75 cents

JULY 2, 1962

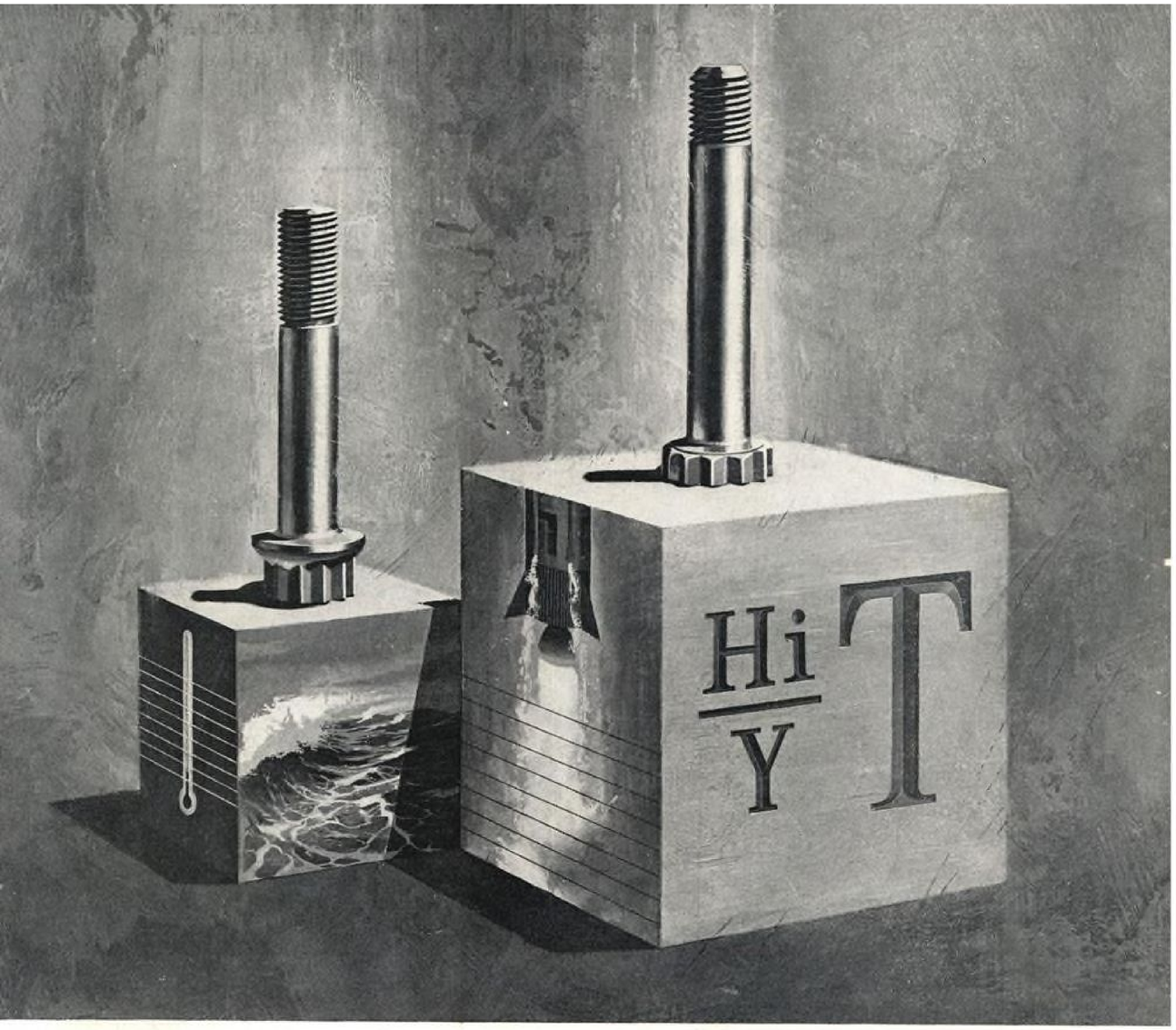
Aviation Week & Space Technology

A McGRAW-HILL PUBLICATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION U.S.A.

NASA-Spearhead to Space



*High-Yield A-286 "Tensilized" Bolts by Voi-Shan

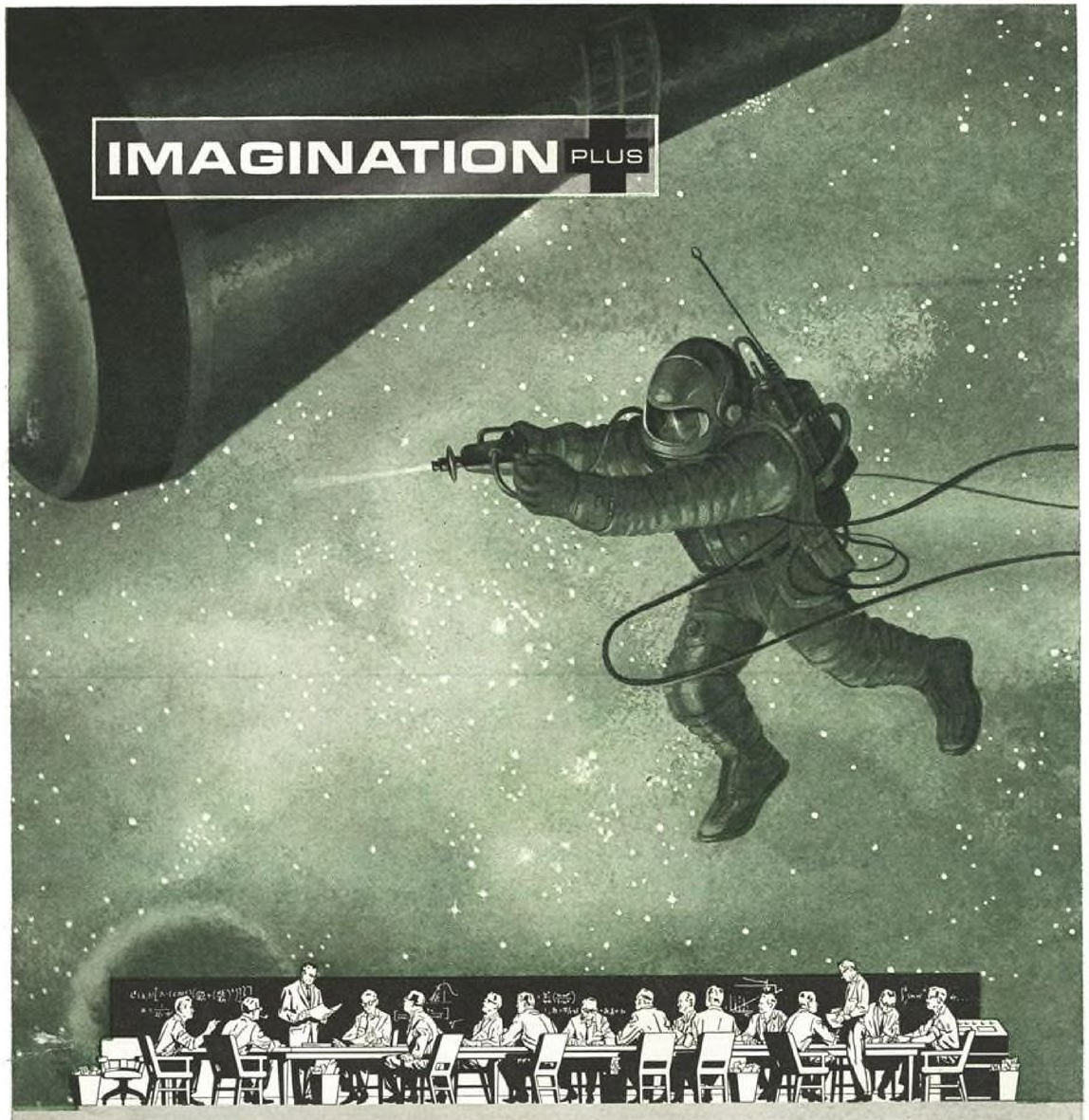
Today's aerospace fastening requirements demand a new dimension in metallurgical capability: Voi-Shan's **"TENSILIZED"** bolt series is the result of technological research and development expressly designed to meet this urgent need. Using A-286 and other super alloys, Voi-Shan's exclusive methods of manufacture offer these bolts at greatly increased strength levels with ***HI-Y** (significantly higher than the typical 80% yield-tensile ratio). ▪ These bolts offer excellent mechanical properties through high and low temperature ranges. **CRYOGENIC** properties considerably exceed room temperature properties. Superior performance is further guaranteed by unusual resistance to corrosion in **SALT WATER** and other difficult aerospace environments. To make your fastening system complete Voi-Shan also offers mating locknuts for all of these super alloy bolts.

ALLOY	TEMPERATURE RANGE	ROOM TEMPERATURE STRENGTH LEVEL (uts)
A-286	−425°F — 1200°F	220,000 psi (Min.)
Waspaloy	−425°F — 1500°F	240,000 psi (Min.)
Inconel 718	−425°F — 1500°F	260,000 psi (Min.)

Complete detailed information on Voi-Shan's **"TENSILIZED"** bolt series and other aerospace fastening devices is readily available. Write on your company letterhead to:

VOI-SHAN MANUFACTURING COMPANY
A DIVISION OF VOI-SHAN INDUSTRIES, INC.
8463 HIGUERA STREET, CULVER CITY, CALIFORNIA

VSI



BENDIX-PACIFIC *at work in space communications*

BENDIX-PACIFIC 25th ANNIVERSARY

Compact and reliable, the Bendix-Pacific Series 300 Telemetry solid state, sub-miniature, modular components have set new performance standards in space communications. Behind the Series 300 is the "imagination plus" of Bendix-Pacific...creative engineering and over 16 years' experience in telemetry which have combined to make Bendix-Pacific the recognized leader in this field. Now at work on virtually every major U.S. space vehicle, Bendix-Pacific telemetry components are another example of the broad capabilities which have made Bendix-Pacific a leading supplier of equipment and systems for Airborne Radar, Data Handling, Guidance, Hydraulics/Pneumatics/Electromechanics, Military Navigation, Oceanics and Telemetry.

Bendix-Pacific Division

THE Bendix CORPORATION

For information on how Bendix-Pacific's "imagination plus" can go to work for you in any of these fields, write or call Bendix-Pacific Division, North Hollywood, California.



CRITICAL-MISSION HARDWARE IS FORGED BY WYMAN-GORDON

Aerospace forgings are the long-time specialty of Wyman-Gordon. Intimate association with every milestone in the history of flight—Kitty Hawk to Canaveral—developed here a unique range of sophisticated skills and special facilities for hot working metal to the critical requirements of both sky and space.

Moreover, Wyman-Gordon pioneering first brought to operational use many of the light metals, superalloys and refractory materials which have significantly advanced performance from jet ceilings to space-craft apogees. Broad-front research in the industry's most completely staffed metallurgical and developmental laboratories continues to extend size, configuration and strength-to-weight design parameters of components for frame, propulsion, guidance and support applications.

Whatever the problem in forging any such critical-mission hardware, Wyman-Gordon experience can prove invaluable to its solution—an engineering team stands ready to counsel on your designs.

