. He is to have the ability to fly the glider through re-entry and select his landing spot from an area of the earth's surface larger than the continental United States—a distinct military advantage over manned non-lifting bodies.

This selection area, or footprint, at the start of his re-entry maneuver covers an area of several thousand square miles from the landing site (see picture, p. 237). This would enable the pilot of a later operational vehicle to pick a landing spot with confidence and security, and would make the marshalling of large numbers of recovery forces unnecessary.

Alternately, the large footprint offers a choice of de-orbit points if the landing selection is fixed. The pilot has about 10 min. in which he can initiate re-entry and still hit the landing site, Defense Department's Dr. Harold Brown told Congress recently. The 10-min. period contrasts with a 1-to-2 sec. interval for the high-drag Gemini and Mercury capsules, Brown said.

The large footprint offers military advantages, Brown said. If a vehicle were attacked in space or if a solar flare erupted, the pilot could be brought back quicker and easier than if he were in a non-maneuvering re-entry vehicle. If the vehicle were on an operational mission, it might orbit the earth once, re-enter and land at a secure base before countermeasures could be taken. Freedom to choose among many landing sites would compound an enemy's difficulties in attempting to neutralize the system.

Finally, controlled lifting re-entry and landing site selection are two essential steps in a progression toward an operational military Aerospaceplane (see p. 245). Ability to lift off from a variety of sites and ability of the pilot to control boost would round out this capability.

Pilot control of boost is under study now and this capability may be incorporated as a backup mode in the Dyna-Soar program.

The penalty Dyna-Soar pays for its large footprint is in volumetric efficiency. The portion of the total volume used for the mission, rather than for the structure needed to withstand the heat of maneuvering re-entry, is lower than that of a vehicle like Gemini. No deliberate effort was made to optimize glider volumetric efficiency, however, and flight experience may prove that the choice of structural safety factors was too cautious. Subsequent generations of Dyna-Soar might have stubbier wings—or useful payload, such as radars or cameras, might be housed in wing sections.

X-20's pressurized, environmentally-controlled instrumentation compartment has sufficient volume for transporting four men, albeit in somewhat crowded quarters. The instrumentation compartment is one of three distinguishable sections and is situated between the pilot's compartment and a secondary power bay at the rear of the glider.

Design of the fuselage above the instrumentation compartment might permit transfer of men from the X-20 to an orbiting space station. Dyna-Soar's mixed-gas (oxygen and nitrogen) environment, pressurized to 0.5 atmosphere, favors the glider over Apollo or Gemini for this role. The National Aeronautics and Space Administration spacecraft are supported by pure oxygen environmental systems.

With a natural mixed gas environment in the glider, and the likelihood that a space station intended to support men for longer than two weeks will have a mixed gas, "shirt-sleeve" environment, the task of compression/decompression in crew exchanges might be eliminated or simplified.

Similarly, the fuselage above the instrumentation compartment might be fitted with sensor bays. For example, cameras could be installed in the compartment and used when the vehicle was in orbit and properly oriented by its own and the Martin Titan 3 transtage reaction controls.

By military aircraft standards the X-20 will not be a large aircraft, but it will be a large space vehicle. Its overall dimensions are roughly comparable to those of a Lockheed T-33. Length is 35 ft., wing span about 20 ft., with wings swept to a 70 to 80 deg. angle. The glider will weigh between 10,000 and 15,000 lb. Lift over drag ratio will be in the order of 1.5, compared with about 0.25 for Gemini.

With the exception of its 18 in. dia. nose cap, a windshield and its windows, the glider is entirely metallic, largely composed of exotic columbium and molybdenum in shingled construction to permit expansion during the high heat loads of re-entry. Molybdenum is used on the hottest surfaces. Columbium, the more docile of the two, has less strength at high temperatures but can be welded.

Dyna-Soar has stimulated the development of these rare metals and led to new manufacturing capabilities for rolling and extruding them, a capability that also is being used in the Titan 3 booster. For example, Boeing has developed methods of welding, extruding and spinning Rene 41 in sizes and shapes never used before.

This makes it useful for top surfaces of the Dyna-Soar fuselage and internal structures.

The new metallurgical breakthroughs are regarded by USAF as important by-products of X-20 development, part of an essential manufacturing base necessary for space glider progress.

The glider will be radiation cooled, a technique only successful at temperatures stretching above 2,000F. A heat-resistant radiation conductive shield will cover the windshield and the front quarter windows and will be jettisoned after re-entry.

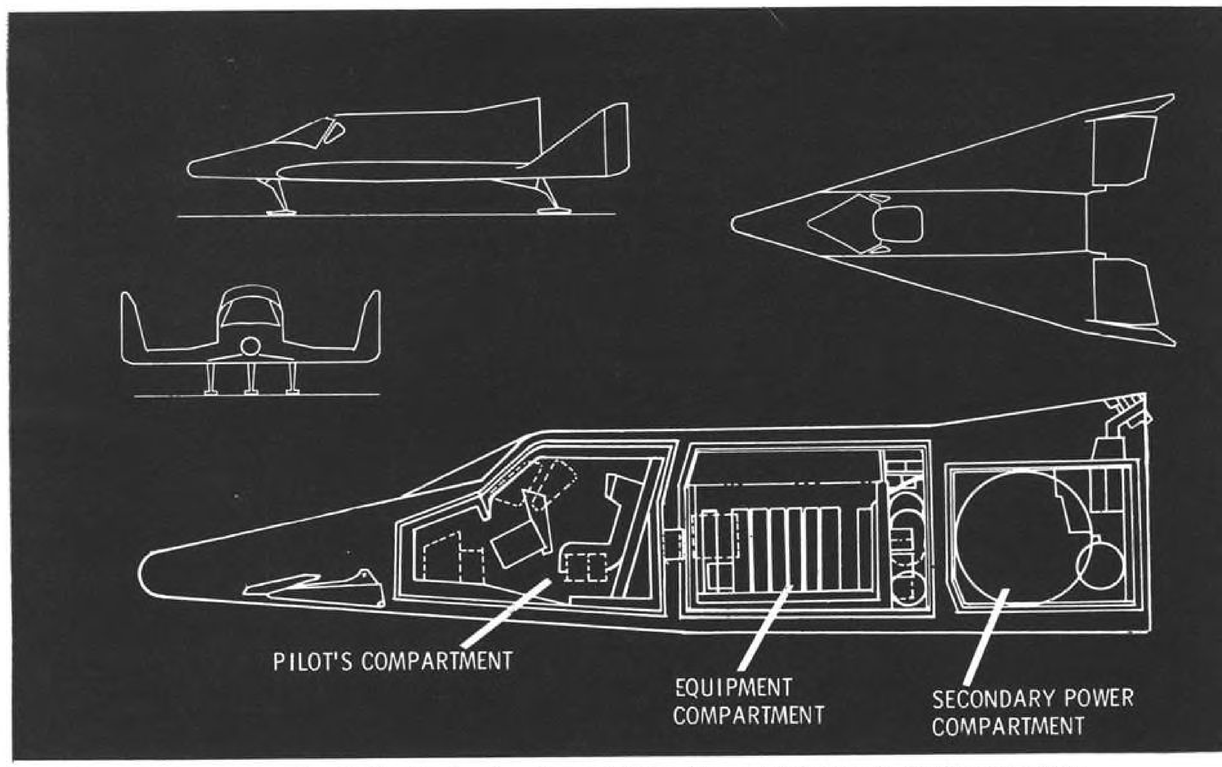
Single side windows which will not be subjected to such high temperatures will not be covered.

These provide pilot vision at forward angles up to 45 deg.

A Douglas F5D has been configured with this window arrangement for reassurance that a pilot can land with side window vision only, if necessary.

To protect the glider's nose from high temperatures, two separate types of spherical ceramic nose caps are in development. Ling-Temco-Vought is pursuing one approach and Boeing another.

Wings and fuselage are built as an entity, and wings can be bolted off. Fins



GLIDER THREE-VIEW and inboard profile line drawings show the contribution of aeronautical design to the Dyna-Soar shape.



"Don't tell me about 99% quality. Would you ride in it?"

(From an imaginary but realistic exchange between a Source Selection Board and Tapco.)

Source Selection Board (cont.): This thing has *hundreds* of components. Put in just one that's only 99% good, and there goes your mission.

TAPCO: I didn't mean 99% *performance*. Our stuff *works*. Our reliability factor is 99 and five or six more nines. Sometimes we express it in thousands or tens of thousands of hours mean time between failures. Or a failure probability per cycle of one times ten to the minus eight power. That's as close to perfection as you can get.

SSB: But you said 99% quality.

TAPCO: Right. *Quality*. Actually, it's 99.4%. We've delivered better than 10 million missile and aircraft subsystems, components, parts — rocket nozzles, APU's, fuel pumps, you name it. Of all these just six-tenths of one percent required corrective action.

SSB: Let's hear about those.

TAPCO: Sure. Most of those oddballs were in the early roll-off stages. In many cases the problem wasn't quality control but *communications*. We and our customer hadn't reached complete understanding on requirements, checkout procedures, or test-stand correlation, the sort of things engineers and quality people get together on and iron out.

SSB: I hear you. But would you *ride* in it?

TAPCO: *Yes*, I'd ride in it.

If you'd like to continue this conversation in terms of your specific requirements, write R. A. Paetz, Director, Requirements and Contracts, Tapco, TRW, 23555 Euclid Ave., Cleveland 17, Ohio.

TRW/TAPCO *a division of Thompson Ramo Wooldridge Inc.*

DESIGNERS • DEVELOPERS • MANUFACTURERS OF AEROSPACE SUBSYSTEMS INCLUDING ROCKET MOTOR NOZZLES, FUEL PUMPS, AUXILIARY POWER SYSTEMS, UNDERWATER PROPULSION SYSTEMS, REACTION CONTROL SYSTEMS, AND ELECTRICAL POWER EQUIPMENT

are angled out to provide stability and rudders can be differentially activated and act as drag brakes. The elevons work differentially for roll and longitudinal control and together for longitudinal control. They are displaced by hydraulic pistons.

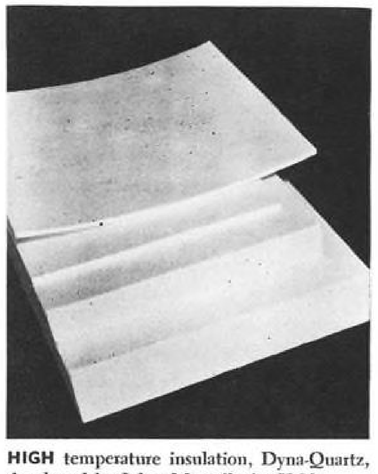
The entire vehicle will be painted black to achieve the highest possible emissivity, since roughly three-quarters of every Btu absorbed must be re-radiated. Since molybdenum and columbium both oxidize at high temperatures, they must be coated. Molybdenum disulphide was chosen as the coating after extensive research.

Airplane design philosophy, with an emphasis on redundancy, is incorporated throughout the glider. It will have double channels from the control stick to the actuators, double actuators and considerable duality in its hydraulic system. There will be double auxiliary power units, with one capable of assuming the load if the other malfunctions. The pilot, of course, provides additional redundancy. Should either the glider's inertial guidance or automatic flight control system fail, the pilot can still re-enter and maneuver the glider to a landing.

The pilot's cabin looks much like that of a normal aircraft, with a right side-arm controller and an energy management display the primary exceptions. The controller is at the pilot's right to avoid interfering with his pressure suit. Some avionic gear and a retractable metallic-skid nose landing gear also are in the forward compartment.

In the high-gravity boost phase of flight, the pilot's seat will be rocked forward so blood will collect in the abdominal portion of his body, rather than in his head. This would cause stomach pains at most but avoids the danger of blacking out the pilot.

After launch, the seat will swing back



HIGH temperature insulation, Dyna-Quartz, developed by Johns-Manville for X-20.

Dyna-Soar's History Full of Re-Examinations

Dayton—Origin of the Dyna-Soar boost glide vehicle concept is traceable to a bold World War 2 idea for an extremely high-velocity, rocket-boosted lift body to be used by Germany for bombing New York. This concept vehicle would have skipped along the upper fringe of the atmosphere, re-entered to drop its bombs, and glided to a landing in the Pacific, where its crew would have been picked up by submarine.

Predicated on the use of a steel structure, the German plan now is considered unfeasible, particularly in view of the advances in exotic materials required by the Dyna-Soar.

In the early 1950s, Walter Dornberger, who had commanded German rocket development at Peenemunde, got Bell Aerosystems interested in an extension of this idea—a rocket-launched, global-range bomber. In 1954, some Air Force money was made available for this effort, called Project Bomi.

While these ideas now are considered naive, they led to additional studies. The results were channeled into a Dyna-Soar development plan. The 118 P high-altitude reconnaissance vehicle studies followed in 1956. Then came the Brass Bell project, a long distance reconnaissance vehicle concept; the Project ROBO (rocket bomber) study series and the National Advisory Committee for Aeronautics' Hywards study, aimed at bettering the contemplated performance of its X-15 rocket research aircraft.

In 1957, a development plan for an orbital re-entry glide vehicle, called Dyna-Soar, was formulated. It incorporated many ideas explored earlier, and an industry competition was approved. Teams headed by Boeing and Martin finally were selected in 1958 from among nine bidders to conduct parallel, one-year studies, which cost Air Force about $9 million each.

What had begun as widely different concepts ended in rather similar approaches for a medium lift/drag space glider. Air Force picked Boeing to manufacture, assemble and test the glider.

Before Air Force was allowed to proceed with Dyna-Soar, the basic vehicle configuration—which had been derived so tortuously—was thrown open for re-examination to see whether the medium L/D vehicle was the best choice. Defense Dept. ordered these so-called Phase Alpha studies, which stretched from January through March of 1960 and resulted in virtually no change in the Boeing approach.

Participants included Boeing, Martin, McDonnell, Lockheed, Hughes, Avco and the National Aeronautics and Space Administration. Concepts explored ranged from pure ballistic shapes to low L/D winged vehicles and medium L/D vehicles.

Hughes and Lockheed jointly explored a piloted, recoverable and reusable delta-shaped space vehicle with folding wings, intended to operate with varying payloads at 100 to 1,000 mi. orbits for periods up to 24 hr. (AW Oct. 3, 1960, p. 54).

Avco examined an umbrella-like structure with woven Rene alloy surfaces. Drag could have been modulated by controlling the extension of the umbrella structure. Fore and aft deviations were possible, but side-course deviations were not. Still another approach studied under Phase Alpha was an inflatable wing structure.

Finally, in April, 1960, the Boeing selection was approved by Defense Dept. and the Dyna-Soar program formally began. Martin was picked to supply the Titan 1 booster for suborbital flights in the absence of an adequate booster for orbital flights. During the suborbital phase, or Step 1, Titan 1 would have taken Dyna-Soar to re-entry regimes just below orbital velocity (18,000 to 19,000 fps. as opposed to 23,300 fps.)

These velocities would have exposed the glider to critical re-entry heating, permitted testing of emergency procedures, abort and abort sensors and permitted verification of glider design.

Seven or eight months later Titan 2—a higher-energy booster using storable propellants—was substituted for Titan 1. It would have made possible even higher ballistic re-entry velocities—in the order of 20,000 to 21,000 fps.

Planned phases of the Dyna-Soar program were Step 2A, to explore R&D aspects of orbital flight; Step 2B, to examine possible operational use of the glider for military and other needs; and Step 3, the development of a complete orbital weapon system for undefined missions.

As part of Step 2, an Air Force selection board late in 1961 picked the Titan 2 with 100-in. solids (the Solid Titan or Soltan), as an appropriate booster for the orbital phase of Dyna-Soar. This followed a review of possible boosters including Titan 2 with a high energy upper stage, three Titan 2s strapped together and the Phoenix system (AW Mar. 27, 1961, p. 50).

Also under Step 2, Boeing and other organizations conducted extensive studies of potential military uses for the Dyna-Soar system. The Air Force does not identify what missions were examined. It merely indicates the results were promising. But Boeing is known to have looked at such missions as bombing, reconnaissance, ferry and support.

These studies, conducted throughout 1960 and early 1961 under the Bomb Orbital Strategic System (BOSS) and Weapon Development Glide Entry (WEDGE) program, were detailed in Aviation Week & Space Technology (AW Apr. 10, 1961, p. 26). Some of these and related studies were done under small contracts from Air Force Systems Command's Aeronautical Systems Div., Air Force Special Weapons Center and the then Ballistic Missiles Div.

During 1961, Boeing proposed compressing the program through its Project Streamline to save about $250 million. Key to the plan was the use of the Saturn booster and elimination of suborbital flights, first made necessary by the absence of an adequate booster for orbital flight.

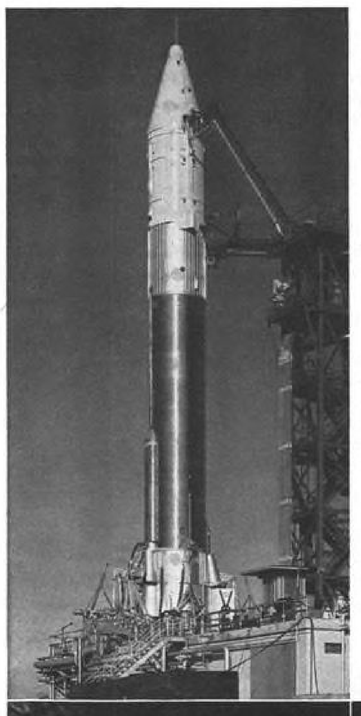
Eventually, Streamline was modified and adopted. Suborbital flights were eliminated in December, 1961. Formal selection of Titan 3 as the booster came late in February, 1962, and release of funds followed last December. This delay caused further re-direction of the program.

In the summer of 1962, the glider was re-designated X-20 to underscore the experimental nature of the program. The name Dyna-Soar is retained, however, largely as a popular name for the program.

Eliminating the suborbital flights advanced the date of orbital flights as originally projected in Step 2A by three years. But as a result of re-direction and re-scheduling and forced funding stretchouts, in which DOD has not made available all the money appropriated by Congress, the "streamlined" flight date now approaches within one year of the original orbital flight schedule.

Present objectives call for the first orbital launch early in 1966. As many as 20 air drops from a modified Boeing B52C are scheduled to begin early in 1965 to familiarize pilots with the glider and to gain flight experience on subsystems (AW May 6, p. 19).

for Space Information Systems, strength favors General Precision



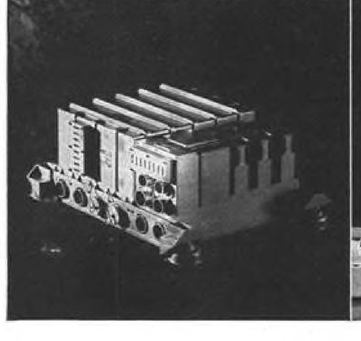
General Precision's Information Systems Group (ISG) has built both major elements of a space information system. ■ One is the on-board subsystem that gathers space data and performs preliminary processing. Proof of capability: a Librascope computer aboard NASA's Atlas-Centaur will be the first to guide a space vehicle to a soft landing on an extraterrestrial body. ■ The other is the ground-based subsystem that completes the processing and displays the desired information after transmission from the spacecraft. Proof of capability: A Librascope multiple-computer system will play a key role in USAF's 473L command-and-control system to be installed in the Pentagon. ■ Send for the story of ISG's 25 years in environmentally designed information systems and latest work on advanced computing techniques.

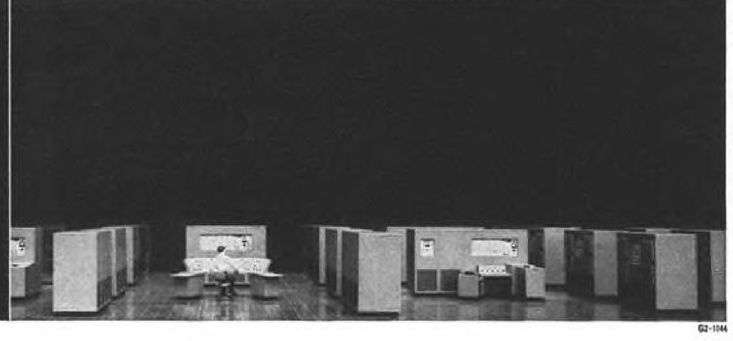
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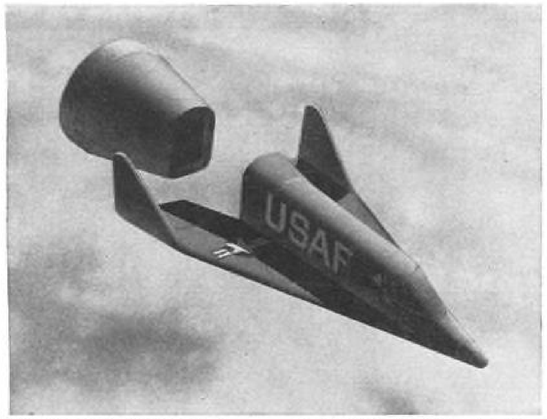


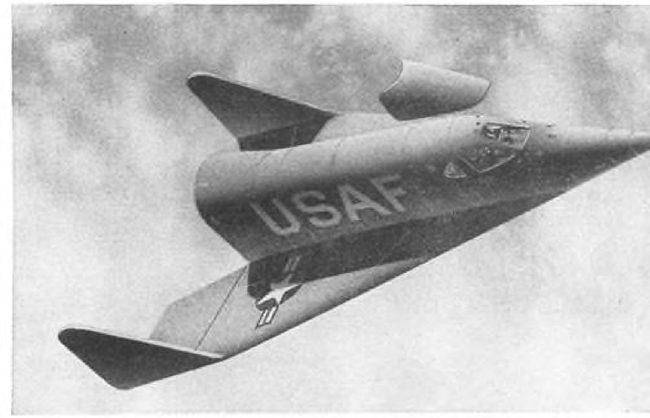




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DYNA-SOAR MISSION phases are depicted in the three drawings on this page. At left above, the X-20 Titan 3 adapter section is being jettisoned after the glider is in orbit. At right, a heat shield is ejected from the windshield and quarter windows after re-entry. Single side windows, which give the pilot a 45 deg. forward view, are uncovered.

to a more normal position. The seat will be equipped for ejection at subsonic speeds.

The pilot's compartment and the instrumentation compartment are fully controlled, while the secondary power bay is environmentally controlled but not pressurized. If necessary, the bulkhead between the pilot and instrumentation compartments can be removed.

Air Force anticipates that each X-20 will be reusable after piloted flight. Even though the vehicle is radiatively cooled, at least some metal deformation is expected. What refurbishing will be necessary is still unclear, but in the worst case, most or all of the external skin probably will have to be replaced.

Auxiliary power and environmental control equipment will be housed in the auxiliary power bay. Cryogenic hydrogen is circulated throughout the glider's three compartments as a coolant for the pilot, equipment and power bay and later is fed to the auxiliary power unit and consumed as fuel. Inert nitrogen serves as a heat sink for transfer of heat from the equipment to the walls.

The environmental control unit is made by AiResearch Div. of Garrett Corp. The auxiliary power unit—a hydrogen-oxygen turbine—is made by Sundstrand Corp. About 24 kilowatts will be required.

A transition section attached to the glider mates with Titan 3 transtage. The forward portion of the transition section is conically shaped, flaring into a cylindrical portion that mates with the booster. The forward portion of the transition section will house a Thiokol solid-propellant acceleration or abort rocket which provides high thrust for a short period to separate and boost the glider away from the booster in case of an emergency on the pad or during launch, and permits the pilot to attempt to land the glider. Separation would occur along an abort plane within the transition section, aft of the rocket nozzles.

The transition section also can carry extra hydrogen, oxygen and environmental and power equipment for additional orbits. Both the transition section and the booster's transtage are jettisoned prior to re-entry.

Present Air Force test plans call for a series of about 20 air-launched drop tests, similar to the North American X-15 tests, to begin before mid-1965 over Edwards AFB, Calif. (AW May 6, p. 19). A Boeing B-52 will be fitted with an underwing pylon (AW July 1, p. 97) from which the glider will be dropped at speeds of Mach 0.8 at altitudes of 40,000 to 45,000 ft. The pylon will be designed to permit the Dyna-Soar pilot to eject while the glider is slung under the mother ship's wing.

The purpose of these tests is twofold. They will:

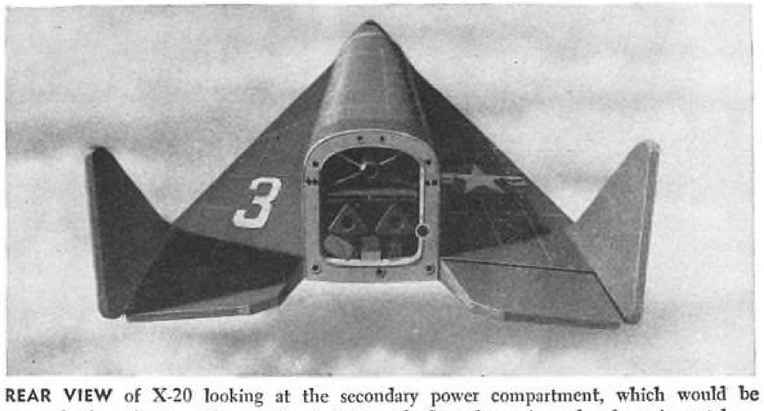
• **Give the six X-20 pilots** opportunities to fly the X-20 and to take it through the terminal phase of its flight.

• **Provide flight experience** with the glider's control surfaces and with the auxiliary power units and glider subsystems.

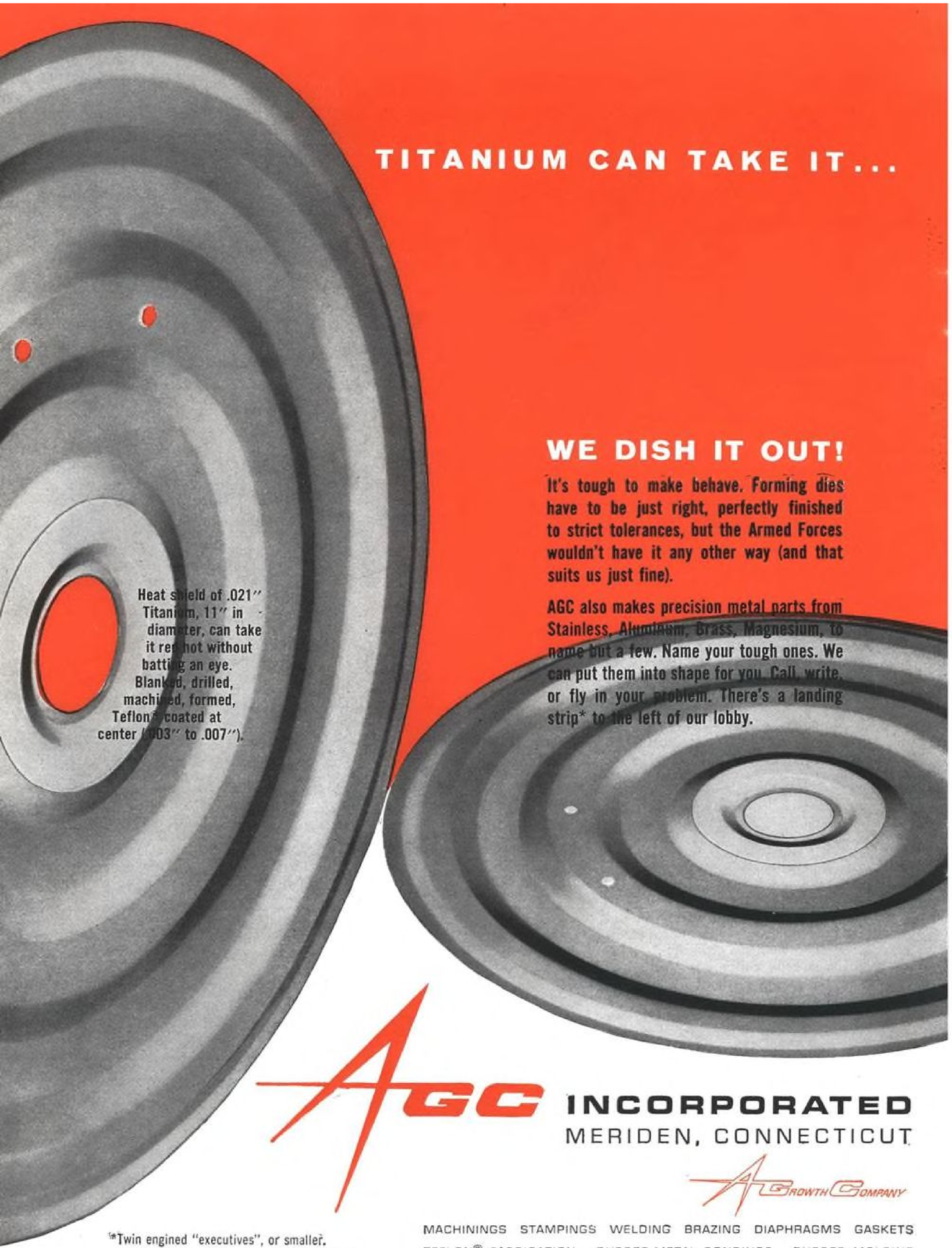
In some of these flights the X-20 will be equipped with its acceleration rocket, which will be fired to boost the glider to speeds up to Mach 1.5 to familiarize pilots with the craft at transonic speeds.

A series of about 10 X-20 orbital shots, to be launched from Complex 40 at Cape Canaveral, Fla., is expected to get under way early in 1966. The first two will be unmanned, single-orbit shots (AW July 9, 1962, p. 15) to be followed by an undetermined number of manned, single-orbit flights and multi-orbit piloted launches. The first X-20 glider now is being fabricated at Boeing.

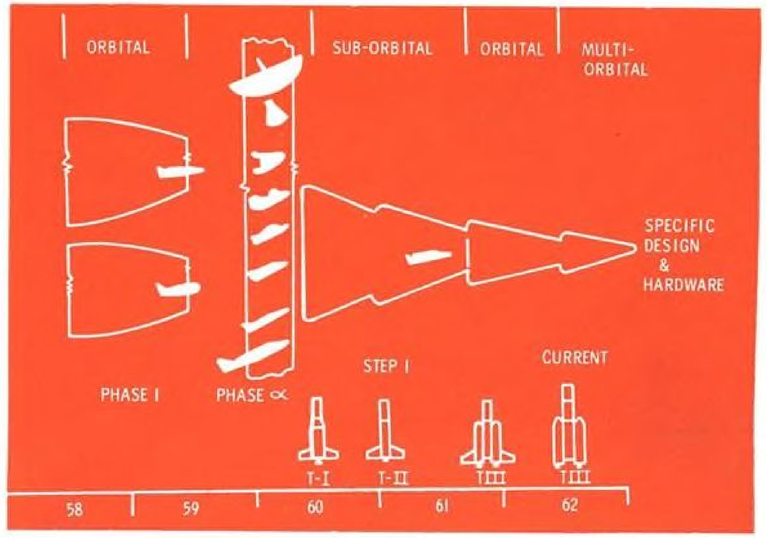
The first two unmanned shots will be launched into highly elliptical earth orbits with apogees of about 50 mi. and perigees effectively beneath the earth's surface—hence they can be regarded as long ballistic shots. Flight duration will be approximately 90 min., with boost,



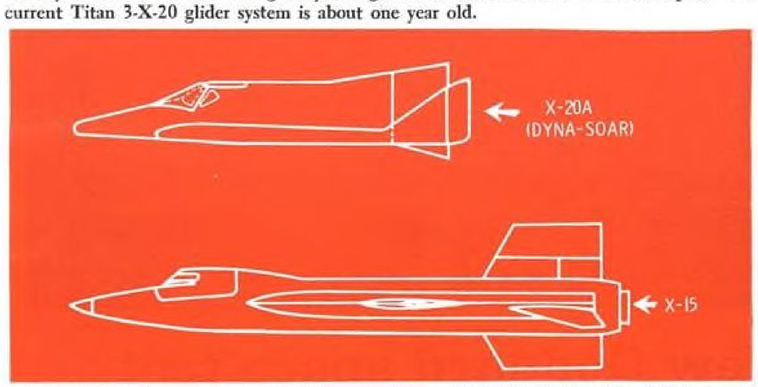
REAR VIEW of X-20 looking at the secondary power compartment, which would be exposed when the transition section is jettisoned. Spaceframe is made of exotic metals.



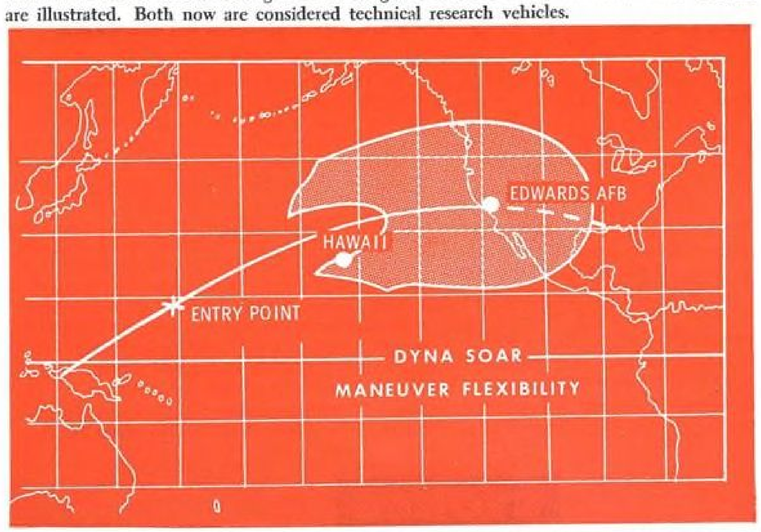
*Twin engined "executives", or smaller.
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DYNA-SOAR evolution is illustrated in these silhouettes, mission objectives and times. Variety of both blunt and lifting body configurations was considered in Phase Alpha. The current Titan 3-X-20 glider system is about one year old.



RELATIVE SIZES of the Boeing X-20 boost glider and the North American X-15 aircraft are illustrated. Both now are considered technical research vehicles.



MANEUVERABILITY of the Dyna-Soar glider produces a large landing footprint, the shaded part of the drawing. The footprint covers several thousand square miles.

orbital flight and re-entry phases lasting about 30 min. each.

Objective of these flights will be to see how smoothly Dyna-Soar separates from its Titan 3 booster, which concurrently will be in its early launch trials. The gliders are scheduled to descend at Edwards AFB for possible recovery with the aid of a microwave command guidance system, but USAF would consider recovery of even portions of the first two Dyna-Soar gliders as a bonus.

AMR Launch

Launch will be along the Atlantic Missile Range with X-20 flying over the Indian Ocean and along the Pacific Missile Range. Boost vehicle burnout probably will occur over Grand Turk Island.

The transition section and the transtage will be jettisoned at injection for these flights.

On later piloted, single-orbit missions the transition section and the transtage may remain attached to the glider after injection, as they would be for multi-orbit missions, to subsequently inject the glider into a necessary circular orbit and then to initiate the de-orbit maneuver. In the single-orbit case, however, their retention with the glider would be solely for training purposes.

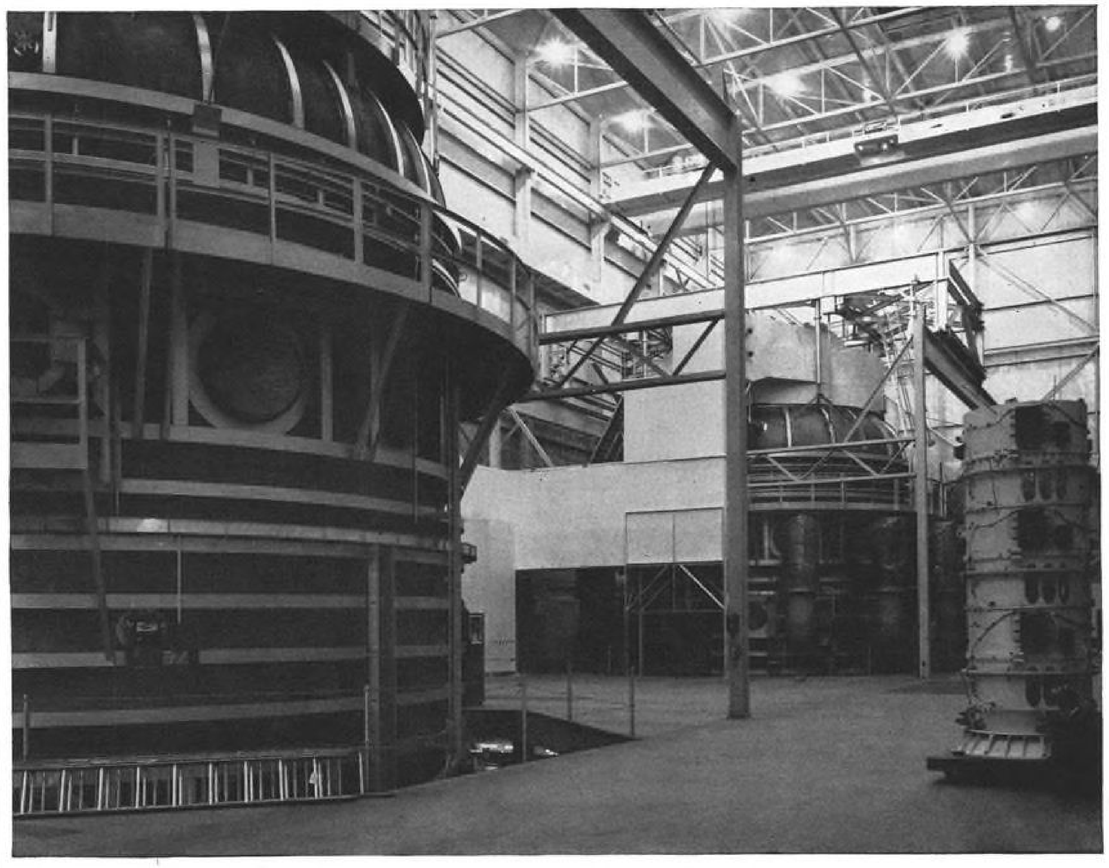
Apogee would occur over the Indian Ocean and re-entry will begin over the Pacific. Ideally, the glider will follow a single shallow trajectory. However, its maximum heat, perhaps as high as 4,000F, will be generated during the re-entry phase. It will make a first deep penetration, arriving at its most critical point, then will angle upward into the upper atmosphere to cool and to take the heat impact on its undersurfaces and leading edges. Then the glider will successively angle down and pull out, effectively stepping down and using its lifting capability to derive relief from the heat.

The glider's re-entry trajectory will resemble a decreasing, damped oscillatory pattern.

Reaction Control

In the piloted case, sufficient footprint would remain when the glider arrived over Edwards AFB to overshoot the area and make a landing at Holloman AFB, N. M.

For the multiple-orbit missions, the transtage will re-fire at the glider apogee point to inject the vehicle into a circular orbit. For the de-orbit maneuver, reaction controls on both the glider and the transtage will orient the glider and the transtage will re-fire as a retro maneuver. X-20 will turn, and separation will occur along the plane separating the glider from the transition



New Goddard space test chamber goes into operation

NASA recently put into service the Dynamic Test Chamber (DTC), foreground above, at Goddard Space Flight Center, Greenbelt, Md. Behind it is Goddard's Space Environment Simulator (SES) scheduled to go into service at a later date. These two 35-ft. diameter, 60-ft. high chambers have been described by NASA as among the nation's most advanced aerospace test facilities. They will provide for complete check-out of NASA space vehicles and scientific probes.

The SES chamber, to be equipped with a collimated solar simulator, is capable of operation in the 10^{-9} Torr range under full load conditions. During acceptance testing, it attained the 10^{-10} Torr scale.

On the basis of successful experience on other large, sophisticated space chambers, Stokes was named prime contractor to furnish and install vacuum and cryogenic systems for both the SES and DTC facilities. As a team member, CryoVac furnished all cryogenic systems, including 20°K helium cryopumping apparatus.

Stokes offers unique total capability in the successful completion of demanding technical facility assignments: experienced project management teams; complete design capabilities; trained crews of technicians for field erection and startup. For information on space test installations of any size or complexity, call or write **Space Systems Department, F. J. Stokes Corporation, 5500 Tabor Road, Philadelphia 20, Pa.**

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section. In later test flights, digressions will be made so the pilot must turn the glider during re-entry to land at Edwards.

Mission control center for the test flights will be at the Satellite Test Center at Sunnyvale, Calif. Initial launch control will be handled from Titan 3 Pad 40-41 complex at the Cape.

Sites along the Pacific Missile Range will be specially instrumented for the Dyna-Soar series. There may be two land sites in addition to PMR headquarters—probably at Wake, Midway, Johnston or one of the Hawaiian islands; and two ship sites, to provide near-continuous coverage. These sites will track the glider and record telemetry and voice communications.

Because the X-20 communications system will operate not in the more customary UHF or S-band but in the super high frequency (SHF) band, special acquisition and tracking equipment must be installed on the range. The signals of the new system, made by Radio Corp. of America, are expected to penetrate the ion sheath generated during re-entry that would be opaque to lower-frequency signals. The communications blackout would be acute for a Dyna-Soar, which remains surrounded by the ion sheath for perhaps 20 to 25 min., compared with a fraction of that for a Mercury capsule.

The RCA spaceborne system will transmit voice and telemetry from small antennas, no larger than a silver dollar, and its transmitted signals will be a beacon for tracking. Range and range-rate capabilities will be added to the ground antennas. Flight tests of the system are scheduled for this fall in a Boeing C97 over Newport, Del., to check airborne portions against prototype ground equipment.

To thoroughly investigate problems of lifting re-entry flight, the X-20 will be instrumented extensively during its test series. About 775 measurements of all types, such as pressure, temperature and acceleration, will be made from among more than 1,000 measurements Air Force is prepared to make. These measurements will be collected and multiplexed onto a hybrid 144,000-bit PCM-FM/FM instrumentation subsystem made by Electro Mechanical Research. Data will be recorded within the glider as well as transmitted to the ground so that a permanent on-board record will be available after flight.

The several FM/FM channels will carry primarily analog data such as intertial guidance updating and flutter measurement. The former, compared with tracking information calculations, would indicate any sizable discrepancy so the pilot could be alerted if his inertial system malfunctioned or accumulated unexpected errors.

Adaptive Autopilot

X-20 will have an adaptive autopilot being developed under subcontract to Boeing by Honeywell. Essentially, this will be the same system with altered gains that is now installed in one of the X-15 vehicles.

The inertial guidance system will be a combination of a Honeywell platform and an Autonetics Verdan computer. In selecting equipment for X-20, a heavy emphasis was placed on relatively well developed hardware, such as the Verdan and the adaptive X-15 autopilot, on which flight experience would be accumulated before Dyna-Soar flew, according to the Air Force.

Hardware Emphasis

Another example of the emphasis on available hardware is Air Force's selection of the Sperry Phoenix Co.'s microwave command guidance system for terminal control of the two unmanned orbital flights. This system will be used in the hope of recovering some X-20 hardware. The Sperry system was used in the USAF-Lockheed QF-104 program. The glider's reaction control system, built by Bell Aerosystems, is a carryover from the X-1 and X-15 programs. The Sundstrand APU, which was conceptually supported only in earlier advanced technology contracts, is an exception to the general approach on X-20 hardware.

Air Force is exploring the possibility of permitting the pilot to control the booster in flight—which may be a large step into the future of piloted space

Dyna-Soar Funding

Dayton—Cost of the Dyna-Soar program is expected to run more than $800 million. This covers Titan 3 boosters and associated costs and provides for about 10 boost glide vehicles.

Funding breakdown to date, according to Jack Trenholm, deputy director of the program at Air Force Systems Command's Aeronautical Systems Div., is roughly as follows:

- Period through Fiscal 1960—$51 million. This was spread over three fiscal years.
- Fiscal 1961—$58 million.
- Fiscal 1962—$100 million. This figure, approximately $87 million short of the total appropriated by Congress for the year, is the amount released by the Defense Dept. for the program.
- Fiscal 1963—$130 million. Approximately $157 million was appropriated by Congress. Money obligated for Dyna-Soar by end of March, 1963, according to information given Congress by the Air Force, was $92.5 million.
- Fiscal 1964—$125 million requested by the Administration.

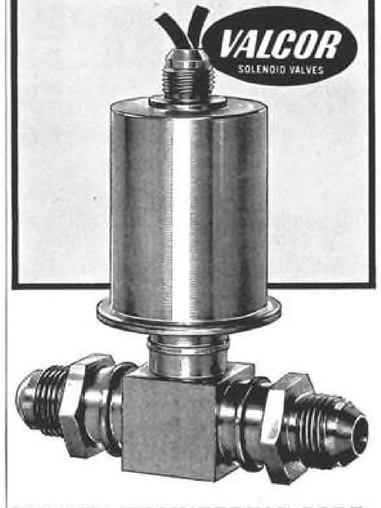
A solenoid valve that operates at −423°F or 1000°F

Valcor's engineers originally designed this solenoid valve, of series 412, to operate completely submerged in liquid hydrogen (—423°F). The unique application required a valve that would eliminate the use of any non-metallic parts coming in contact with the media, internal or external. All materials had to be critically analyzed because of the destructive forces inherent in such extreme temperatures.

The all welded construction, which Valcor has developed to a new state-of-the-art, helped resolve many of the problems. During the exhaustive series of tests, it was known that many of the problems in operating a solenoid valve under the extremes of low temperature had a correlation to problems created by high temperatures. The result—a **one** valve concept that with minor variations could be used for high or low temperatures...

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CH 5-1665 (Area Code 201)

flight. The technique, called Pilot in the Booster Loop (PIBOL), appears to be feasible. Although it is the subject of some differences within the Air Force, it is being proposed as a backup or emergency mode for Dyna-Soar.

Tests conducted on the Navy centrifuge at Johnsville, Pa., and at a fixed base simulator at Boeing have convinced some Air Force program people that PIBOL is feasible. Subjects showed an ability during g-loading to operate controls and read instruments.

Sooner or later, partisans of PIBOL contend, it will not be economically feasible to discard boosters, making a form of reusable booster or combination air-breathing and space vehicle essential. Then the pilot probably would be called upon to fly through what is now a boost phase, and he probably would prove to be an asset.

Booster Backup

If nothing else, the pilot might add a degree of redundancy to the booster. Flying the boost trajectory from displays on the glider's instrument panel, he could make decisions or countermand undesired abort decisions resulting from non-catastrophic malfunction or improper indications of abort sensors. He would not have throttle control, but could terminate boost.

Pilot control would not necessitate any changes in the glider, so it might be an inexpensive way of getting more safety in the system. The pilot would require access to the booster flight control system from his side arm controller and rudder pedals to fly the booster to injection. He might use the glider's inertial system, for example, to fly the booster if the booster's inertial system should fail.

This capability would give the pilot control from boost through orbital flight and then re-entry.

Wiring Changes

It appears now that very little hardware would have to be added, most changes being in wiring. Since the booster's flight control system uses booster guidance for stabilization, stability augmentation components would be installed on the booster. A pair of additional accelerometers attached to the boost vehicle would drive the eight-ball display in the X-20 cockpit. The pilot would attempt to keep the outputs of these nulled during the boost phase.

PIBOL currently is being studied by Martin, Boeing and the Air Force. A Boeing simulation study indicated that the pilot could fly the booster almost as well as the automatic system could.

X-20 is now locked in the Titan 3 schedule, and part of the latter's R&D shots will be devoted to simulating the glider's mass equivalents but not its aerodynamic shape.

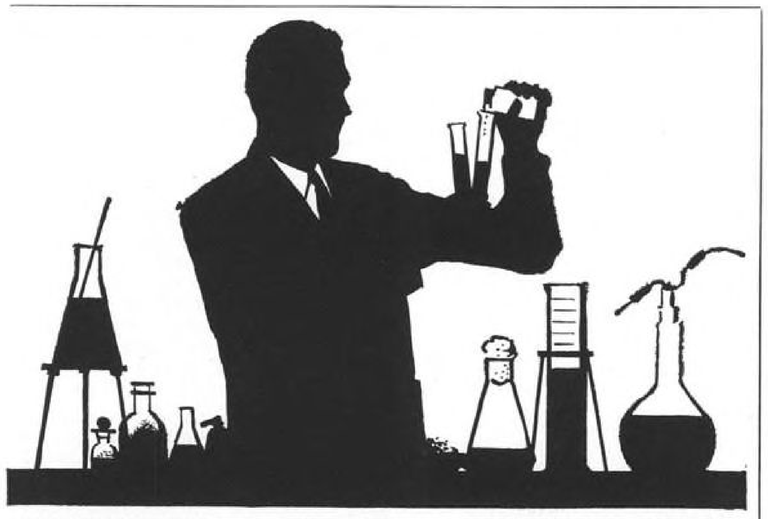
Dyna-Soar and the safety of its pilot place difficult constraints on Titan 3. For the Dyna-Soar boost trajectory, the launch vehicle must travel an extremely narrow velocity-altitude corridor, keeping the glider within the sensible atmosphere for periods longer than an unmanned, non-lifting body requires. At all times, the booster-glider combination must be at a velocity, altitude and orientation such that in case of abort, glider speed and altitude of termination of abort rocket thrust will permit the pilot to land safely.

Pressure Suits

Although X-20 will have a natural environment, pilots will wear pressure suits, at least in initial flights. The neck ring between suit and helmet has been eliminated, giving the pilot greater ease in turning his head. The helmet also is wider, providing a greater field of vision.

National Aeronautics and Space Administration, which has served as technical advisor throughout the history of Dyna-Soar, recently joined Air Force in a position paper strongly supporting the program.

The two agencies presented this position to Defense Secretary Robert McNamara last May.