WYMAN — *Forgings of Aluminum, Magnesium, Steel, Titanium and*
WORCESTER
HARVEY, ILLINOIS
DETROIT, MICHIGAN LOS ANGELES, CALIFORNIA

GORDON — *Beryllium, Molybdenum, Columbium and other uncommon materials*
MASSACHUSETTS
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AVIATION WEEK and Space Technology

July 2, 1962
Vol. 77, No. 1

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Published weekly with an additional issue in October by McGraw-Hill Publishing Company, James H. McGraw (1860-1948), Founder. See panel below for directions regarding subscription or change of address. **Executive, Editorial, Circulation and Advertising Offices: McGraw-Hill Building, 330 West 42nd Street, New York 36, N. Y.** Printed at Albany, N. Y. OFFICERS OF THE PUBLICATIONS DIVISION: Nelson L. Bond, President; Shelton Fisher, Wallace F. Traendly, Senior Vice Presidents; John R. Callaham, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator; Daniel F. Crowley, Vice President and Controller. OFFICERS OF THE CORPORATION: Donald C. McGraw, President; Hugh J. Kelly, Harry L. Waddell, Executive Vice Presidents; L. Keith Goodrich, Executive Vice President and Treasurer; John J. Cooke, Vice President and Secretary.

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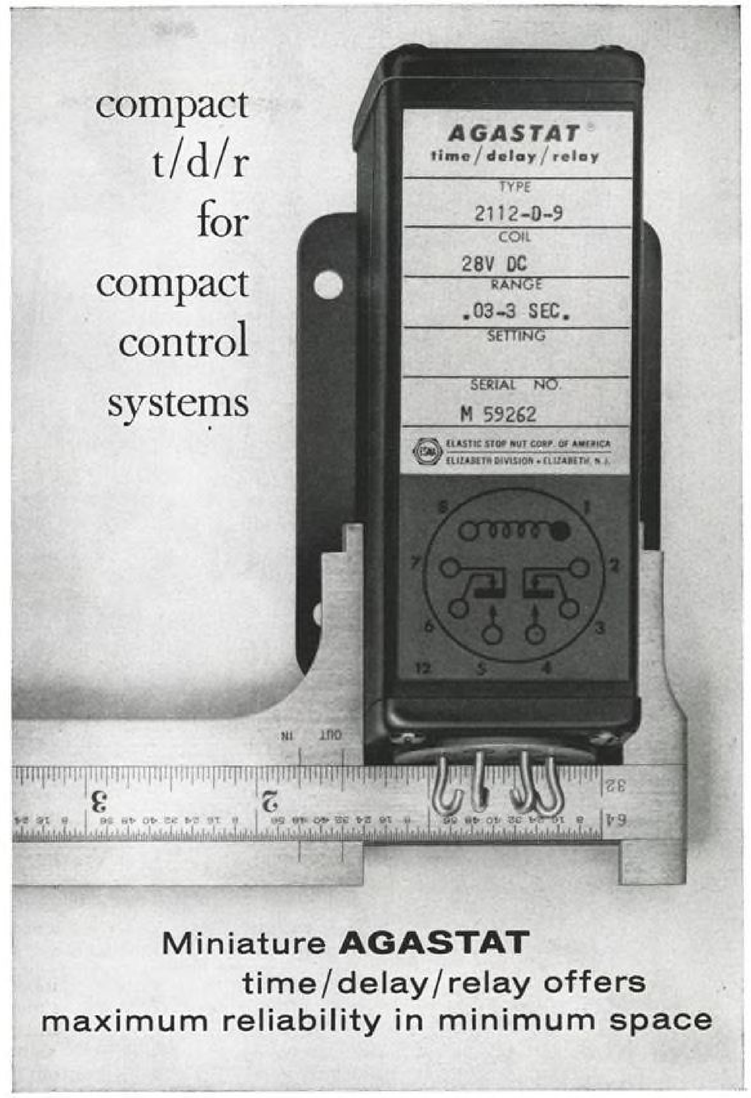
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←CIRCLE 4 ON READER SERVICE CARD

compact t/d/r for compact control systems



Miniature **AGASTAT** time/delay/relay offers maximum reliability in minimum space

For control systems where reliability *and* size are important design considerations, specify the Miniature AGASTAT time/delay/relay.

Only 1½ in. square, less than 5 in. high, and weighs as little as 15 oz. Six adjustable models provide delays from .03 sec. to 3 minutes—on pull-in or drop-out. Electrically-operated, pneumatically timed for instant recycling and freedom from voltage-variation drift. Choice of ac or dc operating voltages, with solder lug, octal plug or AN connector terminals.

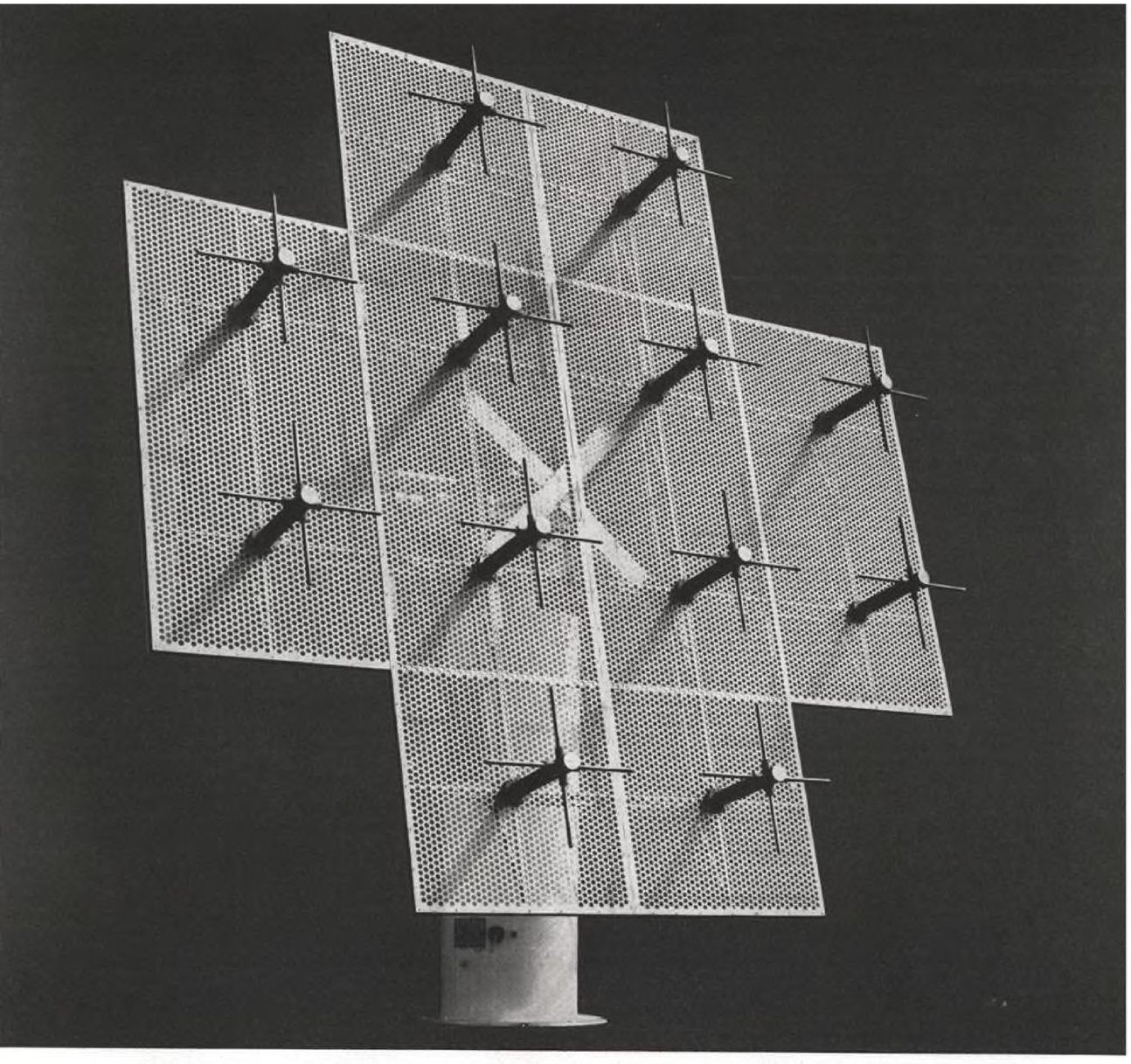
Since 1931, AGASTAT time/delay/relays have been specified for reliability and accuracy in almost every industry with electrical control requirements. Wouldn't this be a good time to learn what this proven performance can mean in your timing circuit?

We'll gladly send complete details. Just write Dept. M2-17.

AGASTAT® TIMING INSTRUMENTS
ELASTIC STOP NUT CORPORATION OF AMERICA
ELIZABETH DIVISION ■ ELIZABETH, NEW JERSEY

IN CANADA: ESNA CANADA, LTD., 12 GOWER ST., TORONTO 16, ONTARIO, CANADA

CIRCLE 5 ON READER SERVICE CARD



Specifications / Telemetry Antennas

The above dipole array is one of a family of high-performance tracking and acquisition antennas covering various telemetry frequency bands including 215-260 Mc and 370-410 Mc. These arrays have integral hybrids and provide both sum pattern and difference pattern outputs. Either manual or automatic self-tracking systems can be mechanized with complete polarization diversity . . . right and left circular, horizontal and vertical linear. Light weight and flat configuration results in lower mass moments and inertias, allowing use of smaller mounts and less complicated servo systems.

ARRAY NO. 1
Medium Gain Array *(above)*
PERFORMANCE

Frequency Range:	215 Mc - 260 Mc
Gain:	17.5 db
Sidelobes:	26 db (Principal planes) 17 db (Diagonal planes)
Null Depth:	35 db
Weight:	225 lbs.
Size:	12′x 12′x 1.5′
Beamwidth:	22.5 deg.

ARRAY NO. 2
High Gain Array
PERFORMANCE

Frequency Range:	215 Mc - 260 Mc
Gain:	21 db
Sidelobes:	20 db (All planes)
Null Depth:	35 db
Weight:	425 lbs.
Size:	18′x 18′x 1.5′
Beamwidth:	14 deg.

r a n t e c

Rantec Corporation • Calabasas, California
call Los Angeles, DI 7-5446 • TWX: see Directory

Eastern Regional Office • 7930 Barnes Street, Office 3 • Philadelphia 11, Penn. • RA 8-7500 • TWX: see Directory



TOTAL CAPABILITY IN SOLID ROCKETS

RESEARCH...DEVELOPMENT
...PRODUCTION...FACILITIES



PRODUCTION Aerojet-General has manufactured over 100,000,000 pounds of solid rocket propellants and delivered more than 700,000 solid rocket engines. One reason for this impressive record: Aerojet-General's unique continuous mix facility—capable of turning out solid propellant at the rate of 1,000,000 pounds a month —the only facility of its size and type in the free world.

AEROJET GENERAL TIRE GENERAL

SOLID ROCKET PLANT / Sacramento, California

Engineers, scientists: investigate outstanding opportunities at Aerojet.