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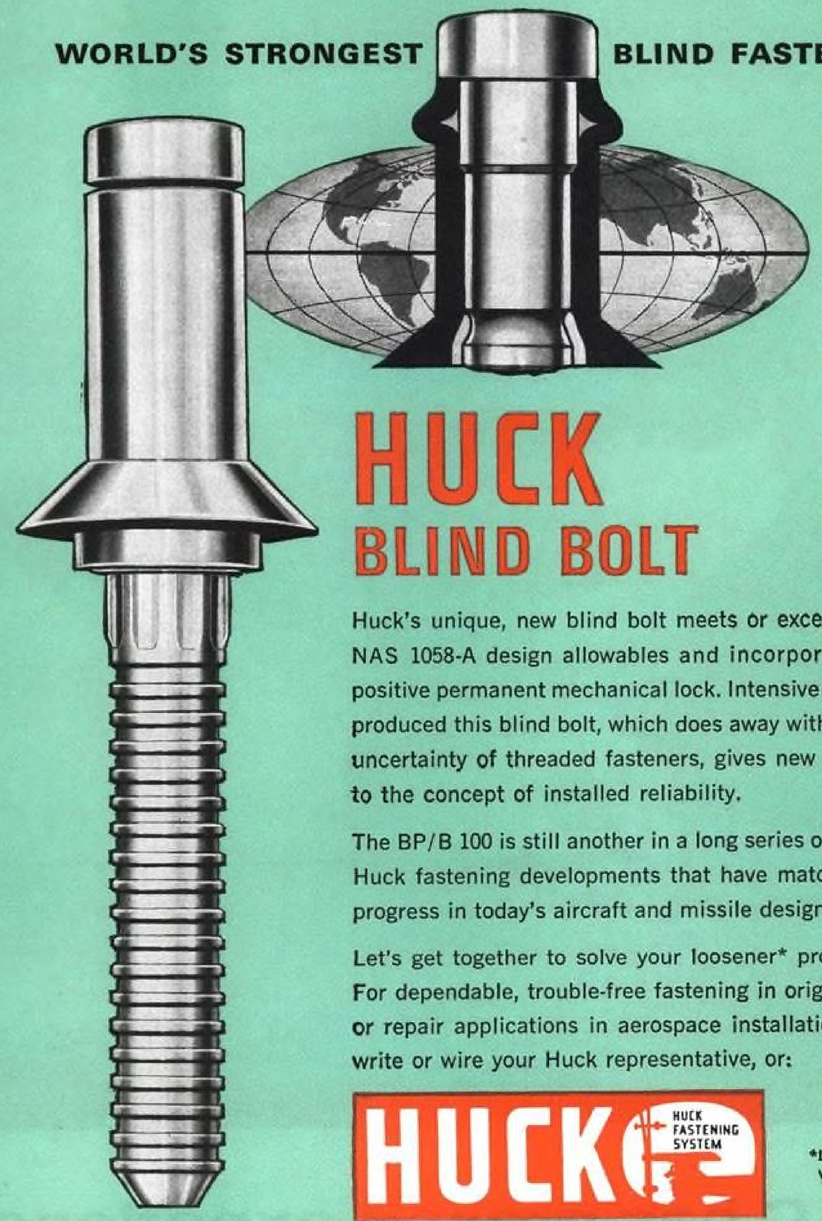
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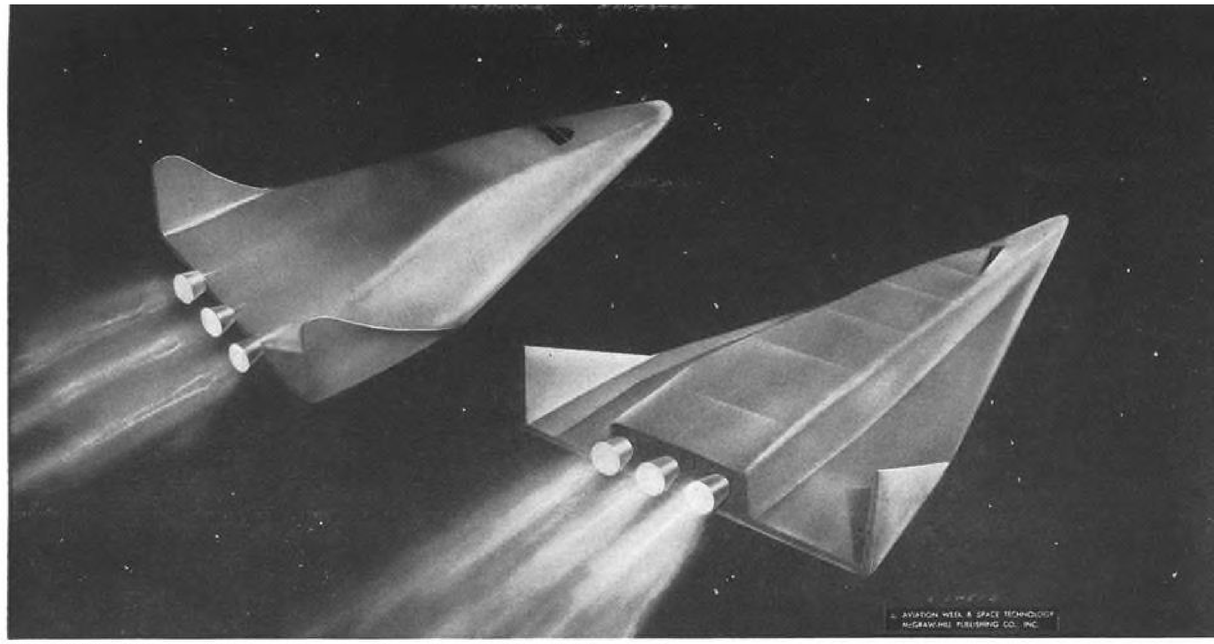
U.S. Spacecraft	Launch Vehicle	Remarks
Mercury	Atlas D	Two 3-orbit and one 6-orbit manned missions successful; 18-22 orbit mission planned.
Gemini	Titan 2 ✓	Rendezvous techniques development; 14-day mission with 2 men; continued development of spacecraft technology; USAF sharing cost.
Apollo A ✓	Saturn 1	14-day earth orbit test of 3-man command module.
Apollo B ✓	Saturn 1B	Earth-orbit test of rendezvous of command and service modules with lunar excursion module (LEM).
Apollo C ✓	Saturn 5	Circumlunar flight with command and service modules.
	Saturn 5	Tentative lunar orbit mission to drop LEM loaded with supplies for landing mission to follow.
	Saturn 5	Lunar orbit of composite spacecraft with 3 men, followed by descent to surface in two-man LEM and exploration.
Lunar Excursion Module (LEM) ✓	Saturn 5	Vehicle to land two men on lunar surface from lunar orbit.
X-20 (Dyna-Soar)	Titan 3C ✓	Hypersonic glide re-entry research in one-man vehicle.
Manned Orbital Development Station (MODS)	.....	Under study.
Manned Orbital Space Station (MOSS)	Saturn 5	Possible 12-man long-life station under study.
Tiros	Delta ✓	IR studies and photography of clouds for meteorological satellite development.
Nimbus	Thor-Agena B ✓	First operational meteorological satellite.
Synchronous Meteorological Satellite (SMS)	.....	Formerly called Aeros.
Echo 2	Thor-Agena B ✓	Passive communications satellite with 135-ft. diameter rigidized sphere.
Telstar	Delta ✓	AT&T funded project to develop wide-band commercial communications satellite.
Relay	Delta ✓	Feasibility tests of low-altitude, one-way active repeater satellite.
Syncom	Delta ✓	Lightweight two-way active repeater satellite in synchronous orbit.
Advanced Syncom	Atlas-Agena B ✓	Larger, more sophisticated follow-on to Syncom 1. Hughes has study contract.
Medium-Altitude Random-Orbit Comsat	Atlas-Agena B ✓	Air Force planned system of random-orbit comsats to be launched in groups of up to 8 satellites.
Oscar	Thor-Agena B ✓	Non-governmental comsat for amateur radio operators; piggy-back launches with Discoverer satellites.
Transit	Thor-Ablestar ✓	Orbiting navigation beacon development.
Agena D Gemini Target ✓	Atlas D	Rendezvous target for 2-man Gemini spacecraft.
Ranger	Atlas-Agena B ✓	Lunar impact; high-resolution photography; landing of survivable instrument capsules on the moon.
Surveyor Lander	Centaur	Unmanned lunar lander with payload for examination of lunar crust and environment.
Surveyor Orbiter	Centaur	Selenodetic satellite for lunar reconnaissance and photographic mapping; to monitor lunar radiation.
Mariner 1, 2	Atlas-Agena B ✓	Scaled-down Mariner A spacecraft which successfully completed Venus fly-by on Dec. 14, 1962, taking magnetometer and radiometer data.
Mariner B	Centaur	Advanced, heavier version of Mariners 1 and 2 which will drop survivable instrument capsules to the surface of Mars and Venus.
Mariner C	Atlas-Agena D ✓	Mars fly-by vehicle.
Voyager	Saturn 1B	Mars/Venus orbiter.
Solar Probe	Atlas-Agena B ✓	Designed to come within 0.2 A.U. of the sun's surface for close-up observations.
Pioneer	Delta ✓	Solar-orbiting spacecraft (perihelion 0.8 A.U., aphelion 1.2 A.U.) for measurements during the International Quiet Sun Year. Formerly known as PIQSY.
Outer Planets Spacecraft	.....	Fly-bys and orbitings of the Jovian planets.
Out-of-Ecliptic Plane Spacecraft	.....	Investigations of phenomena out of the ecliptic plane.
Interstellar Probe	.....	Solar system escape spacecraft.
Discoverer Series	Thor-Agena A, B ✓	Development of Agena vehicle and test of designs, techniques and components for military and scientific satellites.
Explorer Series	Juno; Scout; Delta ✓	General name for NASA scientific earth satellites. Explorer 1 was first U.S. satellite.
Orbiting Astronomical Observatory (OAO)	Atlas-Agena B ✓	Orbiting telescope for mapping of heavens in UV spectrum.
Orbiting Geophysical Observatories:	..... ✓	Study of radiation belts, magnetic fields and ionosperic phenomena.
EGO S-49	Atlas-Agena B ✓	Eccentric-orbiting geophysical observatory.
POGO S-50	Thor-Agena B ✓	Polar-orbiting geophysical observatory.
Orbiting Solar Observatory (OSO)	Delta ✓	Study of solar UV and X-radiation.
Helios	Thor-Agena B ✓	Advanced orbiting solar observatory; to study particle radiation as well as electromagnetic radiation.
ANNA 1-B	Thor-Ablestar ✓	Joint Army-Navy-NASA-Air Force geodetic satellite.
Injun	Thor-Ablestar ✓	Investigation of earth's radiation belts.
Greb (SR Series)	Thor-Ablestar ✓	Study of solar and cosmic radiation.
Traac	Thor-Ablestar ✓	Test of gravity-gradient stabilization system for Transit satellites.
Arents	Atlas-Agena B	Advanced research environment test satellite to study environmental conditions and radiation in synchronous orbit.
TRS-1	.....	Radiation belt mapping.
Bios 2	Atlas-Agena B ✓	Long-term exposure of primates and other biological specimens; recovery by ejected capsule.
Lofti	Thor-Ablestar ✓	Test of propagation of very low frequency radio signals in ionosphere.
Energetic Particles Satellites:	.....	Measurement of artificial radiation created by high-altitude nuclear blasts.
S-3a (Explorer 14)	Delta ✓	
S-3b (Explorer 15)	Delta ✓	
Atmospheric Structures Satellite S-6	Delta ✓	Study of composition, density, pressure and temperature of upper atmosphere.
Fixed-Frequency Topside Ionosphere Sounder S-48	Scout	Study of ionosphere from above by measuring electron distribution, electron density and cosmic noise level.
Micrometeoroid Detector Satellite S-55 (Explorer 16)	Scout	Study of spatial-temporal distribution of micrometeoroids as hazard to spaceflight.
Polar Ionosphere Beacon S-66	Delta ✓	Study of ionospheric behavior and electron content, as well as conditions which disrupt communications.
Interplanetary Monitoring Platform (IMP) S-74	Delta ✓	Ascertain Project Apollo radiation hazards; increase solar flare prediction capability; study solar-terrestrial relationships.
Large Micrometeoroid Detector Satellite	Saturn 1	Obtain better statistical information of meteoroid distribution with larger area. To be flown in boilerplate command module during a test of Saturn 1 booster.

Excerpts from AVIATION WEEK & SPACE TECHNOLOGY 1963 International Aerospace Spec Tables

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TWO VERSIONS of an Aerospaceplane are shown above in this artist's concept.

Aerospaceplane May Be Two-Stage Vehicle

Dayton—Air Force now believes a first generation Aerospaceplane will be a two-stage rather than a single-stage-to-orbit vehicle. The first stage could be either a horizontal-takeoff, air-breathing aircraft or a vertical-takeoff booster such as Titan 3, configured to be recoverable.

The second stage will be rocket powered. It will be either a winged vehicle like the Dyna-Soar X-20 glider (see p. 230) or a high-volume lifting body with an aerodynamic shape (see picture above).

Aerospaceplane, as distinguished by the Air Force from the aerospace plane concept, will take off and land horizontally. This is the approach being pursued by the Air Force Systems Command's Aeronautical Systems Div. (ASD) at Wright-Patterson AFB, Dayton, Ohio. The complete concept also includes the possibility of vertical rocket takeoff. A study of all approaches—expendable, vertical takeoff, horizontal landing and horizontal takeoff and landing—is being conducted by AFSC's Space Systems Div. (SSD) at El Segundo, Calif.

ASD has made extensive use of industry studies, coupled with a substantial in-house effort. Work at SSD has been entirely in-house. The divisions are working closely together.

National Aeronautics and Space Administration is aiding the Air Force with a program of applied research and exploratory development related to hypersonic air breathing vehicles (AW Feb. 11, p. 26). The cooperative effort was begun last fall when a team from the Air Force and NASA mapped a two-year program for each to follow to avoid overlapping effort.

Complete system design studies for Aerospaceplane were made independently of each other by General Dynamics/Astronautics, Lockheed Aircraft Corp., Douglas Aircraft Co., Republic Aviation Corp., the Boeing Co., Goodyear Aerospace Corp., and North American Aviation, Inc. Three of this group—General Dynamics, Douglas and NAA—were given $500,000 contracts each by ASD recently for development planning studies for the first generation Aerospaceplane (AW July 1, p. 33).

Defense Dept. requested $19 million for Fiscal 1964 for development of Aerospaceplane components. A total of $17 million was appropriated for Fiscal 1963. Funds for studies and other purposes and development under other programs are not included in these totals.

The first generation Aerospaceplane mission may be to act as a shuttle between the earth and a manned orbital space station, carrying three or four men and supplies (see p. 214). Since it would be required to rendezvous with the station in orbit, it would make use of the knowledge gained from the Gemini program, in which the two-man capsule will rendezvous and dock with an Agena vehicle.

Aerospaceplane's aerodynamic lift will enable it to maneuver during its ascent in the atmosphere and match its orbital plane to that of the vehicle it wants to intercept.

Aerospaceplane is an outgrowth of Study Requirement (SR) 89774, which was written in 1957 and aimed toward eventual development of a recoverable space booster.

Studies, some of which were funded by Air Force, were submitted by 17 companies.

By 1959 Aerospaceplane had evolved as the Recoverable Orbital Launch System from Development Planning Study 89774, a single-stage-to-orbit, horizontal-takeoff vehicle, powered by air-breathing engines in the atmosphere and by rockets outside the atmosphere. Fuel would have been liquid hydrogen and liquid or gaseous oxygen or liquid or gaseous air.

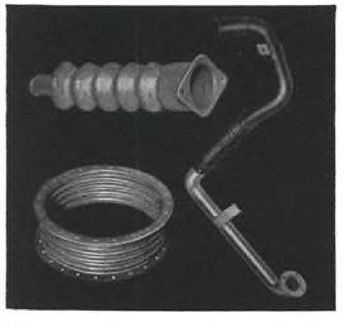
The vehicle would have collected air at near-orbital speeds at the outer fringes of the atmosphere, between 325,000 ft. and 360,000 ft. The air would have been compressed and liquified and then fractionally distilled to produce straight liquid oxygen.

Since it takes 5 to 8 lb. of liquid oxygen to burn with 1 lb. of liquid hydrogen, the idea of takeoff and climb with a minimum of oxygen aboard was attractive. This type of approach was first revealed by AVIATION WEEK & SPACE TECHNOLOGY on Oct. 31, 1960 (p. 26).

Under Study Requirement 651, further studies of vehicle configurations, types of propulsion and aerodynamics

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multiplied the possibilities—and the problems (AW June 19, 1961, p. 54). It soon became clear that the structural fraction, or structure weight divided by the gross weight, of the single-stage-to-orbit approach was too large and probably could not be made small enough until the 1970's.

Shuttle Needed

In the meantime, it became necessary to meet the shuttle operational requirement for an earlier time period. Two stages would have a favorable structural fraction. Thus, because of the time element, that approach became the first generation vehicle and the single stage the second generation.

Until last month the last contracted study had been made in 1961, which was the last time the secretary of defense had approved studies in this area. But companies had continued on their own to refine and adapt their Aerospaceplane concepts. The award of the contracts to General Dynamics, Douglas and NAA on June 21 was the first break in the study moratorium.

The first generation Aerospaceplane program may differ in one major respect from the Dyna-Soar program. Aerospaceplane is now thought of as an operational system rather than just a research project. Thus the first vehicles would be operational prototypes instead of an end in themselves.

Second Stage

The second stage Aerospaceplane could resemble Dyna-Soar superficially in external appearance. But that second stage would have a rocket powerplant and would have to provide for storage of cryogenic fuels, introducing several new sets of problems.

The first stage, which will be powered by air-breathing engines, will make use of technology gained from the USAF-North American B-70 Mach 3 aircraft program. It will be a hypersonic cruise vehicle (AW Feb. 11, p. 26) and will carry the second stage either piggy-back or slung underneath, as the Boeing B-52 carries the North American X-15 research aircraft.

The major effort associated with Aerospaceplane has gone into studies, applied research and development of propulsion systems. A whole family of systems using liquid hydrogen as a base and ranging from air-breathing to pure rockets using liquid oxygen, have been explored.

The breakdown of studies under SR 651 is:

• **651B—Air collection** enrichment subsystems. This includes air compressors, liquid air separators, heat exchangers and tankage. Marquardt Corp. and Linde Air Products Corp. did work in this area. (SR 651A was a study of all the propulsion technologies and was supplanted by the more detailed studies listed here.)

• **651C—Mach 8 ramjet.** This effort is aimed at providing a subsonic air flow ramjet which will go beyond the present Mach 3-4 ramjets to Mach 8, the speed at which the second stage would be launched. Marquardt is doing this work.

• **651D — Liquid air cycle** engine (LACE). Marquardt is following this approach.

• **651E—Supersonic combustion** ramjet (SCRAM). Marquardt, General Electric Co. at Evendale, Ohio, and General Applied Sciences Laboratory at Westbury, N. Y., are doing applied research in this area. SCRAM is in such an early stage that it probably would be applied to the second-generation vehicle.

• **651F—Turbo-accelerator** (advanced turbo-ramjet). No company has been selected for this work.

• **651G—Advanced structures** and materials. Lockheed, North American, Solar, Armour Research Laboratory, General Dynamics/Astronautics and Texas Instruments, Inc., are working in this area.

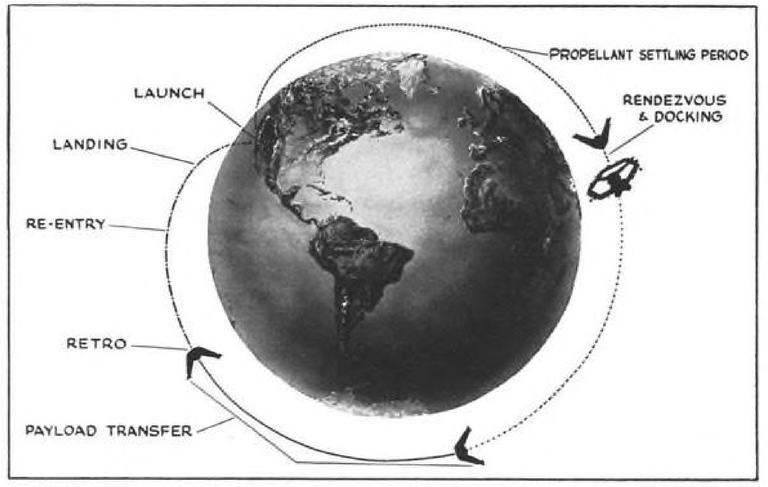
Two other studies have been recommended and are awaiting approval. They are:

• **651H—Hypersonic inflight** refueling subsystems (HIRES).

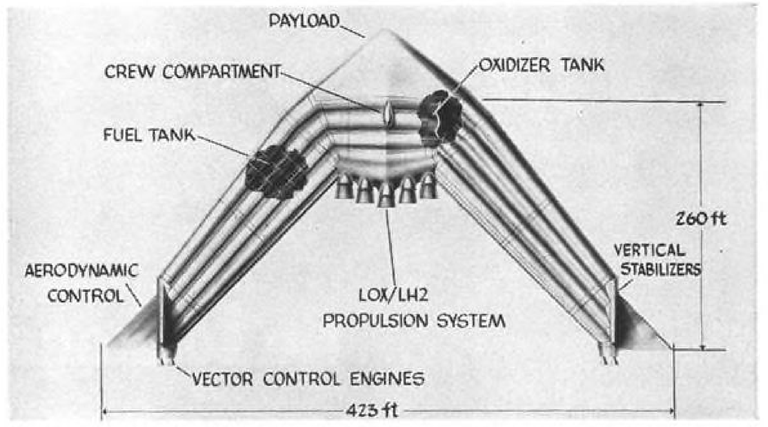
• **651J—Aerospaceplane** aerodynamics.

Most of the approved studies include enough applied research to prove the feasibility of a subsystem.

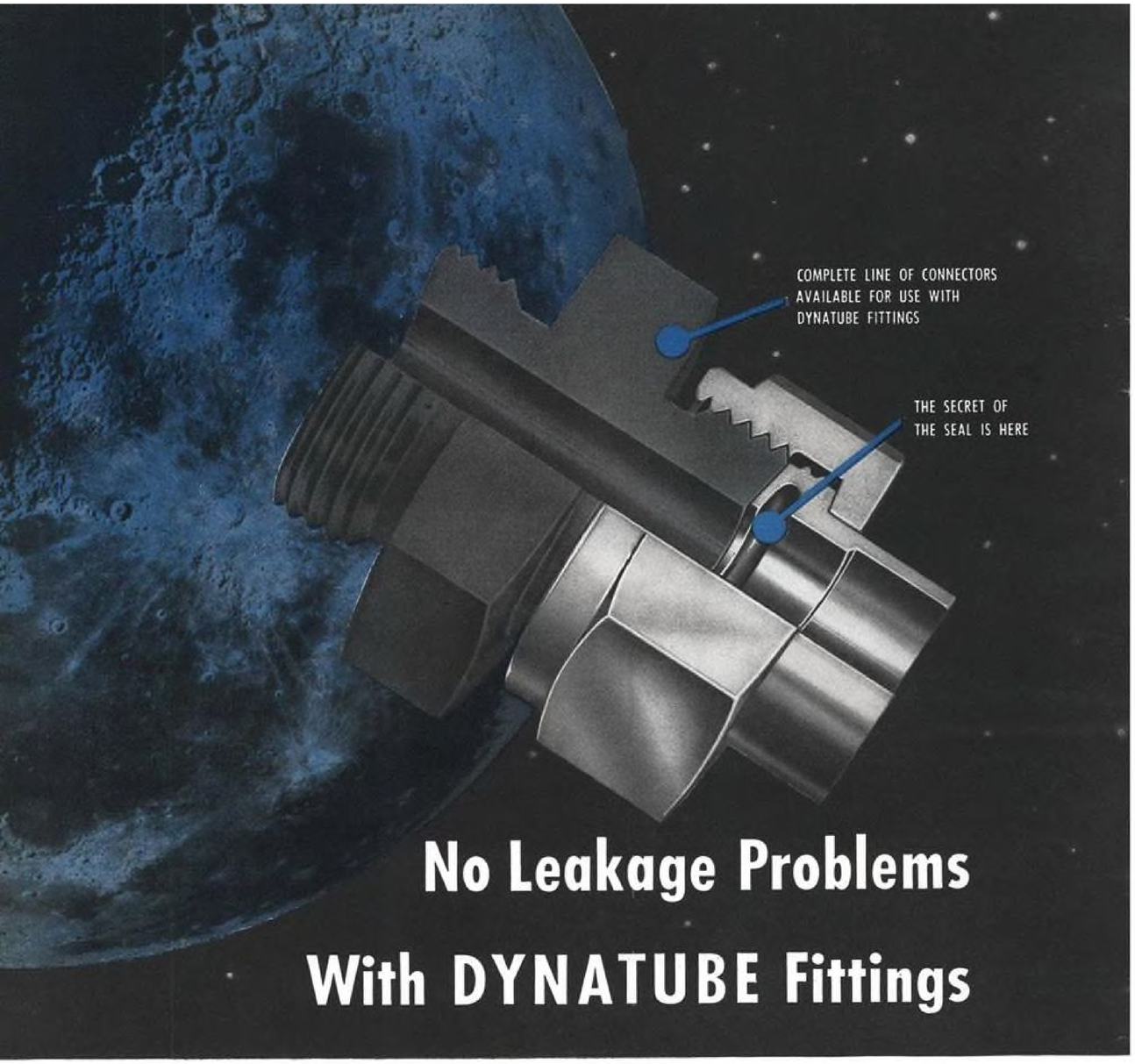
Funding of the SR 651 series breaks down this way, with the first figure being the Fiscal 1963 appropriation and the second the budget request for Fiscal 1964: SR 651B, $2 million and $3



ARTIST'S CONCEPT SHOWS Aerojet-General Corp.'s conjectural Astroplane flying into orbit from the Pacific Missile Range, orbiting, rendezvousing and then docking with a space station. Propulsion would be generated by 10 1.5-million lb. thrust engines.



AEROJET-GENERAL CORP.'S CONCEPT of a recoverable one stage-to-orbit vehicle is similar to USAF's Aerospaceplane concepts. Vehicle's tankage also would serve as an aerodynamic lifting surface. Wing spread would be 423 ft.; weight about 10 million lb.



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million; SR 651C, $3 million and $3 million; SR 651D, $5 million and $5 million; SR 651E, $3 million and $3 million; SR 651F, none and $1 million; SR 651G, $4 million and $4 million.

NASA has requested $5 million for hypersonic aircraft work in Fiscal 1964. This work also will be applicable to civilian earth-to-earth hypersonic transportation and transport to and from space stations.

Most of the NASA work in structures, including engine inlet shapes, and in metallurgy is being done at the Langley Research Center. In the propulsion area, some work on supersonic flow combustion is being done at Ames Research Center. Lewis Research Center is doing some research and testing on high-Mach ramjets, and the Flight Research Center is doing some testing on propulsion systems.

Over-all, NASA is examining the technology and concepts of hypersonic flight in order to determine just what research has to be done. It is also analyzing missions that might be incorporated into military and NASA requirements.

In general, the propulsion studies have covered a wide spectrum in order to see what approach would weigh the least and yet perform both the air-breathing and rocket power tasks. For horizontal takeoff, the turbine engine seems to be the only practical solution for the first stage of the two-stage vehicle. For the single-stage vehicle, a combination rocket-ramjet probably would have to be developed. The present effort for the first-generation Aerospaceplane is concentrating on air-breathing engines for the phase from takeoff to Mach 8.

Structural problems for both stages will require a jump from the technology of the Mach 4 to 5 speed region to that of Mach 8. Basic structures will probably make use of stainless steel, titanium, Inconel and other alloys. But the refractory shields on structure leading edges, which will have to withstand the heating of Mach 8 climbout and re-entry speeds from Mach 20 plus down to Mach 8 for short periods on repeated missions, will have to be made of molybdenum or columbium.

A great deal of research and development will have to go into combining these metals with the basic structure so that they will be able to withstand 1,500F to over 2,000F heating and transmit the heat to heat sinks or whatever other system is devised to absorb the heat for a period of minutes.

Three major problems face the structure design engineers. One is concerned with inlet shape. An aircraft traveling at speeds from Mach 5 to Mach 8 at extremely high altitudes will have to have relatively large inlets, or air scoops, to gather enough air for combustion. The second problem is how to mate these large inlets with the body and still achieve minimum drag and high lift. Designs will have to be translated into models and tested.

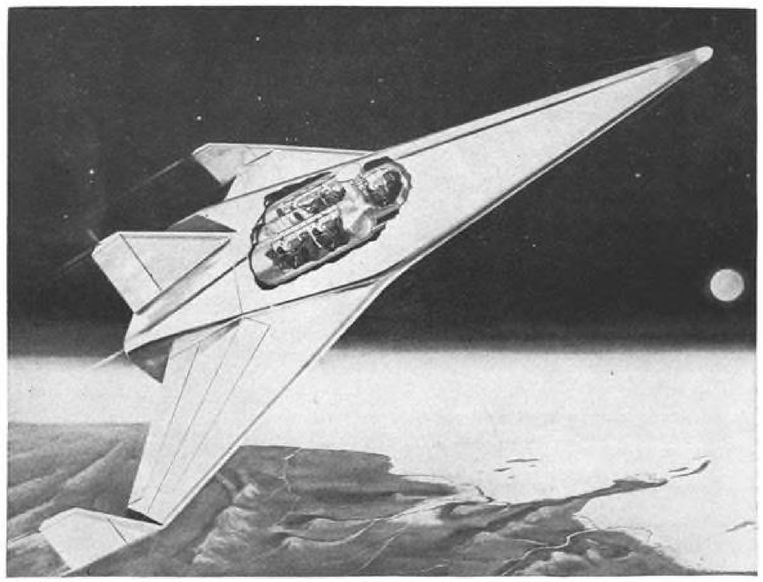
Heat differentials between the internal cryogenic storage areas and the hot exterior present the third problem. Liquid hydrogen has a temperature of —420F. The heat differences could be more than 2,420F between inside and outside.

Although the X-20 hasn't flown yet, much of what has been learned about structures from that program has provided helpful information for the aerospace plane program. The use of molybdenum as a refractory coating and for the fabrication of honeycomb is an example.

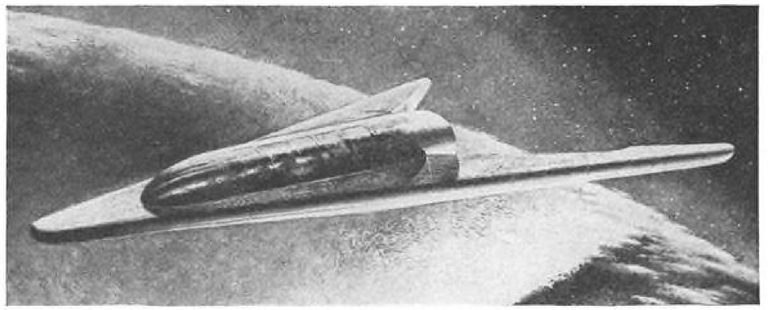
Whether the second stage of the two-stage vehicle is winged or has a lifting body, the shape of the vehicle will have to be different from the X-20. The X-20 has blunt trailing edges for the fuselage and wings. Since it carries no fuel, its aerodynamic center of gravity will remain the same throughout a flight.

But a vehicle carrying fuel has to have that fuel evenly distributed through the volume of its interior so the center of gravity will not shift as fuel is used. The X-20 shape with fuel added would be unsatisfactory. The second stage of Aerospaceplane will have its volume evenly distributed.

The strongest argument offered by Defense Dept. and Air Force officials for pursuing the Aerospaceplane concept is the potential for flexibility of operation and economy not offered by other systems. For instance, a capsule in orbit would have to expend its own weight in fuel to change its orbital plane 30 deg. The Aerospaceplane would re-enter the atmosphere in the upper reaches, make the turn using aerodynamic lift, and ascend again to the new orbit.

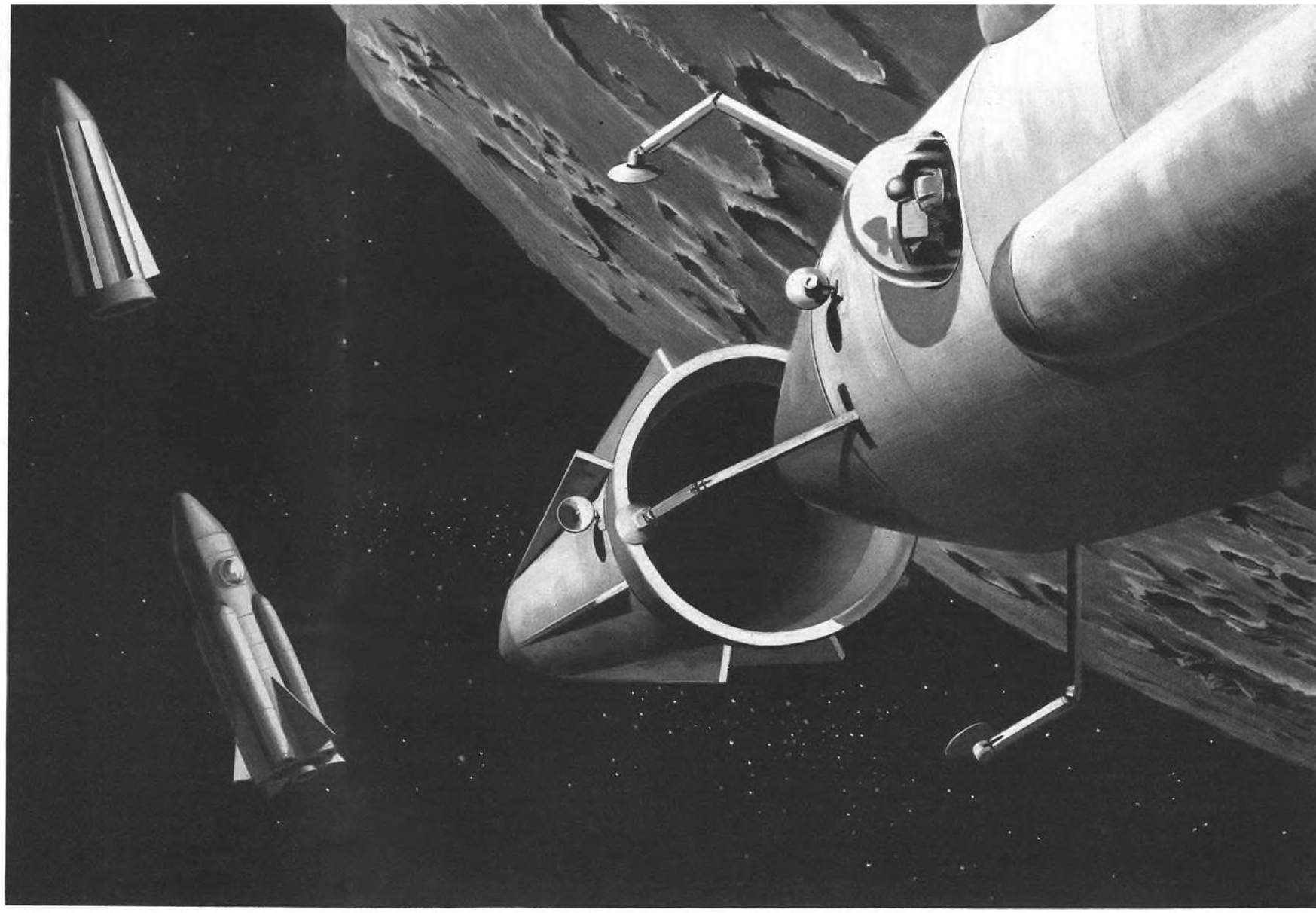


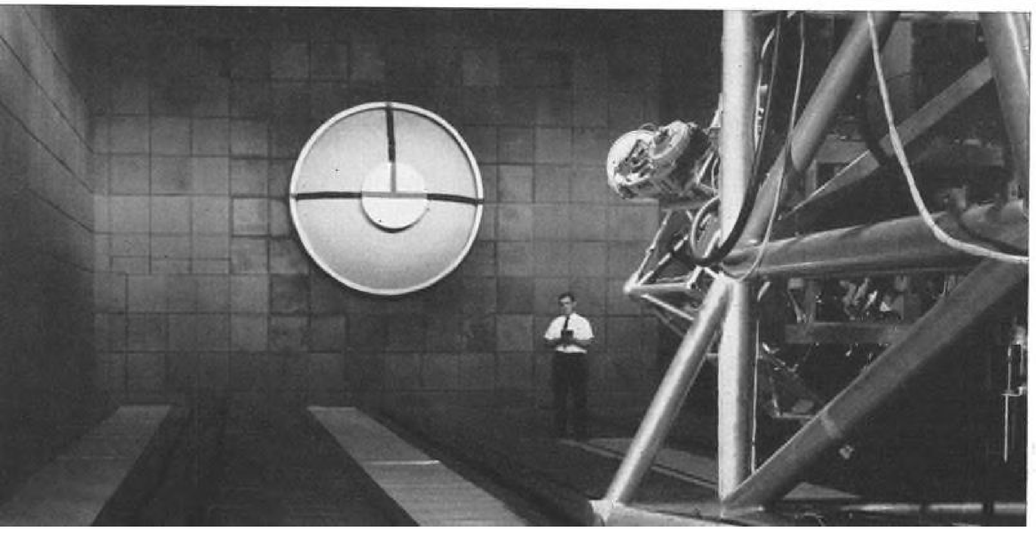
AEROSPACEPLANE envisaged by General Dynamics/Astronautics would contain passenger section as well as cockpit and would be the third stage of a three-stage vehicle.



FOLDING-WING Aerospaceplane proposed by Lockheed would use lightweight superalloys, such as thin gage Rene 41 nickel-base alloy.







Top illustrations (left to right): Landing, Rendezvous, Docking.

Left: Raytheon's Prototype Rendezvous Radar installed in the Martin Marietta Company's Closure Test and Training Facility.

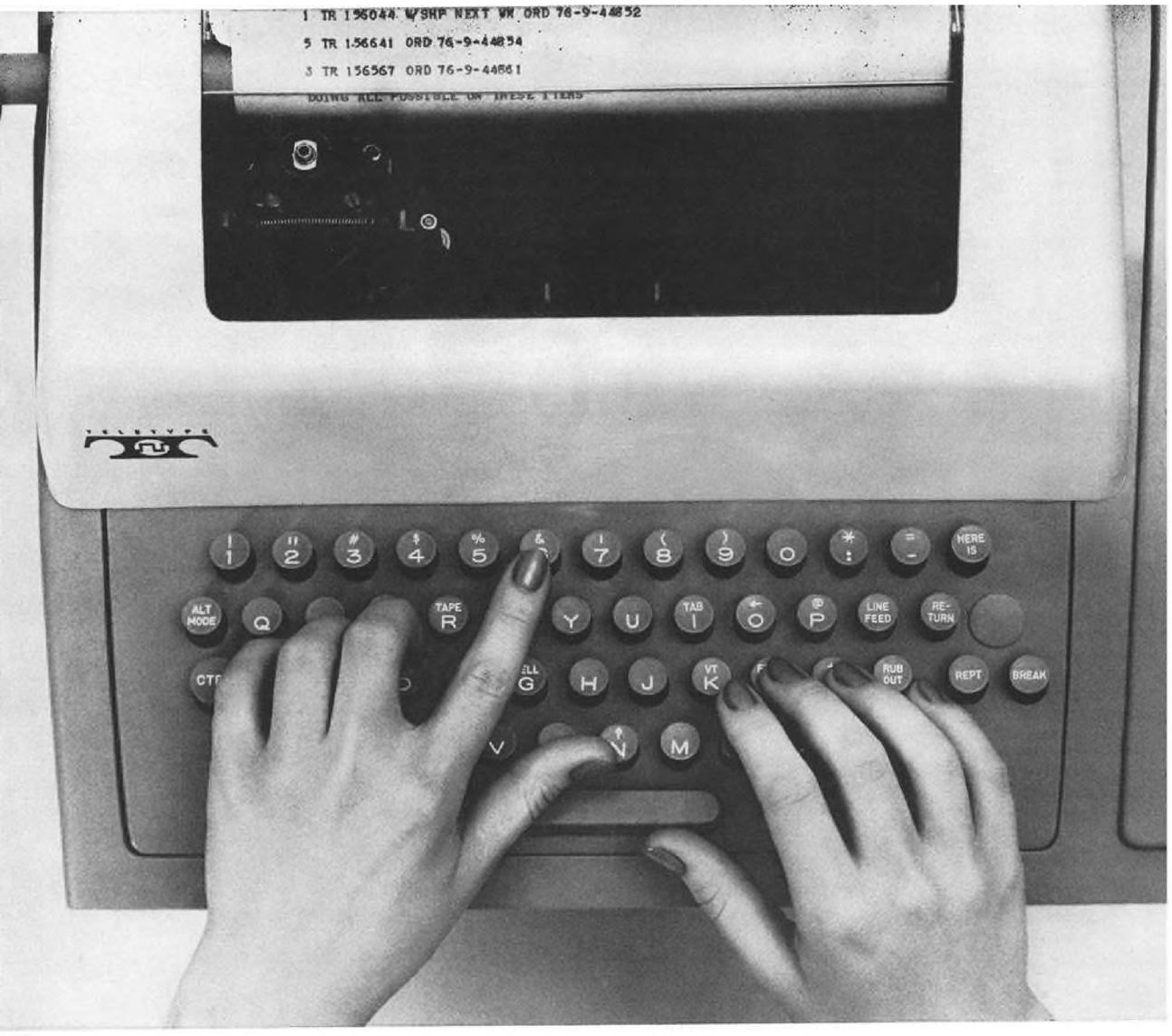
RAYTHEON . . . a leader in radar for space vehicles

Raytheon — leading designer and manufacturer for ground-based, aircraft, and missile systems — has developed and is testing prototype space radars for RENDEZVOUS . . . DOCKING . . . LANDING.

Currently being explored under Raytheon's in-house space radar program are several interesting configurations. One of these, the Raytheon Rendezvous Radar, has been installed in the Martin Marietta Company's Closure Test and Training Facility at Denver, Colorado. It is applicable to such systems as Apollo, Lunar Logistics System, Mars Excursion or Command Module, Satellite Inspectors, and Manned Space Stations. Variations of the system are now being tested for particular missions.

For additional information — or a discussion of how the same Raytheon integrated system capability can be applied to your requirements — contact Neil A. Montone, Director, Marketing, *Space and Information Systems Division, Raytheon Company, Bedford, Massachusetts.*

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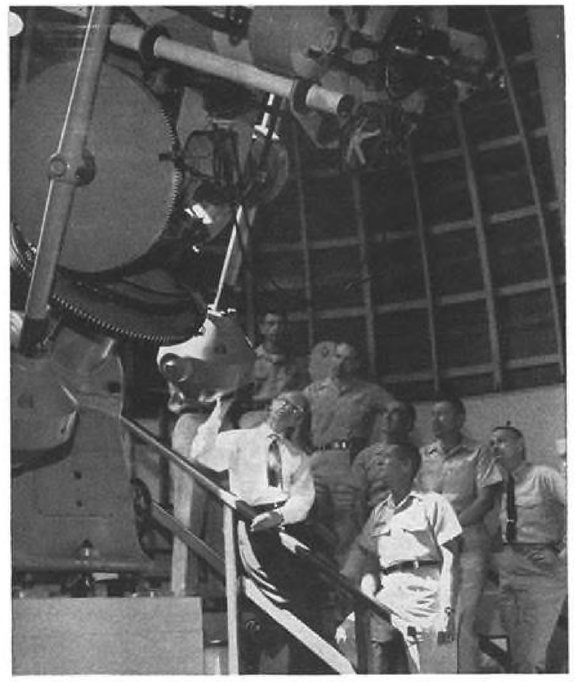
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AEROSPACE PILOT training includes simulated flight in Navy's Johnsville centrifuge, left, and field trip to Griffith Observatory.

USAF School Trains Future Space Pilots

Edwards AFB—Air Force is selecting the most highly qualified younger pilots for training in the Aerospace Research Pilot School here with a conviction that a key Air Force role in manned space flight is only a matter of time.

The graduates—approximately 36 per year—will have met the majority of astronaut requirements. But more important, they will provide a broad base of pilot-engineers who are well versed in the technology of space and can be used for future planning, supervising and testing.

The newly revised curriculum (AW Apr. 8, p. 65) is a combination of two six-month courses—the experimental test pilot course and an aerospace research pilot course. They were reduced from eight and seven months, respectively, to form the one-year training period.

USAF considers the new course a natural broadening of the experimental test pilot school to meet space-age requirements. The test pilot school, since its move to Edwards from Wright-Patterson AFB, Ohio in 1951, had provided well qualified pilots as long as airplanes were the only consideration.

Space Missions

But when man-in-space missions such as Dyna-Soar became a requirement, it became necessary to give test pilots a working knowledge of orbital mechanics, energy management, boost and re-entry techniques and radiation hazards.

Since USAF test pilots spend between 40 and 60% of their time in non-flying jobs such as working with contractors on mockups and design details, it was necessary to begin educating them in the mechanics of space flight to insure competent contract supervision of space-related hardware programs.

Pilots assigned to the USAF-Boeing Dyna-Soar program, with the exception of a single aerospace course graduate, initially had little first-hand knowledge of space-related technology, for example.

Related objectives of the school are to provide a pool of potential astronauts for future Air Force space missions and to give Air Force strong representation in such potential National Aeronautics and Space Administration programs as space stations, lunar bases and Mars missions.

At the moment, the only approved Air Force program that is certain to require space pilots is Dyna-Soar. USAF also hopes to make some flights in the Gemini program and is seeking Defense Dept. approval for a military orbital development station (see p. 214).

But solely on the basis of the present situation, only an estimated 10% of the school's graduates could expect to become actual space pilots. The remainder would be assigned to positions in space development or flight test programs which best utilized their special training.

The aerospace course was started at Edwards in 1961 and was then independent of the experimental test pilot course. Graduation of the first five students on Dec. 5, 1961 represented a tribute to the efforts of the four founders of the course—Majors Thomas U. McElmurry, Robert S. Buchanan, Frank Borman and Arthur Torosian. All were graduates of the test pilot school and Buchanan, who has a Ph.D. in astronautics, now directs the aerospace portion of the curriculum.

Program Opposition

The four pilots' goal of preparing pilots for the Air Force role in space originally received support only at the congressional and Air Force headquarters level. Opposition lower in the chain of command indicated a concern for economy and lack of comprehension of potential usefulness of the graduates.

Support for the aerospace course increased rapidly, however, with increas-

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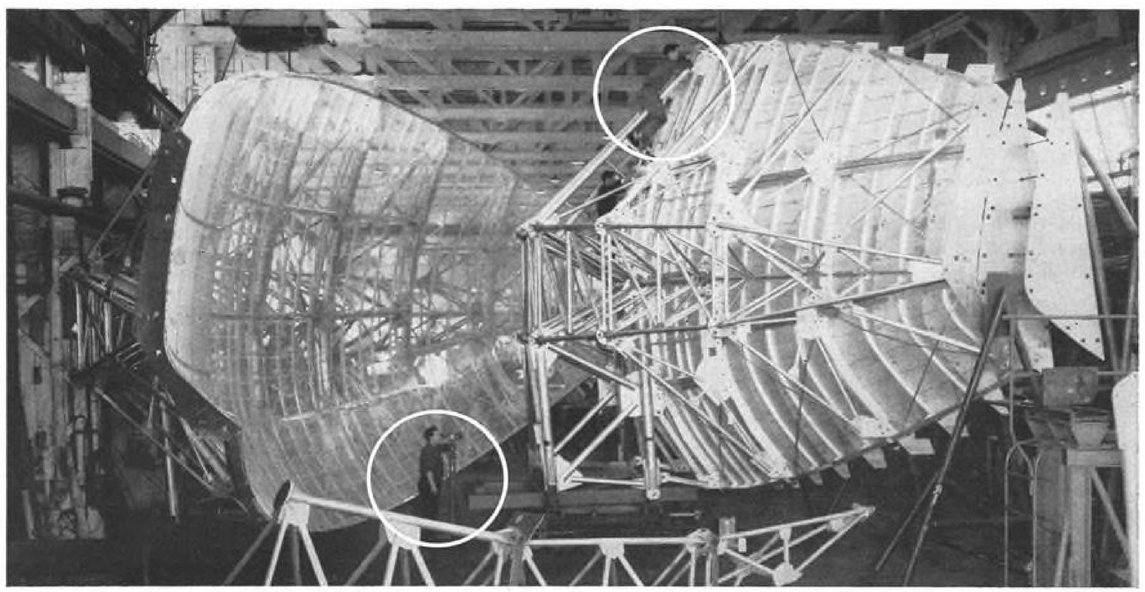
TO TOUGH CONTRACT METALWORKING PROBLEMS



Problem: To machine Minuteman first stage forward domes inside and out to a thickness tolerance of ± .025".
Solution by Bliss: Special jigs that firmly support the entire thin-walled, high-alloy forging at all points of its surface during machining operations.



Problem: To develop and produce "swiveling" thrust vector control nozzles for Minuteman, Dyna-Soar, other rockets.
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Solution by Bliss: Precision prefabrication of subsections followed by final assembly by manual welding under constant checking by optical instrument.

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mgly friendly congressional backing. This was due in part to the reasonableness of requests for money for appropriate training devices.

Three rocket-boosted Lockheed NF-104As and a $3.5-million space simulator have now been approved and five other less sophisticated simulators were built locally and inexpensively with a minimum of outside contracting. Expensive cutways and other elaborate training devices are not being used.

Present Aerospace Pilot School Commandant is Col. Charles E. (Chuck) Yeager who was the first man to fly faster than Mach 1 in the Bell X-1 on Oct. 14, 1947. Col. Yeager's background in experimental aircraft research and his prestige both in Congress and in the Air Force have been key assets in his efforts to establish the aerospace research pilot education program as a vital and respected Air Force function.

Navy Quota

A quota from each aerospace class has been allocated to the Navy. Neither Navy candidates nor Air Force students will have had test pilot experience before they attend the school.

Military Assistance Program (MAP) countries and other friendly nations will continue to utilize the first half of the course, as they have in the past, receiving training as experimental test pilots. The first combined class which started July 1, includes five foreign students—one each from Norway, the Netherlands and Italy and two from Canada.

The inclusion of foreign and non-Air Force students from the U. S. results in an average beginning class of 18 students.

This number dwindles to about 12 who are eligible to continue with the six-month aerospace course. The school, therefore, will turn out about 18 experimental test pilots a year.

Pilots of other government agencies and industry are allowed to attend the experimental test pilot course, but only military candidates are considered for the year-long course. Federal Aviation Agency has sent a number of personnel through the test pilot course and NASA now has one pilot attending.

Contractor Use

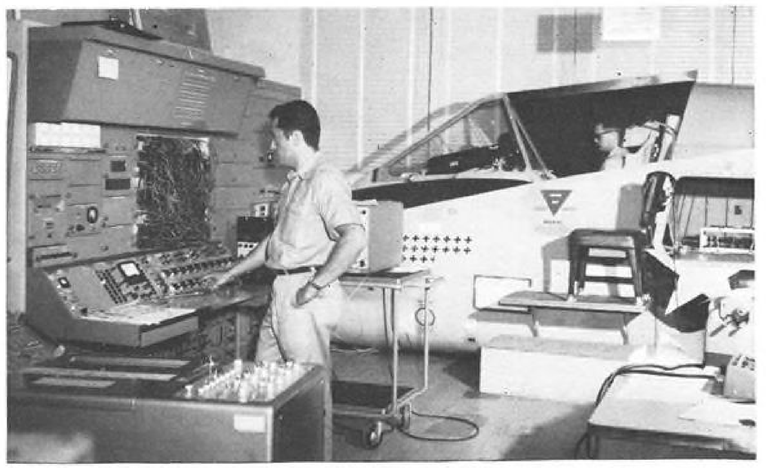
Air Force contractors have sent a number of pilots to the experimental test pilot school in the past and still are eligible for the six-month test pilot course. One Lockheed pilot is now enrolled.

USAF is reimbursed for expenses of non-Air Force students.

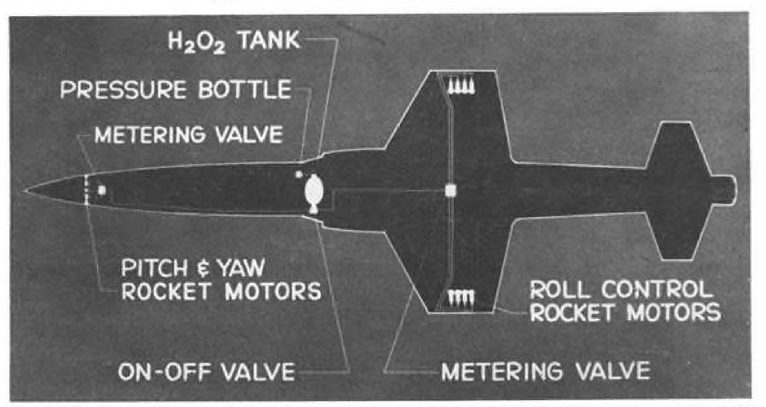
Army pilots, whose flying has not yet involved jet aircraft, theoretically could qualify for the year-long course under recently relaxed regulations allowing experienced helicopter pilots to qualify for admission. It is likely, however,



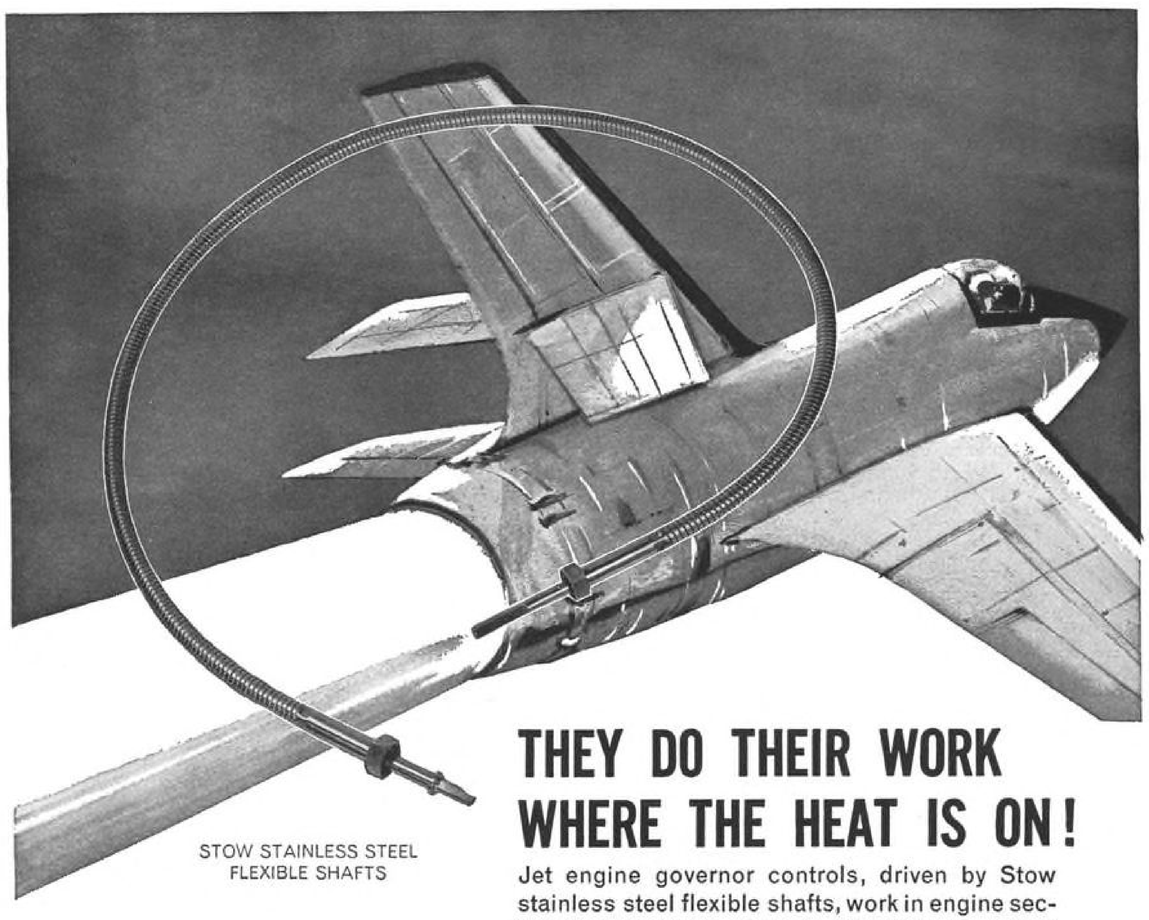
LOCKHEED F-104, instrumented for variable stability, is one of 33 aircraft—28 of them jets—used for training at Aerospace Research Pilot's School.



SALVAGED COCKPIT from Convair F-106 that crashed is used with analog computer to serve as a flight simulator for aerospace students. Iron crosses on fuselage represent kills made in World War 2 by pilot who flew F-106 before its crash.



LAYOUT of reaction control system used in variable stability F-104 which serves as an aerospace trainer. School also is to get three rocket powered NF-104s.



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that any future schooling of Army pilots will be limited to special classes, attending only the test pilot course. An all-Army experimental test pilot class of seven was graduated in 1960.

Flight experience requirements for the aerospace course, now fairly lenient compared with those first established are:

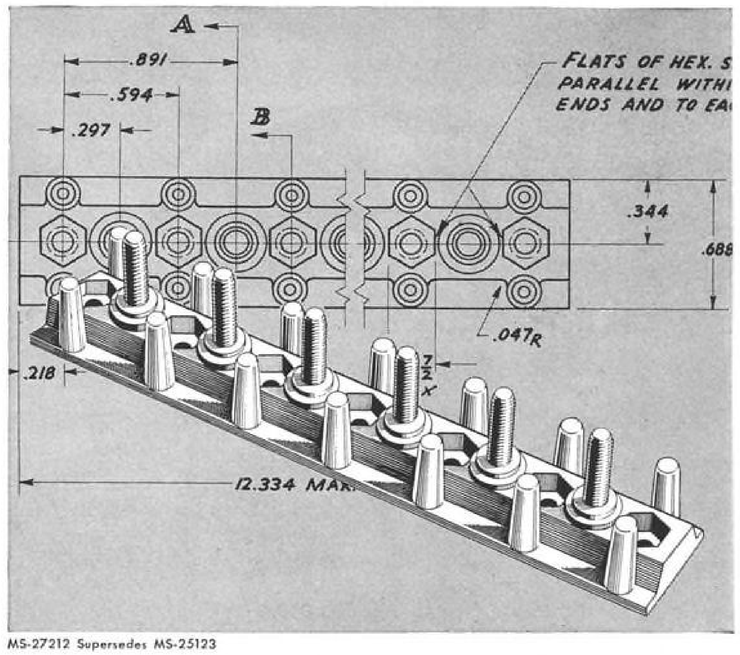
- **Candidates must have** a degree or equivalent in engineering, physical science or mathematics. College grades are most important. Generally, a B-average in math and science is considered the minimum. Mathematics through calculus is mandatory.
- **Pilots must be** on flight status and have extensive experience in front-line aircraft. This is defined to include: turbojet or jet transport and jet bomber (500 hr. first pilot time), helicopters (500 hr. in several types with some jet time also preferred), and Century-series jet fighters (500 hr.) Flight time requirements are somewhat flexible and small discrepancies can be waived. The school prefers to have at least one helicopter and one transport pilot in each class.
- **Candidates must not** have reached their 33rd birthdays at the time of application. Where two men have equal qualifications, preference will be given to the younger man.
- **Candidates must be** recommended by their commanding officers. This provides valuable information on motivation and capabilities of the applicants. Proper motivation is given great consideration by the screening board.
- **Pilots must pass** a five-day medical



FULL pressure suit used in F-104 zoom flights, in which plane is depressurized before engine shutdown at 77,000 ft.

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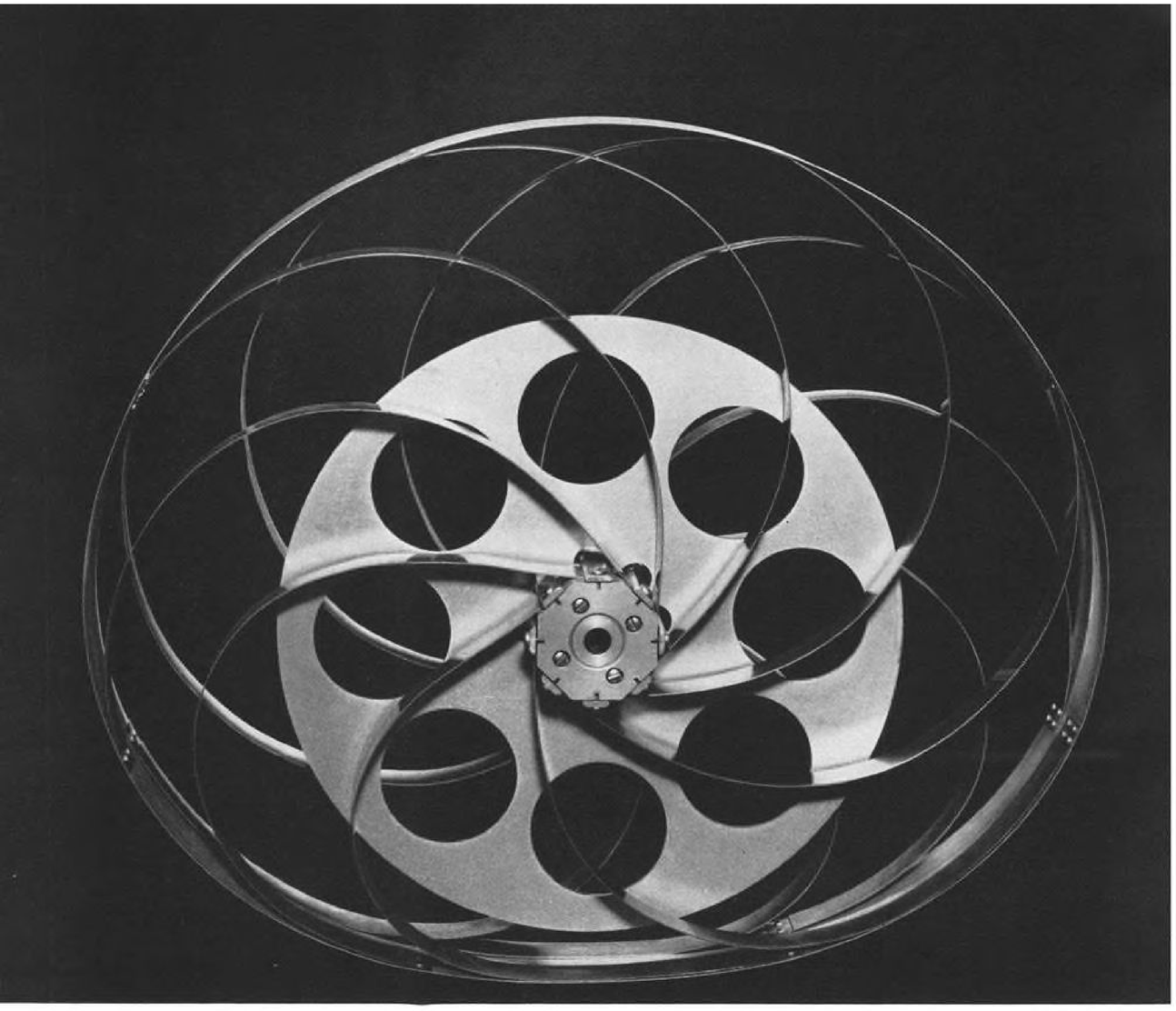
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and psycho-physiological examination equivalent to that given to NASA's astronauts.

Admission to the aerospace course formerly required that candidates have 2,000 hr. of flight time and be graduates of the Air Force Experimental Test Pilot School, Navy Test Pilot School or Empire Test Pilot Course. These requirements resulted in so few eligible candidates that some flight time requirements were waived last fall.

Flight time requirements also were reduced in an attempt to lower the average age of graduates. By the time an Air Force pilot with a college degree had built up 1,500 hr., which qualified him for the test pilot school, and had gained appreciable experience in testing —enough to total 2,000 hr., including jet time—he was in his middle 30s. By this time he had reached or passed minimum astronaut age requirements.

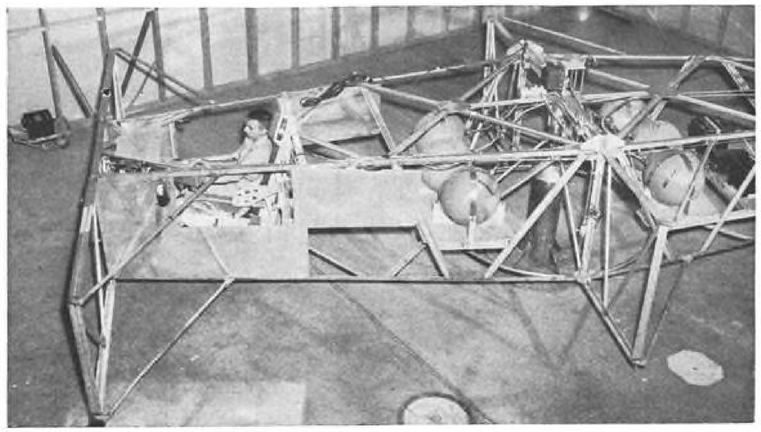
The revised requirements, therefore, were aimed at a younger group of academically-qualified candidates, with less emphasis on flight experience. It is planned to assign graduates to test pilot work. In this way, they will be able to meet current astronaut requirements within a few years and still be well within the maximum age limit.

Average age of the current class is between 29 and 30, and a future average age of 28 is hoped for. One approach to reducing the average age of applicants has been to talk to Reserve Officer Training Corps and Air Force Academy students before they graduate. School staff members maintain contact through correspondence with a large number of students from college on through squadron tours until the pilots can meet minimum entrance requirements.

The experimental test pilot course, as in past years, educates students in the intricacies of flight testing. It is taught by a seven-man staff on a junior-senior-year college level. With the reduction in course length from eight to six months, flight time has been cut from slightly more than 140 hr. to about 120 hr. and academic instruction has been cut from 265 hr. to between 230 and 240 hr. Maj. George D. Hendrix heads the experimental test pilot course.

The aerospace school, the only one in the U.S. which offers pilots formal training in space research, is characterized by tough academic instruction and extensive work in space simulators. Competition in the Air Force for a chance to attend the course is keen. In the past, between 300 and 400 applications were received for the average class. Applications are carefully screened by a board at the school and forwarded to USAF headquarters for a final selection.

All instructors have advanced degrees (M. S. or Ph. D.) and all are pilots. Course material is prepared by the instructors, and courses are taught on a senior or post-graduate college level. By the end of this year, 39 students will have completed the seven-month aerospace course when the 16-man class, which began May 13, graduates. Next graduation will be late next June when the class that started earlier this month, completes its full year of instruction.



BALLISTIC CONTROL simulator at Edwards AFB is driven by reaction jets powered by high pressure nitrogen in spheres at right. Unit is floated on air-bearing.

The aerospace research pilot curriculum consists of the following:

• **Academic instruction.** Engineering fundamentals and mathematics are reviewed prior to instruction in eight basic academic courses. For example, differential equations are reviewed in four hours. Academic courses are aerodynamic theory, flight mechanics, guidance and control, propulsion, instrumentation and communications, celestial navigation and astronomy, aeronomy and bioastronautics (at Brooks AFB, Tex.). About 200 hr. of classroom work is offered, which is the rough equivalent of about two-thirds of the studies required for a masters degree.

• **Flight training.** This is conducted in Lockheed F-104s, Convair F-106s and a McDonnell F-101. F-106s and the F-101 are specially modified to simulate variable stability and variable lift-drag ratio, providing valuable laboratory training to back up academic theory. The school has six Lockheed T-33s, five North American T-38s, three Martin B-57s, 15 F-104s, three F-106s and one F-101.

Prior to the arrival next month of the rocket-boosted F-104s capable of zooming to 120,000 ft., standard F-104s are used for energy-management maneuvers to altitudes of about 90,000 ft. Since the aircraft is depressurized prior to engine shut down at about 77,000 ft., pilots learn to control their aircraft in fully-inflated pressure suits. Pilots fly a total of about 86 hr. during this phase.

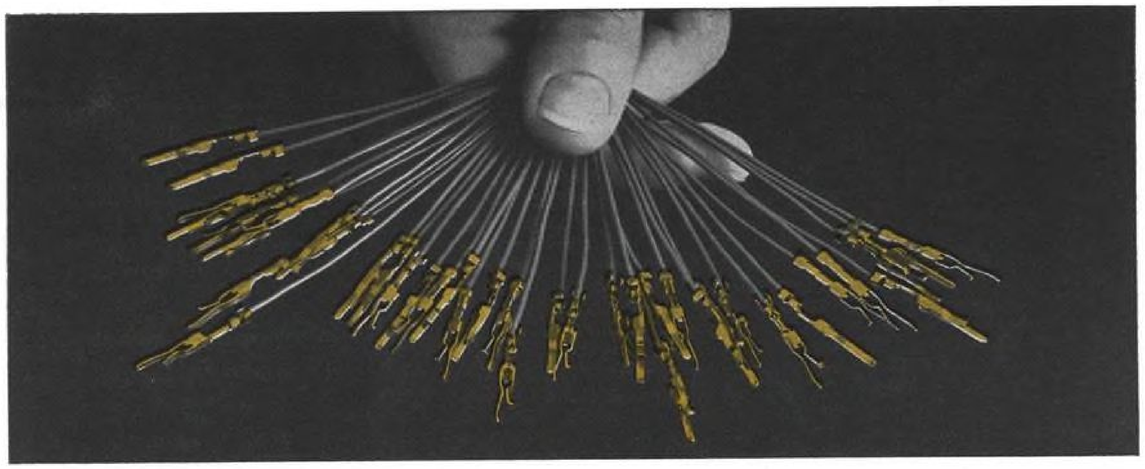
• **Simulator training.** Simulators are used to duplicate space-vehicle characteristics and missions which cannot be done with aircraft. In the school's three simulators (reaction control, static aerodynamic and static space), the Navy's Johnsville, Pa., centrifuge and a selected industry space simulator, students receive about 55 hr. of simulator time.

A wide range of general space missions is flown with various stability, control and aerodynamic characteristics during boost, ascent, orbital rendezvous and re-entry. A $3.5-million full space mission simulator will be built by Link Div., General Precision, Inc., in a new addition near the classroom building by next July. A complete space mission may be run in the simulator including: lift-off, orbital injection, rendezvous, de-orbit and re-entry.

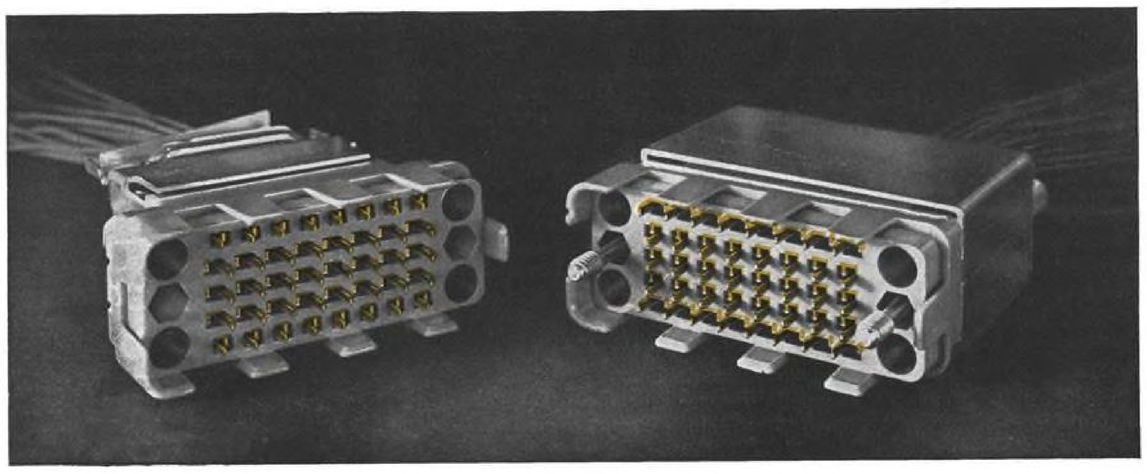
• **Field trips.** One week is devoted to field trips to facilities engaged in development and testing of space vehicles and related systems and components. Total time spent away from Edwards for outside training including the field trip is seven weeks. This includes three weeks at Brooks AFB (bioastronautics), two weeks at the Johnsville centrifuge and one week at an industry space simulator. (Martin-Baltimore and Chance Vought simulators have been used in the past).

Simulation devices at the aerospace school are not programed for specific missions such as Gemini or Dyna-Soar. Rather, they aim to provide a background in typical space missions.

Higher performance aircraft than the NF-104s also are being considered. The school would like to have as many as six planes capable of Mach 3.2 to 3.3 acceleration and altitudes up to 285,000 ft. Many proposals for modifying existing aircraft have been suggested by industry, but any decision to go ahead may be delayed until the NF-104s, scheduled for delivery next month, are evaluated.



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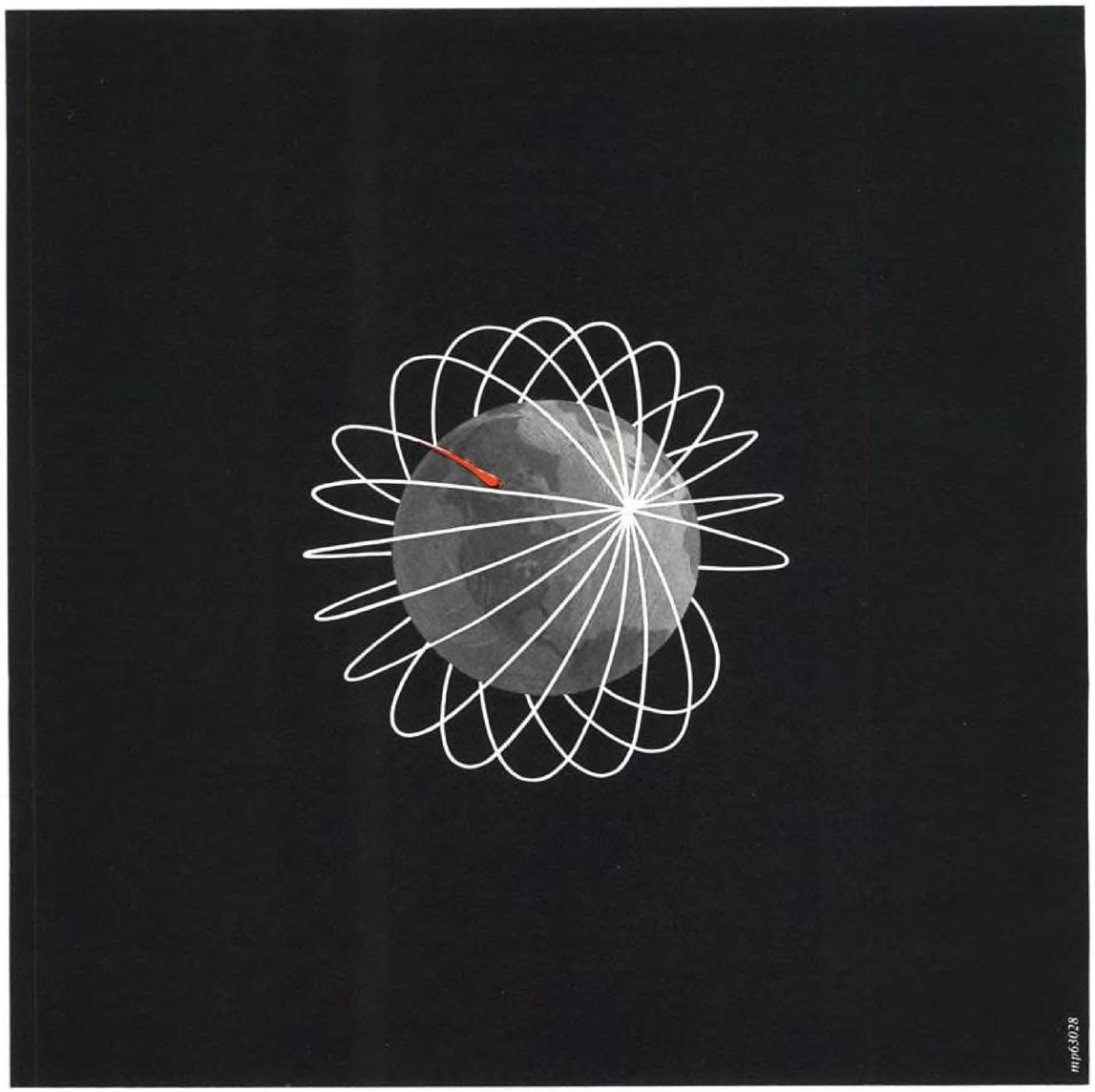
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Support



Member of NASA's second group of astronauts floats free in zero-gravity trajectory in USAF-Boeing KC-135. Astronaut is wearing extra-vehicular life support pack.



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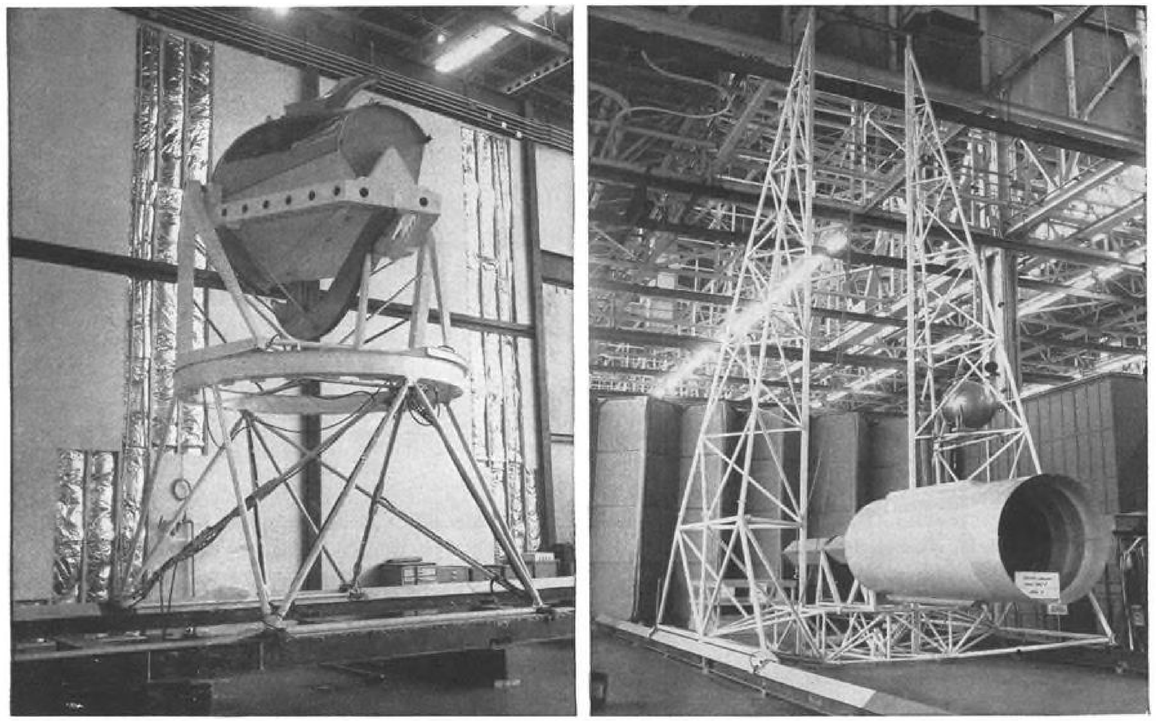
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GEMINI SIMULATOR at McDonnell plant will be used to simulate last 100 ft. of flight and docking with Lockheed Agena stage. Left, crew station on gimbal and translation structure. Right, Agena on target structure. Docking adapter has not been added.

Astronauts Trained to Be More Than Pilots

Houston, Tex.—Astronaut training in the U. S. is oriented towards broadening the pilot's usefulness in the manned space flight program beyond his primary role of flying the spacecraft. Just as Project Mercury proved an invaluable tool in providing baseline engineering data for future spacecraft and systems, the Mercury astronauts developed the human factors pattern which will help determine how useful man can be in space.

In Mercury, the trained man proved he not only can survive the weightless environment, but also can function as a systems operator and as a scientific observer and experimenter.

Because his training brings him intimately to all phases of the program, the astronaut is able to apply his special knowledge and skills as a test pilot to provide much useful engineering input in spacecraft, systems and operations development.

Mercury proved that the astronaut selection and training programs met the mission requirements and basically were sound. In proving new spacecraft, astronauts are selected on the basis of having demonstrated "bonus skills" as test pilots, so that they are able to contribute to the program in the same manner as they would in an experimental aircraft program.

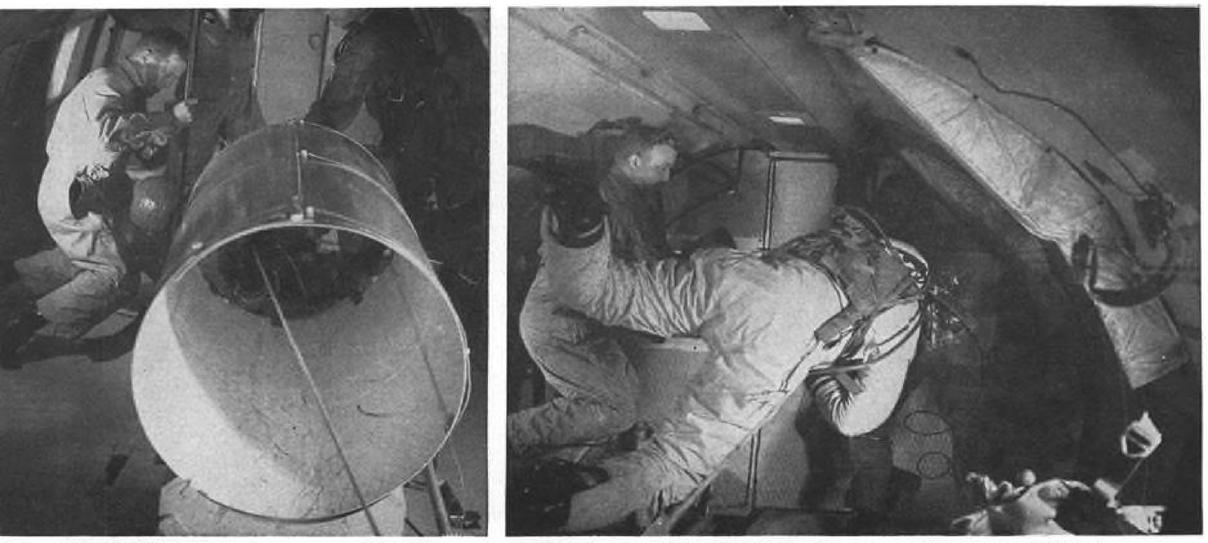
For operational spacecraft, engineering and test pilot requirements will be relaxed, since bonus skills such as scientific training may be desirable. In the selection of the third group of astronauts, expected to join the present astronaut pilot pool at the Manned Spacecraft Center here in October, certification as a test pilot, although still preferred, is no longer considered mandatory by National Aeronautics and Space Administration.

Thus, follow-on crew selection for Gemini and Apollo programs, at least, will be a process of refinement rather than introducing major deviations from basic requirements, according to Dr. Robert B. Voas, assistant for human factors at NASA's Manned Spacecraft Center.

Astronaut selection continues to be based on the fact that the small crews planned for missions programed prohibit carrying anyone as a passenger in the sense that a scientist would be on board only to carry out experiments. Carrying a non-pilot member in the Apollo lunar mission would mean that the two astronaut flight crew members would operate on 12-hr. shifts over the five days that such a flight requires. In the case of the lunar excursion module, having a non-flying scientist aboard would provide room for only one pilot, who would be severely taxed in the event of an emergency, such as an abort prior to landing on the lunar surface.

Initially, scientific work will be carried out by the astronaut-pilots, who are being given training, including weekly seminars of science lectures by authorities in the fields, designed to mesh engineering thinking into scientific channels. Studies will educate the astronauts to perform scientific tasks properly and to communicate effectively with scientists.

An example of the new courses being covered is selenology, or the geology of the moon. Since astronauts will be the first men to land on the lunar surface, they are being taught to study the surface with a geologist's viewpoint. "You just don't want to reach out and grab any rock on the moon's surface," Dr. Voas points out. "The specialist would



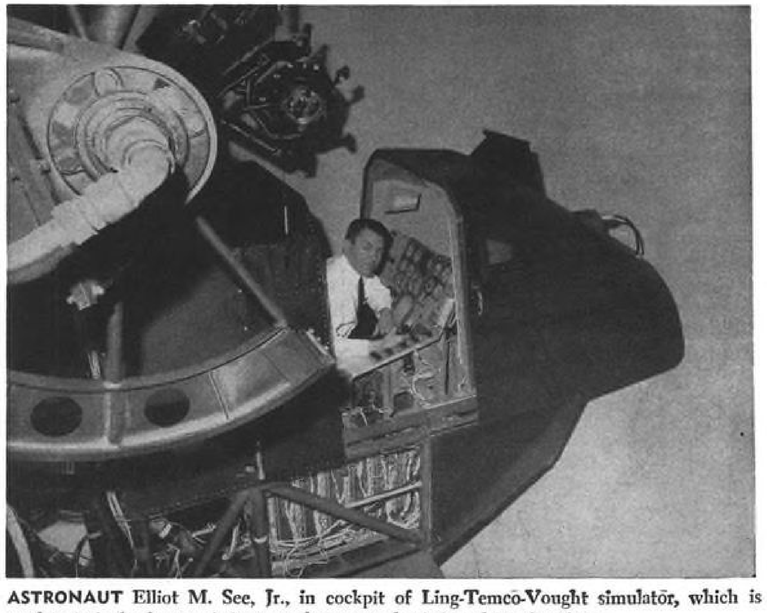
AIR FORCE research on maneuverability in space is conducted on weightless trajectories flown on modified Boeing KC-135.

want particular samples and a record of the circumstances, such as exact location, so he could develop meaningful data."

The course in selenology includes field trips to a meteor crater near Flagstaff, Ariz., for study and sample-gathering. Study of the moon through an observatory telescope and discussions with astronomers round out training.

Current feeling within MSC is that scientifically-oriented pilot candidates probably will be brought into the Apollo program within the next two years. They probably will be chosen from young men who have a scientific degree and have contributed noteworthy papers to earn the recommendation of senior scientists. Indications are that when scientists are chosen to accompany future missions, they will have to meet physical criteria very near those for the flight crew and they probably will have to have some flight experience. Just how far the flight experience criteria will be relaxed to accommodate them is still under consideration.

The space scientist like the space pilot will be trained to live and work in the new environment, learning to operate much of his equipment in restrained quarters, while wearing a pressure suit.



ASTRONAUT Elliot M. See, Jr., in cockpit of Ling-Temco-Vought simulator, which is used to train for lunar missions, rendezvous and mission abort situations.

To develop skills in working in a weightless condition, the scientist may practice experiments while under water.

Technicians here also point out that much equipment that would be used by scientists in space has yet to be developed in reliable, compact configurations suitable for use in the limited space aboard a space vehicle. Under zero-g, for example, liquids follow peculiar paths. Equipment that doesn't require sealing on earth has been found to leak lubricants in space and can be contaminated by floating debris without lubrication.

The increased mission scope and vehicle complexity of Projects Gemini and Apollo impose requirements for a far broader training curriculum and more sophisticated training equipment than were required for schooling Mercury astronauts in the Mercury mission. The on-board systems of these spacecraft are far more complex than those used on Mercury and there will be much greater pilot participation in operation of these systems than on Mercury.

Additional tasks that Gemini and Apollo crews must train for include: navigation, correction of flight trajectories, controlled landings on the earth and lunar surfaces, checkout and launch in earth orbit and in orbit around the moon and on the moon, and rendezvous in earth and lunar orbit. In addition, the pilots will become indoctrinated in the more complex ground preparations, launch, tracking and recovery operations involved in these more ambitious programs.

Project Mercury training, which developed the over-all learning curve for future programs, pointed up a need for closer grouping of training facilities. These lessons are being applied by concentrating training equipment here, where the pilots live, and at Cape Canaveral, from which they launch. Like Mercury, the pacing item in training is availability of equipment. There is an added delay because delivery of some training devices will await completion of permanent facilities at Clear Lake, 20 mi. south of Houston.

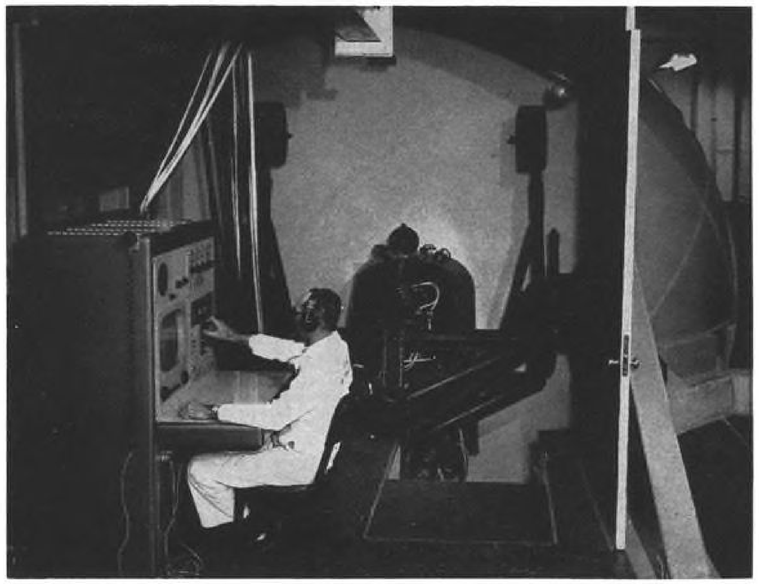
Early in the Mercury training program, when there were no ground rules as to what was required, the philosophy was to utilize any training device or method that had even remote value. It was also the rule to make the training as difficult as possible, to "overstress" the activity even though study indicated that the task was relatively easy.

Lessons learned as a result of this training philosophy and in actual flight experience have indicated that some training was of little value and could be eliminated and some overstress features could be eased.

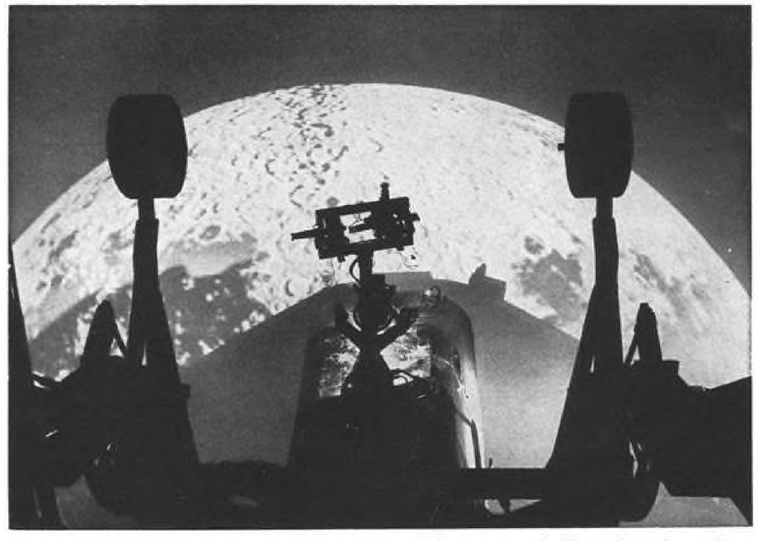
Examples of equipment the astronauts have decided can be eliminated are the Air Lubricated Free Attitude Trainer (ALFA), used for orbital and retrofire attitude control training and earth reference for navigation training, and the Multi-Axis Spin Test Inertia Facility (MASTIF) which could be rotated up to 30 rpm. in all three axes with the astronaut damping out these rates to bring the device to a stationary position. Much of this training can be accomplished in a fixed base simulator —in fact, procedures trainers being developed for Gemini and Apollo are fixed base because it is felt that the closest sensation to zero-g actually is lack of motion. Consideration is being given towards a moving simulator to study the effects of disorientation due to tumbling—one such future study involves a full-size Apollo spacecraft in a complete freedom-of-motion device.

The original astronauts were subjected to accelerations of up to 14g, but it appears that this also is unnecessary. The new group in training will be subjected to maximum accelerations of approximately half this value. Initial group of astronauts also was subjected to temperatures up to 250F inside a steel box while wearing ventilated space suits, to simulate effects of heat loads during re-entry; this facility will not be used in future training.

The most significant area of astronaut training will be in systems management, which grows in importance as the vehicles and their missions increase in complexity and duration. As spacecraft operate for longer periods of time away from a ground maintenance facility, they become more dependent upon the crew for continued functioning. Dr. Voas likens this to returning to the early era of aviation when the pilot was an operator, crew chief and maintenance man for his aircraft. And many of the systems require manual inputs from the pilot to function, as differentiated from the Mercury concept where systems were automatic and actuated by timers or ground signals.



SAFETY MONITOR control panel with closed circuit television screen enables safety engineer to monitor pilot during flight in Ling-Temco-Vought simulator. Below, film projector produces image of lunar surface on sphere surrounding the simulator. Star field patterns and earth horizon line can be projected for earth-orbit missions. Projector is mounted above gondola. Elongated arms are counterbalances.



Therefore, increased use of systems training devices will provide crew members with an intimate knowledge of every component and function of the onboard equipment—not only how it works, but of all the contingency conditions. Crew training specialists tend to think the astronauts will spend more time studying malfunctions than they will normal operation of the systems.

Diagrams and blueprints have been found to be poor substitutes for working models of the system. In Gemini training, systems training aids are flat, upright boards pictorially depicting each major spacecraft system. They are an electrical power source flow provided by the fuel cells and back-up batteries; the entire electrical sequential system from liftoff to landing; the environmental control system coolant circuit for cooling spacecraft equipment, the cabin and pilot; the environmental control system oxygen circuit for the cabin, and for main and emergency pilot sup-



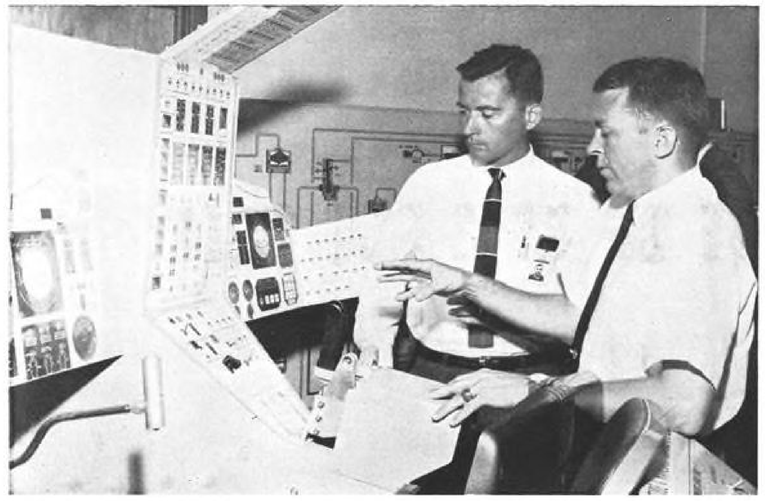
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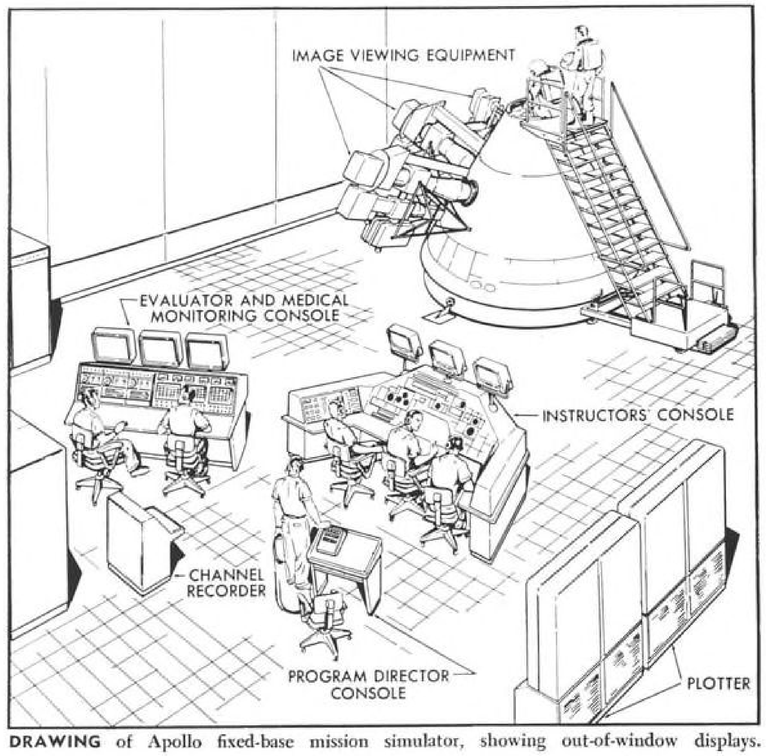
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PILOTS JOHN W. YOUNG (l.) AND ELLIOTT M. SEE, JR., study a mockup of the Gemini cockpit panels. Two control sticks visible in picture, plus panel switches, activate illuminated systems schematic boards (behind Young).

ply, and the attitude and maneuver control system circuit for directional control during both orbital and re-entry phases of a flight.

The schematic boards display the operational flow pattern by light traveling from component to component throughout the system. Malfunctions can be introduced and the signal flow will choose an alternate route, detailing to the operator the automatic switchover that occurs, or the manual switchover that he must activate to maintain the system function. Thus the astronaut can study types of component failures, or the possibilities that make a component inactive by actually observing the physical makeup of the



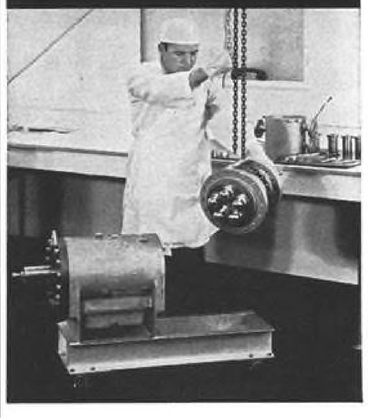
DRAWING of Apollo fixed-base mission simulator, showing out-of-window displays.

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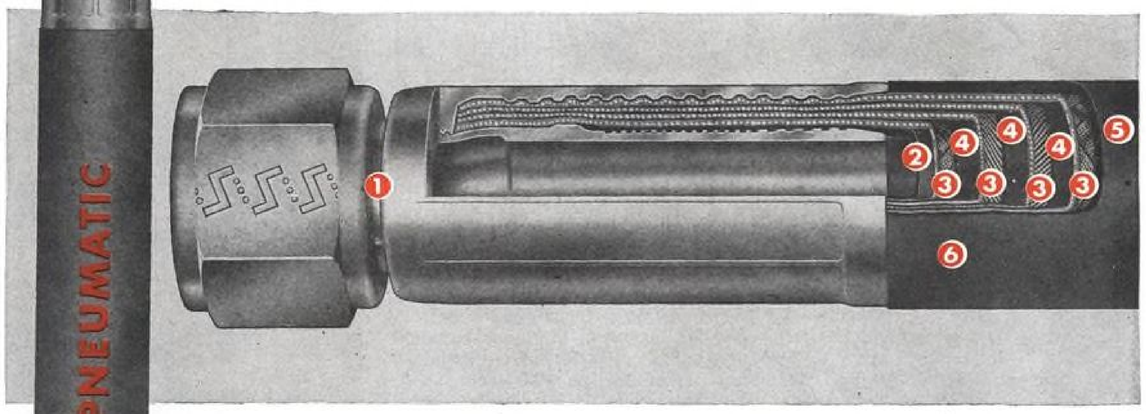
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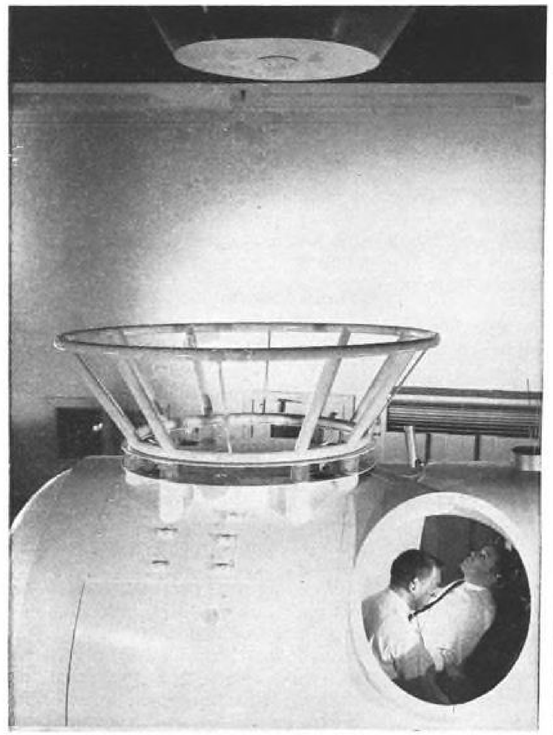
HOSE NUMBER	134	135	136
OPERATING PRESSURE PSI MAXIMUM	4,000	6,000	8,500
NORMAL PROOF PRESSURE	8,000	12,000	17,000
ROOM TEMP. BURST PRESSURE	16,000	24,000	34,000
DASH SIZE & OD TUBE SIZES AVAILABLE	-4, -6, -8, -10, -12	-4, -6, -8	-4, -6, -8
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TWO-MAN LUNAR LANDING MODULE simulator built by the Martin Co. for NASA has been used to practice rendezvous and docking operations. Simulator can move about 25 deg. around each axis to mate with simulated nose of Apollo command module (above).

component and its location in the signal flow route.

First of these Gemini pictorial systems trainers have been delivered to MSC's temporary training site at Ellington AFB, Houston, by Burtek, Inc., of Tulsa, Okla., which is building them under subcontract to McDonnell Aircraft Corp., prime Gemini spacecraft contractor.

Biggest challenge facing MSC, according to Harold I. Johnson, technical assistant to the chief of flight operations, is development of out-of-the-window animated display systems, and these are among the major training aids considered for future manned space flight programs. The center is interested in new ideas and concepts that will provide true-to-life displays for training in flight, navigation, lunar and earth takeoff and landing and rendezvous for Gemini, Apollo and LEM spacecraft.

Some new trainers associated with Gemini and Apollo will cost three to four times that of Mercury training equipment, an indication of how complexity increases to achieve faithful reproductions of the actual spacecraft. However, it is not generally appreciated that the training devices play an invaluable dual role in preparing not only the astronauts, but also the engineering staff in equipment and procedures checkout.



NEW PILOTS Edward White (left foreground) and Neil A. Armstrong (center, rear) sit in a three-man spacecraft simulator, built by Martin Co., with Mercury astronaut Walter M. Schirra (right foreground).

Trainer Up-dating

In the Mercury program it was found necessary to maintain the trainers in up-to-date configuration. Initially, the Mercury simulator at Langley Research Center was a generalized configuration, while the trainer at Cape Canaveral was re-configured to duplicate the latest operational spacecraft layout. By the end of the program both trainers were maintained on this status.

Future trainers also will have to be designed so that they can be modified to keep pace with their operational spacecraft, according to Johnson.

There are about two dozen future training devices, some of them delivered; some modifications of existing equipment, such as the Gemini part-task trainer, which is a modification of the MSC-based Mercury procedures trainer; and others undergoing shakedown trials at the contractor facilities, or still in design or study stages.

Flight trainers are the most complex of these systems, because they are replicas of the spacecraft with all interior displays simulated through hybrid ana-

log-digital computers and including out-the-window views. Two each of the Gemini and Apollo trainers are being procured from Link with McDonnell Aircraft and North American as prime contractors respectively. One each will be based here, and the others at Cape Canaveral for terminal training prior to the actual mission. These trainers will fit into the fundamental mission simulation complexes, permitting all personnel connected with the launch, tracking and recovery to train as a team. LEM mission trainers also will be procured.

Apollo Trainers

Apollo part-task trainers under consideration are three static devices to simulate earth launch and re-entry, navigation and trajectory control conditions, and orbital and rendezvous.

Nearing completion at McDonnell is a Gemini-Agena training device that will simulate the last 100-ft. of the rendezvous and docking maneuver. The Gemini crew station will have four degrees of freedom—yaw, roll, pitch and lateral translation. The Agena simulator will have two degrees of freedom in vertical and range translation. Design is such that it will be capable of being used later to simulate Apollo docking maneuvers.

The centrifuge, considered one of the most valuable training aids for astronaut familiarization in re-entry and abort programs, is planned for installation at Clear Lake. It will be about the same size as the Navy unit at Johnsville, but will have lower maximum acceleration levels, probably not exceeding 30g. However it will carry a heavier payload, permitting simulation of a three-man Apollo cabin. MSC will utilize the Johnsville facility until mid-1965. Also to be used will be the smaller Ames Research Center centrifuge, which has a vertical maneuver capability providing simulation of Saturn launch and vibration characteristics.

Egress trainers will include McDonnell's Gemini static test spacecraft 5, which will be a fairly detailed spacecraft configuration. An egress trainer for the Apollo program has not yet been finalized, but it will probably also be a static test article.

Lunar landing simulators include an improved version of the Bell Aerosystems free-flight trainer, which will be used initially as a research vehicle to size the braking and control jets and to optimize cockpit displays. This vehicle will be powered by a General Electric turbojet automatically controlled to produce a lift equal to 5/6ths the weight of the spacecraft and thus simulate the effect of lunar gravity. Langley Research Center is constructing a tethered landing simulator controlled from a huge A-frame. This facility is geared primarily towards research and development rather than training.