Look to **FAFNIR** for leadership in ball bearings





When you must have reliability... look to **FAFNIR** for precision bearings

Reliability gets top priority in helicopters. To help assure reliability, designers use Fafnir Teflon-lined Bearings. These bearings perform smoothly, dependably under high loads. And they are self-lubricating. For *leadership* in bearings, look to Fafnir. The Fafnir Bearing Co., New Britain, Conn.

MADE IN U.S.A. This stamp on a Fafnir Ball Bearing means finest quality and workmanship . . . dependable supply . . . competent engineering help . . . and responsibility in meeting your bearing needs. It's worth bearing in mind.

FAFNIR
BALL BEARINGS

Circle Number 8 on Reader-Service Card



Sanborn® 7-Channel FM tape system for $6800* complete

uses interchangeable FM and direct record/reproduce electronics entirely contained in 7″ x 19″ panel space

COMPARE PERFORMANCE, PRICE PER CHANNEL

Here is the ideal combination of high performance *and economy* in a 7-channel, 4-speed system that meets IRIG Telemetry Standards. *Versatility* is another advantage. The Model 2000 system uses interchangeable Sanborn FM or direct record/reproduce electronics — all solid-state, in 7″ of panel space — and you can have any combination of direct and FM channels simply by changing circuit cards. Recording capability may be extended beyond the system's minimum input levels through the use of Sanborn "850" and other compatible amplifiers.

The Model 2000 Magnetic Data Recorder has four speeds and uses standard ½-inch tape on 10½-inch reels. All controls are on the front, and several convenience features are included: an integral FM Alignment Meter that eliminates the need for electronic counters, an automatic squelch, a tape footage counter, and provision for using one channel for flutter compensation.

Complete details are available from Sanborn Sales-Engineering Representatives in principal cities throughout the U. S., Canada and foreign countries.

**Price FOB Waltham, Mass., in Continental U. S. A.; subject to change without notice. State and local taxes must be added where applicable.*
(Specifications subject to change without notice)

SPECIFICATIONS

Input ± 2.5 V into 10,000 ohms, single ended, adjustable.

Output ± 2.5 V into 1,000 ohms or more, single ended; level, position adjustable.

Bandwidths (Max)

Speed	*FM*	*Direct*
3¾″/sec	0-625 cps	50-6,250 cps
7½″/sec	0-1,250 cps	50-12,500 cps
15″/sec	0-2,500 cps	50-25,000 cps
30″/sec	0-5,000 cps	100-50,000 cps

(100% modulation on FM = ± 40% carrier deviation)

Linearity Max dc nonlinearity: 0.5%

Drift ± 0.5% of full scale for 10 V power line change, 10°C ambient temperature change, or for 24 hours at constant power line voltage and ambient temperature.

Signal-to-Noise Ratio (Min)

Direct: 40 db at all speeds.

FM: 40 db RMS at 30″/sec and 15″/sec; 35 db RMS at 7½″/sec; 33 db RMS at 3¾″/sec.

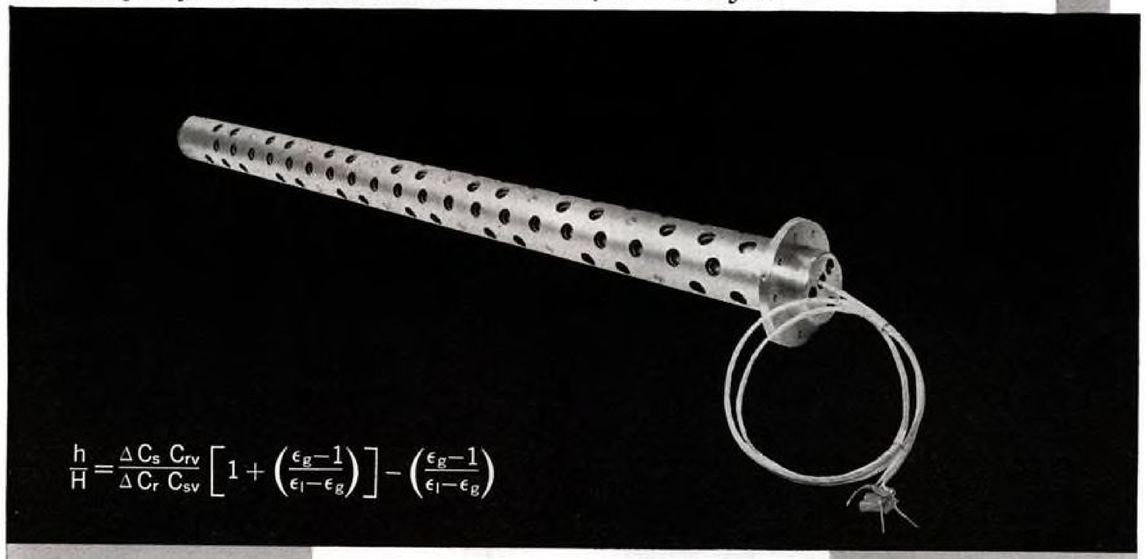


Readout, as well as input monitoring during magnetic recording, may be provided by this compatible 17-inch, 8-channel Viso-Scope or other Sanborn monitoring instruments, or by direct writing systems.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

Circle Number 9 on Reader-Service Card

How many ways can **TRANS-SONICS,** INC. *serve you?*



LIQUID LEVEL

is measured in many ways. This sensor does it by variable capacitance and forms part of a complete Trans-Sonics* system. With its solid state black box, the sensor provides a digital output accurate to 0.1 inch in 4 feet.

Automatically corrected for density changes, this Trans-Sonics tank gaging system is suited for cryogenic as well as conventional fluids. Independent of voltage and impedance variations, and with a response time of four milliseconds, it is now used to measure LOX and RP-1 usage rates in an airborne environment. The system provides important data relating to propellant utilization, booster weight distribution, and will safeguard the performance of critical mechanical assemblies.

Variable capacitance is only one of several techniques used by Trans-Sonics for the measurement of level. Differential pressure, piezo-electric effects, and mutual inductance are also used for systems having either analog or digital outputs. From liquid hydrogen to sea water, Trans-Sonics devices are providing accurate and reliable results in the most demanding situations — may we tell you more? Write, wire, or phone — !



*TM

To put the sure in measurement...

TRANS-SONICS, INC.
DEPT. 1A, P. O. BOX 328
LEXINGTON 73, MASSACHUSETTS



In Space Technology... LOOK TO PARSONS for Performance

Parsons has substantially aided... and will continue to aid... the United States in its military use and peaceful exploration of space. The design and field engineering, or construction of rocket fuel plants, static test stands, launch facilities, tracking complexes, ground and airborne electronics, in addition to feasibility studies for permanent lunar facilities to support men and equipment for indefinite periods, demonstrate the diversified capabilities of The Ralph M. Parsons Company.

The conquest of space *will* be achieved by industry and government working as a team. And teamwork, plus resources, plus services from Parsons all add up to *total capability, single source responsibility.*

PARSONS

THE RALPH M. PARSONS COMPANY

ENGINEERS • CONSTRUCTORS

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Another great Astrojet–the 990–joins the American Airlines fleet.

American Airlines has launched the most advanced jet airliner in the world: the 990 Astrojet.

Here is the new shape of commercial aviation. You will notice two extra aerodynamic bodies on each wing. These are speed capsules, designed to smooth out the airflow at high speeds.

Here is the new brawn of commercial aviation. We believe the 990 is the strongest airplane ever built. It has tremendous structural integrity. Many extra safety factors have been built into it.

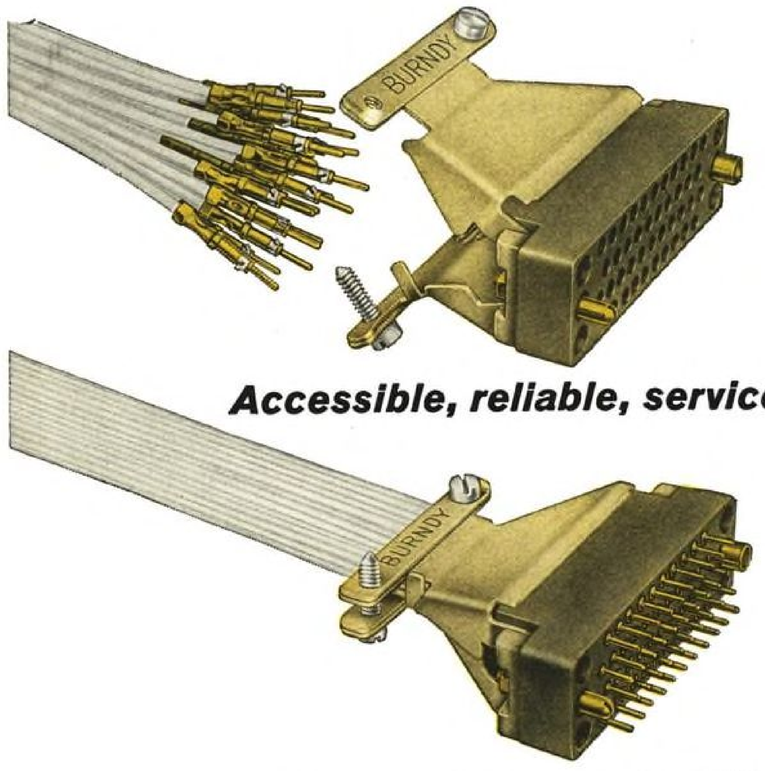
And here is the new comfort of commercial aviation. Wide aisles. Wonderfully deep, wide armchairs. A spacious, club-like First Class section. And a pleasant surprise for jet travellers: 3-and-2 seating in the Coach section.

For a new experience in flying, try the most advanced jet in commercial aviation: the 990 Astrojet.

Astrojet is a Service Mark of American Airlines, Inc.

AMERICAN AMERICA'S LEADING AIRLINE

BURNDY
MAKES ALL TYPES OF ELECTRICAL
CONNECTORS



Accessible, reliable, serviceable...

open and shut case for MS HYFEN.

Miniature rectangular HYFEN® provides high density connections, and is available in 14, 20, 26, 34, 42, 50 & 75 contact sizes with hoods to fit all sizes. Crimp-type, snap-locked contacts accommodate wire sizes #18 thru #26, and are removable without disassembling connector. Hoods are aluminum alloy, swing-type, clamshell design . . . can be opened to remove or insert contacts without being removed from connector block. Crimped connections comply with MIL-T-7928. HYFEN mates with all existing solder types. Complete line of BURNDY installation tooling available. Write OMATON Division for details.

BURNDY
Norwalk, Connect.

Circle Number 13 on Reader-Service Card

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

The Effect of Lead in Alloy Steels, PART I

The subject of leaded alloy steels will be discussed in two parts. Here we deal with basic definition, reason for excellent machinability, and purpose of closely controlling the lead additive. Part II, which follows in this series, will touch upon working properties, and discuss when leaded alloy steel should be used.

WHAT IS A LEADED STEEL?

A leaded steel is any steel, carbon or alloy, to which lead has been added to improve its machining characteristics. This lead additive, generally held within the limits of .15 to .35 per cent, may be added to any standard AISI or SAE steel. The percentage of lead does not, to any practical degree, alter the mechanical properties of the base steel.