MSC is also considering using the Bell X-14 vertical takeoff and landing test aircraft as a familiarization device, and may buy a Bell Model 47 helicopter fitted with various masking devices on the bubble canopy for VTOL familiarization, lunar excursion module landing visibility studies and out-the-window displays.

A Gemini paraglider trainer, using a boilerplate spacecraft which will be dropped from a helicopter for practicing the terminal landing maneuver, is in the program.

Lunar Display

In the study stage is an Apollo three-dimension lunar trajectory simulation facility, which would show in scale size the relative movements of the earth, moon and spacecraft systems. The display could be computer tape-driven to simulate any Apollo mission and would be useful in visualizing planned trajectories and abort conditions in three-dimensional, mobile form, by both astronauts and ground operations crews of MSC.

Training facilities also include two contractor-furnished operations. A moving base simulator at Ling-Temco-Vought, has been used for a variety of missions, including earth orbital, rendezvous, lunar trajectory, lunar orbital, lunar rendezvous and various abort modes of the spacecraft and lunar excursion module. Martin Co. lunar excursion module simulator has been used for LEM rendezvous and other flight modes. However, MSC is leaning more toward an in-house training capability, largely because of the need to reduce astronaut travel.



EIGHT OF THE NINE NEW ASTRONAUTS inspect a full-scale mockup of the Gemini at McDonnell's St. Louis plant. They are (l. to r.): John W. Young, Edward White, Elliott M. See, Jr., Neil A. Armstrong, Thomas P. Stafford, James A. Lovell, Jr., Charles Conrad, Jr., and Frank Borman. Missing was James A. McDivitt.

NOT ALL RUST IS RED

By the laws of nature, *all* materials deteriorate in some manner—and the common deterioration process for metals exposed to air and water is called "oxidation."

The product of this oxidation may be any of several colors, depending on the metal itself. The color will usually be blue-green for copper, black for lead, white or gray for aluminum and zinc, or red-brown for most types of steel. The oxidation process and the resulting corrosion products on all of these metals are similar except in color, but the persistent image when the word "rust" is used is the red-brown oxidation of steel.

Neither the presence of rust on any metal nor its color is an exact indication of the metal's corrosion resistance. USS COR-TEN Steel, for example, has 4 to 6 times the corrosion resistance of structural carbon steel, because it quickly forms a tightly adherent dark brown rust that is a *barrier* against further corrosion. In fact, designers frequently *want* rust for aesthetic reasons: the blue-green oxide patina of century-old copper roofs is one example, and some designers leave USS COR-TEN Steel unpainted to develop the rich brown rust color.

However, rust itself is normally considered undesirable and has become associated in the minds of many people with rapid corrosion of the metal which will eventually lead to failure. To take commercial advantage of this obvious fact, some manufacturers of materials that compete with steel persistently claim that their materials do not rust. The kindest thing that can be said about such a statement is that it is misleading. To prove this point for yourself, you may enjoy taking a little test that has delighted many engineers as well as laymen.

Here's the background:

The United States Atomic Energy Commission conducted an exhaustive series of corrosion tests to guide them in the selection of materials for use in water-cooled nuclear reactors. Samples of over 100 materials were suspended in pure, still water in a 500°F. autoclave for three to six months. The specimens were then rated for their corrosion resistance, Class I having the best corrosion resistance, Class III having the poorest corrosion resistance. Now, take a pencil and classify the following materials as you think they made out in the tests.*

Material	Class I High Resistance	Class II Medium Resistance	Class III Low Resistance
1. Quartz			
2. Tungsten Carbide			
3. Platinum			
4. Vanadium			
5. Monel			
6. Silver			
7. Stainless Steel (Type 410)			
8. Aluminum			
9. Titanium			
10. Beryllium			
11. Fluorocarbon Plastic			
12. Copper			
13. Polyethylene			
14. Brass			
15. Nickel			
16. Lead			
17. Magnesium			
18. Stainless Steel (Type 302)			
19. Zinc			
20. Cadmium			

Here are the answers: 3, 9, and 18 were in Class I. 5, 7, 11 and 15 were in Class II. *All the rest* were in Class III.

Incidentally, if carbon steel had been included in the test, it would have ended up in Class III also.

Are the above results misleading? No —*because the exact conditions of the test are defined. They would be seriously misleading if they were suggested as an accurate classification of corrosion resistance under any other conditions.* As test conditions change, corrosion rates would also be expected to change.

There are several excellent reference works that outline the corrosion resistance of various materials. A standard work is, "The Corrosion Handbook" published by John Wiley & Sons. There are many other reference books on this subject, which contain a monumental amount of data on the corrosion of design materials. Even so, the surface has barely been scratched, for there are literally millions of possible combinations when you take into account all the design materials and all the chemical or atmospheric environments in which they might exhibit some corrosion.

But one thing is certain: you cannot justify the use of a material on the basis of its relative corrosion resistance alone. For example, there are many steels and other materials that have greater corrosion resistance than carbon steel, yet carbon steel is still the most widely used metal in the world. It has been the basic design material for just about every large ship, bridge, building, and tower ever built. Carbon steel is used because it has the strength and stiffness for the job; and, even when it must be protected by paint or other coatings, it is still the biggest bargain in any industry.

Certainly the word "rust" has, through casual usage, become associated with the oxidation of steel. Even experienced engineers and designers often use this word "rust" loosely, but they are not misled as to its *meaning*. The "rusting" of metals is an important consideration in their design work, whether that "rust" be red, white, gray, green, or black. But, no matter how loosely they may use the word, they recognize as professional men that not all "rust" is red.

• • •

*From *Corrosion and Wear Handbook for Water-Cooled Reactors*, United States Atomic Energy Commission, Division of Reactor Development, Naval Reactors Branch.

Test Conditions. The classification of materials was based on corrosion tests conducted in high-pressure autoclaves containing high-purity water at 500°F. No circulation of the water was provided for, other than movement resulting from thermal circulation. In general, the water contained 10 to 30 cc. of oxygen (STP) per kilogram of water, and the initial electrical resistivity was 500,000 ohm-cm or greater. The tests lasted from 3 to 6 months.

Definition of Classifications—*Class I:* Materials showing the highest resistance to corrosion. These may be used with the least amount of consideration for the particular application. Weight changes in this group were generally on the order of +10mg/dm²/mo (weight gain attributed to adherent scale). *Class II:* Materials were appreciably less corrosion resistant than those listed in Class I. They require some consideration in their application in order to insure satisfactory performance. Weight changes in this group were generally on the order of +50 mg/dm²/mo. Many of the materials are subject to minor pitting, especially in crevices. *Class III:* Materials in this group usually show weight changes on the order of several hundred mg/dm²/mo and/or are susceptible to severe localized attack.

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"Here's why you should come to U. S. Steel with your corrosion problems"

—Herb Phelps, Division Chief, Corrosion Technology Division, Applied Research Laboratory, U. S. Steel Corporation



Dr. Herb (E. H.) Phelps got his BChe from Clarkson College of Technology, and his MS and PhD from Case Institute of Technology. He joined USS in 1955 after three years in corrosion work at Wright Air Development Center. He is a member of the National Association of Corrosion Engineers and the Electrochemical Society.

"Corrosion losses in the United States amount to about $7 billion every year, and here in our Applied Research Laboratory at Monroeville, Pa., we're doing something about it," says Herb Phelps. "In fact, we're doing substantially more than anyone else in the industry, which seems to me a good reason to come to U. S. Steel when you're looking for steels to solve corrosion problems.

"The story of our corrosion program goes all the way back to March 1, 1929. That was before my time, but the steel that resulted from the first program—USS COR-TEN High-Strength Low-Alloy Steel—is still more in demand than any other high-strength, corrosion-resistant steel on the market. When COR-TEN Steel was introduced, our tests enabled us to show that it had 4 to 6 times more resistance to atmospheric corrosion than carbon steel had. This ratio has been fully substantiated by later testing programs that have also developed atmospheric corrosion data for hundreds of other experimental compositions. Experience has shown that in many applications there is a definite relationship between these corrosion test data and service performance.

"Over the years since 1929, we have exposed over 64,000 samples of steel in corrosion tests, some of them for as long as 30 years.

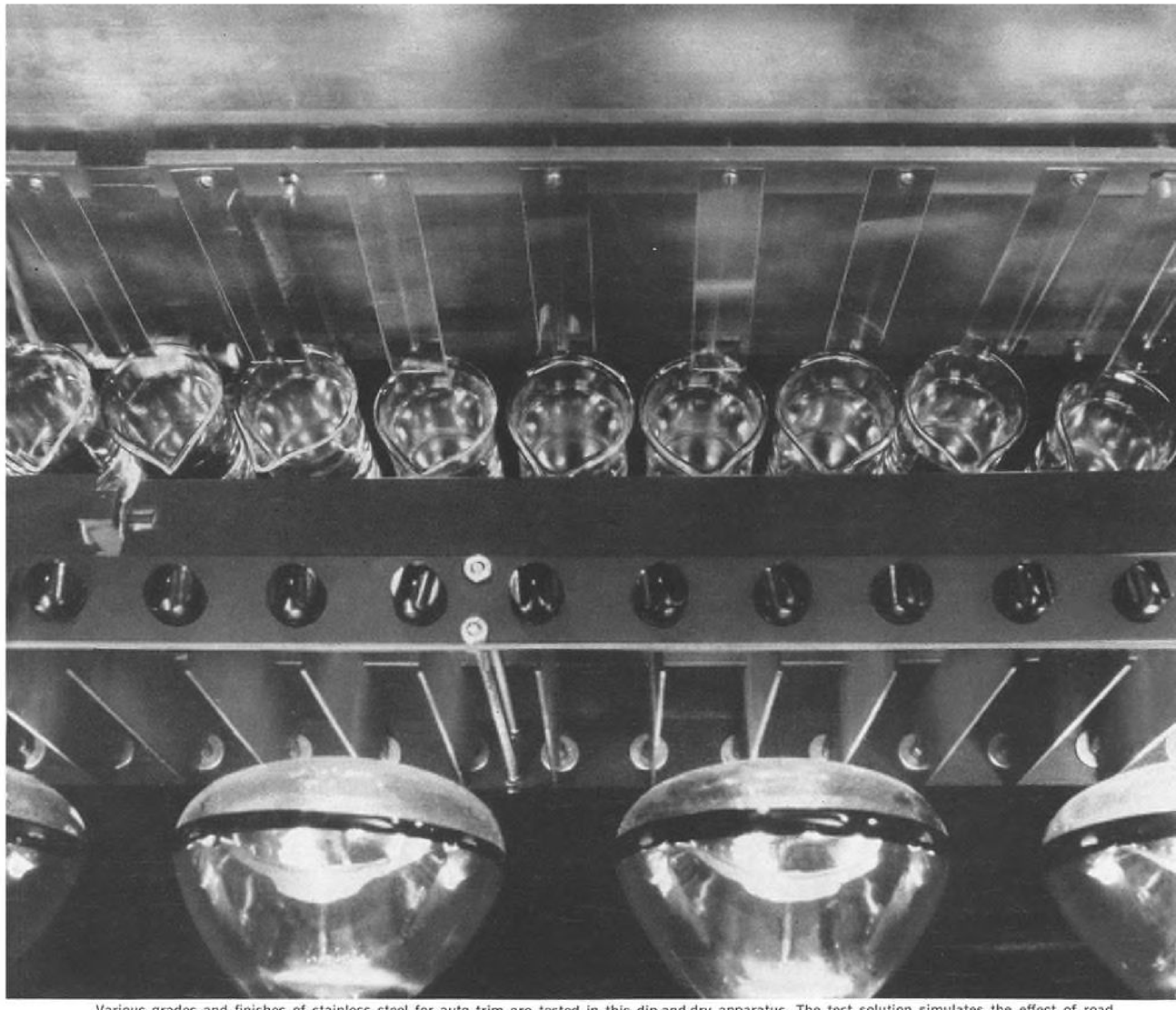
"Today, we literally have acres of test racks around the country, exposing samples of every steel used in metalworking to rural, industrial, and coastal atmospheres. We also have test samples on the roofs of buildings in several major cities in the United States. We have hundreds of samples built into structures, inserted in pipelines and vessels used by dozens of processing industries, and during the winter months we even expose samples underneath the front bumpers of about 70 automobiles to determine the effects of road salts. Every sample is measured or examined for corrosion loss, some of them several different times.

"But that's only part of the story. Here at the Applied Research Laboratory, we have a full-time crew of 28 technicians who complete over 100 test programs every year on applications for steel products. We probe the corrosive effects of a great many materials . . . from soft drink syrup to liquid fertilizers. We're trying to find out the cause of stress corrosion, for example, and how proper design and special treatments can prevent it. We investigate things as mundane as the corrosion of stainless steels by dairy cleaning compounds, and as exotic as corrosion-erosion of sensitized stainless in a thorium dioxide-uranium trioxide slurry, which is the rather high-sounding name for a certain type of fuel and coolant for a nuclear-reactor power plant.

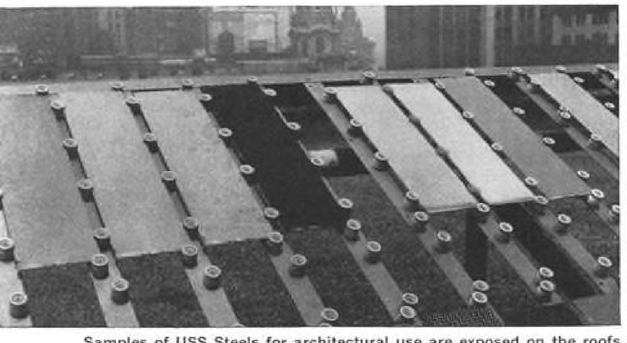
"I think you'll agree that if you have a corrosion problem, we're the people to talk to. Many of our test installations include samples related to customer service, and we often investigate customer corrosion problems in the field. We have cooperative corrosion testing programs going on at all times involving anything from the development of longer lasting auto mufflers to the development of steels that are destined for service outside the earth's atmosphere.

"That's about it. Our corrosion program is just one more reason why you get **more** than steel when you buy from United States Steel."

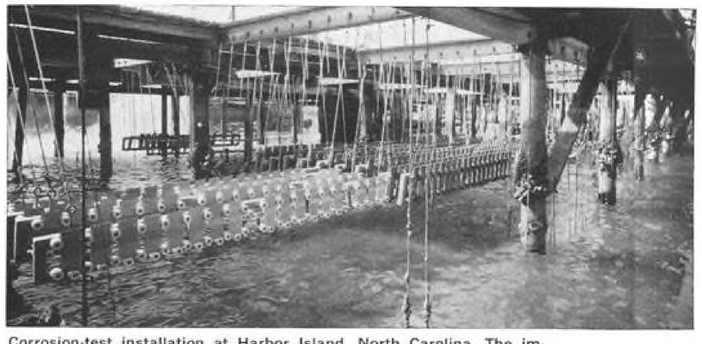
One thing Dr. Phelps didn't mention. In addition to the industry's finest metallurgical and technical service, we deliver the finest products you can buy. If you need corrosion-resistant steels—and we have a full-sized family of them, from USS COR-TEN High-Strength Low-Alloy Steel to the entire array of stainless steels—call U. S. Steel. USS and COR-TEN are registered trademarks.



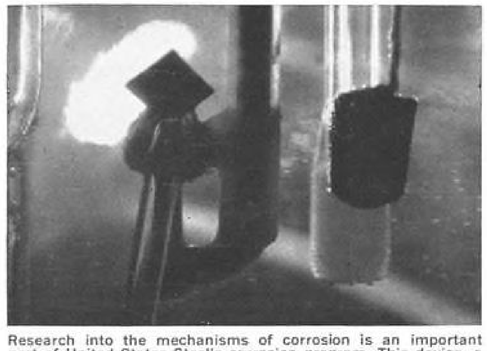
Various grades and finishes of stainless steel for auto trim are tested in this dip-and-dry apparatus. The test solution simulates the effect of road salts. Eight hours of this testing gives USS researchers an idea of the relative corrosion resistance of various steels during the normal life of a car.



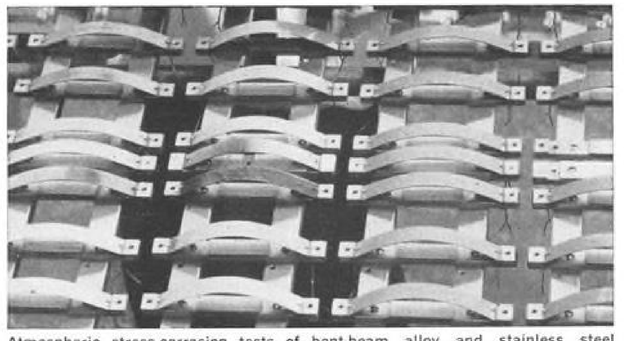
Samples of USS Steels for architectural use are exposed on the roofs of buildings in several major cities across the country. This rack is atop a building on lower Broadway, New York City.



Corrosion-test installation at Harbor Island, North Carolina. The importance of sea-water testing is emphasized by U. S. Navy statistics that point out that every $1 spent to prevent corrosion on ships ultimately saves $90.

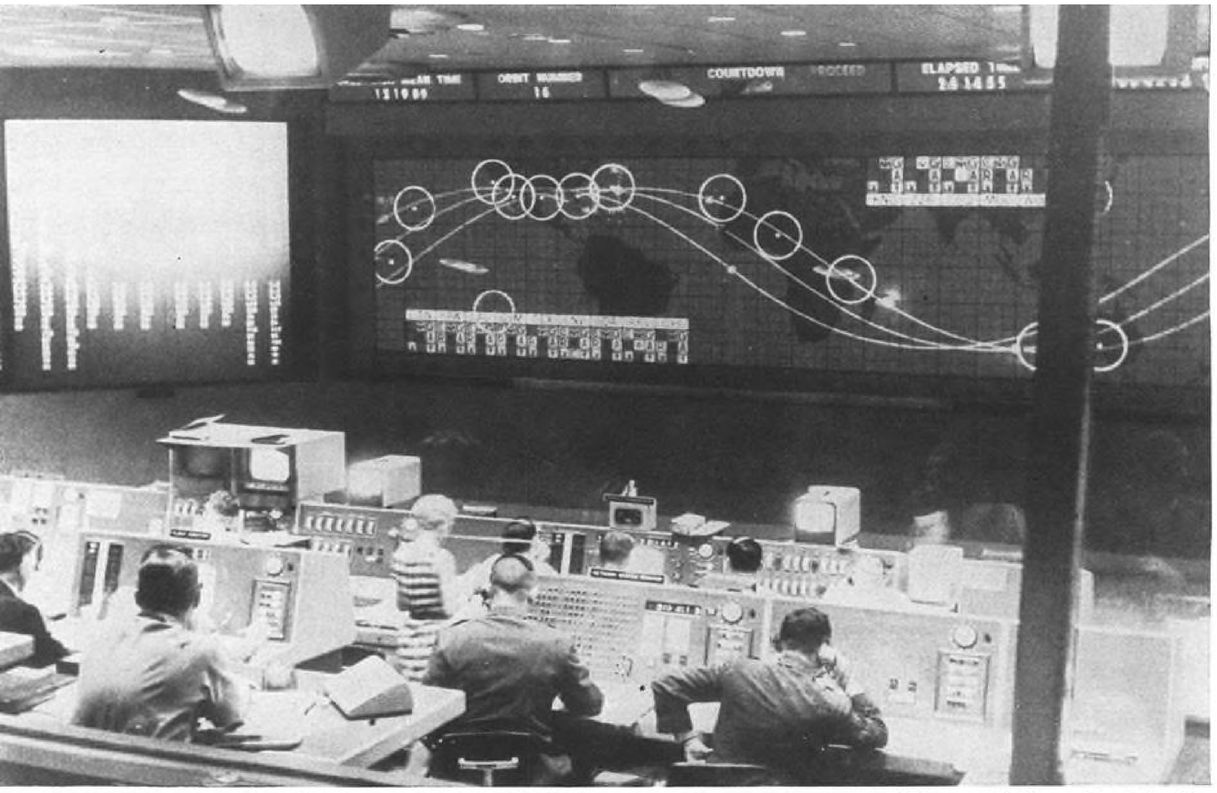


Research into the mechanisms of corrosion is an important part of United States Steel's corrosion program. This device, a potentiostat, measures the current required to maintain a constant potential in the electrochemical processes of corrosion.



Atmospheric stress-corrosion tests of bent-beam alloy and stainless steel specimens offer a guide to specification of steels for aircraft and missile uses. The microstructural characteristics of stress corrosion are investigated in several USS research projects.

United States Steel USS



MERCURY CONTROL CENTER in operation during MA-9. Future manned space flight missions will be controlled from Clear Lake, Tex.

Mission Control Begins New Space Art

Houston—Technique developed by the U. S. for conducting and controlling manned space flight has emerged as one of the most advanced examples of the integration of man and machine, requiring a high degree of human and electronic capability both on the ground and in the spacecraft.

Operational procedures for advanced manned missions is one of many space arts born, developed and tested in the Mercury project. Mercury has laid the framework for procedures and equipment, and has taught what not to do as well as what to do in future Gemini, Apollo, space station and planetary flights.

The genesis of operational control for manned space vehicles is traced to aircraft flight testing, with one significant advancement—experimental aircraft approach their flight boundaries in steps, requiring many flights; manned spacecraft reach the extremes of their design limits on every flight. The immediacy of events in manned flight introduces the element of real time—in monitoring, evaluating, recommending and acting when a normal flight plan must be modified for mission success and crew safety.

Christopher C. Kraft, Jr., chief of the Flight Operations Div. at the Manned Spacecraft Center here, said the mission control concept that has evolved from the six U. S. manned flights consists basically of two phases: a painstaking pre-flight analysis of everything that can conceivably go wrong during a mission, and the resulting ability to react quickly and correctly when an abnormality develops during an actual flight.

Kraft, who was flight director for all Mercury-Atlas and Mercury-Redstone missions, said the program has taught the ground controller the fundamental philosophy that he should do nothing until he is certain that something is wrong; and if an emergency occurs, he must make the right decision immediately.

With these ground rules, it took flight control only 12 sec. to decide to bring the Mercury Atlas-5 capsule out of orbit after two revolutions when the Hawaii tracking station diagnosed that reaction control fuel was being depleted so fast that the tanks would empty before the end of the planned three-orbit flight. Without fuel, the capsule could not have been oriented for re-entry and both the capsule and its chimpanzee passenger would have been lost.

Preflight preparation procedure includes simulated flights and the writing of Mission Rules, a formal documentation of things that could go wrong. The rules are well thought out possible contingencies, but the judgement factor will continue to be an inescapable responsibility for both pilot and ground crew. Mission Rules for MA-9, for example, instructed that the flight should end if both a primary inverter and the backup inverter failed. The capsule has three inverters—one for the suit, one for the automatic sequencer and a backup which can go on the line for either system.

Both the automatic sequencer and the standby inverters went out in Maj. Gordon Cooper's Faith 7 capsule toward the end of the 19th orbit. After a detailed analysis of vehicle system schematics, flight control made the most critical judgement of the mission—that Cooper could safely continue his program for 22 orbits, which he did.

Mercury flight control was conducted with two basic sets of computer programs, one covering launch to the point of injection into orbit and the other covering orbital flight and re-entry.

The most crucial Mission Rules during powered flight, Kraft said, center on committing the capsule to orbit. Conditions which could have aborted Mercury missions included loss of cabin pressure, even if suit pressure held; necessity to use any final backup system, and an injection velocity that was 200 fps. or more below the desired 24,400 fps. Retrorockets could have provided several hundred feet per second in velocity to help attain orbit if booster thrust was a little low, but this would have been self-defeating because it would have meant the retrorockets would have no thrust left to bring the capsule out of orbit.

There was one philosophy underlying mission rules for the period when the capsule was in orbit—keep it there until it reached a retrofire point where it could be recovered quickly.

These launch and in-orbit philosophies will dictate mission rules for controlling both Gemini and Apollo missions, but the added complexities of rendezvous, circumlunar and lunar landing missions multiply the intricacies of flight control for these missions. Where there were two basic computer programs for Mercury, there is a potential for an infinite number of programs in Gemini and Apollo.

Man's ability to be a meaningful part of a space vehicle was only theorized before Mercury, and the capsule fundamentally was fully automatic. With the experience of six Mercury missions, man's ability to control and take corrective action has been proved—only one Mercury-Atlas mission, Cdr. Walter M. Schirra's MA-8 flight, could have completed the planned flight program if a pilot had not been on board.

Both Lt. Col. John H. Glenn in MA-6 and Lt. Cdr. Scott Carpenter in MA-7 manually controlled their flights to assure three-orbit missions. If the pilots had not been there, each of the missions would have been ended after two orbits. Without Cooper aboard the MA-9, the capsule could not have been placed in the re-entry attitude, and consequently would not have survived re-entry heating.

Because of this experience, man's capabilities will be used more fully in Gemini and Apollo. This will make the ground controller's job easier in some ways but more complex in others. Gemini gives the pilot a velocity increment of 700 fps. which he can call on to change his orbit and maneuver for rendezvous. This velocity factor is sufficient for an 0.5 deg. plane charge. The Agena D target vehicle, which would be coupled to the capsule in a successful docking, has another 2,300 fps. velocity increment, sufficient for a 6 deg. plane change. By contrast, the Mercury capsule presented the pilot with no problem of managing energy for maneuvering, since it had no propulsive power of its own.

In Apollo, which has a high energy engine in the service module, there is nearly 15,000 fps. in potential velocity change.

This can be used to change the plane by as much as 30 deg.

A major part of ground flight control responsibility in coming missions will be continuous analyses and projections of the trajectory. Trajectory computations, even with on-board computers, will be an extremely difficult task for astronauts, who will need position and energy utilization information on a real-time basis.

In Apollo particularly, Kraft foresees mission rules with crossover points, where even in an abort of the lunar landing itself, it may be safer to fly a circumlunar profile than to turn around immediately and return to earth.

Mercury also proved the requirement for a centralized facility to control missions and for remote tracking and telemetry ground sites. Mercury control was located at Cape Canaveral, Fla., and during the course of unmanned and manned Mercury missions there, control responsibility evolved into five primary tasks:

- **Preflight preparation,** which involves development of operating concepts, mission documentation, computer programs and training.
- **Mission control,** including supervision and coordination of ground support, command control of unmanned vehicles and mission direction.
- **Spacecraft and crew** performance analysis, to determine the status of both pilot and systems.
- **Flight profile analysis,** which means monitoring the flight, developing alternate courses when abnormalities occur and making the go-no-go decisions from systems, flight dynamics and pilot performance data.
- **Postflight analysis,** a detailed review of the mission and the performance of the vehicle system and the performance of the pilot.

The preflight preparation task is formally documented in three mission handbooks—Mission Rules, The Flight Control Handbook containing vehicle system schematics, and trajectory working papers. The trajectory handbook is supported by a real-time digital computing system because changes from the programed flight path must be compensated for quickly.

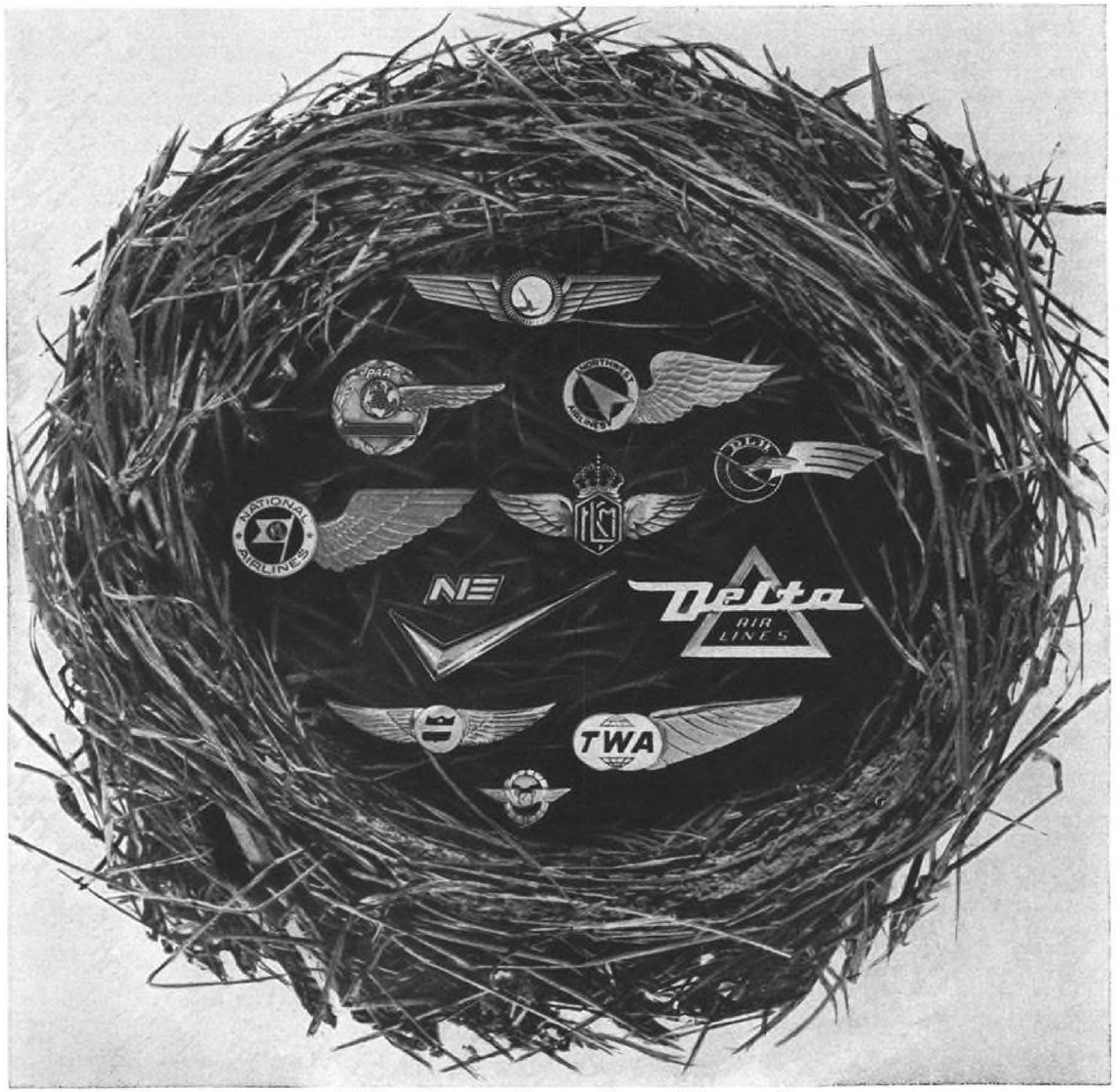
With the completion of the Mercury project, mission control for Gemini and Apollo is shifting from Cape Canaveral to the Integrated Mission Control Center at nearby Clear Lake.

The design concept of the IMCC reflects what has been learned from





DECISION to allow full 22-orbit MA-9 flight is made by Walter Williams and Christopher Kraft (left photo). At right, Robert Thompson, recovery coordinator, plots landing spot for the MA-9 capsule.



Birds of a feather!

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Mercury—keep the control center flexible. Flight controllers will staff the mission operations room. Separate rooms on either side of the control room will be staffed by experts in such areas as trajectories, bioastronautics and systems who will be on call to handle contingencies throughout the flight.

Functions to be performed by the IMCC represent a logical outgrowth of Mercury control which Kraft believes will remain valid through planetary missions. Philco Corp., which is responsible for designing and equipping the IMCC, prepared this nine-task summary of the new center:

• **Preflight operations.** Requirements are to exercise all flight controller positions, provide closed loop simulation exercises and spacecraft telemetry and trajectory data in open loop exercises, simulate command responses, check out remote sites, monitor booster and spacecraft checkouts, and determine launch time and azimuth.

Preflight operations concept calls for the use of the redundant operational equipment, operational programs and operational communications equipment in simulations, and to use simulation equipment both for exercises and checkouts.

• **Operational information.** Requirements are to collect spacecraft telemetry in real time and tracking data from remote sites, obtain data such as weather and solar activity which could affect the mission, collect selected information for post mission analysis, and receive voice communications from the pilot. Operating concepts for this task call for use of high-speed recording, control of remote site data and sampling rates, recording and play back, filtering of stale and static data and direct relay of astronaut voice.

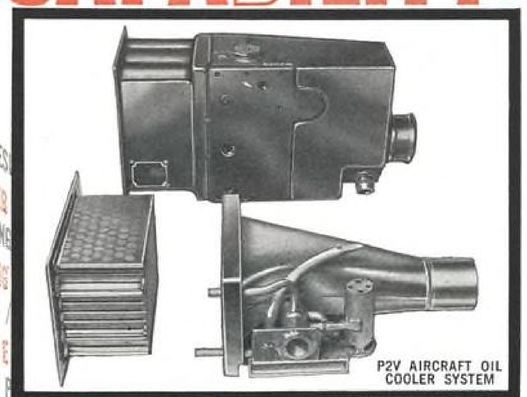
• **Scientific and engineering information.** Requirements are to coordinate and plan scientific experiments, collect and record engineering telemetry, voice and video, and to evaluate and update the flight plan. Concepts are essentially the same as those for operational information.

• **Flight data evaluation.** For this task, the IMCC will determine spacecraft ephemeris, monitor and evaluate telemetry and voice from the spacecraft, determine trends and hazards of the vehicle system, flight dynamics and life support systems, change nominal mission plans as required, and evaluate weather and environmental data. Task concept involves development of mission rules, use of flexible computer driven displays, versatile voice and video communications, and rapid data access.

• **Advise crew.** This task calls for a continuous flow of information to the crew on flight test plans, flight maneuvers and aborts, rendezvous maneuvers,

CAPABILITY:

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AERO-THERMODYNAMICS / AER
MANUFACTURING / FINISHING
TAPE-CONTROLLED MACHINING
HYDRAULICS / HYDRAULICS
ENVIRONMENTAL TESTING / E
PLATING / HOT FORMING / F
DIP BRAZING / DIP BRAZING
ENVIRONMENTAL SYSTEMS / E
PRECISION WELDING / PRECI
CLEAN ROOM FACILITIES / C
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QUALIFICATION TESTING / Q
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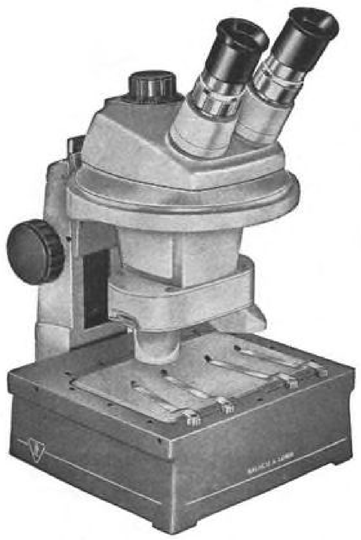
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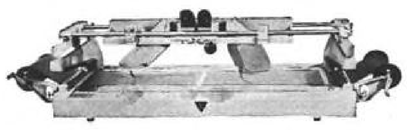
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entry maneuvers, operation of spacecraft systems, management of consumables and in-flight test and maintenance.

• **Issue commands.** Requirement is to determine and transmit clock settings, inputs to the on-board computer, attitude and velocity data for maneuvers, and in-flight calibration data. Basic operating concept is to assure command tasks are a centralized command responsibility.

• **Vehicle control.** This task covers control of the unmanned Agena D vehicle in a Gemini rendezvous mission. Requirement is to track the Agena and determine its ephemeris, receive and evaluate Agena telemetry, determine commands, and transmit the Agena's position and status to the Gemini crew.

• **Recovery.** With this responsibility the IMCC will predict the landing point and locate the spacecraft after normal and aborted re-entry and direct recovery forces to the landing point.

The other key function to be performed by the control center is monitoring and controlling the complete manned spaced flight Ground Operational Support System (GOSS), the enormous worldwide complex of data acquisition and handling, communications, and tracking facilities which supports both the IMCC and the Launch Control Center at Cape Canaveral. Management of GOSS involves radar scheduling and control, management of systems and subsystems, providing communications and circuit control and logistics support, maintaining readiness of the network, and providing data handling and error control.

Physically, the IMCC will be a three-story, 113,000-sq.-ft. structure with the communications center and computer complex on the first floor. Second and third floors will contain identical mission control rooms. Kraft said that it is not planned to run two missions concurrently, but IMCC can conduct one mission while it is checking out another. International Business Machines is equipping the real-time computer complex. Contract calls for the control center to be ready 74 weeks from the contract award date, which Philco formally received last Mar. 27.

In addition to the computer complex (AW Dec. 24, p. 52), the IMCC basically consists of three principal elements—communications, control and display, and simulation and checkout.

Communications system will control worldwide GOSS communications. Control and display system, linked to the computer complex, will have as its heart a high resolution television system consisting of two circuits. One will link the Clear Lake site with the launch site at Cape Canaveral and the other will transmit on-board television from Apollo through the Deep Space Instrumentation Facility in California.

Pound for Pound, Here Is the Strongest Bolting Yet

New SPS Hi Ti 20 titanium fasteners beat beryllium for strength-to-density ratio, offer 200,000 psi minimum tensile

Titanium now tops *all* metals in the fastener strength-to-weight race, thanks to advanced SPS manufacturing techniques and perceptive alloy selection. At 200,000 psi tensile and 120,000 psi shear, new Hi Ti 20 fastening beats the best previous titanium bolting (NAS 621) by a full 25%.

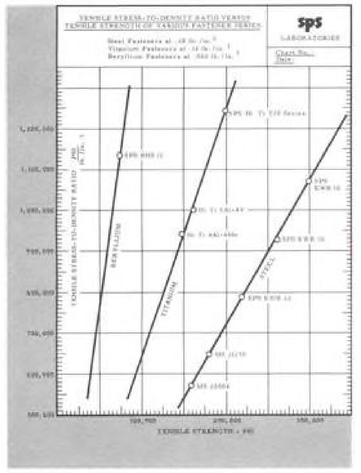


Fig. 1: Hi Ti 20 parts have a strength-density ratio of 1,240,000, compared with 1,136,000 for beryllium bolting and 1,071,000 for supersteel. It would take a 350,000 psi steel bolt to match Hi Ti 20 for strength per pound.



New Hi Ti 20 systems boost titanium fastener performance a full 25%, offer 200,000 psi min. tensile, 120,000 psi min. shear. Fatigue life at 100,000 psi max. stress (70,000 for shear systems) exceeds 65,000 cycles. Locknuts are the first ever made of titanium for general application on mating titanium threads.

Here are the mechanical properties of new SPS Hi Ti 20 Series bolts:

Bolt Properties	Minimum Spec. Requirements SPS-B-173
Tensile strength, psi	200,000
Shear strength, psi	120,000
Fatigue life @ 100,000 psi (cycles)	65,000 avg. 45,000 min.
Fatigue endurance limit, psi*	56,000

*No specification requirement.

Breakthrough Underscores SPS Capabilities

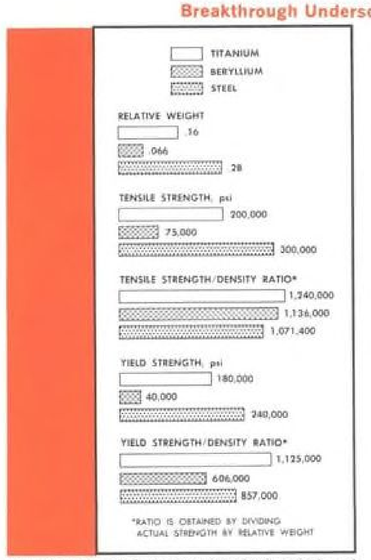


Fig. 2: Hi Ti 20 fasteners top both steel and beryllium in strength/weight ratio (data based on actual bolt mechanical properties).

To produce titanium fasteners for these stress levels, SPS drew heavily on its previous achievements in high-strength-to-weight hardware. Among these—the *first* successful titanium bolts, the first production beryllium bolts, the first 300,000 psi steel bolting.

From this experience, SPS extracted several major solutions to the problem of fabricating truly reliable, high-strength titanium fasteners—

• Proprietary thread rolling techniques developed for the manufacture of superstrength steel bolting

• Use of MIL-S-8879 thread form with large root radius

• Improved heat treat methods for titanium

• Cold working of head-to-shank fillets

These techniques, along with the inherent fatigue resistance of titanium and careful alloy selection, permit heat treat to 200,000 psi minimum tensile. The resultant performance can be seen in Figs. 1 and 2.

First Titanium Locknuts

As part of its Hi Ti 20 program, SPS has also developed titanium locknuts for both tension and shear applications. A proprietary dry film lubricant (SPS K2) makes these the first titanium locknuts that can be used and reused on titanium bolts without galling.

With threads to MIL-S-8879, the tension locknut—FN T20—meets MIL-N-25027 locking torque requirements. It is capable of developing the full strength of Hi Ti 20 bolts and of previous SPS titanium bolts. Both the tension and shear locknuts can be substituted for steel locknuts—with consequent weight savings and enhanced corrosion resistance.

Suggests Re-evaluation of Titanium Fasteners

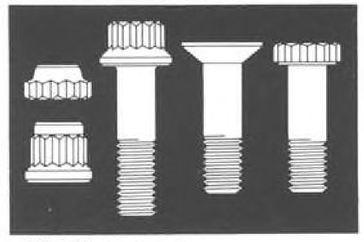
Availability of the Hi Ti 20 system suggests a major re-evaluation of titanium fasteners, both for space vehicles and air breathers. This is especially true because equivalent breakthroughs in supersteel or beryllium bolting do not appear imminent.

Likely applications for new Hi Ti 20 systems include space capsules and satellite packages, and their propulsion, particularly where thrust-to-weight savings can be translated directly to payload. Too, Hi Ti 20 bolting applies to internal structures of Mach 3 aircraft, as well as to conventional problems of landing gear and wing design where great strength is needed at minimum weight penalty.

In view of its 57% weight saving over steel, its tensile strength level and its corrosion resistant properties, the Hi Ti 20 system offers an attractive replacement for NAS 624 and/or MS 21250 bolts.

Availability

SPS Hi Ti 20 titanium fasteners are available on order both in tension and shear systems—#0 through ½ in.—for service to 350°F. Configurations include—



EWB T20—Tension bolt
FN T20—Tension locknut
EWSB T20—Protruding head shear bolt
SFH T20—Flush head shear bolt, Hi-Torque drive
SFT T20—Flush head shear bolt, Torq-Set drive
EWSN T20—Shear locknut

Availability does not stop with these threaded fasteners. SPS is prepared to furnish other practical fastener configurations as well.

(for more information, see note on following page)

(cont. from preceding page)

SPS Overcomes Heat Barrier for Titanium Bolting

Hi Ti 815 fasteners are serviceable to 750°F

Until now, titanium fasteners have been wary of heat. Those made of the alpha-beta alloys have displayed a discouraging tendency to become brittle and lose their fatigue resistance upon exposure to temperatures above 400°F. Conversely, fasteners made of all-alpha alloys—while displaying greater stability—have suffered from inherent lack of tensile strength. SPS overcomes this handicap with a new titanium fastener—SPS Hi Ti 815—that is serviceable to 750°F, yet sacrifices little or nothing in the way of tensile strength (150 KSI).

Techniques used in developing the SPS Hi Ti 20 Series apply also to the new Hi Ti 815. Proprietary thread rolling methods, use of MIL-S-8879 thread form, coldworking of head-shank fillets, special heat treat—these, along with the basic tensile strength of the material (SPS M-179), combine to give the following typical performance:

AVERAGE MECHANICAL PROPERTIES OF ⅜-24 SP T815-6-20 BOLTS AT VARIOUS TEMPERATURES

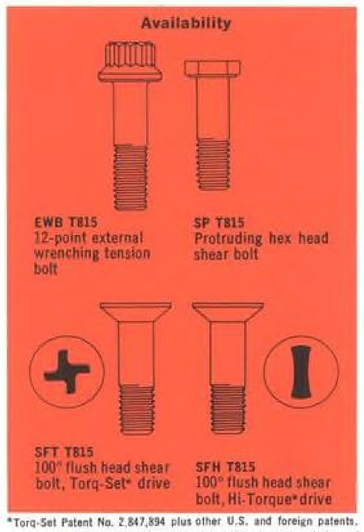
Property	Room Temp. (F)	At 750°F	At Room Temp. after 100-Hr. 750° Soak
Tensile			
Load, lb.	14,500	10,900	13,900
Stress, psi[1]	165,100	124,100	158,300
Yield[2]			
Load, lb.	9,400	6,700	11,600
Stress, psi[1]	107,000	76,300	132,100
Shear			
Pounds	20,900	—	20,600
Stress, psi[3]	94,600	—	93,200
Fatigue (cycles)			
Min. required[4]	30,000	—	30,000
SP T815	907,000	40,500	427,000

[1]Based on tensile stress area (0.08781 sq. in.)
[2]Determined by Johnson's ⅔ approx. method
[3]Stress calculated using twice the area of nom. body diam. (0.22094 sq. in.)
[4]Per NAS 621 Spec.

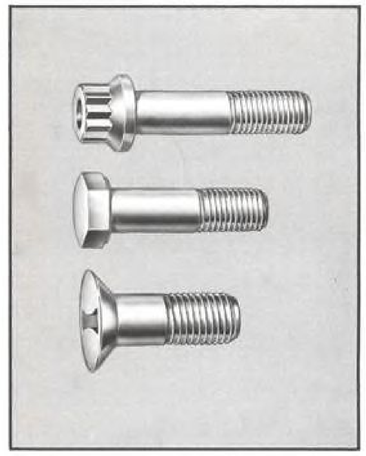
Puts Titanium Bolting In New Light

Availability of reliable 750°F titanium bolting will enable designers to use its light weight and corrosion resistance in a number of applications that might previously have been bypassed—internal components of Mach 3 aircraft, in engines or near them, in missiles, rockets and sensitive payloads. At about half the weight of steel, design possibilities are many and promising.

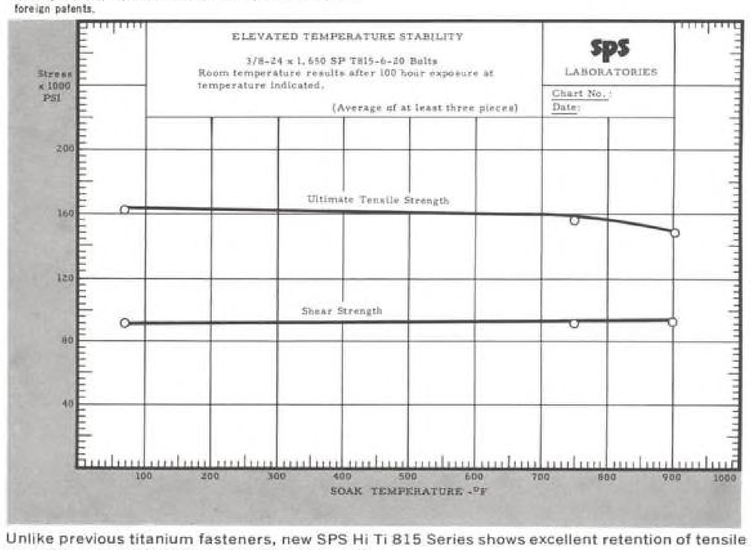
SPS Hi Ti 815 fasteners are being produced in four series, each a modified configuration of existing industry or military standards. Size range is #10 through ⅝ in.



*Torq-Set Patent No. 2,847,894 plus other U.S. and foreign patents. Hi-Torque Patent Nos. 2,677,933; 2,745,120 plus other U.S. and foreign patents.



New Hi Ti 815 bolting is serviceable to 750°F, meets NAS 621 fatigue requirements, and is rated at 145,000 psi min. tensile and 90,000 psi min. shear.



Unlike previous titanium fasteners, new SPS Hi Ti 815 Series shows excellent retention of tensile and shear properties after prolonged heat soak.

More Information on Hi Ti 20 and Hi Ti 815

Laboratory report abstracts are now available both on the new SPS Hi Ti 20 system and the new Hi Ti 815 Series. Write STANDARD PRESSED STEEL CO., PRECISION FASTENER DIVISION, JENKINTOWN 3, PENNSYLVANIA • SANTA ANA, CALIFORNIA.

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Apollo Testing To Begin at White Sands

White Sands Missile Range—Flight and ground tests of major systems of Apollo and its Lunar Excursion Module (LEM) are to start within the next few weeks at the National Aeronautics and Space Administration's new proving grounds here, underscoring the transition of hardware from the drawing boards toward lunar touchdown.

Technical spotlight will be focused on this New Mexico area, which is operated for NASA by its Manned Spacecraft Center, during these important programs:

- **Apollo spacecraft abort** trials, using off-the-pad and Little Joe 2 rocket launches of boilerplate and near-facsimile flight type command modules to qualify the Apollo launch escape systems and the command module. These will begin soon at a recently refurbished former Army Redstone missile site.
- **Propulsion systems** for the Apollo service module and Lunar Excursion Module. They will be static-tested in a new complex to be built on an 87-sq.-mi. site on the west slope of the Organ Mountain, some 20 mi. from the Little Joe 2 launch area. This site, to be occupied by North American Aviation and Grumman Aircraft Engineering Corp. and their subcontractors, is expected to be fully operational next year.

Although NASA personnel are reluctant to discuss missions here other than those officially disclosed, indications are that several other test missions have been considered as possibilities. There is a wide scope of facilities here that could be used, particularly in a period when Apollo test facilities are a pacing factor in flight mission schedules.

Among the missions that might be added to MSC's White Sands work are Gemini testing, including various abort configurations; flight tests of the Apollo service module and the LEM (AW Jan. 7, p. 69)—Grumman is believed to have submitted such a proposal on its vehicle; and use of Little Joe 2 to provide acceleration, high-altitude and other environments for other space systems.

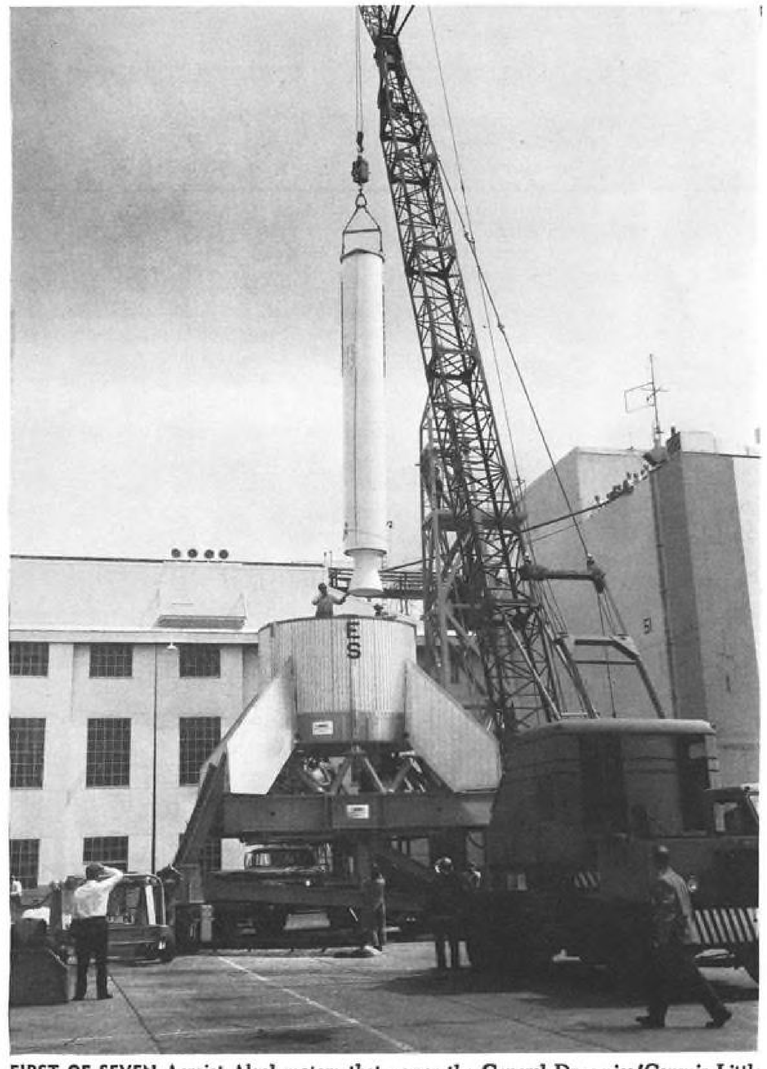
There are indications that Marshall Space Flight Center technicians have looked over MSC/WSMR facilities with an eye to the possibility of using Little Joe 2 to take the Saturn I's Pratt & Whitney RL10-A3 engine, used in the Douglas S-4 stage, to high-altitude, eliminating the need for running this environmental test in an altitude chamber and possibly providing more accurate test conditions.