HOW LEAD IMPROVES MACHINABILITY

Theoretically, lead has an inherent self-lubricating action which reduces friction at the tool-chip interface. This permits appreciably higher cutting speeds and feeds because leaded steels have a lower coefficient of friction than non-leaded steels. Also, because of the finely dispersed lead particles, there are minute interruptions within the matrix which cause a premature breaking of chips. This minimizes build-up within the tool-chip interface, prolonging tool life and improving machined finishes.

Optimum cutting speeds are commonly increased by 25 to 40 per cent. Sometimes, depending upon the condition and grade of steel and the type of machining, these speeds can be more than doubled.

LEAD ADDITION MUST BE CLOSELY CONTROLLED

Lead is distributed throughout the ingot by the addition of pure metal shot. It is forced into the molten-steel stream during teeming (pouring from the ladle to the mold) by means of a fixed air-pressure gun. The lead shot, having a higher specific gravity than the molten steel, tends to segregate at the bottom of the ingot. This is controlled by pouring a predetermined amount of steel in the ingot prior to the lead addition.

Since the uniform distribution of lead is all-important to the machining properties of leaded alloy steels, Bethlehem exercises great care in (1) controlling the lead content through checking by the fluorescent X-ray method, and (2) inspection of billet specimens for lead distribution by means of exudation tests.

Bethlehem metallurgists are "on the scene" where new applications of leaded alloy steels are being developed. If you'd like to consult with them on any problem, just write to us at Bethlehem, Pa. And remember, too, that Bethlehem makes a full range of AISI standard grades, as well as special-analysis steels, and all hot-rolled carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts About Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

Steel

for Strength . . . Economy . . . Versatility

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Circle Number 14 on Reader-Service Card

Circle Number 15 on Reader-Service Card →

turning with tape . . . puts precision and quality into Ex-Cell-O components for advanced space propulsion systems. Spherical pressurized fuel and oxydizer tanks, turned from light, high strength forgings, are typical of the super-precise details the Flight and Space Division produces on Ex-Cell-O Numera-Trol Machines—the most accurate production machine tools ever built. ■ These numerically controlled machines, augmented by equally sophisticated fabricating facilities, are a dependable source for the most demanding powerplant and vehicle components. ■ For detailed information, contact our Representative in your area, or call or write direct. Phone 313-868-3900. TWX DE-175.

EX-CELL-O CORPORATION
Flight & Space Division DETROIT 32, MICHIGAN 62-105

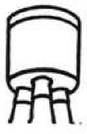


MAN AND MISSILES FLY HIGHER, FASTER AND SAFER WITH PARTS AND ASSEMBLIES BY EX-CELL-O AND ITS SUBSIDIARIES: CADILLAC GAGE CO., MICHIGAN TOOL CO., SMITH BEARING CO. ■ EX-CELL-O FOR PRECISION XLO



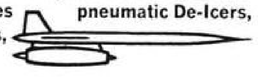
B.F.Goodrich has both feet in space

A veteran of aviation's leather-jacket days, B.F.Goodrich is now one of the most versatile pioneers in aerospace technology. The Project Mercury Astronaut suit is one notable achievement. This suit protects man from heat, from cold, from other space hazards, has built-in communication and air conditioning systems. Next advance will be the space suits BFG is perfecting for crewmen of larger orbital vehicles.



STRUCTURES FOR THE HOT BLUE YONDER. Another skill BFG has mastered is the technique of fabricating nose cones and heat shields to withstand re-entry temperatures in the thousands of degrees. We've played a leading role in making rocket motors of plastics and glass fibers. These cases replace metal; add hundreds of miles to missile range.

THE CONQUEST OF ICE. Ice can be as deadly as heat. BFG has led the way in developing ice protection systems for aircraft, beginning with the first De-Icers which opened the era of all-weather flight. BFG systems now provide protection for jets and missiles. Present capability includes pneumatic De-Icers, Metal-clad Electro-thermal De-Icers, heated rubber and plastic parts.



ROCKET FUELS "BOUND" WITH RUBBER. Our knowledge of polymer chemistry led to development of the major binder fuels used in the most advanced solid fueled rockets. The newest BFG solid propellant packs more punch than previous rubber-based fuels over an extreme temperature range.

JET SAFETY. The most advanced tire ever built has been developed and produced by BFG for a Mach 3 aircraft. It's built to withstand oven-hot temperatures of 360°F for prolonged periods. And the newest brake offered for jet service is the BFG liquid cooled brake, which can serve through repeated "refused take-off" stops.

A brochure, "B.F.Goodrich Resources for Missile and Rocket Progress" tells a detailed story of BFG capabilities. Write for a copy, and tell us of your particular product interest. B.F.Goodrich Aerospace and Defense Products, a division of The B.F.Goodrich Company, Department AW-7A, Akron, Ohio.



B.F.Goodrich

Circle Number 17 on Reader-Service Card

BENDIX COUNTDOWN FOR SPACE

7

PNEUMATIC CONTROLS: Hot gas equipment is being developed for space control subsystems using rotary and linear actuation, reaction jets, and pneumatic computation. A complete subsystem is now being built at E-P under USAF contract.

6

SELF-ADAPTIVE CONTROL SYSTEM: Capable of measuring dynamic sensitivities and adjusting feedback gains in stable fashion without sensing external environment. Automatically blends control of aerodynamic surfaces and reaction jets. Being developed under USAF contract.

5

SATELLITE CONTROL AND STABILIZATION: Eclipse-Pioneer has total in-house capability for producing spacecraft attitude-control systems. In production: ADVENT reaction wheels. In development: sun-sensors and star trackers.

4

STAR TRACKER SYSTEM: A system incorporating multiple star tracking heads, designed to operate without a protective dome in the environment of space; digital readout accuracy of ±5 arc seconds.

3

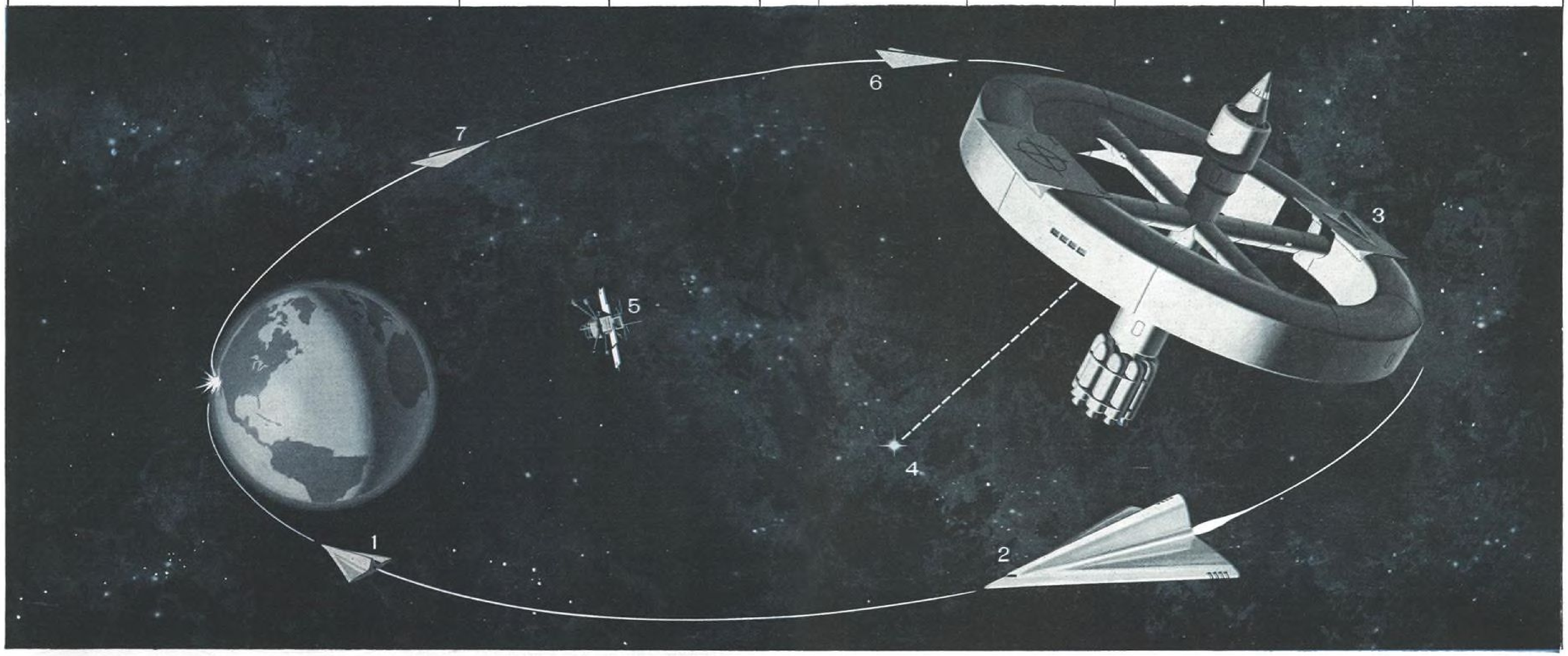
SPACECRAFT RENDEZVOUS COMPUTER: Complete solid-state mechanization for analog and digital airborne computation of navigation, guidance, and attitude-control circuitry required at time of rendezvous. Digital computation at 10 megacycle rate.

2

ADVANCED DISPLAYS AND CONTROLS: Development currently in progress. Human-factor display studies directed toward rendezvous, re-entry, energy-management. Electronic and optical devices will present correlated data with minimum panel space.

1

LETDOWN, APPROACH, LANDING: Safer, more reliable letdown and landing systems—such as inertially augmented flare and runway-alignment, computers, advanced instrumentation (including real-time displays)—are now being developed, flight-tested.



Knowmanship in Action

Technical knowledge, management ability, and craftsmanship all add up to Eclipse-Pioneer's space-age Knowmanship. We pride ourselves on anticipating our customers' needs—and meeting them with technical advancements based on specific requirements. The manufacture of precise components and total subsystem capability are typical of our creative ability as a major contributor to the field of space technology. By applying principles of Knowmanship, we're able to achieve our space mission: research and development for tomorrow's intriguing challenges; products for the critical needs of today. Write: Teterboro, New Jersey.

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Eclipse-Pioneer Division

THE Bendix CORPORATION

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Weld failures cut 89% using vacuum-melted filler wire

[*Weld tests on alloy steel wire used in missile applications revealed nine times as many failures with air-melted wire as with Cannon-Muskegon vacuum-melted wire.*] [*Superior to consumable-electrode melting, Cannon-Muskegon vacuum-induction melting greatly reduces gas levels (nitrogen less than 25 ppm, oxygen less than 25 ppm, hydrogen less than 5 ppm). Combined sulphur and phosphorus run less than .015%.*]

[*These remarkably low gas and impurity levels can be most efficiently obtained with Cannon-Muskegon vacuum-induction melting. You are invited to write Cannon-Muskegon for further details.*]

☚ *Among test samples prepared from air-melted wire, 18 out of 32 failed at the weld.*]

☚ *Among similar samples prepared from the vacuum-melted wire of the same grade, only two out of 32 bars failed at the weld.*]

[*Different alloys of Cannon-Muskegon vacuum-melted welding wire are available in sizes from 1/32" to 1/8", in 36" cut lengths, or in 10 or 25-lb. spools packed in airtight Argon-filled steel containers.*



]



ULTRAMET
VACUUM ALLOYS

CANNON-MUSKEGON CORPORATION

Metallurgical Specialists • 2887 Lincoln Street • Muskegon, Michigan

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Haveg's high purity Silica fabric with a melting point of 3000° F.

This unique product is now being used by all major missile manufacturers in the United States. Some of the larger missiles where Sil-Temp is being used as an ablative component are the Minuteman, Polaris, Titan I, Titan II, Nike-Zeus, Dyna-Soar, Saturn, Scout, Apollo, Nova, Skybolt and Surveyor.

Other missiles which are now in large volume or potentially large volume include the Viper, Mauler, Shillelagh, Bullpup, Subroc and Asp.

Sil-Temp was chosen for this all important program because of its superior quality and product uniformity. Sil-Temp gives better ablative properties, strength characteristics and reliability than any product now being offered anywhere. Haveg's quality control and experienced engineers is definitely responsible for this "fantastic" accomplishment.

For further information on the use of Sil-Temp in the missile, aviation or chemical field where high temperatures are involved, write, wire or phone for folder giving complete data. Our experienced engineers will be happy to work with you on your particular application.

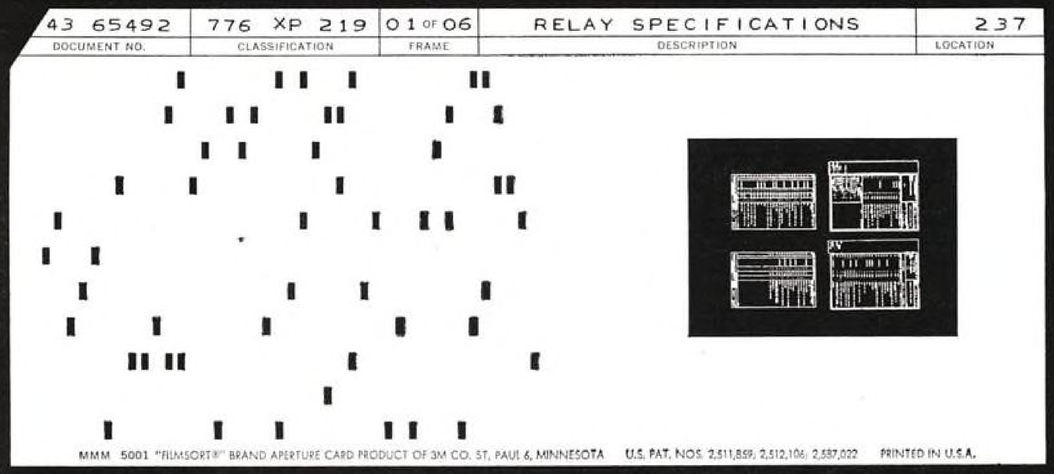
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3M COMPANY

Don't fight paperwork when 3M makes microfilm so easy to use!



Microfilm is fast replacing costly paperwork in hundreds of companies. And 3M is making it so easy—with 3M Microfilm Products. For example, the FILMSORT® Aperture Card, a standard tabulating card containing a frame of microfilm, makes it easy and economical to file, retrieve, reproduce, distribute information—instantly! Does for pennies what it now costs you dollars to do in paperwork. Cuts file space 96%. And THERMO-FAX "Filmac" Reader-Printers make enlarged copies from microfilm, seconds fast! To learn how your company can replace paperwork with easy-to-use microfilm write to the 3M Company, 900 Bush Ave., Saint Paul 1, Minn.

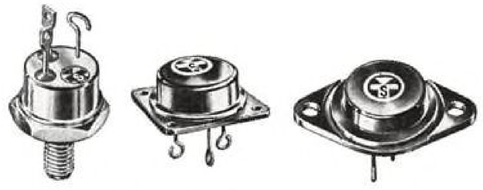
3M Microfilm Products
MINNESOTA MINING & MANUFACTURING CO.

Circle Number 22 on Reader-Service Card

FROM STC THE FIRST...

PNP SILICON POWER TRANSISTORS

WESCON BOOTH 909.



For Technical Data and prices, contact:

SILICON TRANSISTOR CORPORATION
CARLE PLACE, LONG ISLAND, NEW YORK Pioneer 2-4100

Sixteen Different PNP Types:
11/16" hex... 85 watts... STC5550 through STC5555
Square package... 85 watts... 2P389, 2P389A, 2P424, 2P424A
TO-3... 75 watts... STC5080 through STC5085
Characteristics: h_{FE} 10 to 30 @ 2 amps... R_{CE} (sat) 0.5 ohms @ 2 amps... V_{CE} 80 volts... I_C max 5 amps
NPN Complements:
11/16" hex 85 watts... STC1550 through STC1555
Square package 85 watts... 2N389, 2N389A, 2N424, 2N424A
TO-3 75 watts... STC1080 through STC1085

Circle Number 23 on Reader-Service Card

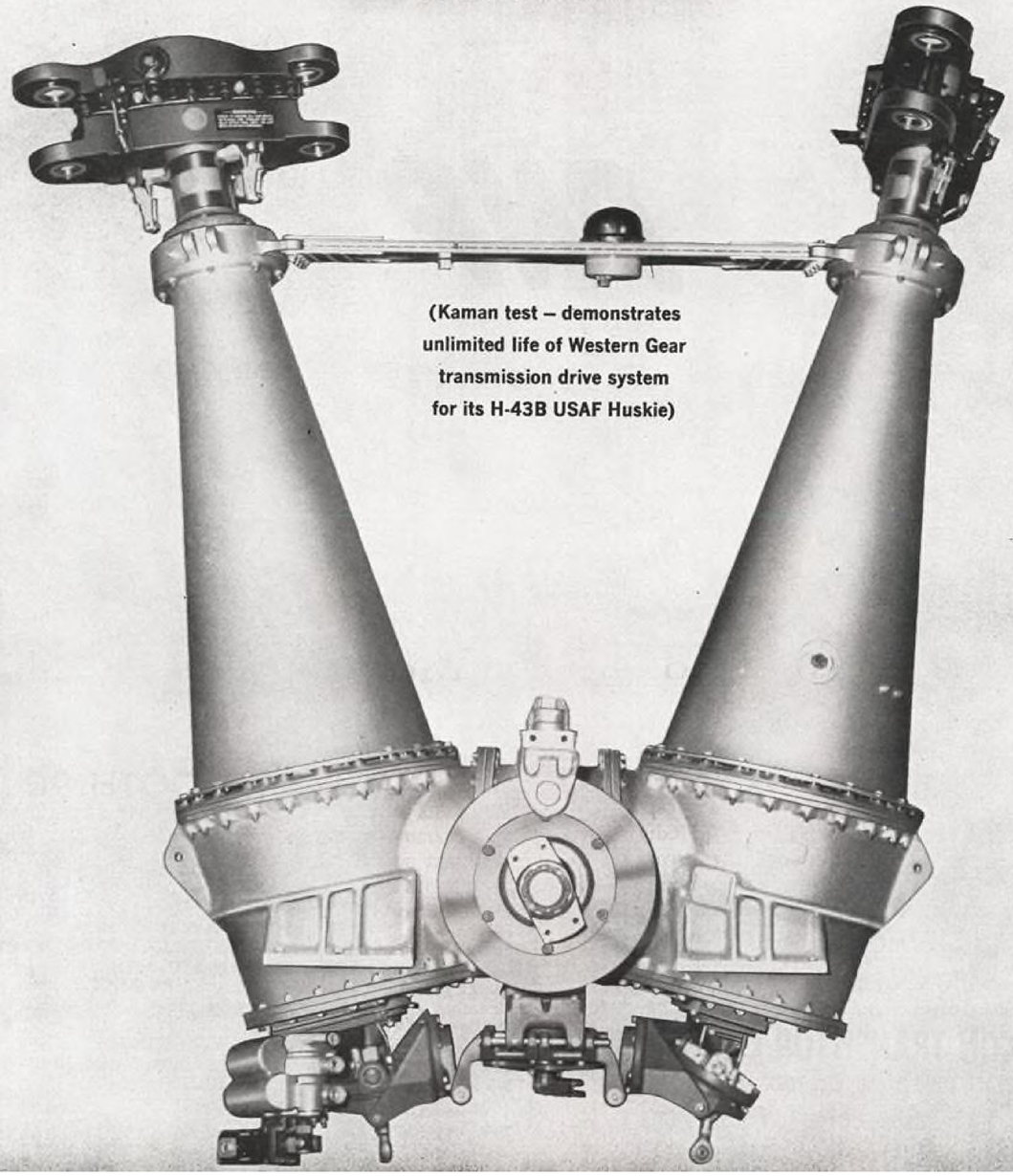
HUSKIE... first with a unitized unlimited life transmission drive system...by Western Gear



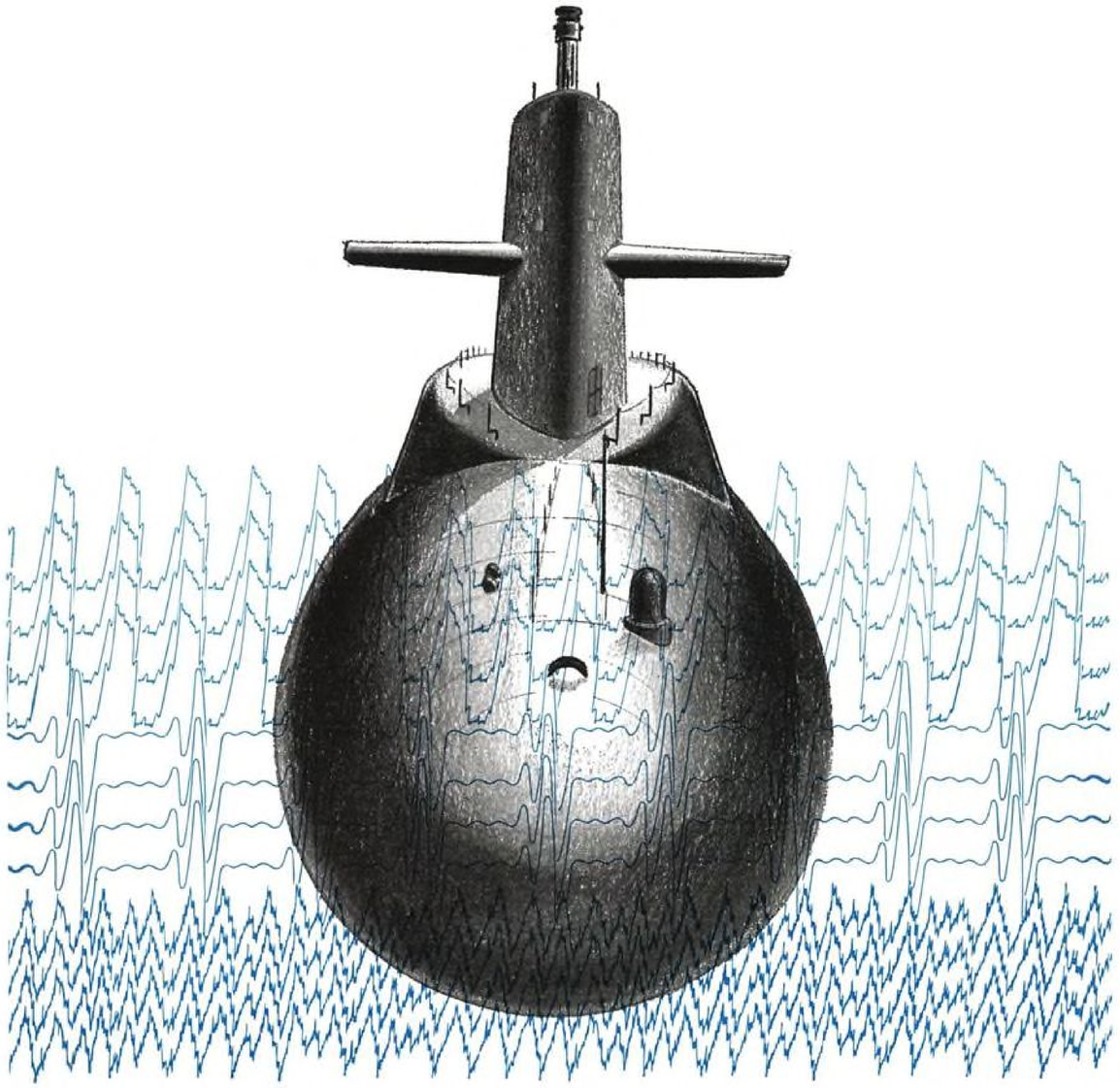
Much more than just component testing! Kaman Aircraft Corporation has established an unlimited life on a completely unitized helicopter transmission drive system for its H-43B USAF "Huskie." This transmission drive, built by Western Gear, was designed as a "unitized" system because of the Huskie's unique intermeshing rotor configuration. The entire system, including rotating controls, hydraulic drive and pump, and generator drive and pump can be lifted out and changed as a single unit. Learn more about Western Gear's work with advanced concepts in high-speed gearing and shafting. Address Precision Products Division, WESTERN GEAR CORPORATION, P.O. Box 192, Lynwood, California. Cable address WESTGEAR, Lynwood, California.