The new NASA site here is the result of the agency's desire to ensure meeting Apollo program schedules by giving major contractors a fully-implemented range and other facilities, strategically located and providing both an isolated test area for engines using highly toxic fuels and an area for land recovery of command modules.

Site selection teams considered a number of locations. The Wallops Island, Va., station, where similar abort systems qualification trials for Mercury were carried out with the smaller Little Joe 1 launch vehicle in 1959-1960, had the undesirable limitation of water recovery of test articles for a spacecraft that must land on solid ground.

Cape Canaveral "traffic" appeared to leave little space in which to put a test program of the magnitude MSC considered; and although this is not mentioned by NASA personnel, both Florida and California, where Edwards AFB and Pacific Missile Range are located, already are heavily occupied with space programs and some consideration was undoubtedly given to spreading the workload into other states.

White Sands featured a strategic location—between the Apollo prime contractor and the Manned Spacecraft Center at Houston, Tex.—and its 4,000-sq.-mi. area provided ample space for isolated engine test area. It also is one of the best instrumented ranges in the free world. Total investment in the 100-mi. by 400-mi. basic range is about $887 million including real estate and



FIRST OF SEVEN Aerojet Algol motors that power the General Dynamics/Convair Little Joe 2 launch vehicle, to be fired next month, is inserted in housing.

buildings. Range resources total some $266 million, and $127 million of this represents instrumentation.

A skilled work force to operate this facility also is available—of approximately 14,200 personnel, representing military services and contractors, some 16% are engineering and scientific personnel and an equal number are technicians. In the normal course of program shifts, this generally gives some assurance of finding personnel skilled in the complex problems associated with rocket programs. Skills are continually exercised. In the past six years, White Sands has conducted an average of 2,000 "hot" missions annually.

Use Through 1970

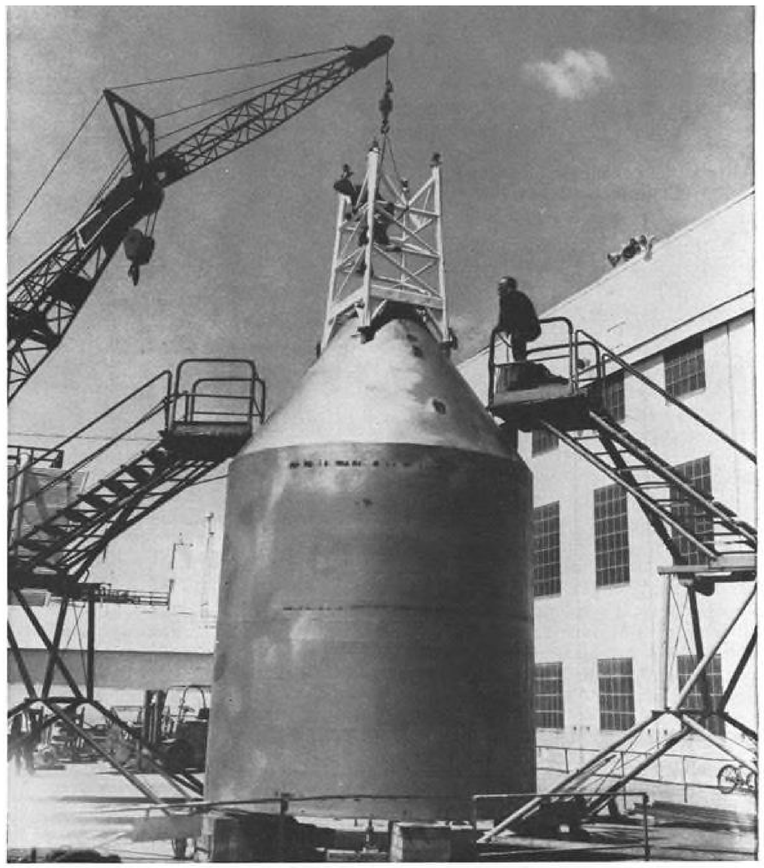
Two agreements were signed last December by NASA and the Defense Dept., providing NASA with tenant privileges covering two installations on the range through 1970, with renewal clauses. Agreement covers Apollo testing and "any other activities of a normal range testing nature" that the space agency may wish to conduct here.

The new NASA facility is linked directly to the Manned Spacecraft Center. Resident Manager Wesley Messing, who controls on-site operations, reports directly to Walter C. Williams, deputy director for mission requirements and flight operations at MSC. As the headquarters for the White Sands office, MSC approves facilities requests. Actually MSC's Apollo Project Office at North American's Downey, Calif., plant has a resident at White Sands, Emery Harris, who either approves or disallows these requests, or checks with Houston to approve or disallow them.

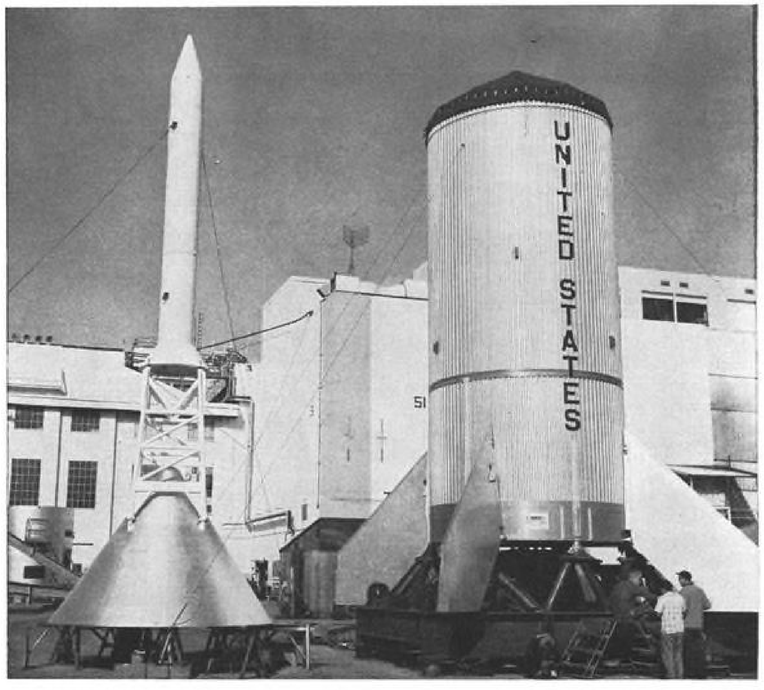
Policy Decisions

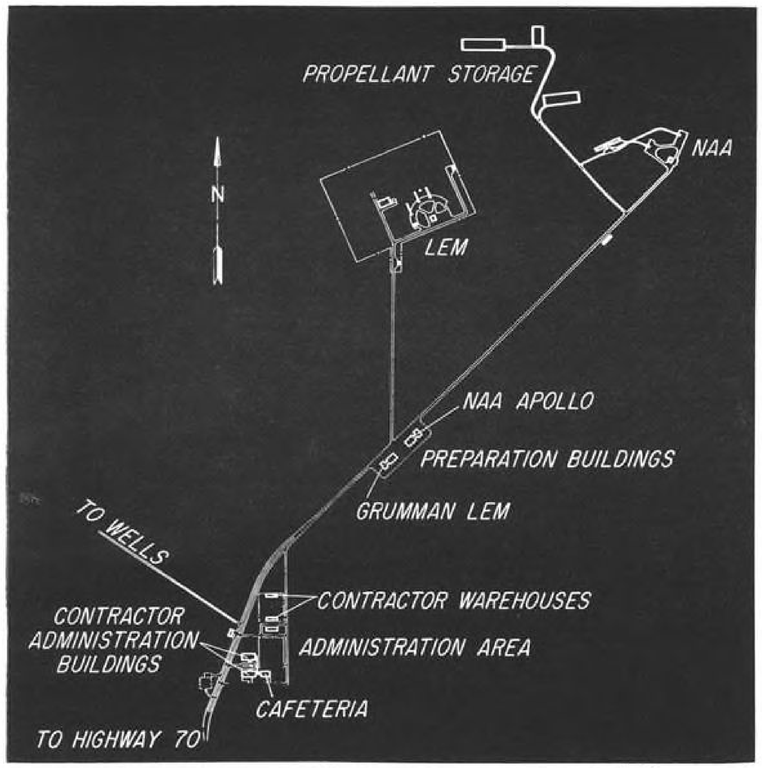
Messing, an alumnus of NASA's Edwards AFB Flight Research Center as is Williams, works closely with Houston on policy matters. Much of the day-to-day operation is handled by his assistant resident manager, Henry R. Van Goey. Line organization at White Sands includes an administrative group, headed by Charles Statz, which handles finance, contracts, budget matters, personnel and travel matters; a facilities group under Gerald Ard, which deals with design, surveillance of facilities operation and plans and estimating; and an engineering group under William Gantz, which is concerned with test conducting, range support and coordination and has three branches—instrumentation, spacecraft systems and operations and test.

Responsibility of the NASA office here is to see that the contractor is furnished the agreed-upon facilities and to manage tests, evaluation and development of hardware here for Houston. Messing now has a permanent allotment



WORKMEN INSTALL the launch escape motor tower on a boilerplate of Apollo command and service modules (above), for a test firing next month from White Sands Missile Range. This is the payload for the first Little Joe 2, which will be qualified as a booster in the first flight. Below, units are ready for shipment.





LOCATION MAP of the second NASA White Sands area where all Apollo spacecraft propulsion units will be tested. Sectors already have been allotted to contractors.

of approximately 60 NASA personnel. Future estimates show possibly twice this number in 1967, when both facilities are operating.

Contractor personnel will be at a considerably higher ratio, varying from time to time depending on the test schedule. Estimates again show total NASA and contractor personnel rising from approximately 300 this year to about 1,000 in 1967, including service contractors handling housekeeping and other tasks.

Philosophy is to provide a national facility to Apollo contractors. They are tenants and conduct the test programs much as they would at their own plants, with NASA personnel monitoring the work to see that it is done according to agreed-upon rules.

Army Support

Range and much other support is provided by the Army on a common service basis, without charge unless overtime is involved. Army furnishes services and equipment, including tracking, range instrumentation; documentation, including photographic and data tapes; and the personnel for these services. It also will handle recovery of the Apollo command modules.

Like other range users, NASA will file a Request for Work and Resources with Army. This is a planning document defining the mission test requirements in broad terms. Army evaluates the request, reports back on what support it can provide and works out any discrepancies. For example, NASA might request tracking of the Little Joe 2 within ± 10 ft.; Army might reply that such accuracies would require NASA to include a beacon in its vehicle.

Test Directive

A definitive test directive is then written out, which details everything needed to support the test; in photo documentation, for example, this would spell out exactly what is desired in types of cameras, film motion speed, camera angles and so forth. Army then breaks the test directive down into individual directives to the facilities concerned, providing a defined work schedule for all personnel.

Army Launch Area-3 (ALA-3) currently is programed through early 1965 on this test series: a Little Joe 2 launch vehicle qualification test taking it to maximum altitude; a pad abort test of Apollo command module boilerplate BP-6 from the cradle; a pad abort test of an Apollo command module configuration very close to an actual flight

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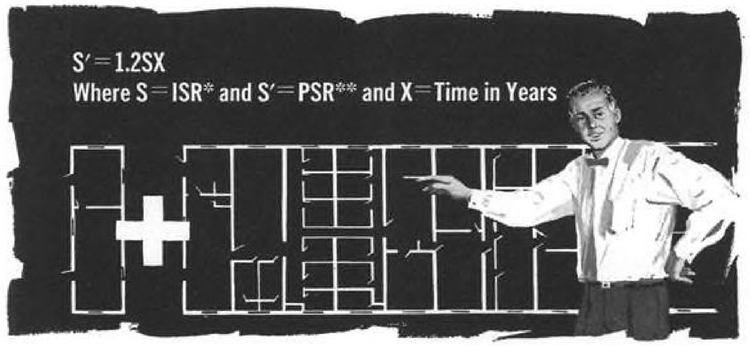
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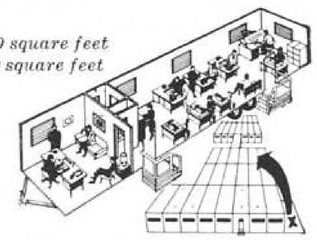
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NASA MAP: spots the 14 temporary locations of the National Aeronautics and Space Administration's Manned Spacecraft Center in the Houston area.

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version structurally and in interior layout, but not fully equipped; a Little Joe 2 launch with command module BP-12 to test abort system at maximum dynamic pressure (q); and a Little Joe 2 launch with another close facsimile of the command module to check out the escape system at maximum q.

First test will be either the Little Joe launch vehicle qualification test or the Apollo boilerplate BP-6 abort test off the cradle. Either could occur in the next few days or weeks. The group not only has new launch vehicles and spacecraft systems to test, but also a new launch facility, and it is working with a range support team new to the mission. Fortunately, with Mercury program terminated, experienced launch personnel have been available to come to White Sands from Cape Canaveral to help in this critical phase.

New Launch Pad

ALA-3 required considerable modification from the Redstone launch configuration, but provided a savings over the cost of a new facility. The work involved building a new launch pad large enough to take both the Little Joe 2 launcher and the special cradle from which the command module abort tests will be made. The power of the Little Joe 2 compared with that of Redstone required locating the new launch pad about 1,100 ft. from the blockhouse, or about twice the distance of the Redstone pad. Height of the Redstone service gantry was raised 33 ft., service platforms were extended out approximately 10 ft., and a white room was added.

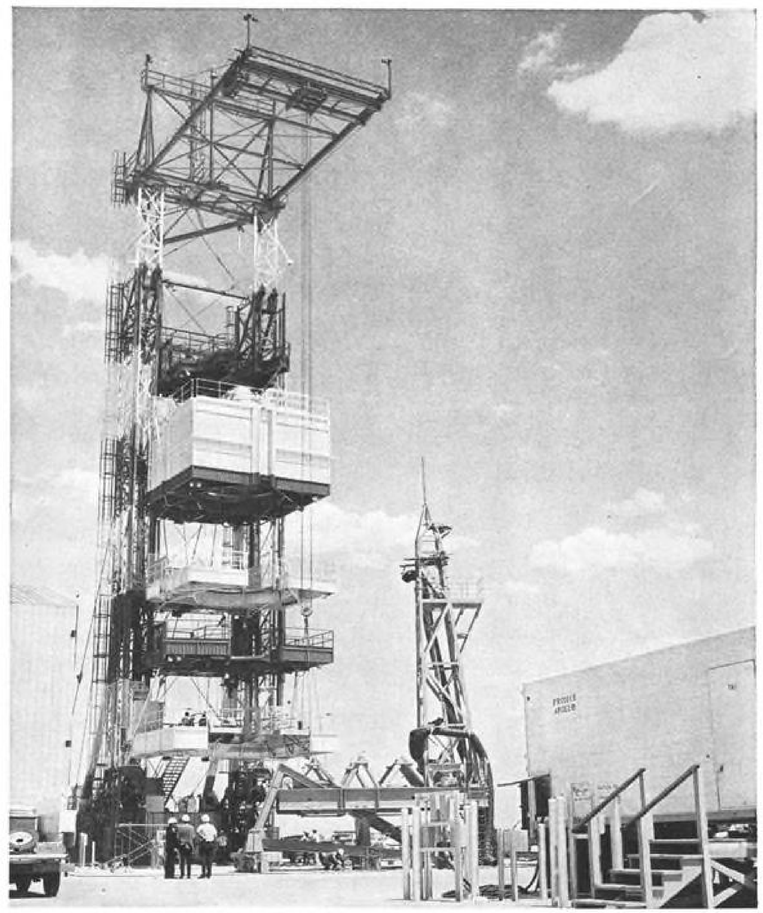
The Little Joe launcher is a steel structure weighing some 100,000 lb. and designed to swivel around on rails through 140 deg. for down-range positioning.

The launch angle can be varied from 75 deg. to vertical. Gantry tracks also had to be extended to the new pad and a utilities tunnel added.

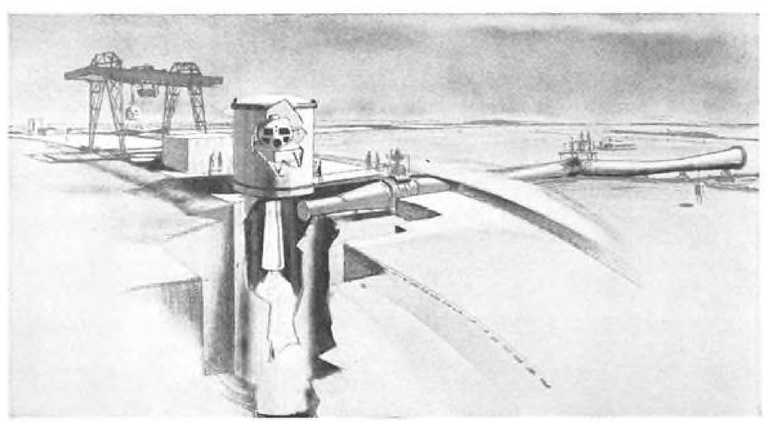
Vertical Assembly

A vertical assembly building for Little Joe 2 has been erected near the launch area. It includes office space and will handle checkout of all instrumentation, alignment of components and weight and balance tests to determine center of gravity of the vehicle. A novel "Teki" hut, consisting of a building that can be disassembled vertically and quickly reassembled, will be used for on-the-pad checkout of the command module prior to pad abort tests. The structure is moved to safety prior to launch.

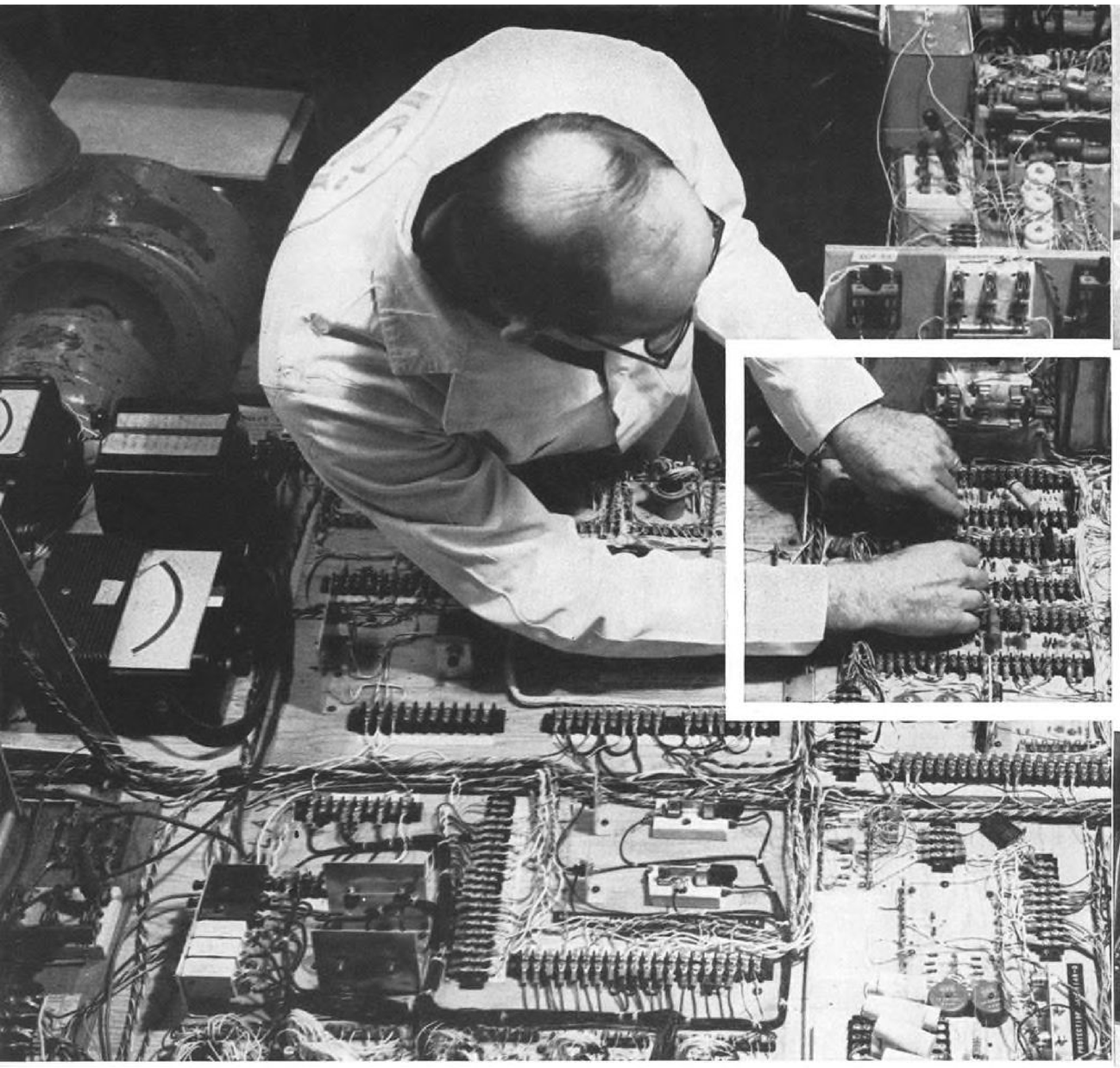
Test set-up in the bunker provides consoles for General Dynamics/Convair, the vehicle contractor; North American, the command module con-

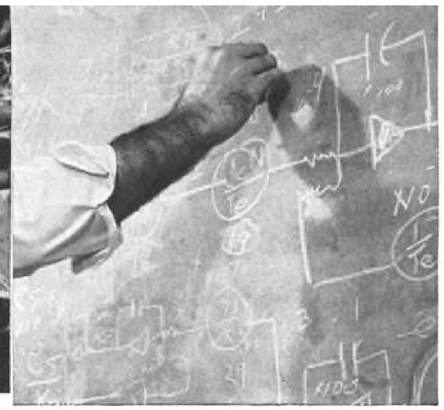


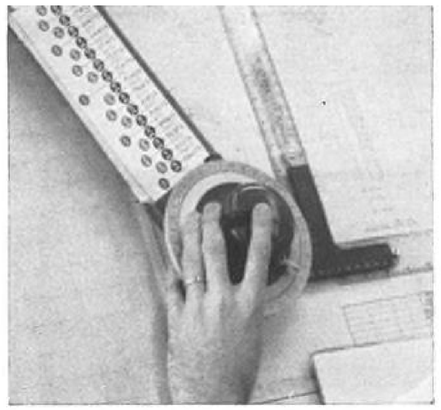
LITTLE JOE 2 gantry at White Sands Missile Range is a modified Redstone missile service tower which has been fitted with an enclosed platform working area. The Little Joe 2 launcher is directly in front of the gantry. First Apollo flight test will simulate an abort condition on the pad to qualify the escape system. This test will be conducted near the Little Joe 2 launching area.

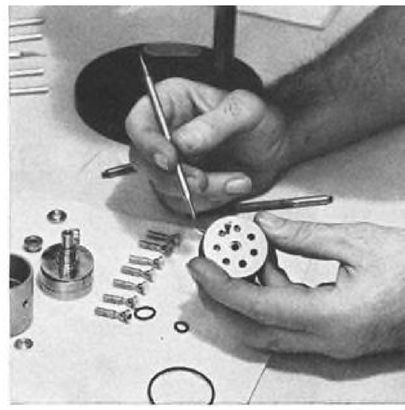


LUNAR EXCURSION MODULE propulsion test chamber at White Sands is designed as a facility in which both descent and ascent engines can be fired in a simulated lunar environment. Drawing shows a cutaway of the test chamber with a lunar bug concept inside. The facility will be ready for tests in about a year.

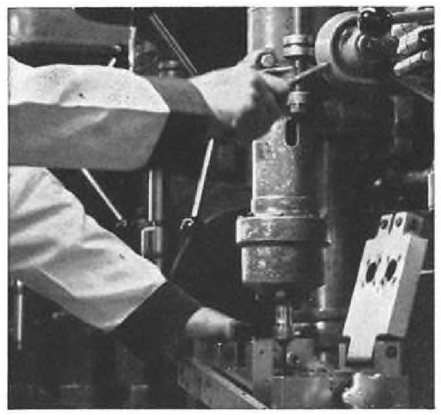




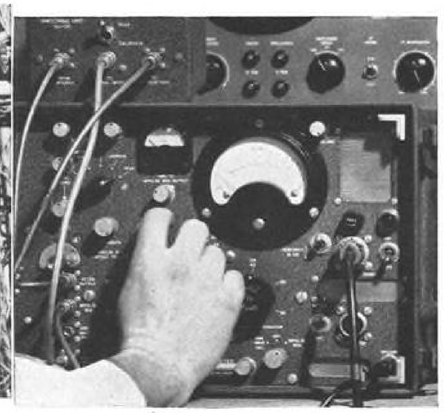


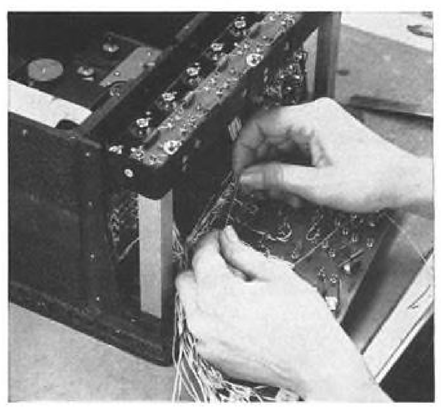


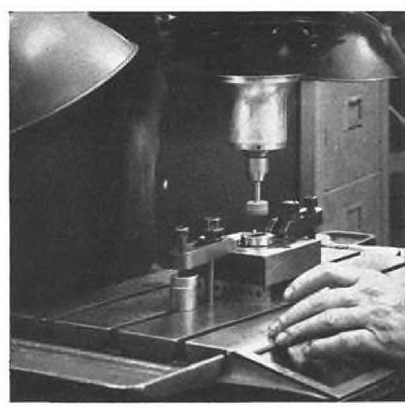
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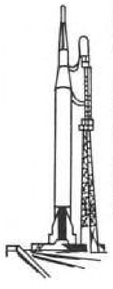
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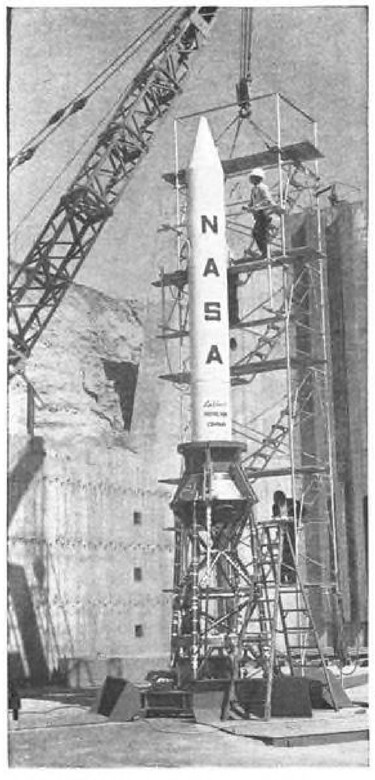
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tractor and a NASA test conductor. When the test conductor is satisfied that all elements of the test program are satisfactory, he will turn a key, passing fire control to the Convair launch operator. In the case of pad aborts, NASA conducts and fires the mission.

The Apollo Propulsion Systems Development Facility (PSDF), some 17 mi. from Las Cruces, will comprise a North American test area, which is scheduled to have its first Apollo service module engine stand operational in September and the second in the spring of 1964; and a Grumman test area, with three stands programmed to be operational before the end of 1964.

The North American facility will be designed to add altitude simulation capability at a later date, if funding becomes available; two of the three Grumman LEM engine stands will have the altitude simulation capability. The engine test area will have a hypergolic fuel storage area common to both contractors. Indications are that engine test programs will begin with boilerplate configurations and the engines will be refined in the course of testing to flight version.

Four miles west of the engine test area will be administration buildings providing office space for NASA.



LOCKHEED solid propulsion Apollo launch escape motor will be tested at White Sands.

Remember the Convair 110?

FIRST OF THE CONVAIR-LINERS . . .



(General Dynamics/Convair Photo)

. . . and Barber-Colman was there!

Remember V-J Day? Plans for peacetime airliners already were on the drawing boards. And less than a year later, Consolidated Vultee's Convair 110 was airborne —accenting comfort instead of weapons systems.

Only one model of this prototype aircraft existed, but from it came more than 1000 related twin-engined transports: the 240, 340, and 440 Convair-Liners; Air Force C-131 and T-29; and the Navy R4Y.

Tailored for safe, comfortable service over medium- and short-range routes, the Convair-Liners carried many improvements suggested by professional airline pilots and engineers. Among them: refinements in the pressurized fuselage, a self-contained stairway in the door, and a cabin heating system designed to eliminate drafts. As part of that system, Barber-Colman temperature controls helped hold cabin temperature at living-room comfort. They also were at work in the cockpit . . . on the first application of temperature controls to an anti-ice system for electrically heated windshields.

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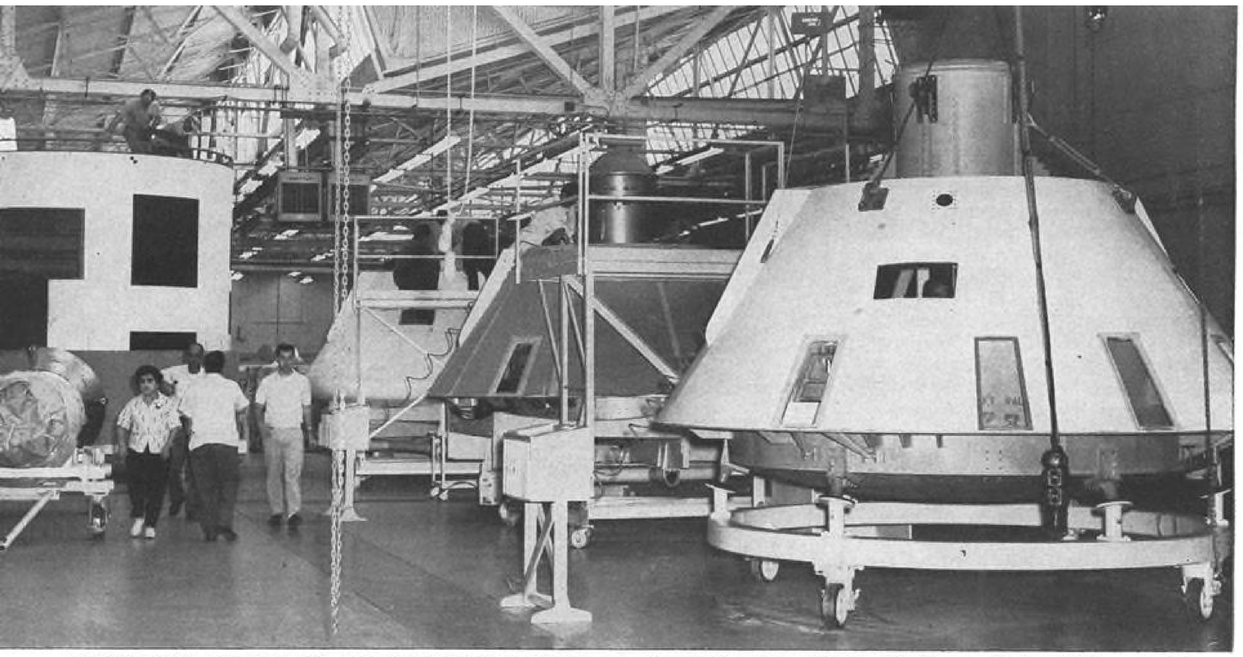
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INTEGRATION, RELIABILITY AND CHECKOUT considerations in the Apollo program begin with the manufacture of the early boilerplate models. Here, at the North American plant in Downey, command modules are assembled for ground and flight qualification.

Integration, Reliability, Checkout Emerge

Daytona Beach, Fla.—National Aeronautics and Space Administration will use General Electric as a staff assistant on the Apollo program to gather and process both design and performance data on all the many parts of the manned lunar landing project, to validate and disseminate this information, and to develop automatic checkout equipment for both spacecraft and launch vehicle.

As the contractor responsible for reliability, integration and checkout in the Apollo program, GE's Apollo Support Dept. of the Command Systems Div. will provide both continuing and on-call service in these areas to NASA's Office of Manned Space Flight, Washington, D.C.; Manned Spacecraft Center, Houston, Tex.; Marshall Space Flight Center, Huntsville, Ala.; and Launch Operations Center, Cape Canaveral, Fla.

The support, both NASA and GE emphasize, will be rendered in an advisory—not a command—capacity. The space agency retains the prerogative of using the company's work as it best sees fit.

Of the three responsibilities assigned to them today, GE personnel feel that integration and reliability are about on a par in difficulty and that checkout—the only real hardware area on the contract—involves a considerably greater effort.

Two separate but compatible checkout systems will be built, one—called PACE (for pre-flight acceptance checkout equipment)—for the Apollo spacecraft, and the other, presently without an acronym, for the Saturn 5 launch vehicle. The PACE system, which consists of a pulse-code-modulation (PCM) ground sub-station, two high-speed digital computers, displays, data transmission and spacecraft-associated equipment, has been designed and developed by the Pre-Flight Operations Div. of the Manned Spacecraft Center.

GE is about to issue task orders and specifications for parts of the first two PACE stations. The first station is expected to be installed at North American Aviation's Downey, Calif., plant where the Apollo spacecraft is being built. Checkout system for the launch vehicle is still under design, but major segments of it already have been developed by the Marshall Center.

In contracting for these checkout systems, NASA stipulated that GE should use available components or subsystems as much as possible and retained the right to decide make-or-buy questions. GE, well aware that avionics manufacturers will be watching the procurement of these systems closely, agreed. The company also feels that off-the-shelf items should predominate, at least in the early stages of the program, until experience can be obtained on the adequacy of the parts of the system.

Reliability assessment breaks out into two major areas—mission success probability and crew safety; and design, manufacturing and test of hardware intended for the program.

GE's role in this area boils down to this—how reliable are the reliability figures submitted by contractors and what is the predicted reliability of all their hardware interacting together? Answers to these questions are vital because of the old chain's-weakest-link maxim and also because, as one GE engineer put it: "As reliability approaches unity, dollars approach infinity."

To bring some standardization into reliability programs of different companies—which are like snowflakes in that no two are exactly alike—GE will develop a variety of survey techniques, check lists, scoring methods, documentation practices, etc., for NASA's use in evaluating a contractor's manufacturing and test operations. Purpose will be to provide NASA with a yardstick against which all Apollo firms may be measured, rather than to challenge the methods of any one company.

In the other area of reliability assessment—mission success and crew safety—GE will attempt to develop a graduated scale of varying success for the major goal of the Apollo program, based on reliability estimates of the equipment to be used. At one end of the scale, a totally successful mission includes crew safety; at the other end, a lost crew means that the mission was not a complete success. Between these extremes are varying proportions of mission success and crew safety. GE will attempt to predict these ratios for NASA's evaluation and/or action.

The company will do this by the construction of mission models. These models are block-diagram flow-charts, with some presently running to 40 ft. in length. Apollo missions are broken up in phases, such as launch, earth orbit, translunar flight, and the phases in turn are divided into critical events, such as first stage ignition, shutdown of the second stage, firing of the shaped charge to separate stages, etc.

Events, one to a block, are tied to each other as they would be functionally in an actual flight. Thus, if squibs must be armed prior to their firing (one event) in order to activate a shaped charge which separates two stages (the next consecutive event), these two blocks would be joined by a single line on the flow chart and would appear to be in series. Redundant circuits would appear in parallel.

Within each block, GE identifies the critical hardware associated with the function. Backing up each of these small fine-print blocks is a booklet containing details on this hardware—mean-time-between-failure rates, duty cycles, etc. From this data, GE can predict the probable success of any block, by itself or mathematically integrated with every other block on the chart.

In building the blocks, GE has selected the lunar landing flight profile as the basic model. Apollo missions preceding the first manned landing, such as a manned circumlunar reconnaissance, could be predicted, using the phases of the model up to but not including the landing, and adding phases peculiar to the mission. At present, GE has identified 13 phases and 112 events in the lunar landing flight profile. The company expects to resolve the events to an even finer grain by September when the figure grows to more than 250.

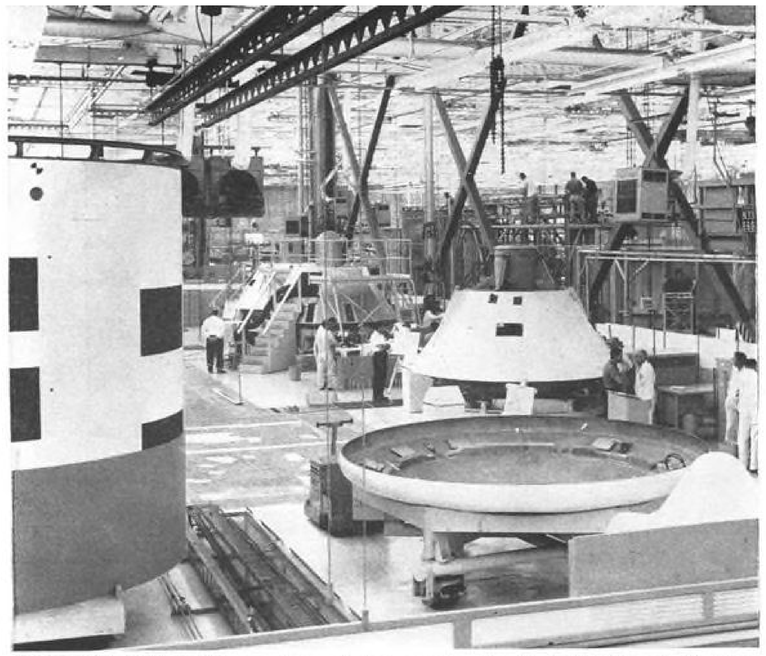
Value of this and other models (GE has constructed models for seven alternate missions, such as earth orbit, circumlunar fly-by, lunar recon, etc.) lies in determining the success probability of subsequent missions, once ac-

Static Test Support

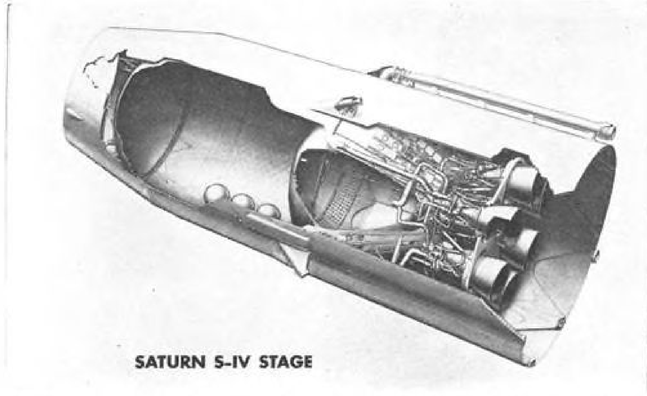
Daytona Beach—Support of the National Aeronautics and Space Administration's Mississippi Test Facility will be provided by a new and as yet unestablished department within General Electric's Command Systems Div. Apollo Support Div. also is part of the Command Systems Div., but will have no connection with the Mississippi support contract.

A GE spokesman said the company has had considerable experience in managing the support of large government plants, such as the Atomic Energy Commission plant in Hanford, Wash.

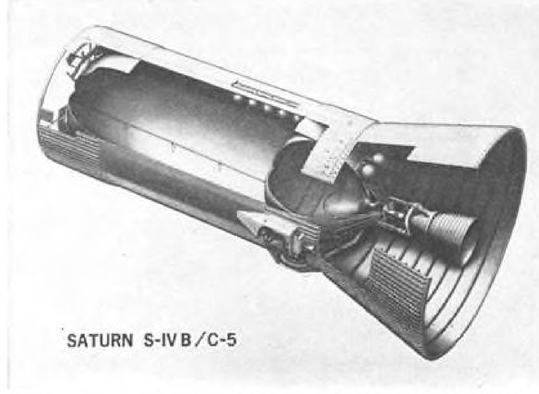
The spokesman said that it is likely that GE will farm out most of the housekeeping functions associated with the contract, now being negotiated, to subcontractors and retain "the considerable technical content" of the support functions involved in the Saturn static test stands.



AFT HEAT shield details are shown in foreground prior to installation of aluminum honeycomb and lead ballasting in production of test modules at North American.



SATURN S-IV STAGE



SATURN S-IVB/C-5

RELIABILITY OF SYSTEMS such as these hydrogen-fueled Saturn upper stages must be assured before manned space flight is attempted using these stages. The Douglas-built S-4 is powered by a cluster of six RL10-A3 engines, and S-4B by a J-2.

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CAREER NEWS FROM HUGHES

Aerospace Divisions in Culver City, California

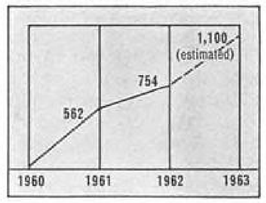
NEW AND CONTINUING PROGRAMS AND PROJECTS

F-111B PHOENIX Missile System
MMRBM (Integration, Assembly and Checkout)
SURVEYOR Lunar Landing Vehicle
SYNCOM Synchronous Communications Satellite
POLARIS Guidance
TOW Anti-tank Missile
ARPAT
VATE Automatic Checkout System
FALCON Missiles
HARD POINT DEFENSE

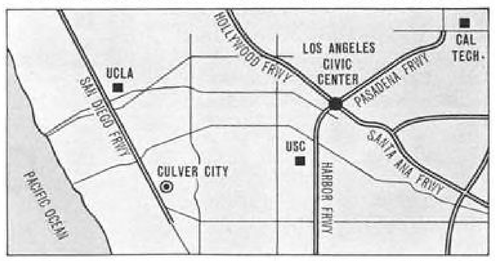
These examples of Hughes Aerospace activities are representative of *more than* 230 major product and service capabilities ranging from aerospace vehicles to ASW systems.

GROWTH OF THE TECHNICAL STAFF

Of the nearly 9,000 employees of these divisions, 2,600 are Members of the Technical Staff. Average length of experience is 10.0 years. Average age is 32 years.



HUGHES/CULVER CITY & LOS ANGELES



Hughes Aerospace Divisions at Culver City offer engineers and scientists a unique combination of urban and suburban advantages. The plant is immediately adjacent to a major freeway. Los Angeles Civic Center is about a half-hour distant. Beach communities are just minutes away. Attractive residential neighborhoods are nearby. UCLA, USC and Cal Tech offer outstanding educational facilities.

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tual flight experience has verified them; in providing a measure against which proposed hardware improvements may be judged; in optimizing trade-offs between mission success and crew safety; and in revealing deficiencies—either in hardware performance (perhaps requiring redundant equipment) or in procedures (can a pilot do all of the tasks required of him in the time allotted?).

Integration, the final area of GE's contract, is perhaps the most frequently misunderstood. Mention the word to 100 aerospace engineers and 99 will give a definition suggesting the type of job Boeing does in assembling the three stages of the Minuteman ICBM.

But by integration, GE and NASA mean:

- **Assuring clear and intelligible** communications between the many government and industrial members of the Apollo team.
- **Developing common methods,** procedures and standards for all major Apollo systems. This would apply to standardized methods of drafting as well as for reporting systems status.
- **Searching for problems** which might fall between different areas of responsibilities, the between-the-cracks problems that go unnoticed for so long because no one is responsible for the areas.

As examples of these first two areas, GE presently is writing a classified encyclopedia of all Apollo systems, in which the hardware and its functions are described; a glossary of terms used in the Apollo program and their meanings as understood by NASA; a handbook of symbols used in various Apollo documents, and a digest-type compilation of all known technical writings on the moon. GE recently worked out two handbooks, one for Apollo facilities and the other for flight equipment, standardizing drafting methods.

These handbooks, encyclopedias, glossaries, etc., will be distributed by NASA to all major contractors involved with the program and, it is hoped, these companies in turn will see that this information filters down to the lowest responsible working levels. In this way, NASA will have at least the machinery for assuring that Apollo does not become a twentieth-century Tower of Babel.

At present, GE's Apollo Support Dept. has about 900 personnel stationed at its headquarters here. There are about 95 GE personnel at the Manned Spacecraft Center, 375 at the Marshall Center and about 175 with the Launch Operations Center at Cape Canaveral.

Manager of the Apollo Support Dept. is H. B. Fancher. Jack K. Records is director for NASA support. General manager of the Command Systems Div., to which Fancher reports, is Richard L. Shettler.

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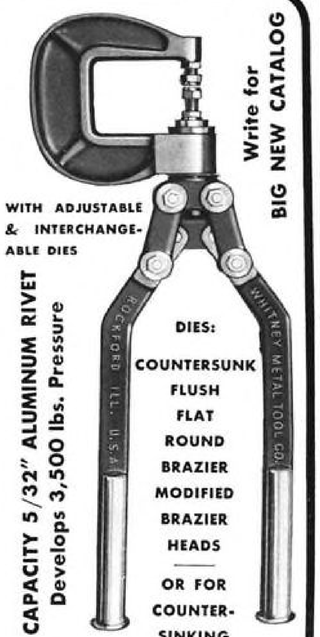
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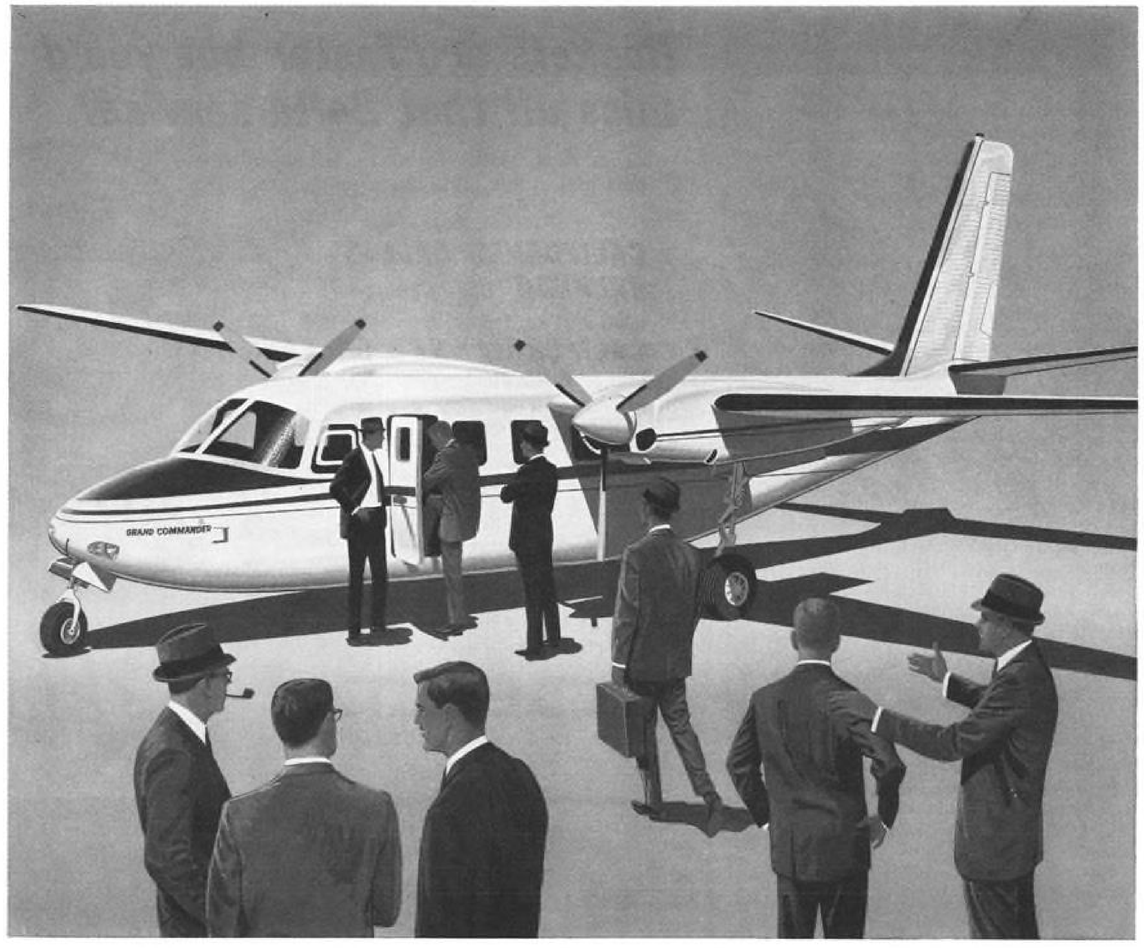


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APOLLO CHECKOUT involves systems such as the Douglas S-4 stage, shown in production.

Cape Preflight Gets Advanced Equipment

Cape Canaveral—Preflight Operations Div. of the National Aeronautics and Space Administration's Manned Spacecraft Center will continue to perform basically the same functions of space craft checkout and preparation for Gemini and Apollo as it did for Mercury, but will be better equipped to do the job for these follow-on programs than it was for the one-man project.

Preflight operations, located here alongside the launch operations center, played a vital, but largely unsung, role in the success of the Mercury program. The division is responsible for checkout, maintenance, inspection and preparation of spacecraft prior to flight. G. Merritt Preston, chief of the division, says his organization functions like a flight-line maintenance crew, research laboratory and job shop.

The division, which has the major instrumentation capability in Manned Spacecraft Center, is using the operational experience it acquired during the Mercury program in the design of automated checkout equipment for Apollo. The equipment, called PACE (for preflight acceptance checkout equipment) is being built by General Electric's Apollo Support Dept. It will allow processing and displaying of large quantities of data in real time. It will allow more flexible test operations and more reliable test operations, because spacecraft test points are provided on the spacecraft and flight connections do not have to be broken. By installing similar equipment at the plants of spacecraft manufacturers—McDonnell Aircraft Corp., North American Aviation, Inc., and Grumman Aircraft Engineering Corp.—consistent and nearly identical test procedures will be provided. With three control modes, manual, manual-semi-automatic, and automatic with manual over-ride, PACE equipment initially will be used predominantly in the manual mode and gradually grow into the automatic mode. It may be developed in time to be of use in the automatic mode during the latter phases of Gemini.

One of the major tasks the division will face in forthcoming manned space flight programs will be trouble-shooting failures. Robert R. Gilruth, director of Manned Spacecraft Center, said failure analysis and corrective actions on faulty spacecraft systems will be conducted at the Cape, "where the availability of the part, the test set-up and the people involved in the test" can best determine the facts.

To meet this requirement, according to Preston, the Preflight Div. will acquire a wide variety of non-destructive test equipment and techniques such as X-rays, mass spectrometers, image intensifiers, ultrasonics and dve penetrants.

Although Gemini offers the possibility of quick replacements of faulty systems, Preston said it would be unlikely that a countdown would be continued after a faulty part had been replaced, if no determination had been made as to the cause of the malfunction, because there would be no guarantee that the replacement part would not fail in the same way.

Until flight data has been acquired on the performance of a spacecraft's systems, it is likely that each failure will be explored in depth at the scene. Although this will be quicker than shipping the part back to the manufacturer's plant, Preston and his people would like to develop a trouble-shooting capability with such a fast response time that missions might only be delayed hours and not postponed for days.