WG PRECISION PRODUCTS DIVISION

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(Kaman test – demonstrates unlimited life of Western Gear transmission drive system for its H-43B USAF Huskie)



new approaches to silence and shock protection

The Navy is always on the lookout for better ways of suppressing sound and attenuating shock. ■ Lord has devoted its special talents to meeting these needs. Here are a few of the results. ■ Modular compounds and laminated structures for acoustical damping. Main drive couplings that transmit power smoothly, silently. Elastomeric covers to seal in sound. Deck mountings that isolate entire compartments. The only complete line of Navy machinery mountings. Protective suspensions for inertial navigational systems. Special mounting systems for electronic gear. ■ To develop new approaches, Lord dives deep into problems, explores them thoroughly, often charts new courses in vibration/shock/noise control. Don't expect just a routine answer from Lord. Expect more. Contact: Lord Manufacturing Company, Erie, Pa. Field Engineering Offices in principal cities. In Canada: Railway & Power Engineering Corp., Ltd.

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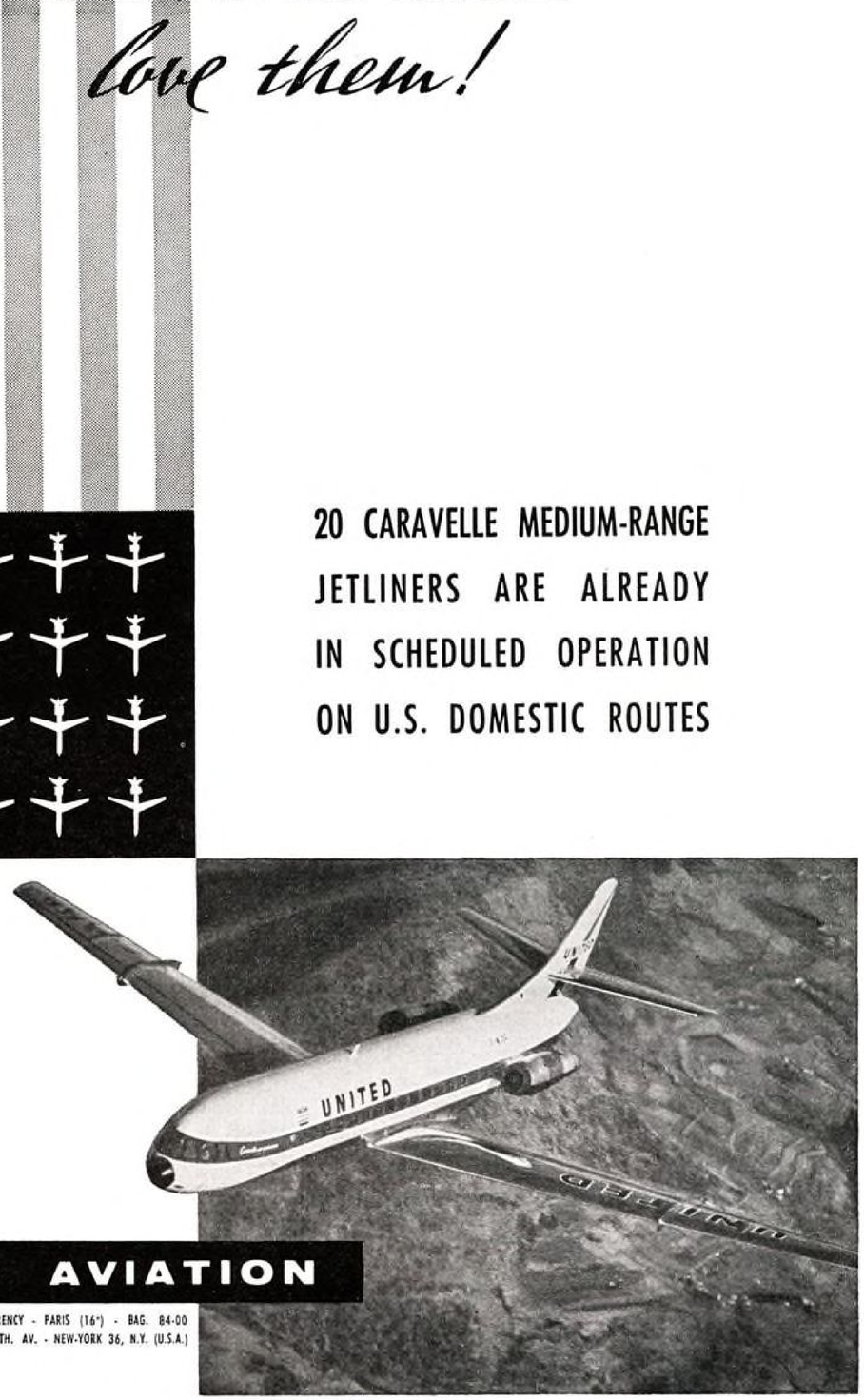
vibration/shock/noise control

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ANOTHER SPECTACULAR SATURN LAUNCHING!

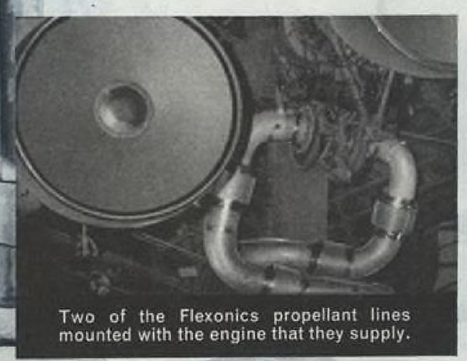
. . . with flex-metal tubing and ducting from Flexonics

Now the world has witnessed another highly successful launching of the mighty Saturn developed by National Aeronautics and Space Administration—the United States' biggest space vehicle, producing more than 1,300,000 pounds of thrust. Vital to this consistent performance are a total of 119 Flexonics propellant and other lines that supply fuel and oxygen to the cluster of eight Rocketdyne engines, as well as Flexonics interconnect and pressurization lines, and high-performance metal hose.

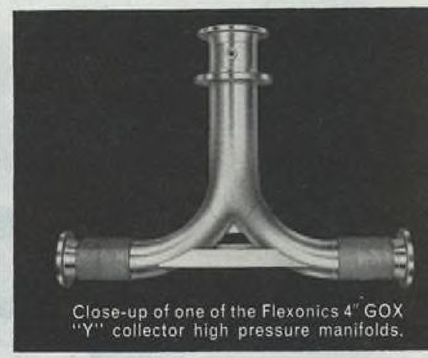
Engineers from Flexonics and George C. Marshall Space Flight Center, Huntsville, Ala., worked together in the designs of these components, just as they are now at work on future Saturn configurations. Teams of design and fabrication specialists adapted Flexonics precision-forming methods to the unique requirements of the Saturn. Exhaustive qualification tests, under simulated flight conditions, proved the soundness and reliability of design before the countdown of the first flight.

To simplify and expedite resolution of *your* next ducting problem, call on Flexonics.

Write for your copy of the big new Flexonics Engineering Guide and catalog of aerospace components.



Two of the Flexonics propellant lines mounted with the engine that they supply.



Close-up of one of the Flexonics 4" GOX "Y" collector high pressure manifolds.

Flexonics

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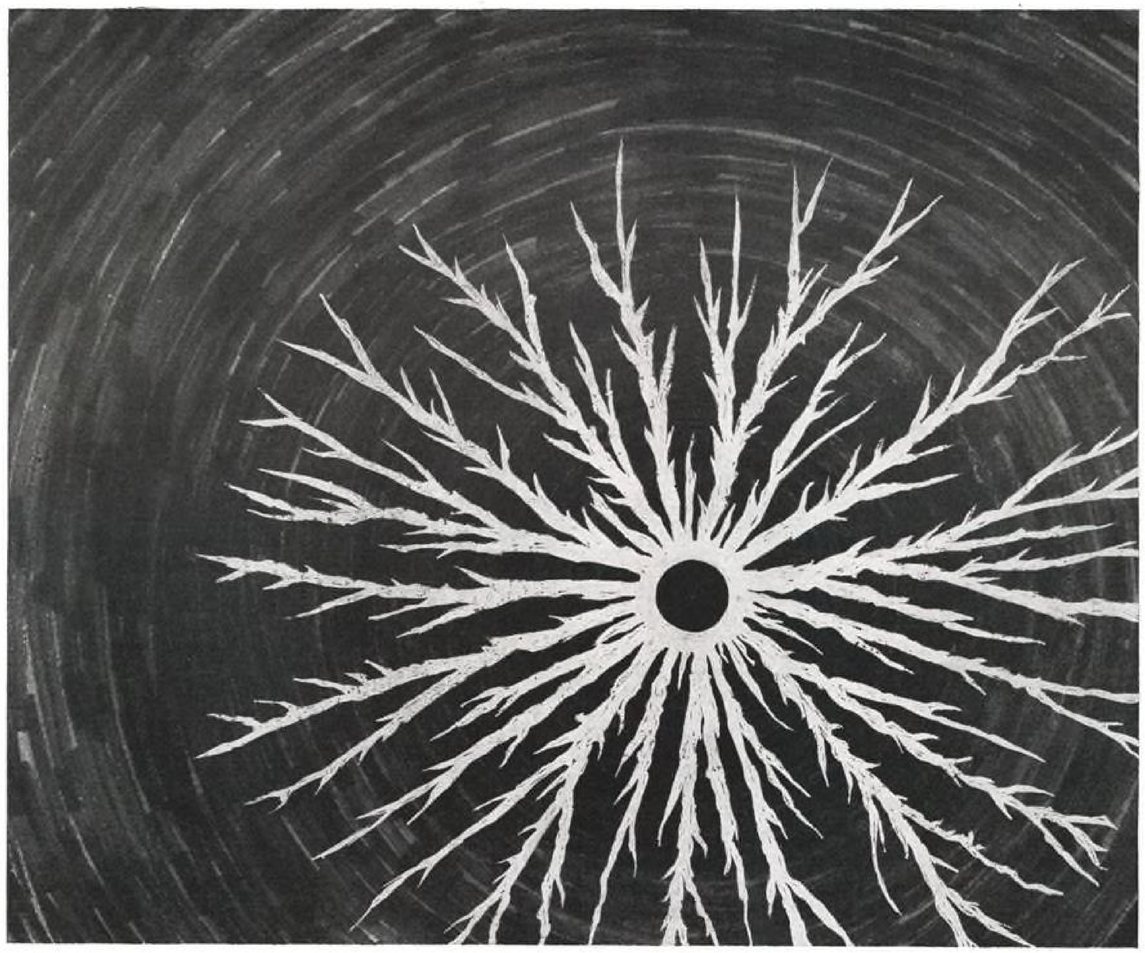
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A-450R

This coined word applies to the emission of electrons which occurs at the time of metal abrasion or fracture. Refined measurement techniques in regard to this factor may lead to the detection of microscopic cracking long before failure ...allowing for part replacement before the onset of fracture in service. □ Triboelectroemanescence is only one of many phenomena involving metal behavior now under study at Douglas. Because structural reliability is a critical consideration in the design of transonic, supersonic and hypersonic aerospace vehicles, Douglas laboratories are engaged in a comprehensive research program relating to metal endurance. This includes corrosion causes and effects, environmental studies, and the effects of steady state loads and intermittent strains under cryogenic through pyrogenic temperatures in causing cracking.

TRIBOELECTROEMANESCENCE
...AND WHAT DOUGLAS IS DOING ABOUT IT

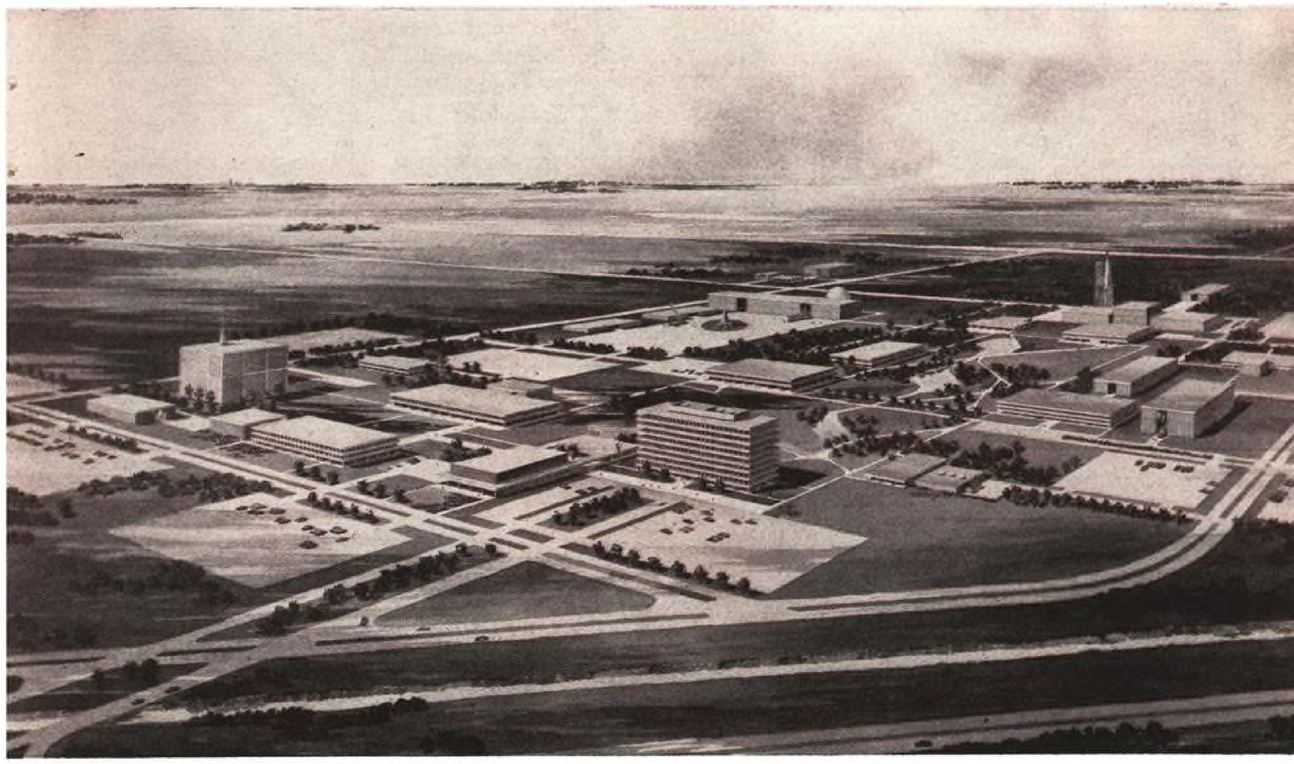


This comprehensive study of metals is one of more than 500 research programs at Douglas. The focus is on technological advancement to meet the needs of a future which will include Douglas air cushion, subsonic, supersonic and spaceplane vehicles.

DOUGLAS

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" . . . the faculty of perceiving in an unhabitual way."



Notwithstanding the fact that William James turned his phrase to define genius, *perceiving in an unhabitual way* is inherent in the philosophy of the United Aircraft Corporate Systems Center. Here, tomorrow's military and space systems are the objective — their development, management and production. While C.S.C. scientists and engineers inherit a legacy of leadership from well-known divisions and subsidiaries of United Aircraft, the breadth and depth of this systems approach takes them far beyond the familiar.

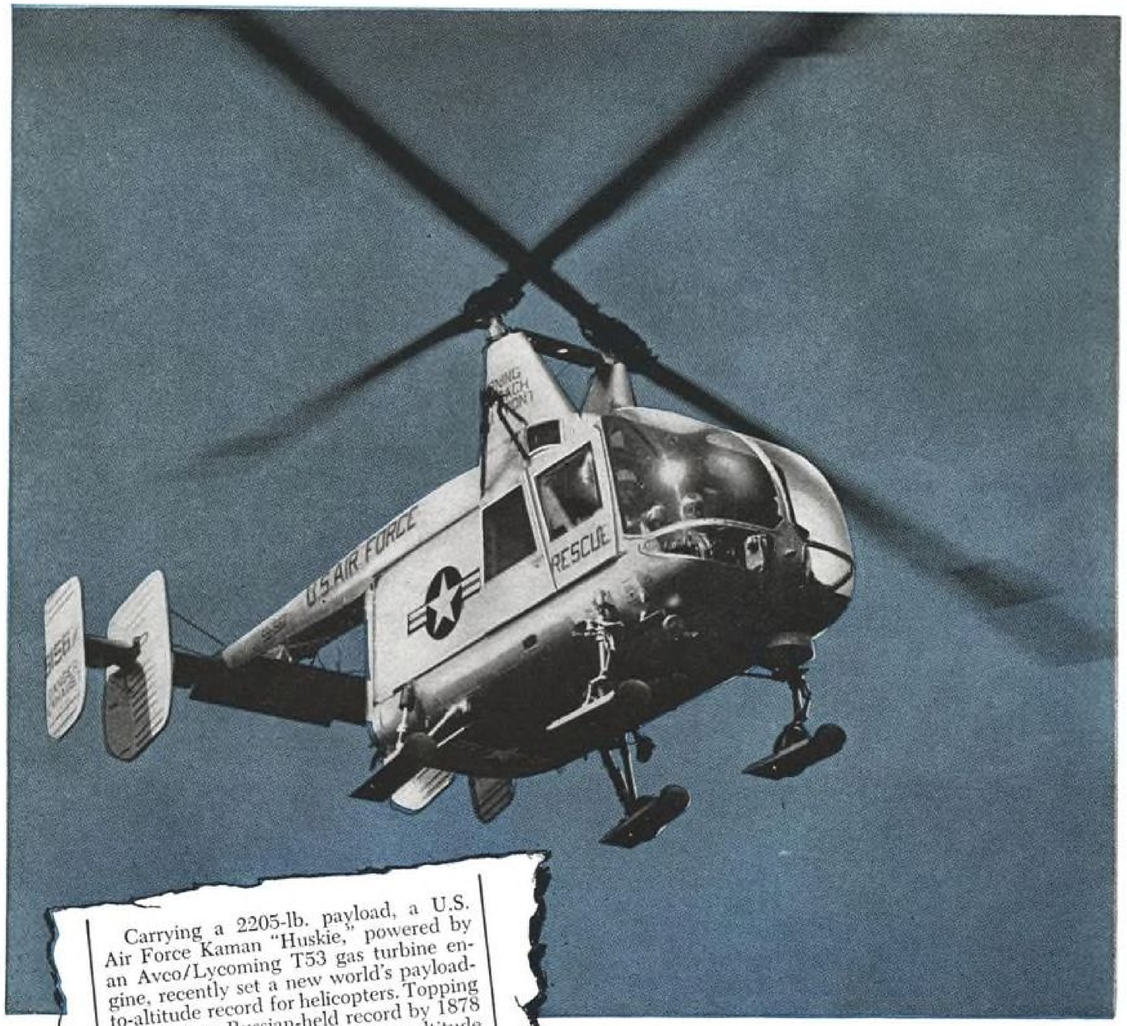
Typical of the highly advanced systems currently being studied are those involving mobile ballistic missiles, terminal air defense, orbital rendezvous and satellite navigation and control. Also, under contract to the U. S. Air Force, C.S.C. is designing and developing a sophisticated system of stellar inertial guidance, while the well-established Weather System Center is assisting the Air Force and F.A.A. in developing vastly improved methods for weather data collection, transmission and forecasting.

In the vanguard of a corporate complex known for its pioneering achievements, the Center is well situated to carry forward its programs. As "working tools", impressive nearby R&D facilities of United Aircraft are among the most capable in the industry.

Expanding programs have created many desirable openings for men who hold degrees in engineering or the sciences. Opportunities are available in *Guidance & Control Systems • Weather Systems Design • Computer R&D • Reliability • Manufacturing Planning and Control • Space Systems Requirements • Operations Analysis • Advanced Weapons Systems • Advanced Programming • Conceptual Design • Electronic Systems Engineering.* You are invited to submit your resume in confidence to Mr. T. W. Wraight, Personnel Manager, UAC Corporate Systems Center, Windsor Locks, Connecticut — an equal opportunity employer.