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2	AIR PRODUCTS	52 MG OF LOX	PITTSBURGH, PA.
1	AIR PRODUCTS	52 MG OF LOX	WIERTON, W. VA.
1	AIR PRODUCTS	62 MG OF LOX	SPARROWS PT., MD.
2	AIR PRODUCTS	178 MG OF LN_2	SPARROWS PT., MD.
3	AIR PRODUCTS	100 MG OF LOX	SANTA SUSANA, CALIF.
1	AIR PRODUCTS	200 MG OF LOX	SANTA SUSANA, CALIF.
1	AIR REDUCTION	54 MG OF LN_2	INDUSTRY, CALIF.
1	AIR REDUCTION	54 MG OF LN_2	S. ACTON, MASS.
1	AIR REDUCTION	270 MG OF LN_2	RICHMOND, CALIF.
1	AIR REDUCTION	108 MG OF LN_2	BEAUMONT, TEX.
1	AIR REDUCTION	43 MG OF LOX	BEAUMONT, TEX.
1	AIR REDUCTION	350 MG OF LOX	BUTLER, PA.
1	AIR REDUCTION	350 MG OF LOX	CLAYMONT, DEL.
1	AIR REDUCTION	330 MG OF N_2	BUTLER, PA
1	AIR REDUCTION	330 MG OF N_2	CLAYMONT, DEL.
1	AIR REDUCTION	330 MG OF N_2	ACTON, MASS.
1	AIR REDUCTION	50 MG OF O_2	CHICAGO, ILL.
1	AIR REDUCTION	50 MG OF O_2	INDUSTRY, CALIF.
2	AMERICAN MESSER	350 MG OF LOX	ALBION, MICH.
1	DRAVO	110 MG OF LOX	FARRELL, PA.
1	DRAVO	35 MG OF LN_2	FARRELL, PA.
1	FORD MOTOR CO.	115 MG OF LOX	DETROIT, MICH.
2	LINDE	217 MG OF LOX	HUNTSVILLE, ALA.
1	LINDE	700 MG OF LOX	HUNTSVILLE, ALA.
1	LINDE	700 MG OF LOX	ASHTABULA, O.
1	LINDE	217 MG OF LOX	PUEBLO, COLO.
2	LINDE	217 MG OF LOX	NEOSHO, MO.
1	LINDE	217 MG OF LOX	EAST CHICAGO, IND.
1	LINDE	131 MG OF LOX	LACKAWANNA, N.Y.
1	LINDE	87 MG OF LOX	YOUNGSTOWN, O.
2	LINDE	87 MG OF LOX	ECORSE, MICH.
1	LINDE	217 MG OF LOX	ESSINGTON, PA.
1	LINDE	87 MG OF LOX	DEER PARK, TEX.
2	LINDE	217 MG OF LN_2/LOX	PITTSBURG, CALIF.
1	LINDE OF CANADA	131 MG OF LOX	SAULT STE. MARIE, ONT.
1	N.A.S.A.	125 MG OF LOX	CAPE CANAVERAL, FLA.
1	N.A.S.A.	56 MG OF LN_2	CLEVELAND, O.
1	N.A.S.A.	35 MG OF LN_2	CAPE CANAVERAL, FLA.
1	N.A.S.A.	64 MG OF LN_2	GREENBELT, MD.
3	N.A.S.A.	75 MG OF LOX	NIMBUS, CALIF.
2	N.C.G.	35 MG OF LOX	CHICAGO, ILL.
1	ROCKETDYNE	100 MG OF LOX	SANTA SUSANA, CALIF.
3	ROCKETDYNE	220 MG OF LOX	EDWARDS AFB, CALIF.
1	ROCKETDYNE	300 MG OF LN_2	EDWARDS AFB, CALIF.

LH_2 STORAGE (−423° F)

AIR PRODUCTS	200 MG	LONG BEACH, CALIF.
AIR PRODUCTS	200 MG	LONG BEACH, CALIF.
AIR PRODUCTS	90 MG	INDIANA TOWN, FLA.
AIR REDUCTION	100 MG	PEDRICKTOWN, N.J.
DOUGLAS AIRCRAFT	90 MG	NIMBUS, CALIF.
DOUGLAS AIRCRAFT	90 MG	NIMBUS, CALIF.
LINDE	342 MG	ONTARIO, CALIF.
LINDE	44 MG	TORRANCE, CALIF.
LINDE	750 MG	SACRAMENTO, CALIF.
N.A.S.A.	100 MG	NIMBUS, CALIF.
N.A.S.A.	100 MG	NIMBUS, CALIF.
N.A.S.A.	227 MG	MERCURY, NEV.
N.A.S.A.	110 MG	MERCURY, NEV.
N.A.S.A.	105 MG	NIMBUS, CALIF.
N.A.S.A.	70 MG	MERCURY, NEV.
N.A.S.A.	250 MG	NIMBUS, CALIF.
N.A.S.A.	250 MG	NIMBUS, CALIF.
PRATT & WHITNEY	90 MG	UNITED, FLA.
ROCKETDYNE	560 MG	SANTA SUSANA, CALIF.
ROCKETDYNE	90 MG	SANTA SUSANA, CALIF.

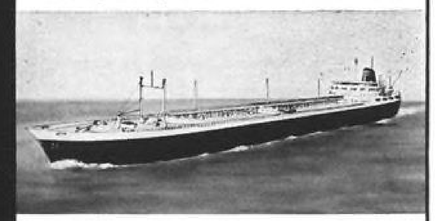
LNG SHIPMENT AND STORAGE (−259° F)

CONSTOCK, TANKER— "METHANE PIONEER"	32,000 BBL LNG	OCEAN TANKER
CONCH, TANKER	170,000 BBL LNG	OCEAN TANKER
METHANE TANKER LTD.	170,000 BBL LNG	OCEAN TANKER
CONSTOCK LIQUID METHANE	35,000 BBL LNG	LAKE CHARLES, LA.
NORTH THAMES GAS BOARD	16,400 BBL LNG	CANVEY IS., ENGLAND
NORTH THAMES GAS BOARD	16,400 BBL LNG	CANVEY IS., ENGLAND
NORTH THAMES GAS BOARD	59,300 BBL LNG	CANVEY IS., ENGLAND
NORTH THAMES GAS BOARD	59,300 BBL LNG	CANVEY IS., ENGLAND
NORTH THAMES GAS BOARD	59,300 BBL LNG	CANVEY IS., ENGLAND
NORTH THAMES GAS BOARD	59,300 BBL LNG	CANVEY IS., ENGLAND
NORTH THAMES GAS BOARD	59,300 BBL LNG	CANVEY IS., ENGLAND
C. A. duMETHANE LIQUIDE	69,189 BBL LNG	PORT ARZEW, ALGERIA
C. A. duMETHANE LIQUIDE	69,189 BBL LNG	PORT ARZEW, ALGERIA

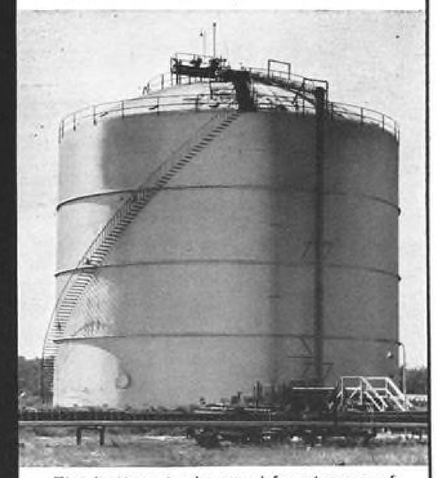
*Capacity is expressed in thousands of Gallons (MG) or Barrels



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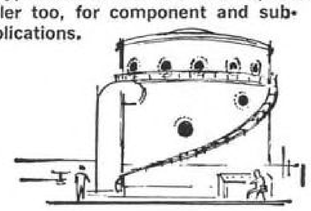
How small is an Environmental Chamber?

As small as Tenney's new bench model Tenney Jr., a mechanically-refrigerated, portable, high-low temperature chamber that sells for only $990. Of course, they range upward in size, too, depending on what you're testing and what environments you need.



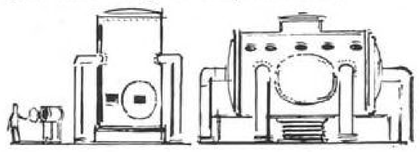
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Aircraft and Power Plant Performance Analysts, BS degree, experienced in flight test, preferably including FAA certification.

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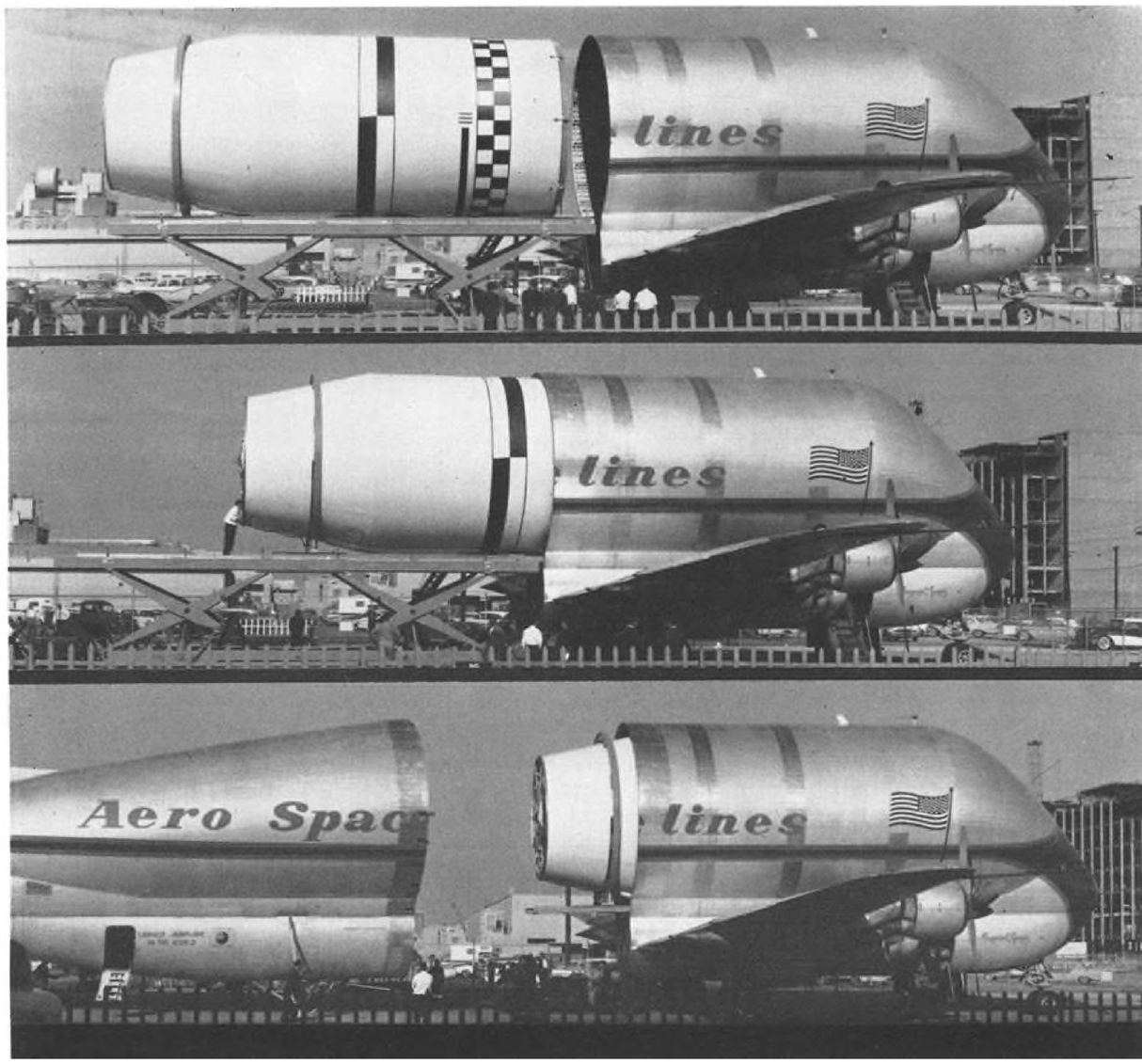
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Modified Boeing 377 to Haul S-4 Stages and F-1 Engines

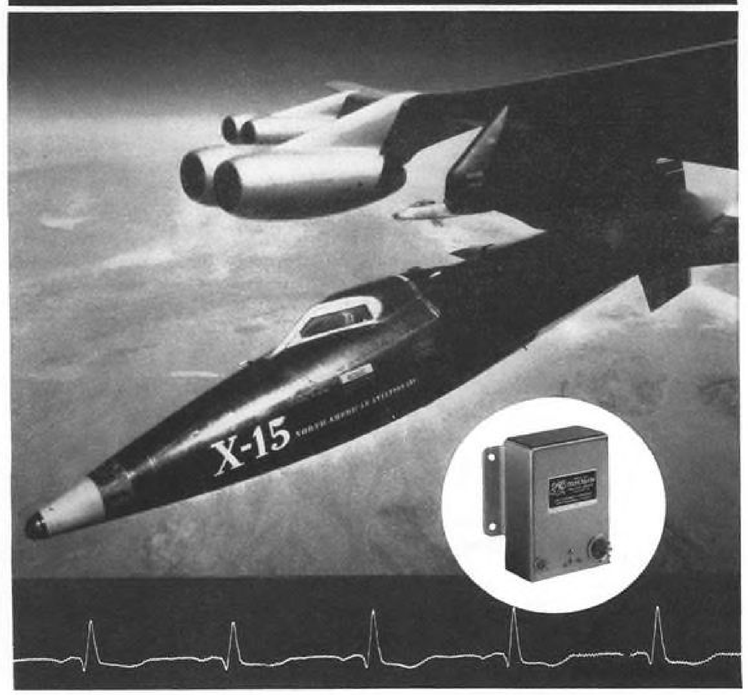
Aero Spacelines, Inc., will transport Saturn S-4 upper stages and F-1 1.5 million lb. thrust engines in this converted Boeing 377PG (Pregnant Guppy) between industry plants on the West Coast and National Aeronautics and Space Administration facilities on the East Coast. Plane (AW June 24, p. 80) recently test-loaded an inert S-4.



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PCM TELEMETRY ENGINEERS

to develop a PCM System utilized in checkout of the spacecraft systems.

SYSTEMS ENGINEERS

to analyze spacecraft vehicle system characteristics and perform system studies of an automatic digital checkout system.

RF SYSTEMS ENGINEERS

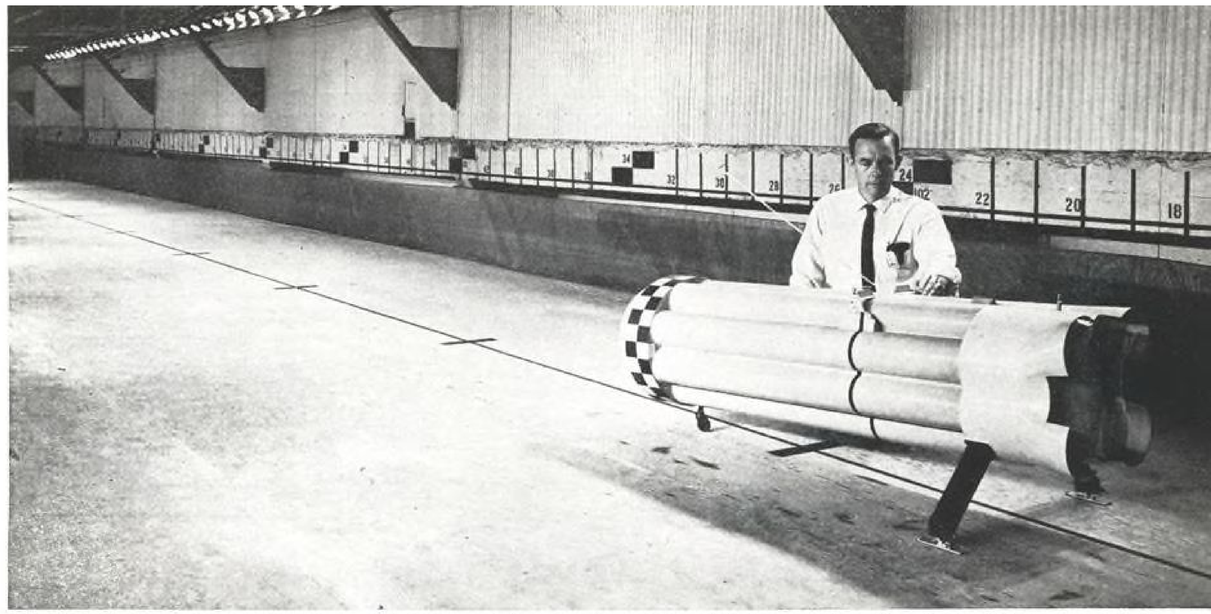
to analyze requirements and establish criteria for RF system checkout equipment.

Send your resume (in complete confidence) to: Mr. A. G. Moseby, Engineering and Scientific Employment, 12214 Lakewood Blvd., Downey, California.

All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

SPACE AND INFORMATION SYSTEMS DIVISION

North American Aviation



INSTRUMENTED one-fourteenth scale model of Saturn 1 first stage is used to study forces and motions that might be expected if paraglider and skid landing gear system were used to recover large launch vehicles on prepared landing surfaces.

Large Vehicles Alter Handling Concepts

Cape Canaveral—Tremendous physical sizes, unprecedented reliability requirements and the necessity for fast re-cycle times have forced the National Aeronautics and Space Administration to adopt new concepts and methods in preparing its launch vehicles for flight.

The size of the combined Saturn 5-Apollo vehicle is awesome. The three-stage launch vehicle and its three-module spacecraft stand nearly 375 ft. tall. Fully fueled on the launch stand, it will weigh nearly 6 million lb., all but 450,000 lb. of which will be propellants.

The first and second stages—the Boeing S-1C and the North American Aviation, Inc., S-2—of the Saturn 5 vehicle alone are about 220 ft. tall—taller by twice than an Atlas-Centaur combination and nearly 60 ft. taller than a complete Saturn 1 vehicle, with payload.

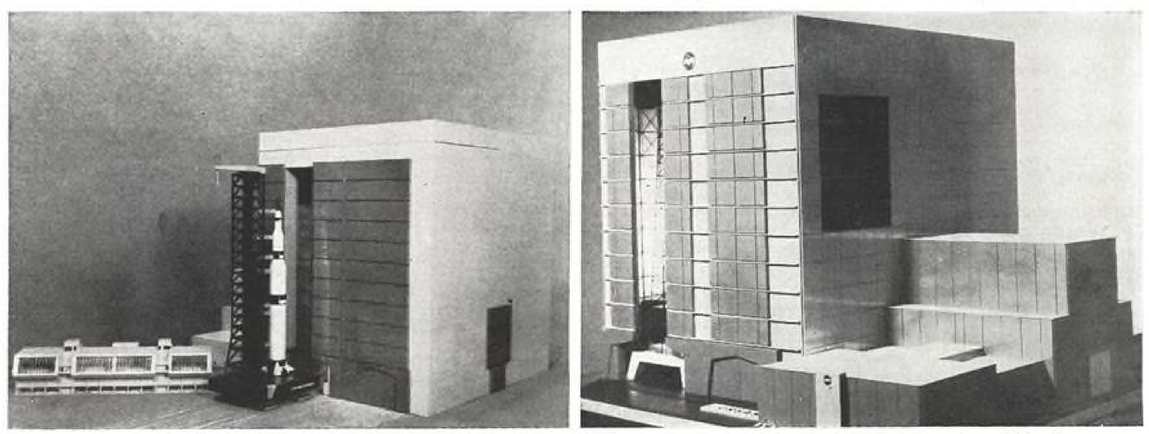
The third stage, the Douglas Aircraft Co. S-4B, at 60 ft. in length and 21 ft. in dia., would itself have been considered a large booster a few years ago.

With these sizes and more than 3,300 test points on the complete three-stage vehicle, NASA's Launch Operations Center decided to assemble the Saturn 5 in a sheltered environment and to use automated test equipment to provide rapid and more efficient checkout of the hardware involved.

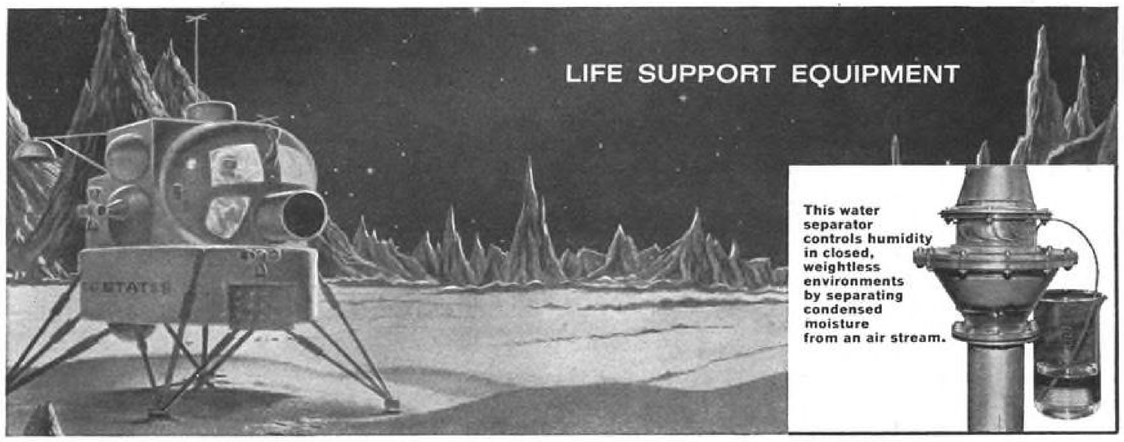
This equipment, to be manufactured by General Electric's Apollo Support Dept. (see story, p. 281), will continuously monitor the status of each stage and report this data back to the launch control center.

Size of the Saturn stages presents some new challenges in manufacturing and transportation. Of the five stages—Chrysler S-1, S-1C, S-2, Douglas S-4 and S-4B—which make up the Saturn 1, 1B and 5 configurations, only the S-4 is being manufactured in a horizontal position. This is the only stage which is small enough to be shipped by air. The others will be shipped by barge.

The S-4, 40 ft. long and 18 ft. in dia.,



NASA USES MODELS of Saturn-Apollo vertical assembly buildings to demonstrate new concepts forced by launch vehicle sizes.



Engineering Opportunities at Hamilton Standard

To meet the life support requirements of long-duration space flights, an efficient, largely regenerable environmental control system will be needed. The primary design parameters: extreme reliability plus simple modular construction for easy maintenance.

The water separator shown above is part of this system now under advanced development at Hamilton Standard. In addition to separating condensed moisture from the air, the device, when integrated with space capsule environmental control equipment, utilizes centrifugal force to pump the condensate to a storage vessel.

Other problems now being studied by Hamilton Standard's life support equipment engineers include: improved cryogenic storage systems for zero g applications, carbon dioxide removal and reduction, two-gas atmosphere pressure control systems, and rejection of metabolical equipment heat via space radiators. All this will require proven techniques in systems analysis and integration in order to insure dependability and efficiency.

Dealing with these and other problems, Hamilton Standard engineers and scientists are a special breed of men. They are men capable of coordinating complex programs, men who can maintain close liaison with customers, men who can visualize and pursue the total program. They are men with a strong analytical bent, willing to wrestle with problems now that can lead to proposals in the years ahead. If you are this kind of man, and you qualify for any of the positions listed, send your resume to:

Mr. H. O. Wakeman, Personnel Department.

DESIGN ENGINEERS—with background in structural design of aircraft or aircraft components. Familiarity with mechanical design of heat exchangers, rotating machinery, hydraulic and pneumatic valves. Familiarity with system analysis involving establishment of schematics and trade-off studies. Some experience in structural and thermodynamic analysis.

ANALYTICAL ENGINEERS—with experience that has emphasized analytical studies in thermodynamics and heat transfer. Familiarity with environmental system concept, analysis, and trade-off studies. Knowledge of turbine, fan, compressor, and heat exchanger design and test analysis.

DEVELOPMENT ENGINEERS—for varied assignments on mechanical systems involving heat exchangers, rotating machinery, hydraulic and/or pneumatic equipment. Should have experience in devising and conducting environmental tests for structural and performance evaluation and preparing component specifications for tests, manufacture, and procurement. Familiarity with thermodynamics, heat transfer, hydraulics, pneumatics, and electricity.

ADVANCED PLANNING ENGINEERS—to conduct preliminary design and research studies, prepare and present new product technical proposals. Requires knowledge of thermodynamics, heat transfer, environmental system analysis, control dynamics, and cryogenics. Some experience in hardware development and cost estimating of engineering programs.

TEST/RELIABILITY ENGINEERS—with experience in structural and failure analysis of mechanical systems involving heat exchangers, rotating machinery, hydraulic and pneumatic valves. Knowledge of fabrication and test procedures for such systems. Preferred background includes familiarity with techniques of reliability analysis, reliability testing, and failure analysis, and experience in applying these techniques in setting system reliability goals, apportioning reliability to system components, and monitoring component and system development to achieve assigned goals.

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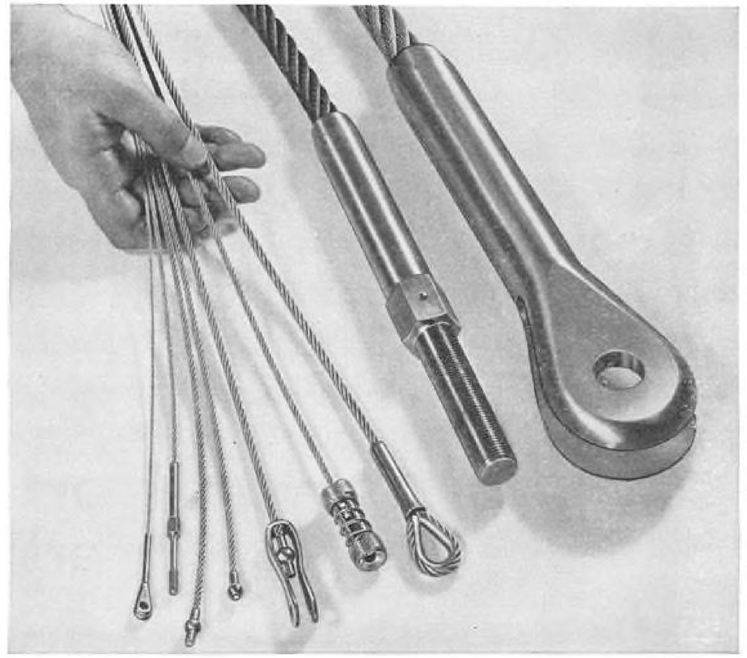
Write for Catalog and application data.

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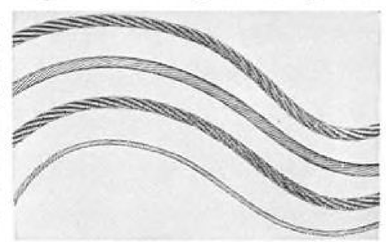
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"No-Mag" cable is non-magnetic, won't interfere with instrument operation. In corrosion-resistance and thermal characteristics, it is superior to standard stainless steel. "No-Mag" aircraft cables also offer high fatigue and abrasion resistance, are available in a complete range of sizes in all the standard aircraft constructions.



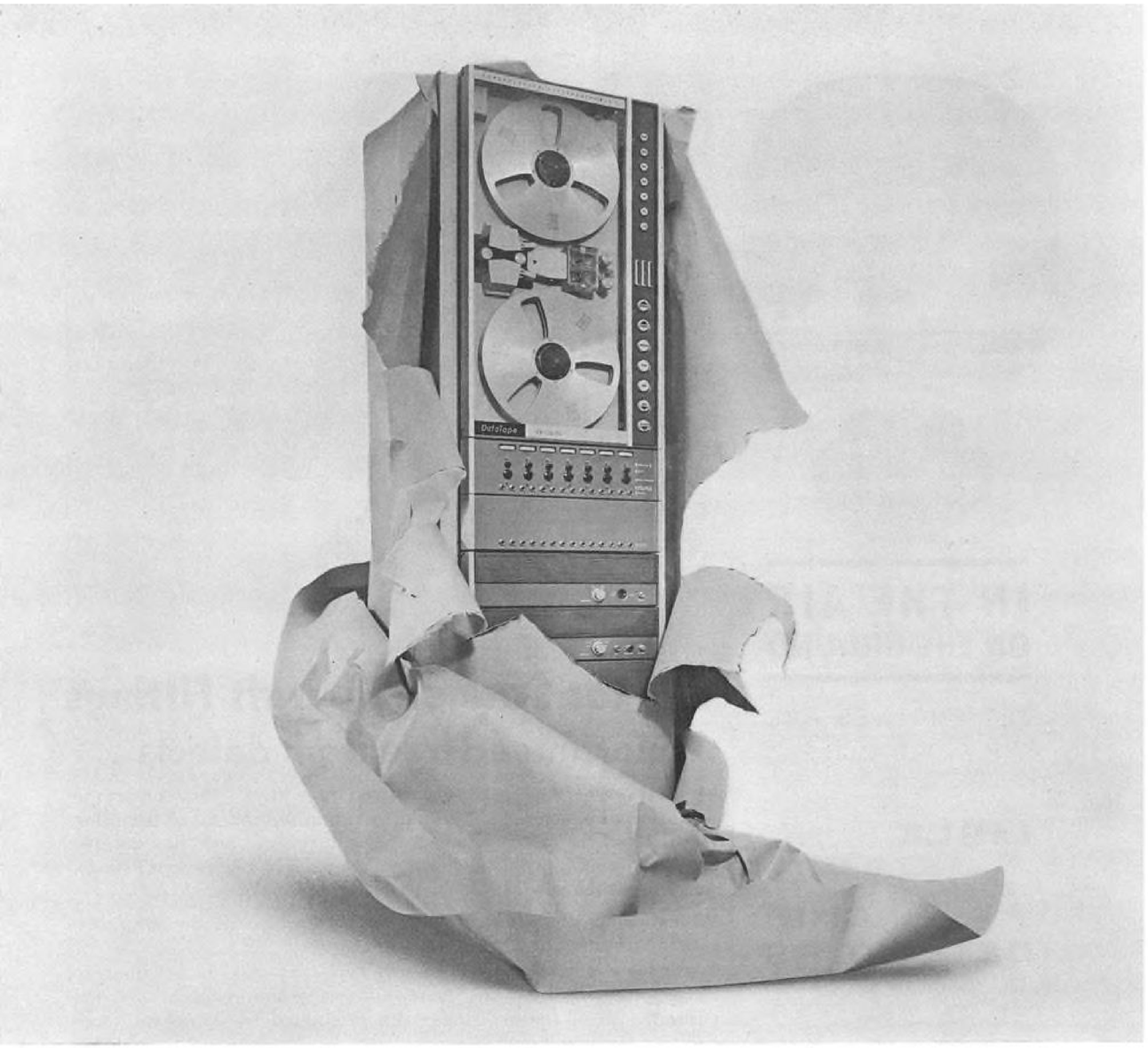
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It's been proven with units built and delivered in quantity.

And the VR-3600's outstanding specifications make it a "state-of-the-art" system, with performance superior to any comparable instrumentation in the extremely wide bandwidth, multi-channel field. Each of the unit's 7 or 14 record/reproduce channels can be used for data storage in the 100 kc to 1.5 mc frequency range...with high signal-to-noise and low distortion characteristics.

The direct system has a full 1.4 mc bandwidth, fully amplitude and phase equalized, with less than 2% harmonic distortion. No intermodulation product exceeds 0.75%, and phase response is held to within 0.2 usec.

In the tape transport, skew is under —.30 usec., flutter is less than 0.30% p-p at 120 ips, tape is constantly cleaned by a vacuum/ionization device and tension is held smoothly constant by a closed-loop servo.

Contact your local CEC sales representative, or write for Bulletin 3600-X15.



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2 more ways to measure with CEC



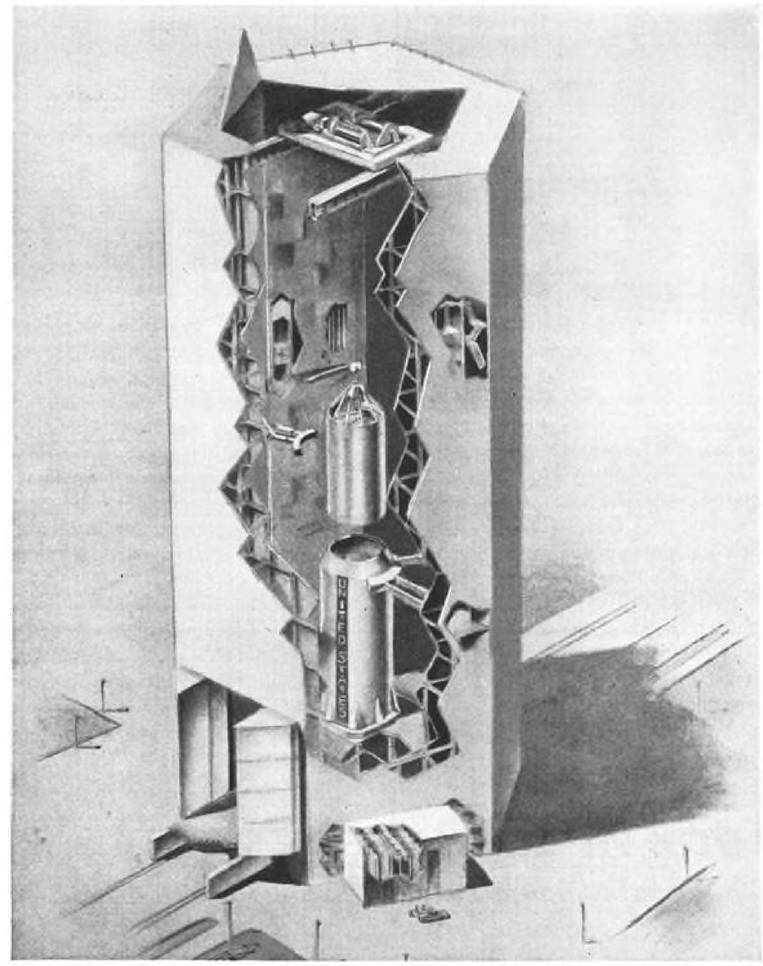
You get twice the bandwidth capability of conventional machines at equivalent speeds with two other CEC wide band tape systems, the VR-3300 portable and the VR-2800. Bandwidth of direct recording/reproducing is 100 cps to 200 kc; 0 to 20 kc with wide band FM techniques. They're designed to fill gaps between the workhorse 100 kc models and more sophisticated machines. Solid state for greater inherent reliability, CEC's VR-2800 and VR-3300 feature standard EMA rack mounting and can be used in the lab, van, ship or blockhouse. Both systems are available for 7 channel (½" tape) or 14 channel (1" tape) operation. Interchangeable electronics means economy in support spares.

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POSSIBLE ASSEMBLY technique for post-Saturn launch vehicles is shown in this Martin concept, which draws on the vertical assembly experience developed for Saturn.

will be carried by a specially-configured Boeing 377 air freighter (AW June 24, p. 80).

S-2 stages will be barged from the manufacturing plant at Newport Beach, Calif., through the Panama Canal to the Mississippi Test Facility for static firings. The stages then will go by barge around the tip of Florida to the Cape Canaveral launch site. S-1 and S-1C stages will be barged between the Michoud, La., manufacturing plant, Mississippi Test Facility and the Cape.

Vertical Assembly

Assembly and checkout will be done in the 514-ft. vertical assembly building being constructed here. The structure will have more than 333,000 ft. of floor space with four high bay areas, each of which can be used for buildup of a Saturn 5 vehicle.

Vertical assembly concept was dictated fundamentally by the over-all size of the vehicle—lifting a 300-ft., 200-ton vehicle from the horizontal to vertical would require an erector of a size and complexity rivalling that of the launch vehicle itself.

Eliminates Bracing

Further, to hold circularity of stages of the sizes in Saturn and to assure alignment of mating points would require heavy internal bracing, which would be dead weight during powered flight.

From the central concept of vertical assembly have come other ramifications. The platform on which the vehicle will be assembled will be the launch table. It will be taken to the firing point by a diesel-powered tracked mover, together with a 380-ft. tower to be used for initial assembly and final checkout.

Fuel lines will be supported by umbilical swing arms on the tower. High-speed pumping requirement can be vis-





Here, at Lockheed Missiles & Space Company's Space Communications Laboratory, scientists are re-investigating the possibility of using the moon to facilitate earth communications. Possibilities for the use of the moon as a relay station for earth-to-earth communications have been largely neglected because the moon's shape and rugged surface greatly distorted a return signal. But Lockheed research into the extension of communications on difficult communication channels, using techniques applicable to dispersive time variant channels, is making significant inroads into this problem.

Another area receiving intense study at Lockheed is satellite tracking of deep space probes. Since tracking accuracy depends greatly on stations being as far from each other as possible, while retaining line-of-sight communications, Lockheed is studying the use of two earth-orbiting satellite tracking stations, 8000 miles apart. Not only would great accuracy be gained by the separation, but it would be further enhanced by the positioning of the stations above the earth's atmosphere, thus eliminating atmospheric distortion.

Examples of other research projects being pursued by Lockheed in the communications area include: Random multiplexing, satellite readout techniques, scatter communications, radar mapping, submarine tracking, modulation of optical energy, communications over multipath channels, and learning systems.

LOOK AT LOCKHEED... AS A CAREER

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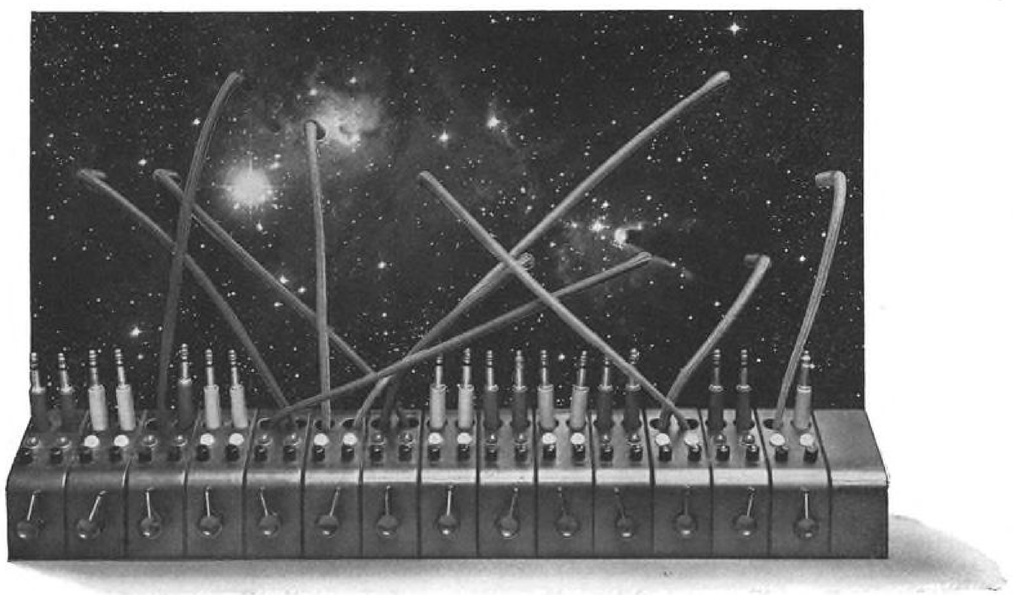
MISSILES & SPACE COMPANY

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LOOK AT LOCKHEED IN SPACE COMMUNICATIONS:

Where outstanding successes have created aerospace leadership



nalized in the propellant demands of the Saturn 5—4 million lb. liquid oxygen, 1.3 million lb. RP-1, and 200,000 lb. liquid hydrogen.

Once propellants have been loaded, Launch Operations Center feels it can accommodate a hold as long as 8 hr. After this time, the combination of fatigue on the part of launch and flight crews, and propellant boiloff, would force a re-cycle of at least one day, and more likely 48 hr.

Replace Vehicle

Of the advantages accruing to the vertical assembly approach, one of the most important is the flexibility allowed in replacement of a spacecraft-launch vehicle combination which may have developed problems after having been moved to the launch site.

With the four-bay assembly building, four launcher-umbilical towers and four launch stands, the center estimates that it could launch as many as 75 Saturn vehicles a year. What makes this conjectural rate feasible is that a launch vehicle and its payload would occupy a stand for no more than a week before it either would be launched or replaced by a second vehicle.

This contrasts sharply with the present system, in which the stand is tied up for six to 10 weeks while the launch vehicle is assembled on it, the spacecraft mated and all checkout tasks performed.

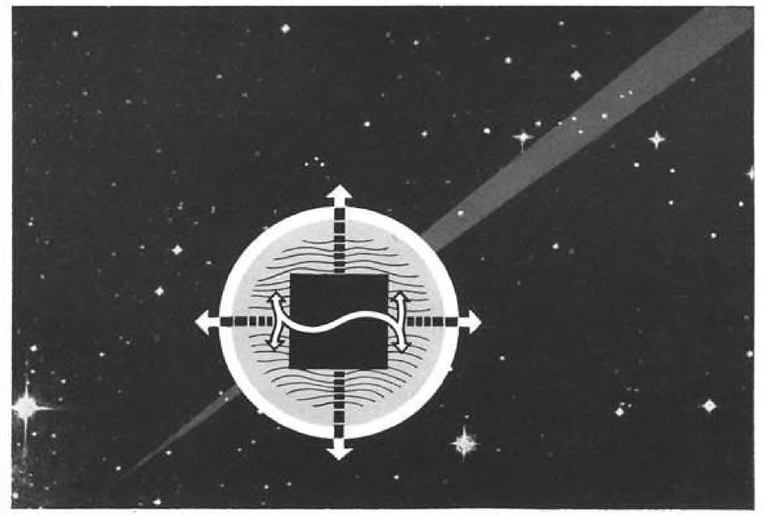
Then, if problems occur which preclude flight, the combined vehicle must be removed piece by piece and the whole laborious process repeated again—several months later.

Flexible Concept

It is not likely that this rate will ever become a reality, as the present goals of the U. S. space program can be met with considerably fewer launches, but it does illustrate the flexibility of the concept. Present NASA plans call for the construction of four bays in the vertical assembly building, but only three launcher-towers and three stands. The vertical assembly building is being so designed and so constructed that two more bays could be added to the building later, if required, and the center has sited the areas for at least two possible future launch stands.

Center personnel stress that this launch capability is being developed to support all NASA centers, and not merely the Manned Spacecraft Center with its manned programs. They say they can foresee the day when extremely large scientific satellites will be flown aboard Saturn-class vehicles.

Among possible non-manned spaceflight missions under consideration are heavy observatory satellites and launch of heavy probes to the planets.



Problem:

FLUID SUPPORT AND CONTROL

Support and attitude-stabilize a measuring element, using fluid techniques. Stabilization must be to an accuracy of 0.1 seconds of arc. In addition, transmit measurement data to the computer with a minimum or no physical connections.

We believe this problem contains many "break-through" challenges of particular interest to capable *Fluid Design, Communications,* and *Servo Control* engineers. Its solution will involve the most creative use of experience and knowledge in these three inter-dependent advanced engineering areas.

Sound like the work you should be doing? Then, send a brief note describing your experience and specific area of interest to **F. M. Keese, Honeywell, 13350 U. S. Highway 19, St. Petersburg, Florida.** We promise a prompt confidential reply and probably an invitation to visit our facilities, meet our people and discover for yourself the added attraction of living here on Florida's Suncoast.

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HONEYWELL ENGINEERS ARE DOING THINGS IN FLORIDA

Turning theory into hardware at Hughes

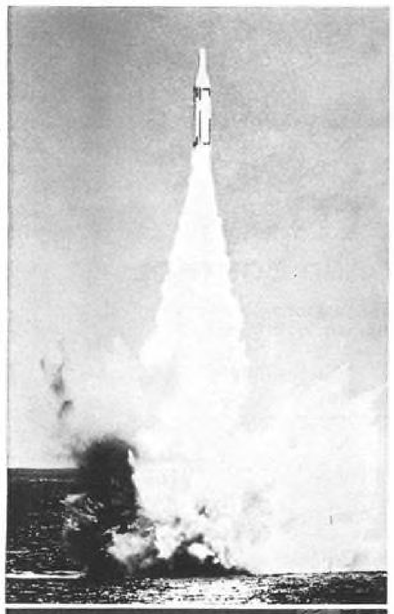
Technological breakthroughs are almost an everyday occurrence in electronics. Everywhere we see many new scientific discoveries being turned to the service of man.

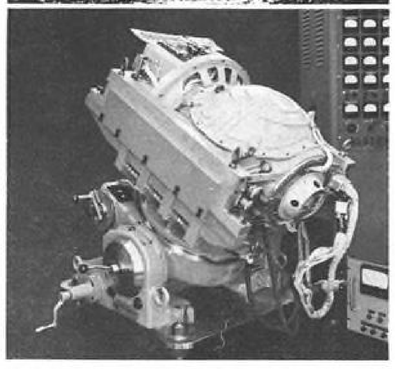
Hughes is one of those companies whose obligation is not only to form these theories, but also to visualize how they might be applied. And then to make that application — both in man's defense and in the betterment of his life.

Today, Hughes technology is being applied in over 500 projects, programs and studies. A few are shown to illustrate: Completely new technologies which are creating new devices... Major improvements in existing technologies... Advanced manufacturing technologies which produce more reliable hardware for duty in this world — and out of it.

More than 5,000 Hughes engineers help create the theories. More than 25,000 other skilled Hughes people help translate their work into practical hardware. Together they are helping create a new world with electronics.

Inquiries concerning employment opportunities at Hughes will receive prompt attention. Qualifications include U. S. citizenship and a B. S., M. S. or Ph. D. degree from an accredited university. Hughes is an equal opportunity employer. Please address your inquiry to Mr. S. L. GILLESPIE, Manager, Employment & Manpower, Hughes Aircraft Company, Culver City 40, California.





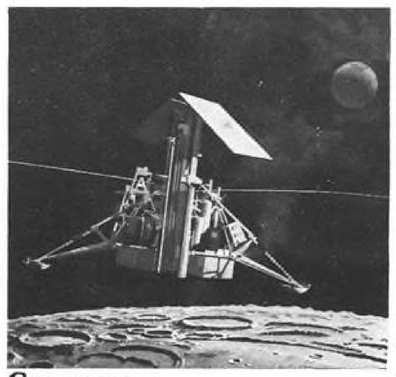
Polaris missile brain

Through the application of its advanced manufacturing technology, Hughes is now a prime contractor in inertial guidance systems (illustrated above) for the U.S. Navy's Polaris missile. It is one of the world's mightiest, most reliable forces for freedom.



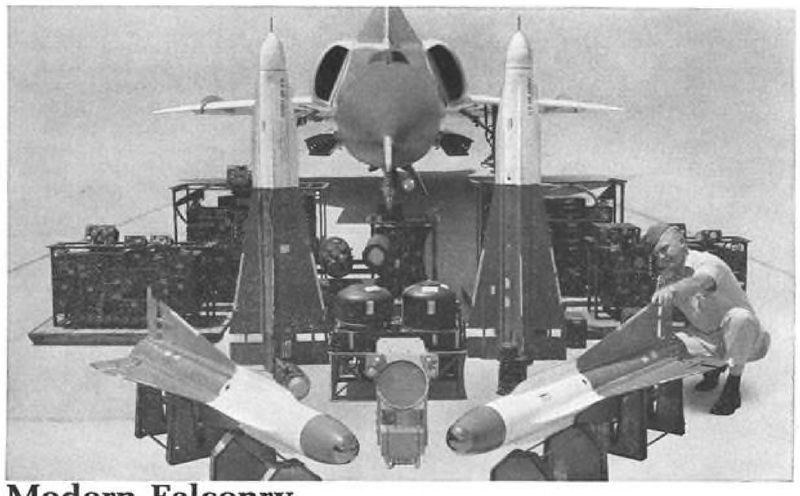
Enterprise "Eyes"

Like giant billboards, Hughes detection and 3-D tracking radar on the 4 sides of the Enterprise tower scan hundreds of miles of air space to track great numbers of supersonic targets. Utilizing Hughes *frequency scanning* invention, these antennas position beams electronically — eliminate mechanical movement and complexity — are "hardened" against damage.



Surveyor

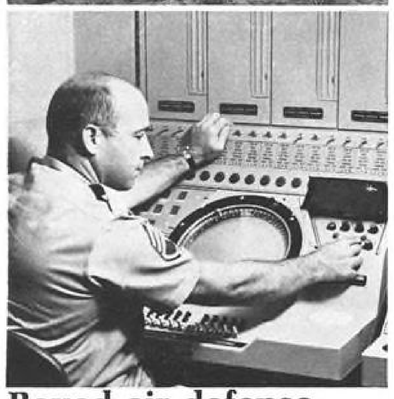
Hughes Surveyor is designed to give information on conditions in flight and "soft land" instruments which will report information about the moon back to earth. The first of seven Surveyors being built by Hughes for NASA under Jet Propulsion Laboratory technical direction is scheduled for launch early in 1964.



Modern Falconry

In the late 1940s, airborne electronics was in its infancy. Yet, in a few years, U.S. Air Force jets were equipped with Hughes advanced weapons control systems armed to fire Falcon missiles. Together (and vastly improved) they have become our most potent air defense weapon. Hughes—the leading builder—has delivered thousands of control systems and well over 30,000 infrared and radar-guided Falcons.





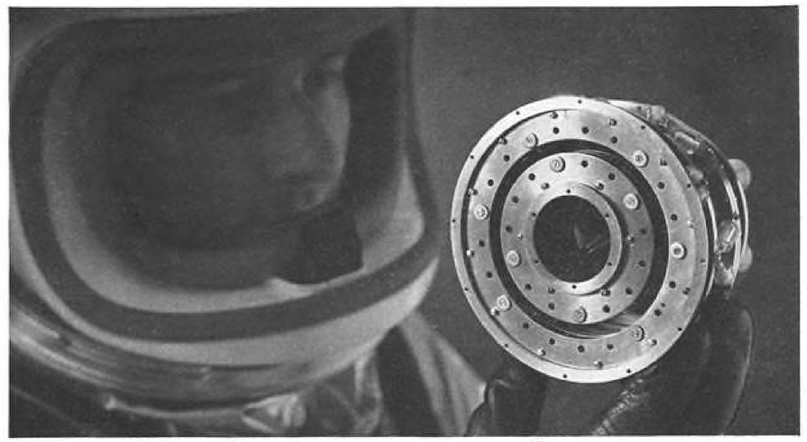
Boxed air defense systems go anywhere

Air-lifted by helicopter to inaccessible areas, Hughes new "packaged" air defense control systems can be ready for operation in minutes. The "helihuts" contain a highly miniaturized "operations central" plus communications networks for battlefield control of U.S. Army and Marine Nike and Hawk missile batteries.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY



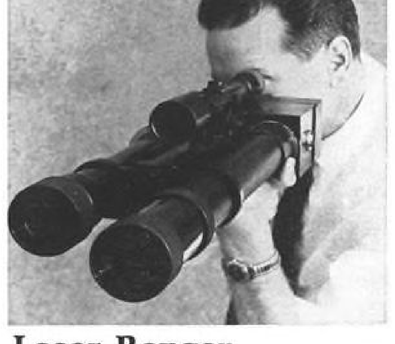
Ion engines for deep-space probes

Hughes research into the theory of electrical propulsion has led to development of ion engines which are called the "ultimate" source of power for deep space trips. Built for NASA, Hughes cesium-powered ion engines have been "test-flown" in space-simulating vacuum chambers—and are scheduled for actual test in space within the year.



Star Tracker

One of many Hughes infrared activities, this stellar tracker will help navigate the Surveyor lunar landing vehicle on its trip to the moon. This tracker will identify the star Canopus simply by the amount of light energy it generates permitting the star to be used as a navigational "fix."



Laser Ranger

Accurately measuring distances to within 15 feet in seven miles, Hughes Colidar* Rangefinder enables artillery spotters, tanks and aircraft to instantly pinpoint targets. The device "bounces" a coherent light beam off the target, computes the distance and reads out the range. Other uses include calculating closing rates between spacecraft and high resolution mapping.

*Trademark Hughes Aircraft Company

Circle Number 311 on Reader-Service Card

PROJECT: F-111 and other Aerospace Programs

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Propulsion, Radar, Flight Controls,

Servo Controls, and Fuel Systems

ANALYSIS–Stress, Flutter and Dynamics,

Structural Loads and Criteria, Reliability,

Maintainability, Thermo, and Environmental

STABILITY AND CONTROL

AERODYNAMICS

STRUCTURAL DESIGN

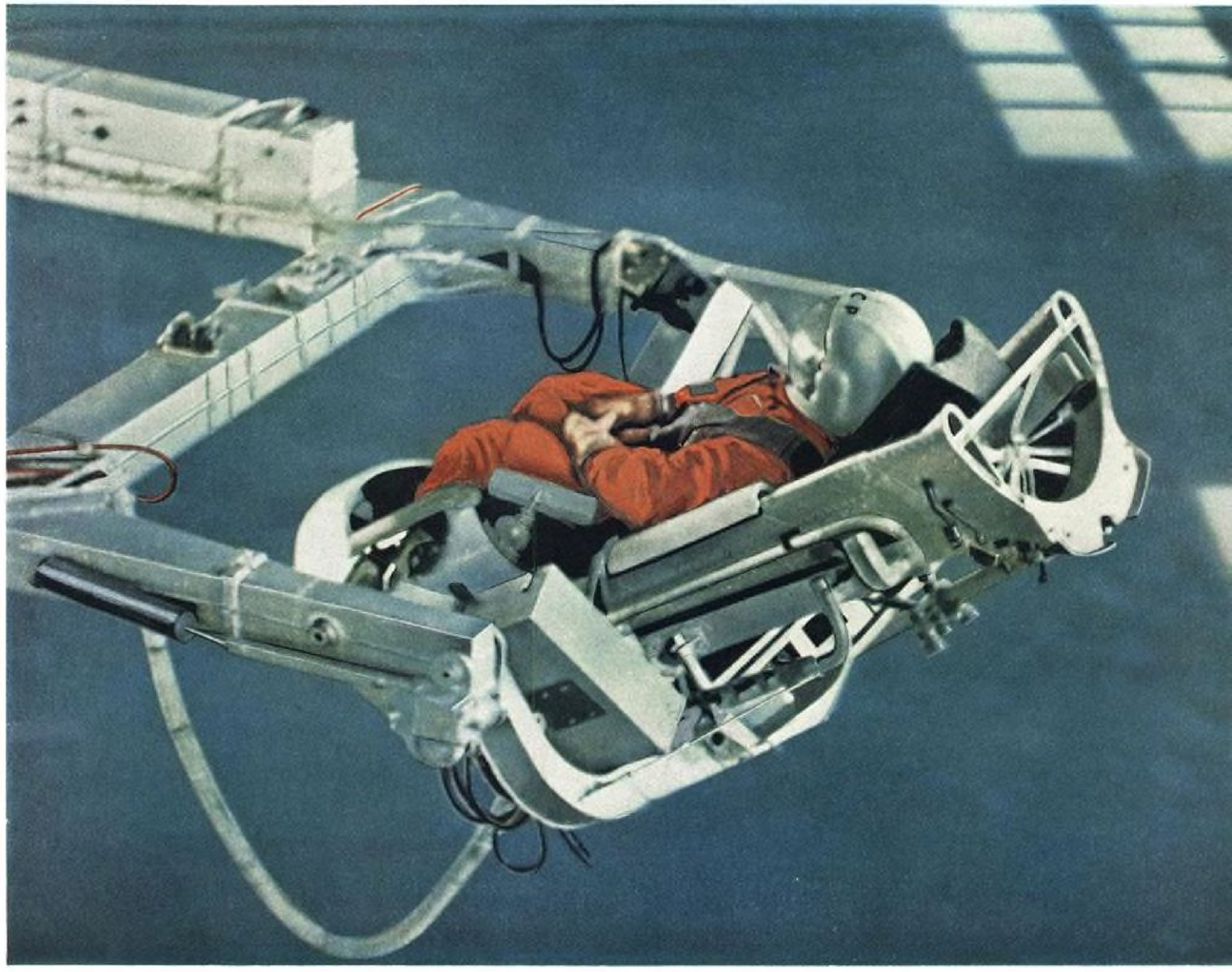
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Soviet

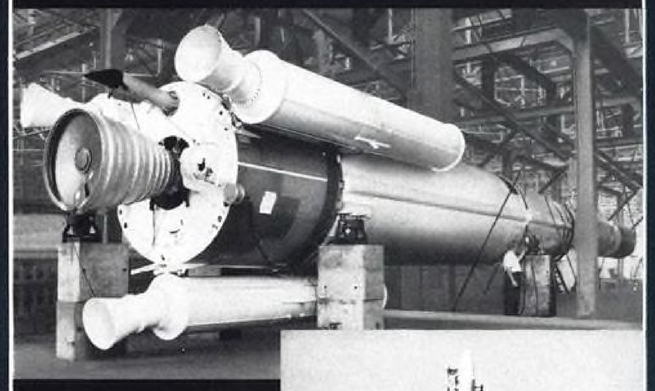


Russian cosmonaut wearing pressure suit undergoes training on centrifuge.



FLIGHT-PROVEN POWER ADDED TO THOR

Improved Thor Standard Launch Vehicle shows its big power source... the MB-3 Block II liquid propellant engine with three Thiokol XM-33 solid propellant motors strapped to its side. This combination nearly doubles payload capacity of the most powerful original Thor models.



Combined with Agena satellite vehicle, improved Thor is readied for launching at Vandenberg Air Force Base.

Photo left shows bird in flight with solid boost added by strapped-on Thiokol motors.



Three Thiokol XM-33 solid motors increase first stage booster thrust to over 330,000 pounds.

New booster reliability for an improved Thor Standard Launch Vehicle. It's delivered by Thiokol's "off-the-shelf" solids. The XM-33's, strapped to the side of the Douglas developed Air Force Thor, have a successful, versatile, and reliable flight record—with Little Joe, Trailblazer II, Scout, Blue Scout, and other research vehicles. Truly a "work horse" propulsion unit, the XM-33, with its flight-proven design concepts and components available on a quick delivery basis, joins the similarly proven Thor to provide a significant increase in payload capability in minimum time, at minimum cost.

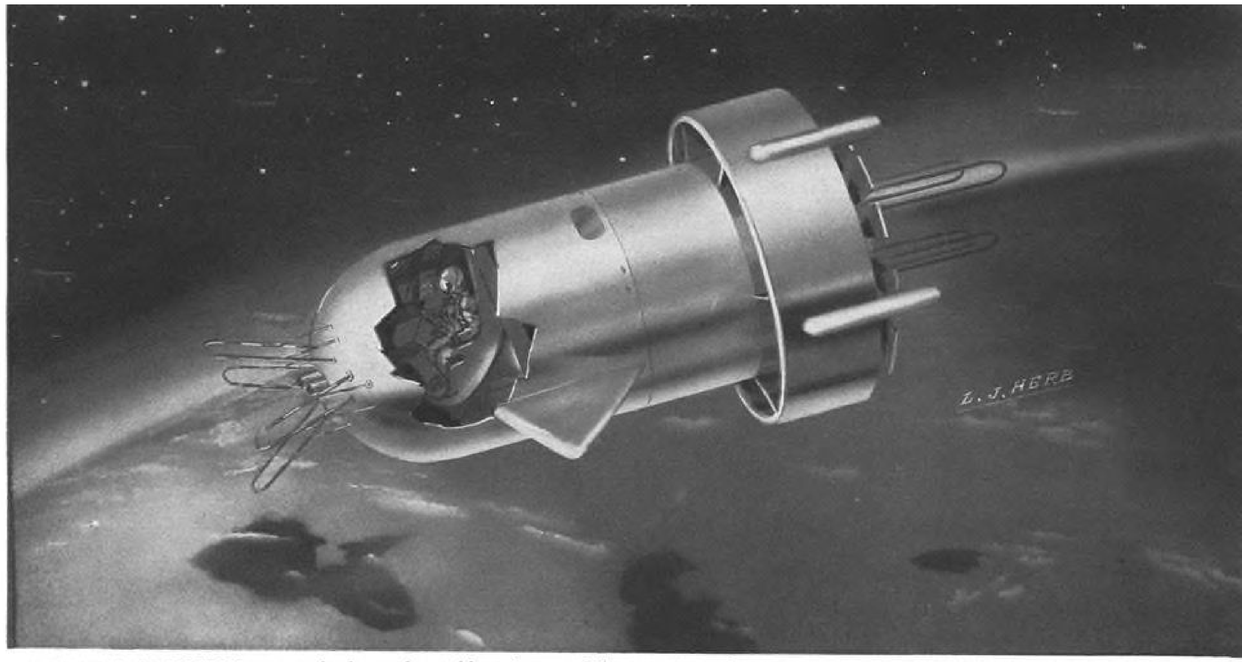
Thiokol

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DRAWING OF VOSTOK spacecraft shows the stubby wings used for re-entry and a cutaway view of the cabin. Spacecraft separates at line aft of the wings, exposing a re-entry heat shield. Artist's concept is based on research by Dr. Eugene Konecci.

Vostok Flights Widen Soviet Experience

Soviet Russia has doubled its previous experience with human space flight and begun to explore the use of relatively untrained cosmonauts through the dual flight of Vostok 5 and Vostok 6.

Learning the capabilities and limitations of a space passenger who has not been exposed to the training and discipline of years of piloting jet aircraft will assume great importance as space flight progresses from short-lived, one-man vehicles to multi-man space stations and lunar and planetary spacecraft.

Valuable Results

In spite of Western speculation that Russia failed to make a planned rendezvous of Vostoks 5 and 6 last month, and orbited the first woman in space to make the best of a bad situation, the dual flight of the Vostoks produced a number of valuable results, including the following:

- **Increased total flight** time of cosmonauts from 192 hr. to 382 hr. (see chart, p. 317), and increased biomedical data on human flight by more than a factor of two if Soviet statements about improvements in data-gathering equipment and techniques for this flight are accurate.
- **Gave Cosmonaut** Valery Bykovsky a total of six hours of flight time free from his seat harness—which should be a valuable contribution to the knowledge of keeping fit on long space flights



COSMONAUT Tereshkova is shown practicing on a rotational device prior to her flight.



SOVIET COSMONAUTS, shown appearing with Chairman Khrushchev at Kremlin are (l to r) Maj. Andrian Nikolayev, Lt. Col. Gherman Titov, Lt. Col. Pavel Popovich, Lt. Col. Yuri Gagarin, Jr., Lt. Valentina Tereshkova, Khrushchev and Lt. Col. Valery Bykovsky.

as well as early data necessary for extravehicular movements in space.

• **Gave Russia** the first information on mental and physiological reactions of the human female to prolonged spaceflight. The data on Cosmonaut Valentina Tereshkova can be compared with the data gathered simultaneously on Bykovsky and with information on the flight of male Cosmonaut Pavel Popovich, whose flight last August was only seven minutes longer than hers.

• **May have provided** extremely valuable military information on direct, cross-course intercept techniques. While the flights of Vostoks 3 and 4 explored co-planer rendezvous, in which both vehicles had a common orbital plane, one of the primary purposes of the Vostok 5-6 flight may have been to make visual, optical, radio and radar observations of a vehicle on a crossing course.

The U.S. is exploring co-planer, ballistic and cross-course intercept under Defense Dept. programs aimed at developing "hardware and techniques for rendezvous with uncooperative objects in space and their inspection or possible neutralization," according to Dr. Lawrence Kavanau, special assistant for space to the director of defense research and engineering.

The limitations of orbital mechanics and the need for quick reaction time in some potential military space situations make cross-course intercept attractive because it offers more latitude than the co-planer approach.

For co-planer rendezvous, the intercepting vehicle must be launched into the same orbital plane as the target vehicle, or have the energy potential aboard to change orbital plane in space. And it can be launched into this desired plane only once each 24 hr. for a nominal earth orbit of 90 min. If the seeker vehicle is not launched into an orbit having almost the same apogee and perigee as the target, it must have the energy potential for vertical maneuvering.

An interceptor could be launched on an orbital course that crossed the orbit of the target vehicle as soon as the orbital parameters of the target vehicle were known—probably within the first three orbits. It would not have the opportunity to fly alongside that an interceptor in a co-planer orbit would, but if it were placed in the proper orbit its path would cross that of the target vehicle twice on each circuit of the earth. Therefore the opportunity for "inspection or neutralization" could be achieved more quickly, more easily and more often.

Vostok 6 was launched precisely as Vostok 5 began its 32nd orbit, and if Vostok 5's orbit had not decayed more rapidly than the Soviets apparently intended it to, the two ships should have passed within sight of each other twice each orbit for the remainder of the flight.

Soviet Academician A. A. Blagonravov said at the cosmonauts' press conference in Moscow last June 26 that "Cosmonaut Bykovsky used the opportunity (of more free time than on previous flights) to observe his companion's spaceship to determine the position of his own spaceship with reference to other bodies in space."

The flight of the first woman in space has been depreciated in the West as having little importance beyond its propaganda value. But completely aside from the biomedical information it produced, the flight of Cosmonaut Tereshkova has at least two practical benefits.

It demonstrated that a healthy person can, with the proper training, withstand the strains of launch, weightlessness and re-entry without having the highly specialized professional background of the military test pilot and it opened the way for the training of scientists for later, more complex missions.

Miss Tereshkova apparently did not begin training until after Cosmonaut Yuri Gagarin became the first man to fly in space in April of 1961. When she was asked at the Moscow press conference what prompted her to become the first woman cosmonaut, she replied:

"After I began to engage in parachute sport, after the flight of Yuri Alekseyevich Gagarin, I dreamed of trying my strength in space. As you see, something came of it."

Although she was not a pilot before she entered this program, she and other female cosmonaut-trainees "flew in transport planes and acquired the techniques of work with a large number of instruments and learned how to correctly distribute and direct our attention," she said.

"A large part of our training was taken up with flight in a weightless condition, though this weightless condition was very short-lived . . . Parachute jumping was of great use . . . We jumped again and again under different conditions . . . Knowledge of flying is necessary to operate a spaceship. When I received training for space flights I learned to pilot planes of various types. It was only after this that I proceeded to learn to pilot a spaceship."

Soviet Space Strategy

"Soviet military strategy acknowledges the need to study the use of space and space vehicles to reinforce the defense of the socialist countries. . . . It would be a mistake to allow the imperialist camp to gain any superiority in this area."—from the Russian book, Military Strategy, which was written by Soviet generals and has received wide distribution in the Soviet Union.

Cosmonaut Selection

Miss Tereshkova then threw in the commercial—that Soviet space ships "are being perfected more and more every year" and that eventually they "will be piloted by engineers, deigners, workers and textile workers like me." Russia listed "the effectiveness of a method of selecting and training cosmonauts" as a major goal of the Vostok 5-6 flight.

More than half of the medical doctors in Russia are women and women make up a large percentage of the workers in all fields of science. Both they and their male counterparts now may be able to look forward to roles in space exploration earlier than initial selection of U.S. and Russian astronauts from the ranks of military pilots indicated they could.

Manual Control

Cosmonaut Tereshkova apparently controlled her craft manually on only one orbit. Soviet scientists said her flight was scheduled to last 24 hr. with a possible extension to 72. The only indication Russia has given so far that she reacted any differently than male cosmonauts have was the statement by Prof. Vladimir Yazdovsky that "considerable fluctuations in the frequency of her heart beat occurred in short intervals." But he added: "Electrocardiography revealed no appreciable cardiac disturbances."



LT. COL. BYKOVSKY, orbited June 14 in Vostok 5, adjusts his space helmet.

Vostoks 5 and 6 were fundamentally the same as earlier Vostoks, but with substantial improvements in the life support system, according to Russia.

Cosmonaut Bykovsky amassed about 6 hr. of free-floating time inside his capsule, in periods of 90 min. each on the 18th, 34th, 50th and 66th orbits. He said he was "particularly impressed" by this and "eagerly awaited" each free-floating period.

"I floated up to the portholes of the spaceship and carried out observations of the ground," he said. "It is extremely curious. The slightest push will send you flying in the opposite direction and

MANNED SPACE FLIGHT EXPERIENCE—U.S. & USSR

Pilot	Launch Date	No. Orbits	Flight Time
Shepard	5/ 5/61	...	0 hr. 15 min.*
Grissom	7/21/61	...	0 hr. 15 min.*
Glenn	2/20/62	3	4 hr. 56 min.
Carpenter	5/24/62	3	4 hr. 56 min.
Schirra	10/ 3/63	6	9 hr. 14 min.
Cooper	5/15/63	22	34 hr. 20 min.
Totals		34	53 hr. 26 min.
Gagarin	4/12/61	1	1 hr. 29 min.
Titov	8/ 6/62	17	25 hr. 18 min.
Nikolayev	8/11/62	64	94 hr. 22 min.†
Popovich	8/12/62	48	70 hr. 57 min.†
Bykovsky	6/14/63	81	119 hr. 06 min.#
Tereshkova	6/16/63	48	70 hr. 50 min.#
Totals		259	382 hr. 02 min.

* Suborbital flights.
† Group flight.
# Joint flight.

Cosmos Satellite Series

Name	Launched	Apogee (mi.)	Perigee (mi.)	Period (min.)	Incl (deg)	Re-entered or Decayed	Time in orbit	Probable launch site
Cosmos 1	3/16/62	540.0	131.4	95.4	48.90	5/25/62	70 days	Kaputsin Yar
2	4/ 6/62	967.2	122.7	100.3	48.95	In orbit	14 mos.+	Kaputsin Yar
3	4/24/62	414.5	130.8	92.5	49.00	10/17/62	176 days	Kaputsin Yar
4*	4/26/62	206.0	186.0	90.6	65.00	4/29/62	3 days	Tyuratam
5	5/28/62	908.3	124.6	101.5	49.05	5/ 2/63	339 days	Kaputsin Yar
6	6/30/62	186.8	162.4	90.1	48.90	8/ 8/62	39 days	Kaputsin Yar
7	7/28/62	218.2	125.2	90.1	65.00	8/ 1/62	4 days	Tyuratam
8	8/18/62	374.4	158.7	92.9	49.00	In orbit	11 mos.+	Kaputsin Yar
9	9/27/62	221.0	188.0	90.0	65.00	10/ 1/62	4 days	Tyuratam
10	10/17/62	208.0	126.0	90.2	65.00	10/21/62	4 days	Tyuratam
11	10/20/62	572.0	152.0	96.1	49.00	In orbit	9 mos.+	Kaputsin Yar
12	12/22/62	270.0	126.6	90.5	65.00	12/30/62	8 days	Tyuratam
13	3/21/63	209.0	127.0	89.8	64.90	3/29/63	8 days	Tyuratam
14	4/13/63	290.8	160.0	91.7	48.90	In orbit	3 mos.+	Kaputsin Yar
15	4/22/63	230.0	107.3	89.7	65.00	4/27/63	5 days	Tyuratam
16	4/28/63	238.1	123.4	90.5	65.06	5/ 8/63	10 days	Tyuratam
17†	5/22/63	492.5	162.5	94.8	49.30	In orbit	2 mos.+	Kaputsin Yar
18	5/24/63	181.4	129.3	89.4	65.00	6/2/63	9 days	Tyuratam

* Recovered, according to USSR.
† Orbital parameters given by USSR. U.S. Satellite Situation Report for June 15, 1963 reports seven objects in similar orbits with average apogee of 446.77 mi. and average perigee of 173.5 mi. Apogees of highest and lowest objects are separated by 108 mi.; perigees, by 58 mi.

with your eyes closed you cannot tell what your position actually is."

Bykovsky said he also caused "panic at ground control" when he mentioned that he had had a bowel movement.

". . . Owing to interference the operator at the ground control got the word 'stuk' (knocking) instead of 'stul' (bowel movement)," he said. ". . . I was bombarded with questions: What has happened to the ship? What was making the knocking? What kind of knocking was it?

"I had to explain that it was only a bowel movement or, to put it simply, I had used my sanitary appliance."

One group of Russia's extensive Cosmos satellite series still appears to consist of test flights for Soviet manned flight. Since Mar. 16, 1962, 18 Cosmos vehicles have been launched—nine from Tyuratam and nine from Kaputsin Yar.

The nine launched from Tyuratam have had orbits inclined at 65 deg. to the equator, the same as all Soviet manned flights so far. Some Western observers believe they are the size of Vostok capsules (AW Apr. 29, p. 22). Analysis of their orbital parameters shows that two have had high perigees—186 and 188 mi.—but that the seven others have had perigees ranging from 107 to 129 mi. and averaging 123 mi. Apogees of the nine shots have been clustered between 181 and 270 mi., averaging 220 mi.

Tyuratam shots included a 3-day and a 4-day flight prior to the Vostok 3-4 flight last year; a 4-day flight last September, a 4-day flight in October, an 8-day flight each in December and March, a 5-day flight last April, a 10-day flight in April and a nine-day flight in May, three weeks before Bykovsky flew. These 8-, 9- and 10-day flights led U. S. officials to predict before Vostoks 5 and 6 that the next manned flight would last that long.

The Kaputsin Yar flights appear to be serving the other announced goal of the Cosmos series—to map the geophysics of near-earth space. They may also be serving paramilitary uses.

The first four had low perigees averaging 127 mi. The next five had slightly higher perigees, averaging 158 mi. Apogees have ranged widely from 158 mi. to 967 mi. but appear to form a pattern.

One Kaputsin Yar shot had a low apogee of 186 mi., or about 300 km. Five had intermediate apogees ranging from about 500 to 900 km., suggesting that this middle region is of most scientific interest to the Soviets. Apogees of these five ranged from 290 to 572 mi.

Two of Kaputsin Yar Cosmos flights have had very high apogees—908 and 967 mi. One is still in orbit and the other stayed up for 339 days. Of the nine launched from Kaputsin Yar, five are still in orbit.



COSMONAUT TERESHKOVA, world's first woman in space, is shown eating food from a squeeze tube during a training session. She was orbited in Vostok 6 on June 16. Lt. Col. Popovich (below) is shown being transported in a bus to the launch pad for Vostok 4 flight. Note size of umbilical cord on right side of spacesuit.



SOVIET UNION'S second cosmonaut, Lt. Col. Gherman Titov, is shown (below) singing in an isolation chamber during one phase of his training for space flight. Titov was launched Aug. 6, 1962, on a 17-orbit flight which lasted 25 hr. 18 min.





HE'S REDUCING THE COST OF AN ENGINE OVERHAUL

It is customary for overhaul shops to use a vapor blast to clean the baked-on carbon from turbine engine blades and discs. This is a slow process. The material to be removed resembles a very tough varnish. Every bit must be removed from the surface of the metal so any cracks present will be easily visible. But slurry covers up the work; the operator works blind; the danger of eroding the metal beyond maximum limits is great.

Airwork looked for a better way—and found it in the dry honer used in an allied industry. This proved to be not only faster—but gave the operator a constant, unobstructed view of the work. The result: less chance of metal erosion—and a better inspectable surface that makes metal flaws easier to spot.

This is one result of our constant effort to reduce costs while increasing reliability. It saves many labor dollars on a Dart engine overhaul . . . and will soon be saving money on piston engine overhauls, too.

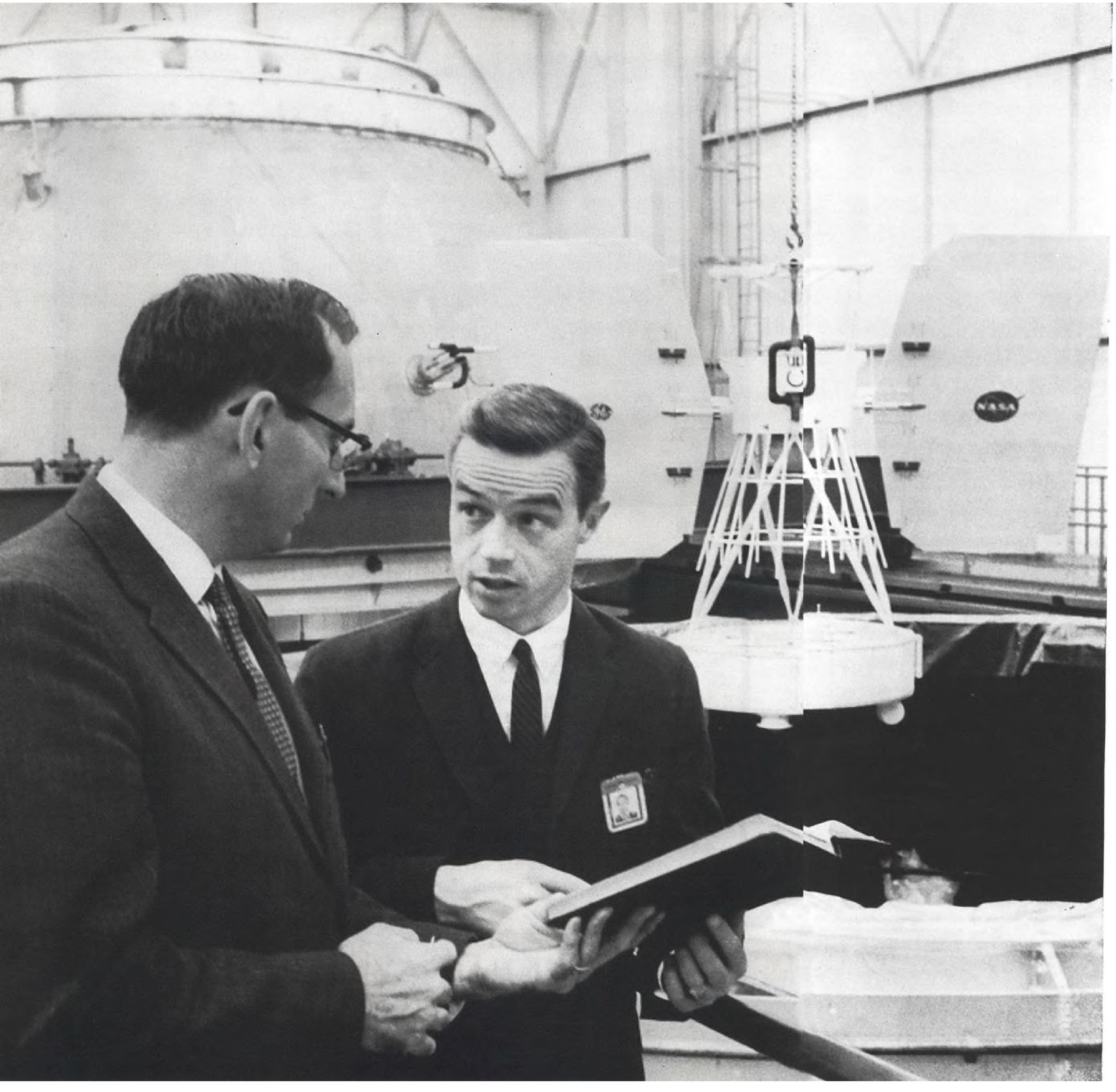
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Congress May Ease NASA Budget Cuts

Space agency's analysis of effect house unit cuts would have on U. S. program is swaying legislators.

By Alfred P. Alibrando

Washington—U. S. space agency officials are persuading some members of the House and Senate space committees that the $489-million cut made by the House committee in the National Aeronautics and Space Administration's $5.7-billion budget request for Fiscal 1964 would either slow down Project Apollo or require a drastic reduction in nearly all other NASA programs.

As a result, the Senate space committee this week is expected to restore some items cut out of the NASA budget by the House committee. In addition, Rep. George Miller (D.-Calif.), chairman of the House committee, said that if the Senate makes some restorations, "House conferees will be reasonable and give the restorations every consideration."

House space committee members were satisfied when they completed their report July 10 on the money portion of the NASA authorization bill that they had pruned to the limit but had not jeopardized the space program (AW July 15, p. 29). Chairman Miller pointed out that the committee and its subcommittee had heard more than 100 witnesses in 75 hearings and had made several field investigations.

In the week that followed, NASA analyzed the committees reductions and concluded that they would be extremely harmful. It was this detailed report, made available to AVIATION WEEK & SPACE TECHNOLOGY, that caused some second thoughts among members of the congressional space committees.

These are the reductions or items eliminated from the manned flight program, and the consequences, as outlined in NASA analysis:

• **Apollo**—Reduction of $120 million in Apollo spacecraft funding would "cause a 4- to 6-month slippage in the command and service modules availability for initial lunar flights . . . in the 1966-67 time period . . . and . . . ground testing effort would have to be minimized, increasing the program risk substantially."

• **Integration and checkout**—Delivery of checkout hardware would be delayed and the systems engineering effort reduced if a $28-million reduction is allowed to stand. Delays in delivery of checkout hardware would have a direct effect on acceptance testing of the Apollo spacecraft and the program's ability to meet flight schedules.

• **Biomedical engineering**—Cut of $5.7 million in this area would throw off scheduled development of Gemini and Apollo space suits, life support systems, survival gear, medical instrumentation and other equipment "critically time-phased with spacecraft development."

• **LEM test stand**—One of four stands for testing of ascent and descent engines on the Apollo Lunar Excursion Module at White Sands, N. M., would be eliminated as a result of a $3.5-million reduction. NASA said this would either stretch out LEM propulsion development or result in less testing and therefore less reliable engines, "thus endangering the lives of the astronauts."

• **Saturn 5**—Deferral of construction of a static test stand at the Mississippi Test Facility for the first stage (S1C) of the Saturn 5 would require that early production stages be shipped to the Marshall Space Flight Center for test firing on a stand intended for testing development stages. This would slow both acceptance testing of production stages and developmental testing.

• **S2 stage**—Construction of an S2 stand at the Mississippi Test Facility also would be delayed by a $1.5-million deferral. Construction on the stand must start by March, 1964, to meet the testing schedule required in the Saturn 5 development program.

• **F-1 engine**—A stand for acceptance tests on F-1 engines at the Mississippi facility is required for "re-test of engines, removed from the cluster of five on the S1C, that have malfunctioned. In addition, all engineering changes, field modifications and change kits must be tested with individual engines before these engines are assembled into the stage." Delay of work on this stand because of a $4.9-million reduction in NASA's budget request would delay development and production of the S1C stage.

• **M-1 engine**—Single most drastic reduction in the engine program was the $30 million cut from the $45 million requested for development of the liquid hydrogen M-1 engine, which is being developed for upper stage propulsion systems in Nova-class vehicles. NASA said the $30-million cut "would require a virtually complete stoppage of work on major components and complete engines." Loss of key engineering personnel now and the necessity for another buildup when the program is resumed would result in great waste and inefficiency, NASA said.

• **Pad 39**—Work on launch complex 39 is well under way and the $25-million cut made by the House space committee is not as severe as it may appear. However, it is estimated that the deferral for Fiscal 1964 could set back completion of Pad 39 by two months or so.

• **Launch support**—A number of facilities required for support of launch activities associated with the manned flight program would be delayed if the cuts stand. These include a new calibration and standards laboratory NASA believes is needed to test and adjust 15,000 gages, meters and other instruments; a launch equipment shop for maintenance and emergency repair of ground support equipment, such as diesel and electrical engines; an optical and electronic components service facility which is to be used for maintenance, repair and storage of 250 TV, movie and still cameras required for engineering data on NASA launches.

Effects of reductions in NASA's unmanned flight programs, research activities and tracking operations, include:

• **Surveyor orbiter**—Program to develop a Surveyor orbiter was cut out completely. Space sciences subcommittee contended that NASA should be able to get data on the lunar surface and topography with existing Ranger and Surveyor programs. However, NASA feels that only an orbiting spacecraft can do the job and is abandoning the idea of modifying the soft-landing Surveyor for the mission. It had asked $28.2 million for Fiscal 1964 with the intention of developing a relatively simple Atlas Agena-launched photo reconnaissance spacecraft.

• **Ranger**—Reduction of $25 million in the Ranger program was mild and is not considered "disastrous."

• **Mariner**—Elimination of $15 million for a Venus flyby mission in 1965 was expected, since the Mariner 2 Venus flight in 1962 was a success and the space agency is currently concentrating its planetary flight effort on a Mars mission.

• **Bioscience**—NASA has been criticized for not having an animal flight program. Ironically, the cut of $14 million from the $41 million requested comes at a time when the agency has nearly completed definition of a bioscience program and is ready to begin development of a spacecraft for the long-delayed long-duration animal flight.

• **International satellites**—The House committee told NASA it would restore a $4-million item for international satellite programs when the agency could present approved and negotiated agreements with other countries. NASA has or is completing such negotiations with several countries.

• **Advanced Project Fire**—An $8.5-million item for re-entry heating experiments at velocities for return from planetary missions was eliminated by the House committee. NASA is stepping up the advanced research necessary before a manned Mars mission can be undertaken and would like this item restored.

• **Tracking** – Workload of NASA's tracking and data acquisition system increases each year and the agency will find it very difficult to absorb a $15-million cut in an area where personnel and tracking equipment already are overworked.

NASA's top management also views with some alarm the amendments to the space act proposed by the House space committee. These amendments, if adopted, would curtail the flexibility that the agency now has in changing programs and reallocating funds as conditions change.

One official estimated that an amendment calling for congressional approval prior to reprogramming of funds for items or programs deleted or reduced by Congress would require more than 100 new subaccounts in NASA's bookkeeping operation.

NASA Budget Figures

Washington—All Fiscal 1964 National Aeronautics and Space Administration budget figures used in the preceding pages of this Manned Space Flight issue represent the Administration's requests to Congress. NASA authorization and appropriations bills are still being considered by Congress.

SST Proposals

Preliminary draft of Federal Aviation Agency's supersonic transport proposal request was sent to engine and airframe manufacturers last week for comment. Comments are due July 25, and the RFP will be issued Aug. 15 for a five-month study due Jan. 15, 1964.

The SST program (AW June 24, p. 39) is outlined in three phases and calls for development of an aircraft to exceed Mach 2.2, with higher speeds justified on the basis of economy of operations. The three phases are:

• Five-month study program outlining the complete development program.

• Detailed design and mockup fabrication.

• Building and testing of the prototype aircraft and FAA flight certification.

Lovell Says USSR Seeks Joint Lunar Effort

London—Soviet space scientists plan to approach their U. S. counterparts for talks on the advisability of a joint program to land a man on the moon, according to Sir Bernard Lovell, director of Jodrell Bank observatory, who has just returned from a three-week visit to Russia.

President Kennedy, however, told a Washington news conference that while he would welcome such an effort, "I don't see it as yet, unfortunately." He said such a venture would require "a breaking down of a good many barriers of suspicion and distrust and hostility" between the U. S. and Russia, and "there is no evidence as yet that those barriers will come down."

Lovell said he has agreed to act as the intermediary between the Soviet Academy of Sciences, National Aeronautics and Space Administration and the British minister for science. The first move would be a joint conference to determine feasibility of the moon shot.

He said the Russians appear to be putting a high priority on a soft lunar landing of an instrument package which they claim could provide 90% of information gained by a manned flight, without the danger.

Lovell also said the Russians are working on a space platform to orbit at about 150 mi. altitude and carry a 36-in. optical telescope. The platform would be manned by a two-man crew, one an engineer and the other an astronomer. The Soviets are building a 230-in. optical telescope, which will be the world's largest, in the North Caucasus, Lovell added.

Lovell said he is convinced the Russians are prepared to abandon plans for a manned moon landing, at least on a national basis, but for prestige purposes they may shortly put a man in orbit around the moon.

President Kennedy said that despite these reports, he thinks the U. S. "ought to go right ahead with our own program and go to the moon before the end of this decade." He said that Lovell's information "is not final," and that any assumption that Russia is not going to the moon "might be wrong a year from now."

The President said, "the point . . . has been not only . . . our excitement or interest in being on the moon, but the capacity to dominate space, which would be demonstrated by a moon flight . . . is essential to the U. S. as a leading free world power. That is why . . . I think we should continue. . . ."

NASA Gives $35,000 to Rogallos

Washington—Francis M. Rogallo and his wife, Gertrude last week received a $35,000 award from the National Aeronautics and Space Administration for early development work on the paraglider. It was the largest cash award ever made by the space agency.

Rogallo is head of a wind tunnel group at the NASA Langley Research Center. The award to the Rogallos was for two inventions that contributed to the development of flexible wings that can be packaged and deployed. Such a flex-wing or paraglider is to be used in landing the Gemini spacecraft on later missions. Other awards by NASA:

• **Walter K. Victor** and Dr. Eberhardt Rechtin of the Jet Propulsion Laboratory, $2,500 each for developing a deep space communication system.

• **Andrew J. Kubica** and Noah S. Davis share a $1,500 award for a unit used to decompose hydrogen peroxide to produce jet thrust. They invented it while employed by the Food Machinery and Chemical Corp.

• **Three NASA employes** William J. Alford, Jr., and Edward C. Polhemus, Langley Research Center, and Thomas A. Toll, Flight Research Center, share a $3,000 award for work that made possible the practical application of the variable sweep-wing configuration to supersonic aircraft.

• **Curt P. Herold,** NASA Launch Operations Center, received a $1,000 award for inventing a multiple quick disconnector to switch from ground to vehicle power supply before launch.

• **Robert B. Hess,** Langley Research Center, received a $1,200 award for devising a plasma accelerator which provides a continuous flow of ionized gas.

• **Elden C. Whipple, Jr.,** Goddard Space Flight Center, received a $1,000 award for an improved method for determining space vehicle orientation.

New Space Contracts

Avien, Inc., Woodside, N. Y., has been awarded a $2.8-million contract by North American Aviation, Inc., for development and production of an optical communications antenna system for the Apollo spacecraft that will be used to track the earth as the vehicle makes its way toward the moon.

In another contract last week, Pratt & Whitney received a $980,000 National Aeronautics and Space Administration award for research on the use of fluorine-oxygen and fluorine-hydrogen combinations as rocket engine fuels.

Probers Told Navy Seeks More F-111s

By George C. Wilson

Washington—Navy Secretary Fred Korth continued the defense of his F-111 (TFX) decision last week by telling the Senate Permanent Investigation Subcommittee he was so convinced of the value of the General Dynamics-Grumman variable sweep wing fighter-bomber that he wanted to more than double the Navy's initial buy.

This would increase the Navy's F-111 purchase from 231 to 592, or 361 more aircraft. The Air Force is slated to buy about 1,400 F-111s, but may increase its buy also. The Navy request for more F-111s is pending before Defense Secretary Robert S. McNamara.

The announced intention to buy more F-111s, coupled with estimates that final drawings for the General Dynamics F-111 will be approved this September, tended to allay fears that the Senate's acrimonious investigation might result in a cancellation of the contract or a flying contest of prototypes between General Dynamics and Boeing, the finalists in the F-111 competition.

Instead, the investigation—now going into its sixth month—is turning into a detailed examination of the Defense Dept.'s present decision-making process, rather than a straight comparison of the General Dynamics and Boeing F-111 proposals. Consequently, the F-111 investigation may well be the beginning of a broad look into the Kennedy Administration's military policy by Chairman John L. McClellan (D.-Ark.) and Sens. Henry M. Jackson (D.- Wash.) and Karl E. Mundt (R.-S. D.), the subcommittee members most disturbed about the F-111 decision. All have other committee posts which have jurisdiction over national security matters.

Korth stressed again last week that his Navy officers expressed to him no distinct preference between the competing proposals, and he therefore chose General Dynamics because its proposal promised to meet the requirements in the most straight-forward, uncomplicated manner. But his testimony failed to satisfy several of the subcommittee members, especially Sen. McClellan, on these broad questions:

• **Progress report.** Both contractors were asked by the Air Force, after the final evaluation but before the contract decision, to submit a progress report on their F-111 designs. Air Force said the reports would be "considered" but not evaluated. Sen. McClellan cited earlier testimony by Navy officials that the changes suggested by Boeing in its 100-page progress report Oct. 19 eliminated the advantages the General Dynamics Navy F-111 promised in speed and maneuverability. He contended Korth should have considered these changes in comparing the two aircraft before making a decision. Korth replied that the changes suggested by Boeing amounted to a complete redesign of the aircraft, and had not been evaluated by the Navy.

• **Korth's analysis.** Subcommittee members and Korth argued over whether he gave enough consideration to the competing proposals to justify reversing the Navy-USAF source selection board's recommendation for Boeing. Korth admitted he had not read the fourth evaluation report and that his official log showed he had devoted a total of 5 hr. and 17 min. in investigating the F-111 just before making his decision.

Sen. Mundt said: "It is quite obvious to me that whatever motivated your decision, it was not the counsel, the advice of the tactical people or technical people upon whom you had to rely."

Korth replied that the naval officers who have expressed a strong preference for Boeing while testifying before the subcommittee did not communicate that viewpoint to him. They said either the Boeing or General Dynamics Navy F-111 would meet requirements. Consequently, Korth said he relied on other considerations such as technical simplicity and operational advantages.

As for his analysis of the competing design, he said the time shown in his log "is not the total time which was spent prior to the decision by any manner of means, and telephone calls and visits down the hall with Secretary Zuckert and others. Time in itself is not an appropriate criteria."

• **Rejecting low bidder.** Sens. McClellan, Jackson and Mundt contended Korth rejected Boeing's lower bid on the F-111 as unrealistic without adequately analyzing the cost estimates. Sen. Jackson said Korth should have sent cost accountants to the firms to analyze the bids. Sen. Mundt said the subcommittee's investigation showed Boeing had a better record on cost realism on government contracts than General Dynamics. Sen. McClellan said rejecting the lower bid summarily on a fixed-price contract threatened the integrity of the whole procurement system, and posed this question to Korth: "If this is to be the practice . . . then how do you expect to get bidders to go to the expense and trouble of developing their products and submitting it, if of the low bid it is to be said: 'Well, just because this is a complex article, we are not going to take the low bid, we will take the high bid'."

Korth replied that "we will take the higher bid if the low bid is unrealistic." He said Navy figures showed the Boeing bid was $130 million less than General Dynamics, $581 million compared with $711 million. Korth emphasized that changes requested by the government on the aircraft would not be covered by the fixed-price contract. The Boeing proposal was more complicated, he said, and therefore was "likely" to require more expensive changes. He said he relied on the cost analysis of Air Force Secretary Eugene M. Zuckert to a large extent since USAF was the contracting agency for the F-111.

In reply to previous criticism about his lack of knowledge about where the various sections of the General Dynamics-Grumman aircraft were going to be built (AW July 8, p. 19), Korth said General Dynamics proposed to fabricate 65.2% (by ampere weight) of the aircraft at its Ft. Worth plant and subcontract 34.8% by weight, including the work done by Grumman. Boeing, he said, proposed to fabricate 38.4% of its basic airframe by weight and subcontract 61.6%. These figures were in rebuttal to subcommittee claims that building the F-111 in plants as far apart as Ft. Worth and Bethpage, L. I., where Grumman's plant is located, might offset any dollar savings McNamara predicted would come from building a bi-service aircraft.

First TFX Flight in December, 1964

Washington—First flight of the General Dynamics F-111 (TFX) tactical fighter is scheduled for December, 1964, with the Pratt & Whitney TF-30 P-1 turbofan engine with afterburner as the powerplant.

Dr. James H. Wakelin, Jr., assistant secretary of the Navy for research and development, told the subcommittee that the TF-30 (designated JTF10A-20 by the manufacturer) has undergone 480 hr. of testing in an after-burning condition, and that Pratt & Whitney has eight engines in a running status. He said General Dynamics is scheduled to receive a metal mockup of the TF-30 Aug. 2. The TF-30 without the afterburner underwent in-flight testing last year on a North American B-45 bomber (AW Apr. 2, 1962, p. 73).

In naming the target date, Wakelin told the subcommittee, "I am sure this will be accomplished." He said "we are indeed quite fortunate" to have a head start on the engine, and that "we would have been in a very bad situation if we had started the development of the TF-30 from scratch. . . ." The TF-30 originally was slated to be used in the Navy-Douglas Missileer subsonic fighter.

The first aircraft will not be equipped with thrust reversers, but Navy Secretary Fred Korth did not rule out adding them as the program progressed beyond the prototype stage (AW Apr. 8, p. 26). Wakelin said "it would slow the engine development down" if thrust reversers were added to the engines now.

Chairman John L. McClellan (D.-Ark.) clashed sharply with Korth on the question of whether time would have been saved by choosing the Boeing F-111 design that had thrust reversers in its proposal. General Dynamics' design calls for air brakes. Korth contended the in-flight thrust reversers proposed by Boeing threatened to lead to complications that would slow down the development program. Sen. McClellan countered that it already appears thrust reversers will be added to the General Dynamics F-111 eventually, leading to time-consuming airframe design changes which will cause more complications than Boeing's original proposal.

Tempers Flare on TFX

Washington—Already strained relations between the Senate TFX subcommittee and Navy Secretary Fred Korth reached the breaking point last week when Korth demanded that Dr. James H. Wakelin be excused from testifying rather than submit to more abuse.

Korth made the request July 17 after Sen. Karl E. Mundt (R.-S. D.) confirmed he had told a newspaperman that the Senate Permanent Investigations Subcommittee had accepted explanations from Wakelin that "we wouldn't have accepted from a call girl or Jimmy Hoffa." Sen. Mundt told Korth he did not mean to disparage anyone, but was pointing out that Wakelin was so highly regarded that the subcommittee accepted from him what would have sounded like an implausible explanation coming from a lesser person. Korth later withdrew his request.

American Purchases BAC 111s

Washington—American Airlines has purchased 15 British Aircraft Corp. BAC 111 short-haul turbojet transports, at a total cost of $40 million, and has taken an option on an additional 15 aircraft.

Configuration ordered by American, which the carrier will designate Model 401, is BAC's Model 400, which was specifically designed for U. S. and Canadian markets (AW May 20, p. 41). Powerplants will be Rolls-Royce Spey 25 engines, which will give the BAC 111 cruise speeds approaching 550 mph. over a 1,000-mi. range with 74 passengers.

The first aircraft will be delivered in July, 1965, with delivery of the total order to be completed by the end of the year. Financing of the initial order will be handled with the company's present assets.

Another major trunk carrier also may announce its order for the British transport before the end of next month, informed sources said.

The American order brings the total of U. S. BAC 111 orders to 31. Braniff Airways and Mohawk Airlines also have ordered the twin-jet aircraft (AW Mar. 4, p. 34). BAC officials anticipate that the American decision will encourage orders from other U. S. trunklines which have been considering both the BAC 111 and the Douglas DC-9 for short-haul turbojet operations.

Advantage of the BAC 111 delivery time over that of any comparable U. S.-built, short-range turbojet was a deciding factor in the American order, BAC feels. The first BAC 111 will fly in less than two weeks, according to Sir George R. Edwards, managing director of the British corporation.

Takeoff weight is 78,500 lb., maximum landing weight is 69,750 lb. and maximum payload will be 16,400 lb., to keep takeoff weight below the 80,000-lb. limit in Federal Aviation Agency's two-pilot crew regulation.

American's Finances

Washington—American Airlines has reported a second quarter net profit of $6 million, as compared with $4.1 million for the same quarter of last year. Earnings for the first six months of this year totaled $4.8 million, against $4 million recorded for the same period of 1962.

American noted that while its revenues increased 1.8% to reach $232.9 million for the first half of this year, they did not keep pace with traffic growth, which reached 3.3 billion revenue passenger miles for a gain of 5.4% over the same period last year. Disparity between revenues and traffic growth was attributed to the airline's lower average fares resulting from family fare and military fare discounts.

On the basis of its earnings, American declared a regular quarterly dividend of 87 cents per share on its cumulative convertible preferred stock and 25 cents a share on its common stock.

BOAC Fare Cut

British Overseas Airways Corp.'s round-trip economy fares between Hong Kong and London will be cut 29% from $1,106 to $784, effective Sept. 1.

The fare is available to travelers spending between 19 and 45 days away from home. Since both points are in British territory, no international agreement is needed for approval.

Because the reduced fares will affect the business of other carriers on the route, BOAC may offer the fares to United Kingdom and Hong Kong subjects only, and may not advertise it outside the two areas.

Nations Ignore U.S. Plea to Isolate Cuba

Washington—U. S. State Dept. failed to make any headway last week in its campaign to halt the flow of foreign airline traffic through Havana, Cuba.

Although U. S. notes asking the governments of Great Britain, Canada, Spain and Mexico to help "isolate" Cuba officially were still being studied by the various governments, both airline and governmental sources indicated that neither Spain nor Mexico plan to reduce their present airline service to the island.

Iberia Airlines, Spain's state-owned carrier, has been providing weekly runs from Havana and claims that it has 2,000 advance bookings from Spanish Nationals desiring to leave the island. Spanish government sources indicated the airline will maintain this service until the need for it has ended. Once this is accomplished, schedules will return to the previous pattern of two trips a month, according to airline officials.

Compania Mexicana de Aviacion, a Mexican airline that suspended passenger flights to Cuba last October, has been conducting weekly mail flights to Cuba each Tuesday. CMA denied reports that it has been bringing passengers on the return flight routed through Merida, on the Yucatan peninsula. Cubana, the Cuban airline, presently brings passengers to Mexico City once a week.

Astronaut Candidates

Houston—Manned Spacecraft Center said last week 71 military pilots have been recommended for possible astronaut duties. The breakdown is Air Force 26, Navy 34, Marines 10 and Army one.

Total of applications received by the center was 271, including three women.

Officials confirmed that Miss Jerrie Cobb of Bethany, Okla., is one applicant.



XV-4A Hummingbird Starts Hover Tests

XV-4A Hummingbird, research VTOL aircraft developed for the Army by Lockheed-Georgia Co., is shown during its first free flight hover test at the company's Marietta, Ga., plant. Note open fairings, which are used for vertical flight, on top and bottom of the fuselage. Thrust from the aircraft's two Pratt & Whitney JT12A-3 engines is diverted to ejector ducts where the flow is augmented by air pulled in from above the fuselage to provide thrust for vertical flight. Conventional flight tests were conducted last year (AW Aug. 20, p. 35). Transition tests for the two-seat aircraft, from hover mode to conventional forward flight, will begin later this summer.

Telstar 2 Silenced; Cause Sought

Washington—After nearly 2½ months in orbit, Telstar 2 communication satellite last week lost its tracking beacon signal and failed to respond to command signals intended to turn it on during several passes over the American Telephone & Telegraph Co. station at Andover, Me.

Telstar 1 operated for about 4½ months before experiencing its first malfunction.

Bell Telephone Laboratories scientists were analyzing telemetry data from the 450th orbit, just before the malfunction occurred, for clues to its cause.

Telstar 2 had functioned normally when it passed over Andover the afternoon of July 16, and telemetry signals were received by the National Aeronautics and Space Administration tracking station at Johannesburg, South Africa shortly afterward. But a few minutes later the Australian tracking station at Woomera failed to detect the 136 mc. beacon signal from the satellite.

During the next scheduled pass of Telstar 2 over the Andover station, it failed to respond to transmitted command signals.

Telemetry data obtained in recent weeks gave no indication of radiation damage beyond what was anticipated, BTL officials said. Early data showed that intensity of radiation which Telstar 2 was encountering was only about one-fourth as severe as that experienced by its predecessor (AW June 24, p. 37). This is because Telstar 2's apogee is considerably higher, taking it above the inner Van Allen radiation belt. In addition, Telstar 1 was launched immediately after the July 9, 1962, Starfish high-altitude nuclear test which greatly increased the intensity of the Van Allen belt.

It had been expected that Telstar 2 would be longer-lived than Telstar 1, not only because of the less severe radiation environment, but also because Bell Telephone Laboratories had had considerably more time for testing and selecting the components used in the satellite.

Heathrow Terminal

London—Construction of a new freight terminal in the southwest corner of London-Heathrow Airport has been recommended by an air freight working party composed of government officials and airline representatives.

Air freight traffic at the airport is expected to increase 500% by 1970, reaching 550,000 tons, compared with 100,000 in 1960.

The proposed freight terminal would be connected to the central area by a tunnel.

Ministry of Aviation has appointed consulting engineers to report on tunnel feasibility. The engineers will also report on projected costs.

BAC, Marconi Teamed In Design of UK-3

London—British Aircraft Corp., prime contractor for UK-3, the first all-British communications satellite, will collaborate in satellite design with Marconi Wireless and Telegraph Co. on basis of agreement signed here last week.

Marconi has been studying problems of propagation for some time, and the company's new mechanical products division has been established to produce a steerable antenna for the project.

Marconi also has recently completed a major study for requirements of a comunications satellite ground transmitting and receiving station.

No Merger Opinion

Washington—Civil Aeronautics Board has issued a formal dismissal order in the proposed American-Eastern Air Lines merger case, which legally relieves the Board of any obligation to explain why it rejected the merger (AW July 1, p. 38).

After 18 months of debate, during which the merger application was opposed by a congressional staff study, the Justice Dept. and a CAB examiner, the Board issued a brief press release indicating that it also intended to reject the merger by a 3-2 vote.

Shortly afterward, American filed a petition to dismiss the proceeding. CAB's dismissal went unchallenged.

British Stress Science in Defense Shuffle

By Herbert J. Coleman

London—Sweeping reorganization of Britain's defense establishment along Pentagon lines (AW Jan. 21, p. 38) will put new emphasis and unprecedented powers in the hands of scientists, under a scheme revealed here last week by Defense Minister Peter Thorneycroft.

Plan, which will be debated this month by Parliament, moves Britain further toward integration of the three services while each still retains its identity. Main points are:

- **Appointment of a secretary** of state for defense, with three service ministers under him, each responsible for his particular arm, but with equal authority as deputies to the secretary.
- **Formation of a defense** scientific staff in which the chief scientific adviser reports directly to the secretary.
- **Ministry of Aviation** is relegated to a position on the fringe of the new organization, reverting, in effect, to its former identity as a ministry of supply but with powers in regulation of civil aviation. Minister of aviation will be consulted on defense policy but will have no formal say in its development.
- **Abolition of historic offices** such as the board of admiralty and the posts of secretary of state for war and air, and the army and air councils. All statutory powers now vested with the secretaries of state will pass to the new secretary.
- **Weapons development** and all research will be controlled by the defense scientific staff. Personnel will be mostly civil servants but scientists will be brought in from industry and universities on part-time and consultant basis.

One defense council will be formed, with the secretary of defense as chairman. Members will be the three ministers of state, the chief of the defense staff, chief of the naval staff, chief of the general staff, chief of the air staff, chief scientific adviser, and permanent under-secretary of state.

Plan's Architects

Architects of the plan are Thorneycroft, Admiral of the Fleet Earl Mountbatten, chief of the defense staff; Sir Solly Zuckerman, chief scientific adviser, and Sir Henry Hardman, permanent under-secretary.

As it now stands, the four men will assume the top posts when the scheme is formally enacted Apr. 1, 1964. It probably will become law next October when Parliament resumes for the winter.

Four top posts of secretary and ministers will be filled from the government, in that each man must be a member of Parliament to hold the appointment. There is no provision for appointing a secretary from private life or industry, as is the case in the U. S.

Thorneycroft will get vastly increased powers. A top government spokesman said he is now, as minister of defense, primarily a coordinator between the three services with certain veto powers in financial matters. Under the new setup, his influence will be channeled in direct lines to all the services, and he will have direct access to the prime minister.

Service ministries are now headed by Lord Carrington, first lord of the admiralty; Hugh Fraser, secretary of state for air, and James Godber, secretary of state for war, all of whom are expected to be reappointed ministers of state. Julian Amery heads ministry of aviation but his future position in seats of defense power remains unclear, aside from collaboration in weapons contracting and procurement.

Separate Identities

Although the three services will preserve separate identities, new ministry plans will be organized wherever possible on a defense, rather than single service, basis, mostly in the field of weapons which can be used or coordinated by all three.

New ministry puts great stress on the need for control and direction of policy and administration, on international lines. Defense white paper explains:

"Major questions of defense policy cannot be discussed in purely military terms; they also need to be examined in relation to foreign and economic policy, and in this wider context they often raise further issues which have a considerable political content.

"Conversely, our political relations with the other members of the commonwealth and with foreign countries bear directly on our defense policy, and the requirements of the government's financial and economic policies equally affect the size, disposition and equipment of the services."

Subject to the supreme authority of the prime minister and the cabinet, these matters will be dealt with by a committee on defense and overseas policy. Prime minister will be chairman. In addition, the chief of the defense staff (Lord Mountbatten) and chiefs of the services staffs will continue to attend meetings of the full cabinet and will retain their rights of access to the prime minister.

Operations Center

Defense operations center will replace the present war room in Whitehall and will be controlled by a defense operations executive body composed of the vice-chief of defense staff, assistant chief of naval staff, director of military operations and assistant chief of the air staff.

Two other new departments are the defense signals staff which will form an integrated defense communications center, and the defense intelligence staff, a pool of intelligence facilities now operated by the three services. Secretary of defense will hold ultimate responsibility for security.

Increasing complexity and importance of research is recognized in the creation of a defense scientific staff. Under the

New Exhaust Studied for Balzac

Paris—New exhaust system for the Dassault Balzac VTOL engines is being studied to permit the experimental fighter to lift off unprepared sites without the use of its special launching grid.

At present, Balzac's eight Rolls-Royce RB.108 lift engines exhaust directly downward through hinged doors in the fuselage (AW June 24, p. 68). Exhaust gas temperatures of about 1,100F prohibit runup use of lift engines except over the launching grid.

New system would deflect lift engines' exhaust rearward during runup or ground roll.

Lift engine exhaust would then be deflected downward only during the necessary few seconds for vertical takeoff performance.

Actually, not all French officials agree that the new system is necessary. They argued that operational use of VTOL fighters implies considerable ground support equipment and a launching grid would not impose a special burden.

It is likely, however, that Dassault will go ahead with the proposed modification in order to counter the criticisms voiced by those French and non-French observers who have expressed doubt about the Balzac weapons system because of its need for a launching grid.



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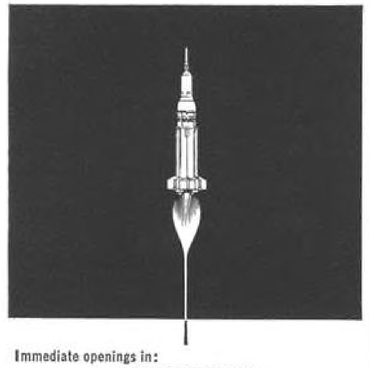
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Environmental control systems (launch facilities design including air-conditioning systems, cryogenic piping and propellant storage.) Theoretical Launch Facilities Design (feasibility and design studies of future space flight systems, earth orbital and lunar base operations.)

MANUFACTURING

Analyze documentation, determine breakdown of assemblies, define operations, sequence and tool requirements; liaison to control product, process, tool design and inventory. **Special Equipment Design . . .** Development, design, analysis, construction and installation of special equipment; pneumatic and hydraulic, or electronic test equipment; special handling techniques in large components.

PROGRAMMERS

Analog Computation (structural dynamics, aero and astro dynamics, control and guidance systems and closed loop hardware simulation.) Digital Computation (information retrieval, data reduction, scientific computation in trajectory analysis, aerodynamic heating, structural and vibration analysis aerodynamics.) Digital Programming to generate large-scale data processing control system.

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RELIABILITY

Develop analysis methods and techniques; analysis in electrical, mechanical, electro-mechanical, structural, propulsion, systems and other areas; evaluate program; recommend engineering changes.

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plan, Sir Solly Zuckerman will be chairman of two new committees to work with defense operational requirements staff and the defense secretariat. They are:

• **Defense research committee,** to oversee all military research which does not directly support approved weapon and equipment projects. Group will advise the secretary and chiefs of staff on all scientific and technical aspects of R&D policy, along with maintaining a constant review of funded projects. Committee membership will be mainly scientific and provisions have been made to include participation by independent scientists.

• **Weapons development committee,** to keep all programs under review to ensure that they are properly matched to available resources, defense policy and operational requirements in the light of what is technically feasible. Ministry of Aviation will be represented on both committees.

Budget Responsibility

Permanent under-secretary of state (Sir Henry Hardman) will be primarily responsible for preparation of the defense budget, now approaching about $8 billion a year. He heads the 25,000 civil servants now in the establishment and this force is expected to stay constant in the first few years of the new ministry.

Traditional link with the sovereign has been retained under the reorganization by Queen Elizabeth's acceptance of the 600-year-old title of Lord High Admiral following abolition of the lords commissioners who at present exercise the office.

Senior officer will be appointed as defense services secretary to act as a link between the sovereign and the secretary of defense.

Entire new establishment will be housed in a single building in Whitehall Gardens; minister of aviation and certain key members of his staff also will have offices in the central structure, now unofficially known as the "Quadragon." Building is now occupied by air ministry and board of trade.

Additional Load

Ministry of Aviation was not included as a full partner in the new setup because, as the white paper put it, the Ministry's wide responsibilities for civil aviation, as well as military R&D, would put a heavy additional load on the secretary, much of it outside the defense sphere.

Thus, Ministry of Aviation will continue to be an independent department, but with its responsibilities for execution of programs of defense research and development and production which are formulated and approved by the secretary of defense.



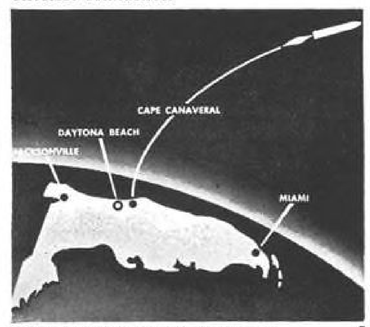
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Turkey, Greece to Receive F-104Gs, F-5As

Washington—Turkey and Greece are to receive Lockheed F-104G and Northrop F-5A aircraft under the Mutual Assistance Program (MAP).

Defense Dept. said the U. S. will furnish the aircraft as grants-in-aid and the countries will furnish bases, facilities and personnel to man and maintain them. Delivery date was not disclosed.

Turkey will receive 38 F-104Gs. This model aircraft can be used as an interceptor or as an attack plane. The number of F-104Gs going to Greece and the number of F-5As going to both nations was not disclosed. The F-5A is also a dual-purpose aircraft.

Both countries have been operating U. S.-built aircraft since 1947. The present move, Defense Dept. said, is a continuation of MAP and marks no departure from past procedures.



NASA REPORTS:

The following letter has been received from the National Aeronautics and Space Administration, Manned Spacecraft center, Houston, Tex.:

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GD/A Test Sites, Labs Placed Under McNabb

Cape Canaveral—All General Dynamics/Astronautics test sites and test laboratories will be grouped together in a Directorate of Test Engineering next month under B. G. McNabb, former chief of GD/A's operations here at the Atlantic Missile Range.

Although the test sites—Atlantic and Pacific Missile Range operations, Pt. Loma and Sycamore Canyon—have been organizationally grouped together before, this will be the first time the approximately 20 laboratories will have been tied together. Purpose of this reorganization will be to achieve an integrated research and development test capability which will serve all GD/A programs and project offices.

McNabb, who has been director of GD/A's operations here at the Atlantic Missile Range for more than six years (AW June 24, p. 38), will be replaced by Kenneth Newton, formerly chief of GD/A's operations at the Pacific Missile Range and, before that, an assistant to McNabb at AMR. Newton was chief test conductor for the Atlas launch vehicle for the flight of John Glenn's MA-6 spacecraft.

Westland, Bell Sign GEM License Pact

Westland Aircraft, Ltd., and Bell Aerosystems Co. have signed a license agreement under which Bell will manufacture and sell Westland/Hovercraft ground effect machines (GEMs) in the U. S. Bell also was given sales rights in Canada and Central and South America.

Westland/Hovercraft currently has three production GEMs—the seven-ton SR.N5, which will carry 20 passengers or two tons of cargo; the 27-ton SR.N2, which carries 70 passengers or eight tons of cargo, and the 37.5-ton SR.N2-Mk.2, which carries up to 150 passengers or 12 tons of cargo.

Bell has two GEMs in operation—the 22.5-ton Hydroskimmer for the U. S. Navy and the 1.5-ton experimental Carabao. The agreement with Westland now gives Bell exclusive rights in the U. S. to build and sell GEMs based on Westland/Hovercraft patents.

The Bell agreement is the second international arrangement negotiated by Westland. Last February, the Mitsubishi Shipbuilding and Engineering Co. of Tokyo was licensed to manufacture Westland/Hovercraft vehicles in Japan, subject to the approval of the Japanese government (AW Feb. 25, p. 41).

Concorde Options

Paris—French and British governments have agreed that no further "option-orders" will be accepted for the Sud-BAC Concorde supersonic transport.

Pan American World Airways placed an option-order in early June for six Concordes (AW June 10, p. 40). The French and British governments apparently now feel that such action merely ties up Sud-BAC production planning without guaranteeing that the reserved production line slots will be used.

Also, down payments involved in transactions like the Pan American order are mainly symbolic and do not contribute to Sud-BAC capital needs, the European officials feel.

More Firms to Seek Comsat Corp. Study

Washington—Unanticipated wide interest has developed in the Communications Satellite Corp.'s request for proposals for a study contract on a multiple access system of communication via satellite (AW July 15, p. 27).

The list of companies expected to submit proposals has expanded to eleven. These include: Hughes Aircraft Co., Motorola, Inc., Philco Corp., Page Communications Engineers, Inc., International Business Machines Corp., Melpar, Inc., and Magnavox Co.

The satellite corporation's original request for proposals was sent to four firms: Bell Telephone Laboratories, Inc., General Telephone & Electronics Corp., International Telephone & Telegraph Corp., and RCA.

U.K. Military Charters

London—Two British state-owned airlines last week served notice on Britain's independent airlines that military charter contracts, historically an independent domain, will be open to BOAC-BEA negotiations with individual services, if the Air Transport Licensing Board approves two applications.

BEA has specifically requested charter approval to Germany, Malta and Cyprus, offering reductions of up to two-thirds of the normal air fares.

In support of these bids, Henry Marking, BEA secretary, told the licensing board that in 1962-63, on the three routes involved, BEA flew with 33,250 empty first-class seats and 184,035 empty economy-class seats.

BOAC has applied for rights to negotiate for troop transport, as predicted in Aviation Week & Space Technology (Feb. 25, p. 52), on routes to the Far East and Africa.

More Military Cargo For Airlines Sought

Washington—Military Air Transport Service was urged to consider shifting more cargo business to commercial air carriers in a report issued last week by the House Government Operations Committee.

Specifically, the committee proposed that more cargo traffic be assigned to commercial lines operating scheduled high-density routes to Europe, Alaska, and the Far East.

Although the airlines' military passenger business has risen sharply in recent years, the committee noted that their military cargo business is scheduled for a sharp drop in Fiscal 1964.

Over the three-year period from Fiscal 1959 through Fiscal 1961, the air carriers' international cargo business from MATS averaged $21.1 million. This increased to $65.7 million in Fiscal 1962 and declined to $63.8 million in Fiscal 1963. The programed amount for Fiscal 1964 is only $29.2 million.

The carriers' international passenger traffic from MATS mounted from $48.8 million in Fiscal 1959 to $77.2 million in Fiscal 1962, and to $102.8 million for Fiscal 1963. It is expected to rise to $128.2 million in Fiscal 1964.

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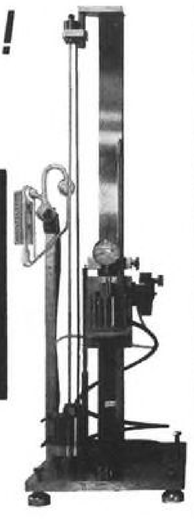
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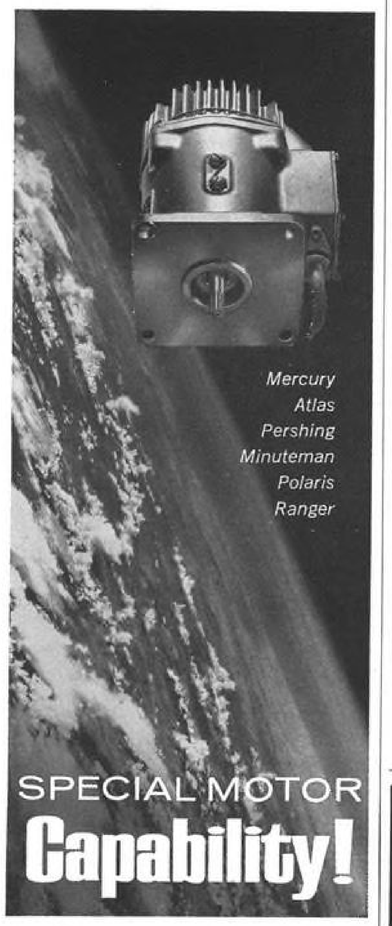
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Jamaican Carrier Using Twin Bonanza

Jamaica Air Service, Ltd., Twin Bonanza, on the ramp at Montego Bay International Airport, is being used in the island's first scheduled internal service, linking north coast resort areas of Ocho Rios and Port Antonio with Montego Bay and Kingston by two daily round-trip flights. Third daily non-stop round-trip connects Montego Bay and Kingston. JAS is a wholly-owned subsidiary of British West Indian Airways.

New Filter Planned for P.1127

London—Hawker Aviation, Ltd., is designing a new filter for the pressure-reducing valve which caused the crash of its P.1127 VTOL strike fighter at the Paris Air Show (AW July 15, p. 27).

R. E. Lickley, Hawker deputy managing director, said a 300-mesh fine filter will be installed in the pressure-reducing valve, which controls activation of the four nozzles of the Bristol Siddeley Pegasus vectored-thrust engine.

Lickley said the crash was caused by ingestion of grit into the valve. This locked the nozzles backward at 20 deg. during an attempt by Chief Pilot A. W. Bedford to transition from hover to forward flight. When the valve failed, the nozzles locked and the P.1127 lost altitude rapidly, crashing in seconds.

Lickley said that Hawker Aircraft is considering duplication of the reducing-valve system in future aircraft so that control of the nozzles would be lost only in a double failure. An immediate fix is the installation of a copper filter to stop ingestion of any particles.

Lickley said the damaged P.1127, the third development airplane owned by British Ministry of Aviation, is repairable, and that five have now been built. Nine airplanes ordered by RAF, U. S. and West Germany, due for 1964 delivery will include the filter fix.

The first Bristol Siddeley Pegasus 5 engine, for installation in the No. 6 development aircraft will be delivered next month. The engine has produced 14,000 lb. thrust.

Douglas Profit

Net profit of $3,444,850 or 83 cents per share has been reported by Douglas Aircraft Co. for the second quarter of Fiscal 1963, which ended May 31. Profit for the same period last year was $2,515,901, or 61 cents per share.

Sales for the second quarter of Fiscal 1963 were $175,913,680, compared with $194,992,029 a year ago. For the first six months of this year, sales totaled $374,338,734, compared with $359,071,928 for the same period in 1962.

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News Digest

Pratt & Whitney was selected last week to develop the Lunar Excursion Module (LEM) fuel cell under subcontract to Grumman, according to Rep. Emilio Q. Daddario (D.-Conn.). Contract value is estimated at about $13 million. Fuel cell contract was one of the largest in the LEM system which had not been awarded (see p. 141).

Syncom 2 active repeater communications satellite is scheduled for launch from the Atlantic Missile Range July 23. Several changes have been made in the Hughes-developed spacecraft (AW June 10, p. 108) since the failure of Syncom 1, launched Feb. 14, 1963. All radio contact with Syncom 1 was lost during or following the firing of the apogee motor. Syncom 2 is to be launched into a 24-hr., 22,300-mi. orbit.

Donald C. Burnham last week was named president, chief executive officer and a director of Westinghouse Electric Corp., succeeding Mark W. Cresap, Jr., who resigned for health reasons. Burnham was formerly vice president of Westinghouse Electric's industrial group.

Sperry Piedmont Co. of Sperry Rand Corp. received a $850,000 contract from USAF last week for an addition to

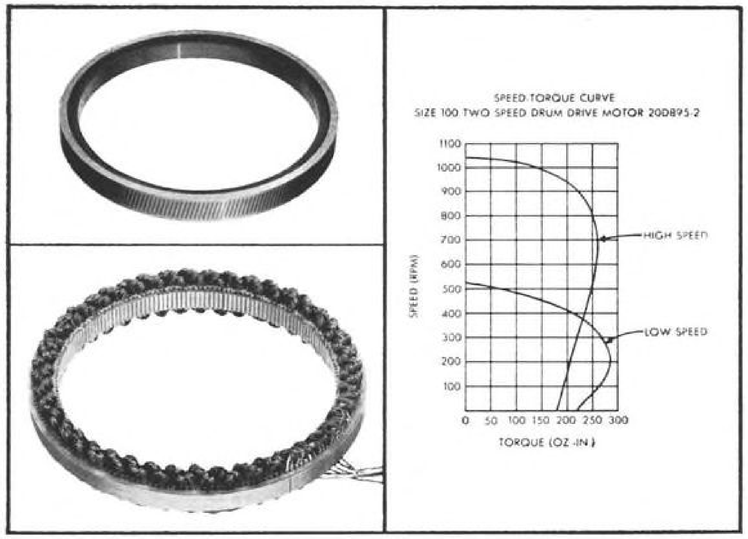
LEM Truck Payloads

Maximum time that two men could be supported for a planned-stay mission on the moon with one 7,000-lb. LEM truck payload is 60 days, according to Grumman studies. Payload would include a 10-ft.-dia. shelter and a two-month supply of life support expendables, but no lunar rover vehicle or mission equipment (see p. 163).

Addition of 750-lb. of mission equipment—for lunar scientific studies—would reduce the mission time to slightly over 45 days, since a comparable weight in expendables would have to be eliminated.

If a lunar rover vehicle and a mobile shelter were included in the payload, with an estimated weight of 1,800 to 1,850 lb., the mission time would be cut to about 25 days.

Mission time then would become a function of the extent of lunar explorations. If the vehicle were used over its full 1,000 mi. range—unmanned and remotely controlled—the mission time would be reduced to about 14 days. Operating the rover as a manned vehicle would reduce its range to a minimum of 400 and a maximum of 700 mi. in the same 14-day mission period.



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Maintainability Engineers. BS degree (preferably EE); seven years minimum in defense industry including three years minimum experience in maintainability plus a combination of field and design engineering experience in the electronics field. Will create and/or direct overall logistics and maintainability programs.

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be built to the central control facility of the Atlantic Missile Range. This expansion is expected to allow USAF to launch two missiles simultaneously and count down a third. Sperry will design, manufacture, install and check out the systems in the annex and train USAF personnel in their use.

Swedish space committee's technical group will launch four Nike-Cajun sounding rockets during the July 22-Aug. 15 period from the Swedish Arctic area to measure temperature variations from 23- to 59-mi. altitude. The launches will seek to determine if sufficient humidity exists at these altitudes for condensation to occur. Program is being conducted for Stockholm University's meteorological institute.

USAF/Boeing Minuteman exploded about 5 sec. after launch from Cape Canaveral July 16 when trouble developed in the first stage of the three-stage solid propellant ICBM. It was the eighth failure for the missile, which has scored 25 successes and four partial successes in almost 2½ years of flight testing.

Saab 105 two-place, twin-engine jet trainer and tactical aircraft under development for the Swedish air force (AW June 3, p. 29), made its first flight recently at Linkoping, Sweden.

Andre Turcat, test pilot with Sud Aviation and winner of the Harmon Trophy in 1959 for his piloting of the Nord Griffon ramjet aircraft, will fly the French-built version of the Sud-BAC Concorde supersonic transport.

MORL Study

Sperry Rand Corp.'s Systems Group has started a six-month study program for NASA to explore control and stabilization problems involved in a Manned Orbiting Research Laboratory (MORL). The contract, for approximately $50,000, calls for a study centering around a four-man laboratory with artificial gravity. Award was made by NASA's Langley Research Center, Hampton, Va.

MORL concept (see p. 77) is based on booster limitations requiring the laboratory to be sent aloft alone to rendezvous with its occupants and supplies on later logistics flights. This calls for an automatic control and stabilization system during the initial portion of flight, and an accurate stop/start system for rendezvous and docking operations.

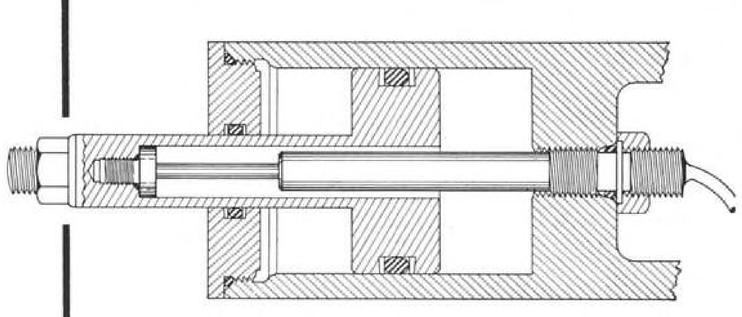
Study is intended to stay within the general confines of hardware expected to be available or easily developed within a "reasonable" time. Primary objective is accumulation of data on different means of stabilizing MORL and evaluation of respective methods.

Soviet Union acknowledged last week that an Aeroflot transport crashed July 13 at Irkutsk in southern Siberia, killing about 30 persons, including the wife of Albania's ambassador to Red China. Earlier, Albania had identified the aircraft as a twin-turbojet Tu-104, bound for Peking from Albania. In the Soviet announcement, which came two days after the accident, control tower officials were quoted as saying the Tu-104 crashed at 10 a.m. less than 2 mi. from the Irkutsk airfield.

S. D. Heron, former director of aeronautical research for the Ethyl Corp., died at age 72 in Detroit recently after a long illness. Since his retirement in 1946, he had served as a consultant to the government, Ethyl and others on engines, fuels and engineering materials.

Ralph Shepard Damon Hall has been dedicated at Clarkson College of Technology, Potsdam, N. Y., to the memory of Damon, whose aviation career encompassed the presidency of four prominent companies. A World War 1 flying cadet, Damon was later president of Curtiss-Wright Airplane Co., American Airlines, Republic Aviation and Trans World Airlines. Damon Hall is occupied by Clarkson's departments of chemistry and electrical engineering and a research laboratory.

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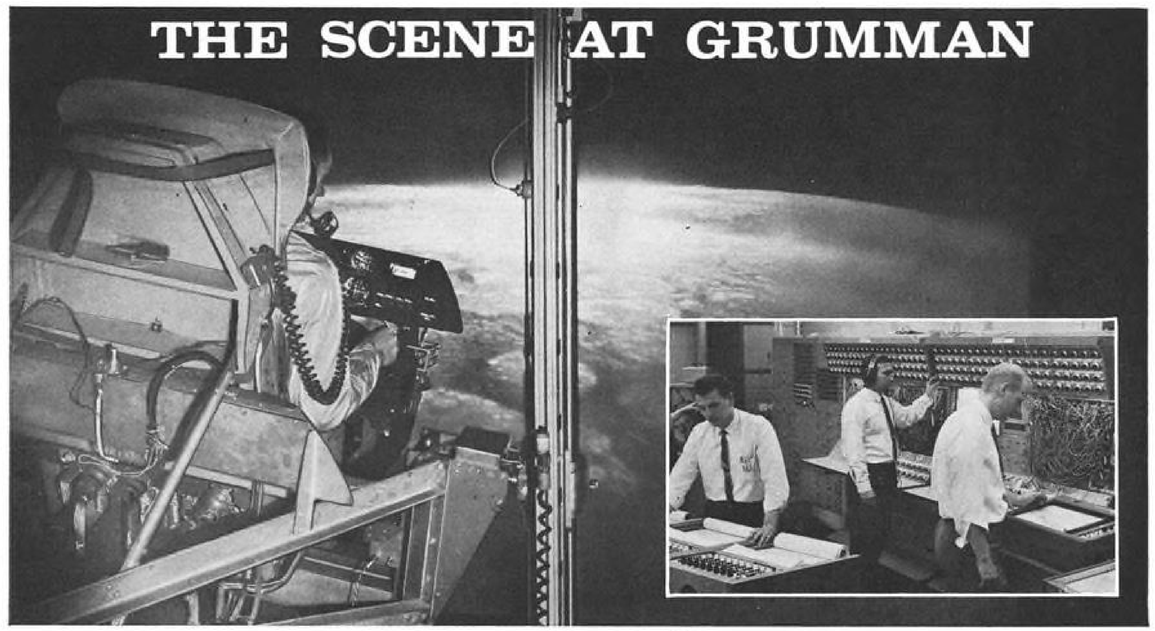
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Shown above at the analog computers are Engineer Robert Herdman (joined Grumman Jan. '63), Morton Hausner, Analog Computer Analyst (joined Grumman '61) and Fred Wood, Systems Simulation Engineer (joined Grumman '54), monitoring simulation of Gray Smith, Advanced Systems Engineer (joined Grumman '50) performing lunar landing.

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Aerospace Environmental Control & Life Support Systems Engineers—BS in ME, Chemical Eng., or EE, minimum 2 years fluid mechanics and/or thermodynamics experience in analysis, design, development, testing, installation for aircraft and space vehicles in one or more of the following areas: ENVIRONMENTAL CONTROL (Cabin, Equipment, Pressure Suit-cooling, heating pressure, humidity, controls); LIFE SUPPORT (Stored, Regenerative, Ecological Systems-CO_2, toxic gases, odor and moisture removal); CRYOGENICS (Storage, Supply, Temperature and Pressure Controls); TESTING (Development, Qualification, Functional Pre-flight).

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Senior Propulsion Aerodynamicists/Aerothermodynamicists — BS or MS with 5 years minimum experience in one or more of the following: Nozzles, Thrust Vector Control, Air Induction Systems, Reaction Jet Systems, Ducted Fans, Rocket Plumes, Pressurization Systems, Airborne Cooling, Boundary Layer Analysis and Control, Rotary Machinery Analysis, Ramjets, Exhaust Systems, Compressible Fluid Flow, Windtunnel Testing, Thrust Reversers, and Hypersonic Airbreathing Propulsion Systems.

Navigation & Guidance Engineers — B.S. in Engineering with a minimum of 3 years experience in Navigation and Guidance systems. Should be experienced in real system and component hardware including analysis, system synthesis, performance and test in aerospace applications.

To arrange an immediate interview, SEND RESUME to Mr. P. W. Van Putten, Manager Engineering Employment, Dept. GR-25

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- Weapons Systems C&C

Advanced Development Projects
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- Data Acquisition Sensing & Detection Systems
- Simulation & Training Complexes

Advanced Systems Projects
- Space Range Systems
- Surveillance Systems
- Space Command & Control
- Space & Ground Military Information Handling Systems

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- Control Systems
- Communications
- Data Processing Systems

Human Factors Sciences
- Man-Machine Integration
- Personnel Subsystem Analysis
- Command Staff/System Exercising & Evaluation
- Human Engineering

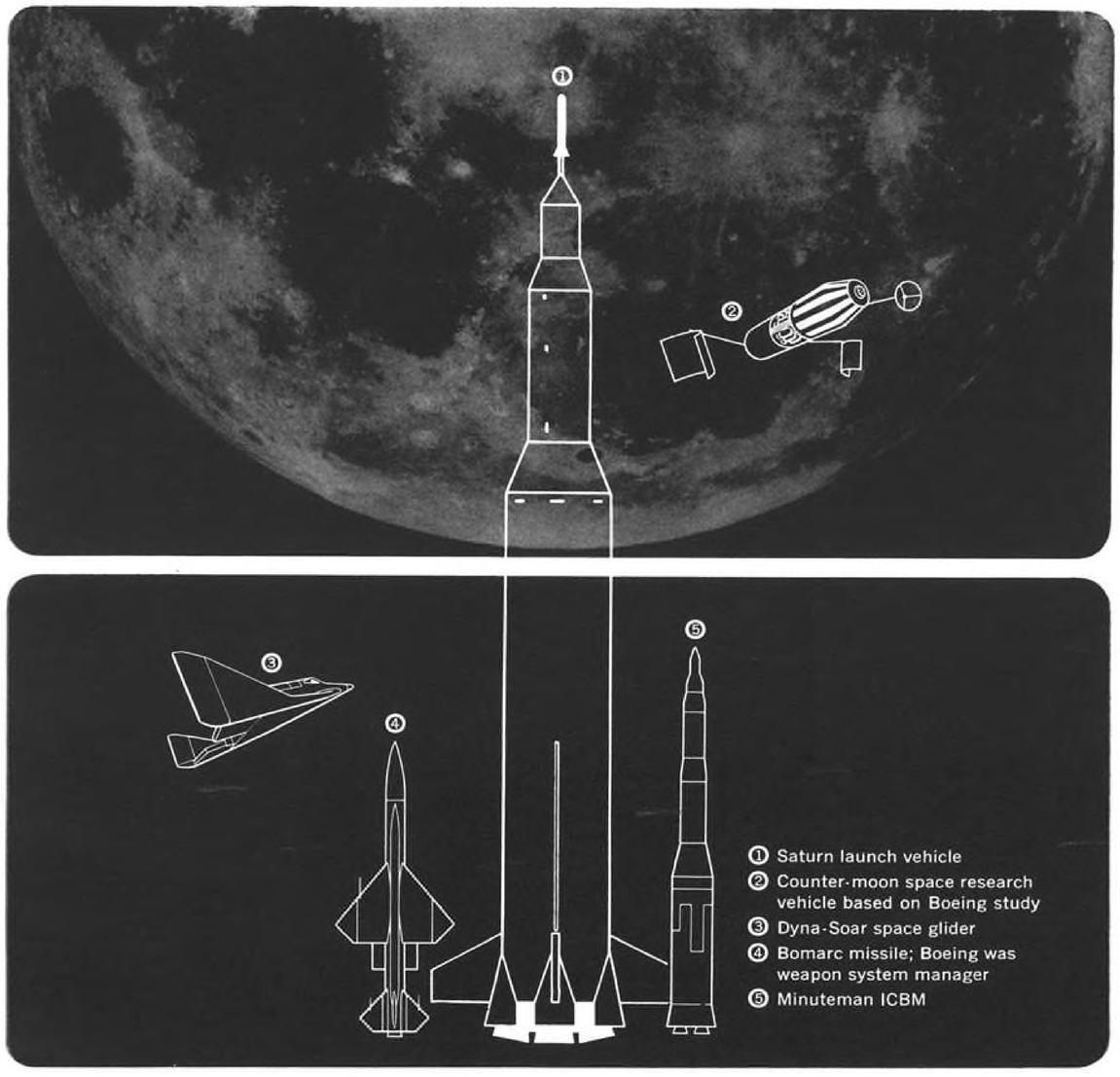
Systems Sciences
- Optimization Techniques in System Design & Control
- Real Time Management & Control
- System Simulation & Scheduling
- Control & Staffing of Human & Human Linked Subsystems
- Gaming Technology

Space Science
- Life Sciences — Bioastronautics, Psychoastronautics
- Manned Space Subsystem
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Whether your own background is largely theoretical, or design . . . systems hardware, or software oriented . . . if you'd like to join us in these efforts, we invite your early inquiry. Write fully in strict confidence to Mr. E. A. Smith, Manager of Employment, Division 19-WD, International Electric Corp., Route 17 & Garden State Parkway, Paramus, New Jersey. (An Equal Opportunity Employer)

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National Aeronautics and Space Administration
at the Aeronautics and Space Committee Hearings,
U.S. House of Representatives, 1963.

General Electric's Apollo Support Department has been selected to assist NASA in the integration support, checkout and reliability assessment of the Apollo system. Without doubt, it takes an unusually mature and competent man to perform under the realization that his individual work can be of significant importance to such a program.

If you are the kind of person who thrives on such responsible work, there's a place for you with General Electric. We've already put together the most impressive team ever assembled in the General Electric Company for this program ... however, there are *many* opportunities still available to the *right* men. From the listings below you can determine your own opportunities. **Contract Programs:**

CHECKOUT ... work consists of two distinct parts. First, a continuation of current engineering study efforts to provide NASA with checkout systems analysis, standardization studies, an integrated space vehicle checkout system specification, studies of test procedures, the application of advanced checkout techniques to Apollo, and system checkout engineering support at NASA field centers. Second, provision of checkout equipment to be included within the integrated launch control and checkout system.

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- ☐ **Systems Engineering**
- ☐ **Cryogenics**
- ☐ **Engineering Writers**
- ☐ **Computer Engineering**
- ☐ **Computer Programming**
- ☐ **Data Processing Display**
- ☐ **Circuitry & Circuit Design**
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- ☐ **Instrumentation & Simulation Systems**

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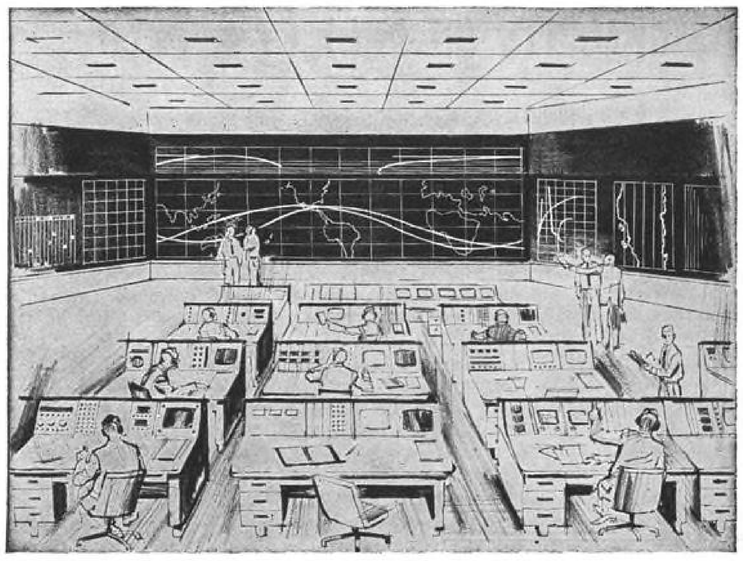
Write today to: Mr. P. W. Christos, Apollo Support Department, General Electric Co., Support Building, Room 64-M, P.O. Box 2500, Daytona Beach, Florida. (Your inquiry will be held in strict confidence. Please include your salary requirements.)

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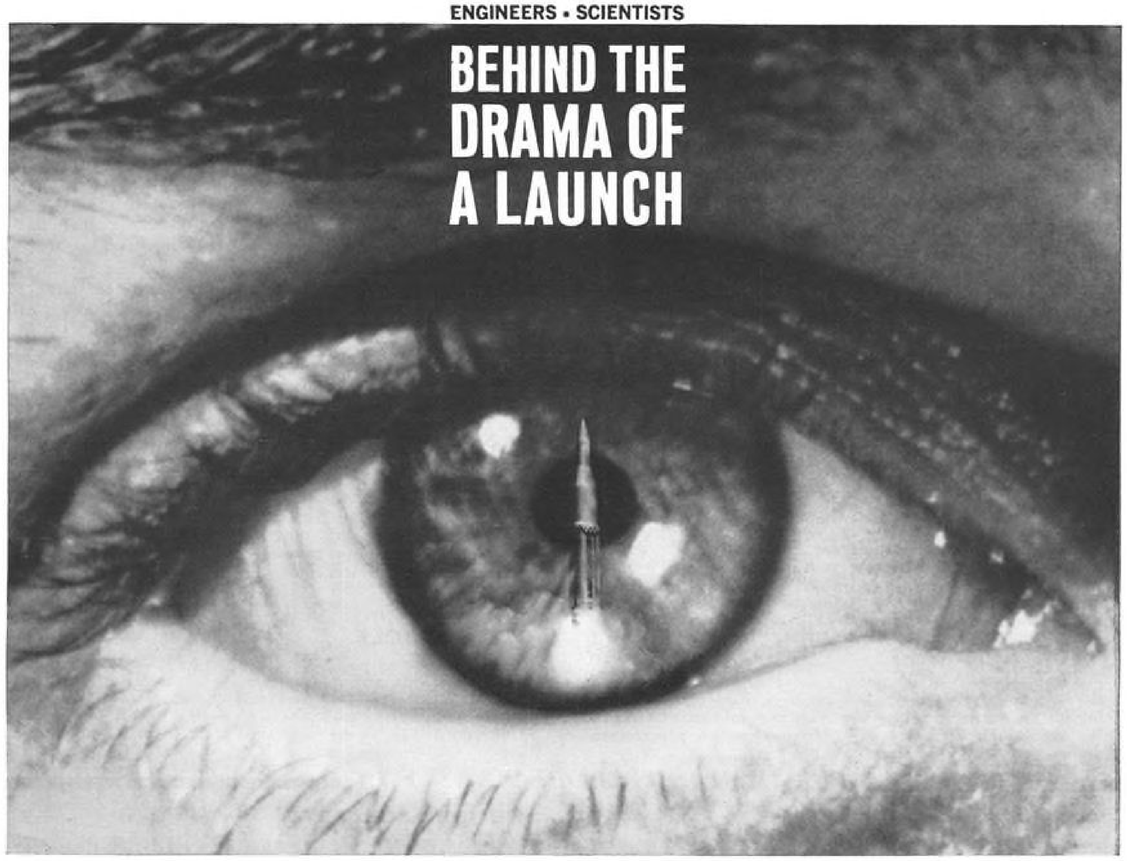
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Bell is currently working on several R&D contracts with the Air Force for the study and development of techniques and systems for guidance and control of advanced orbital and reentry vehicles. These programs include all aspects of manual and automatically controlled energy management, rendezvous and docking.

GEM VEHICLE

Recently a contract was awarded to Bell by BuShips to design and build a high performance vehicle, the SKMR-1 HYDRO-SKIMMER. 65 feet long and weighing 22 tons, it will be capable of operating over a foot above water at a top speed of 70 knots. This is the largest GEM program in the U. S. today.

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- Analysis and development of techniques and requirements for control and guidance of vehicles in rendezvous, docking and lunar landing and take-off missions. Both complete space vehicle systems and single man locomotion systems are involved. A long range company sponsored program is underway in this area and openings exist for exceptional engineers.
- Analysis and development of advanced techniques for energy management of lifting vehicles re-entering from earth and lunar orbits. Methods for optimum control of these vehicles, with respect for vehicle and human limitations as well as for airborne mechanization problems, are required. Immediate openings exist for exceptional personnel with ability to contribute creative ideas to current Air Force contract programs.
- Development of techniques and programs for the digital and/or analog simulation of flight dynamics of aircraft and space vehicles and their control and guidance systems. Several advanced simulation programs are now under development, and immediate openings exist in this area.

MS degree in engineering, applied math or equivalent and 5 to 10 years applicable experience. Salary commensurate with experience.

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To perform propulsion system performance analyses and related flow analyses for aircraft and GEMS powered by ramjets, turbojets, fans, propellers and ducted propellers. BS AE with MS AE preferred and seven to ten years of applicable experience. Salary commensurate with experience.

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To determine requirements and advanced concepts for space vehicles and space propulsion systems through company-funded and contractual advanced design studies. Assignments will include the coordination of activities in the preparation of major proposals, being cognizant of technical approach, scheduling and cost aspects. These positions offer the potential of appointment to technical direction or project engineering responsibilities when contracts result from successful proposals. Requires BS in engineering, with advanced degree preferred, and 8 to 15 years experience in system engineering.

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To participate in G.E.M. system analysis, design, synthesis and evaluation. Must be capable of integrating analytical data from all engineering and scientific disciplines and directing design proposal efforts and small R&D contracts. Prefer recent experience on a hardware GEM program. Salary dependent on experience.

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Kollsman's Apollo Program responsibility consists of optical subsystems including sextants, scanning telescopes and display units, ground support equipment, systems analysis and a concentrated reliability effort for the Apollo Command Module and the Lunar Excursion Module (LEM).

GODDARD EXPERIMENT PACKAGE—(GEP)

Kollsman is providing a telescope spectrometer designed to analyze UV spectra of selected celestial bodies incorporating its own vernier guidance system and its own digital data processing system all designed to operate in an orbiting astronomical observatory.

ORBITING ASTRONOMICAL OBSERVATORY (OAO)

Kollsman has responsibility for providing star trackers for the stabilization and control subsystem of OAO. Six Kollsman units will be mounted in the OAO in a way that three stars can be tracked at all times for precise pointing of the experimental packages that are contained in the observatory.

AN/USQ-28-GEODETIC SURVEY AND PHOTO MAPPING SYSTEM

This Kollsman project is a geodetic survey and photo-mapping system for the RC-135A jet aircraft. Intended to compile accurate geodetic maps of the entire free world, it consists of mapping cameras and an extremely accurate inertial navigation system and digital computer, all combined with an airborne and ground data recording and reduction system.

Immediate assignments are available for creative engineers and scientists at all levels through PhD in the following technical areas:

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Activity involves the design and development of advanced optical and electro-optical systems and sub-systems encompassing geometric optics, physical optics, optical electro-mechanical components and systems (IR through visual).

ELECTRONICS

Assignments in the design and development of complex electronic systems involving digital electronics (circuitry, systems design, logic design), modern circuit theory (active and passive network analysis, feedback systems analysis), solid state circuit design (pulse and video techniques, analog techniques), plus the design and development of complex electronic systems involving communications and radar sub-systems. Some background in optics desirable.

RELIABILITY AND QUALITY ASSURANCE

Senior assignments of large scope and complexity dealing with optical and electro-mechanical equipment, including test specifications, evaluation of equipment and progress, failure analysis and the direction of subordinate engineers.

RESEARCH

Applied research in all facets of optics, including lasers and masers, bionics and medical electronics, digital systems, system analysis and synthesis and advanced control mechanisms.

HUMAN FACTORS

Senior level assignments for candidates with advanced degree in psychology and experience in human factors functions in industry, plus familiarity with applicable military specifications, equipment planning, and human engineering requirements.

VALUE ENGINEERING

Assignments involve planning, organization and implementation of a program of value analysis design to effect cost reduction and improve product reliability. Heavy experience is required in one or more of the following categories: electronics, mechanics, optics.

SPACE NAVIGATION AND GUIDANCE SYSTEMS

Assignments involve studies and development of advanced orbital and deep space navigational guidance and attitude control systems. Advanced degrees are required in mathematics, physics, optics or engineering and an interest in ASTRONOMY, CELESTIAL MECHANICS, OPTICS, INSTRUMENTATION, APPLIED MATHEMATICS, AUTOMATIC CONTROL SYSTEMS and COMPUTER DESIGN.

FIELD ENGINEERING

Assignments in Kollsman's field engineering R&D operations require practical experience with precision optical, airborne computers, cameras, solid state equipment and servo systems. Long term field assignments after training period in New York. A degree in physics, EE, ME or aeronautical engineering required.

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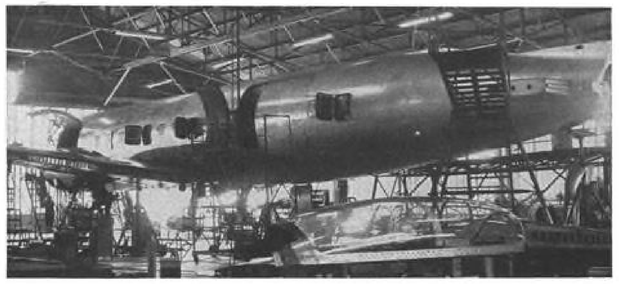
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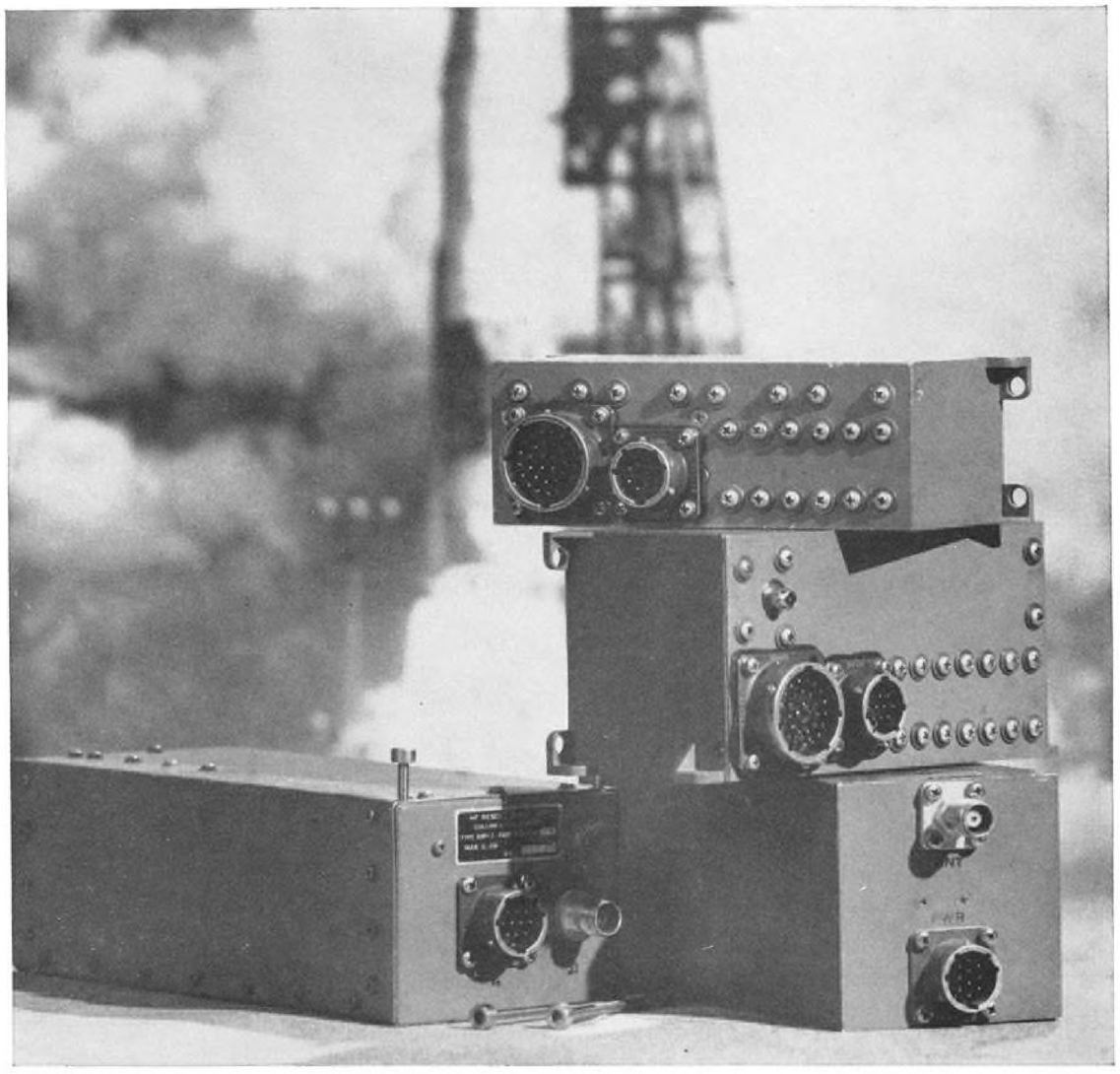
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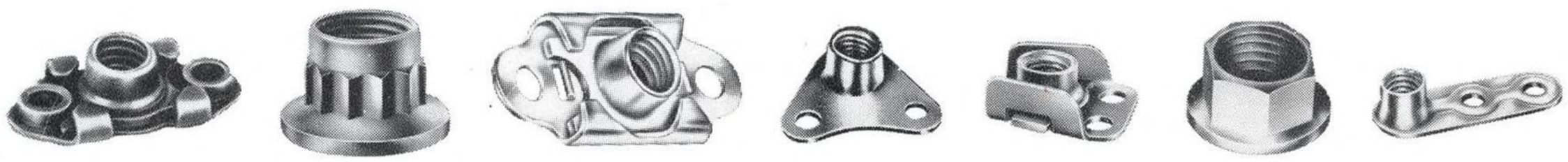
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