United
CORPORATE SYSTEMS CENTER
Aircraft

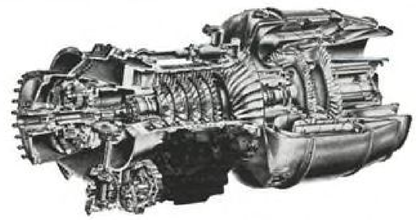
Circle Number 30 on Reader-Service Card



Carrying a 2205-lb. payload, a U.S. Air Force Kaman "Huskie," powered by an Avco/Lycoming T53 gas turbine engine, recently set a new world's payload-to-altitude record for helicopters. Topping the previous Russian-held record by 1878 feet, the "Huskie" soared to an altitude of 26,369 feet.

Rollway Bearings help push helicopter

Somewhat higher than Gilroy's kite!



Cutaway view of the Avco/Lycoming T53 gas turbine engine which powered the Kaman "Huskie" to world-record height.

Top standards of performance and reliability were demanded of the vital components teamed for this record-smashing powered flight.

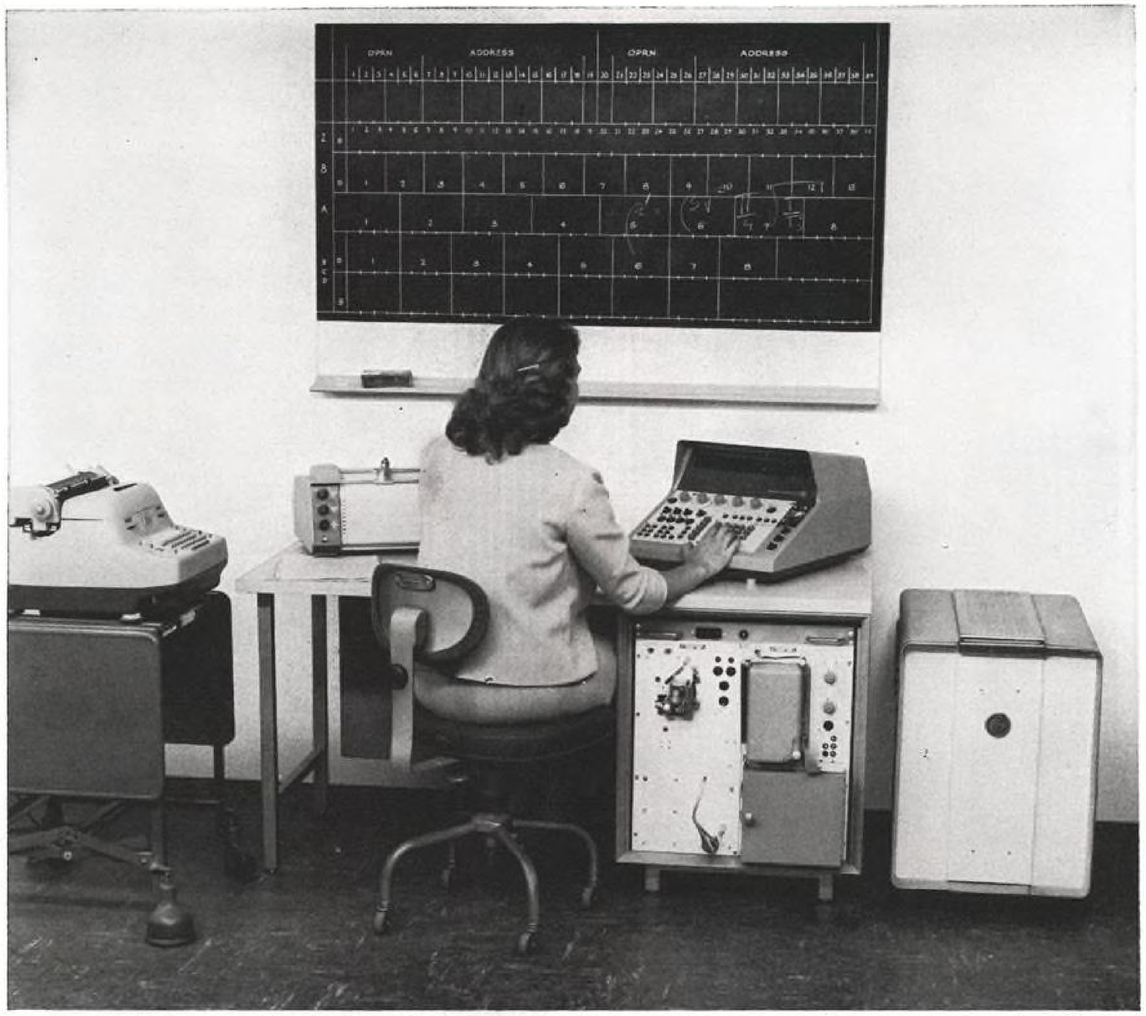
With key bearings located both in the Avco/Lycoming engine and in the Kaman transmission, Rollway is proud to have participated in this outstanding performance.

When you need a bearing with *reliability plus* in a critical location, you are invited to take a critical look at Rollway *Air-Rol* Bearings. Rollway Bearing Co., Inc., P. O. Box 1397, Syracuse 1, N. Y.

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Servomechanisms/Inc. uses Recomp II for the simulation of space systems at its research center near Santa Barbara, Calif.

How to lease a physical laboratory for $2,495 a month.

It weighs a little more than 500 pounds. It's just a bit larger than a desk. And it goes to work when you plug it in.

It can work as a flight test facility, a microscope, an electronics test bench, an environmental test chamber, a space system simulator. And that's just the start.

This particular laboratory is called Recomp.® It is an advanced, solid-state digital computer.

It's amazing the number of things Recomp can do. One big asset is the way it frees technical personnel for creative work.

For example, a company that used to get 2 proposals a year from a top creative scientist, was able to increase this figure to 3½ with a computer (not Recomp). But with Recomp this company is now able to get nine proposals per man each year.

Recomp's accessory line and software advantages are the most up-to-date in the computer industry (they now include an xy graph plotter and card reader capability). And an extensive programming library is available without charge.

There is a Recomp to fit your needs (and budget). For medium-scale needs, Recomp II starts at $2,495 and with a complete line of peripheral equipment goes up to $4,500. Recomp III is perfect for small-scale needs. You can lease one for $1,495, complete.

There is only one way to know exactly what computer suits you best. That's through your own feasibility study. And no computer feasibility study is complete without Recomp. Put Recomp side by side with any comparable computer on the market. Let the facts speak for themselves.

We'll be glad to help you get all the facts. Write today for a helpful guide: "How to Conduct a Computer Feasibility Study."

Write: Recomp, Department 27, 3400 East 70th Street, Long Beach, California.

Recomp

Recomp is a product of Autonetics Industrial Products Autonetics is a Division of North American Aviation

Circle Number 32 on Reader-Service Card



Turn right at Orion

Stretching a point? Not really. Although the constellation Orion is more than 240 light years away, two of its stars, Bellatrix and Rigel, stand out as logical navigation points for space missions.

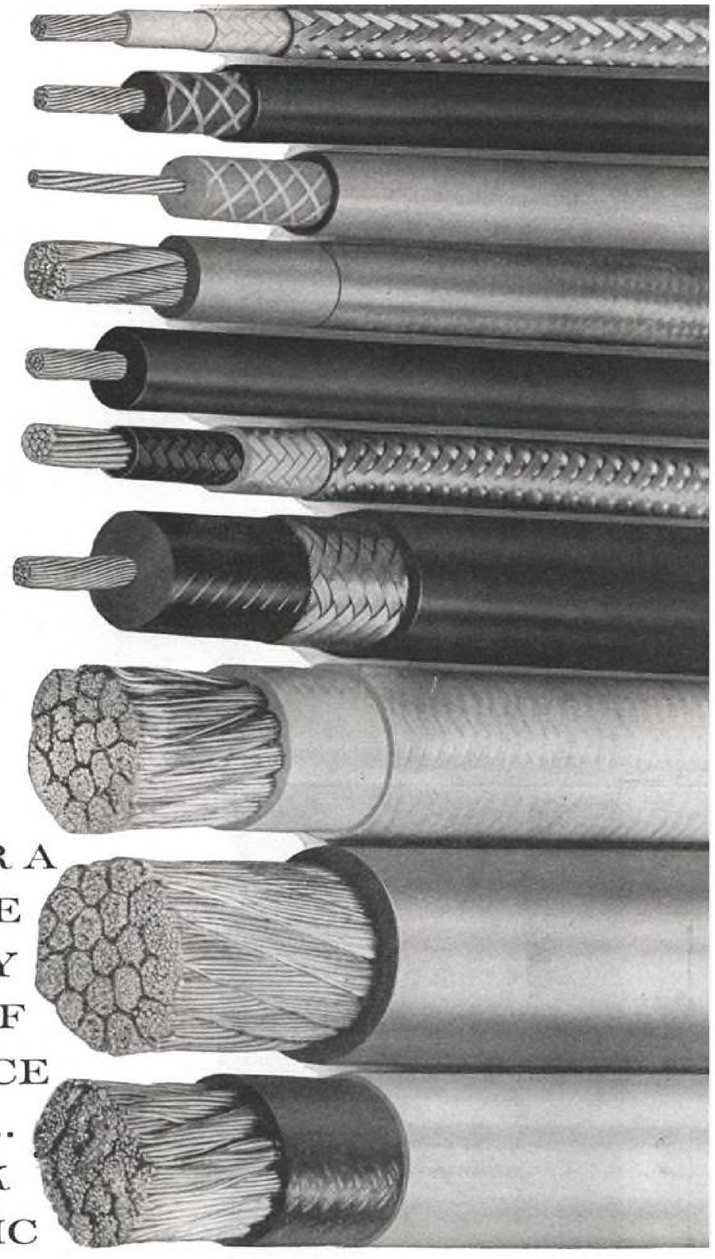
Norden has built and tested two key components for space missions requiring stellar inertial guidance: (1) An all-attitude, four-gimbal inertial platform scaled to meet space vehicle size and weight requirements. (2) An accurate star angle sensor which, through star-fix checks at periodic intervals, can correct platform drift. These self-contained instruments emit no signals and require no earthly contact, yet they could maintain the path of a craft through space indefinitely.

Producing inertial platforms and star tracking devices for stellar inertial guidance systems is evidence of the kind of engineering foresight Norden consistently applies to one primary mission . . . Extending Man's Capabilities.

FOR ADDITIONAL INFORMATION ABOUT NORDEN HARDWARE FOR STELLAR INERTIAL GUIDANCE SYSTEMS, WRITE:

Norden DIVISION OF UNITED AIRCRAFT CORPORATION
NORWALK, CONNECTICUT

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Along with all the other kinds we make, aerospace cable is really big with Packard Electric. For aircraft, missiles, electronics, you can choose what you need from a wide range of types. Sizes from small to medium to large. Single or multiple conductor. All kinds of combinations of construction — including insulations, colors, shieldings, jackets.

And every one designed to withstand extremes of heat, cold, abrasion and moisture — according to your own particular requirements.

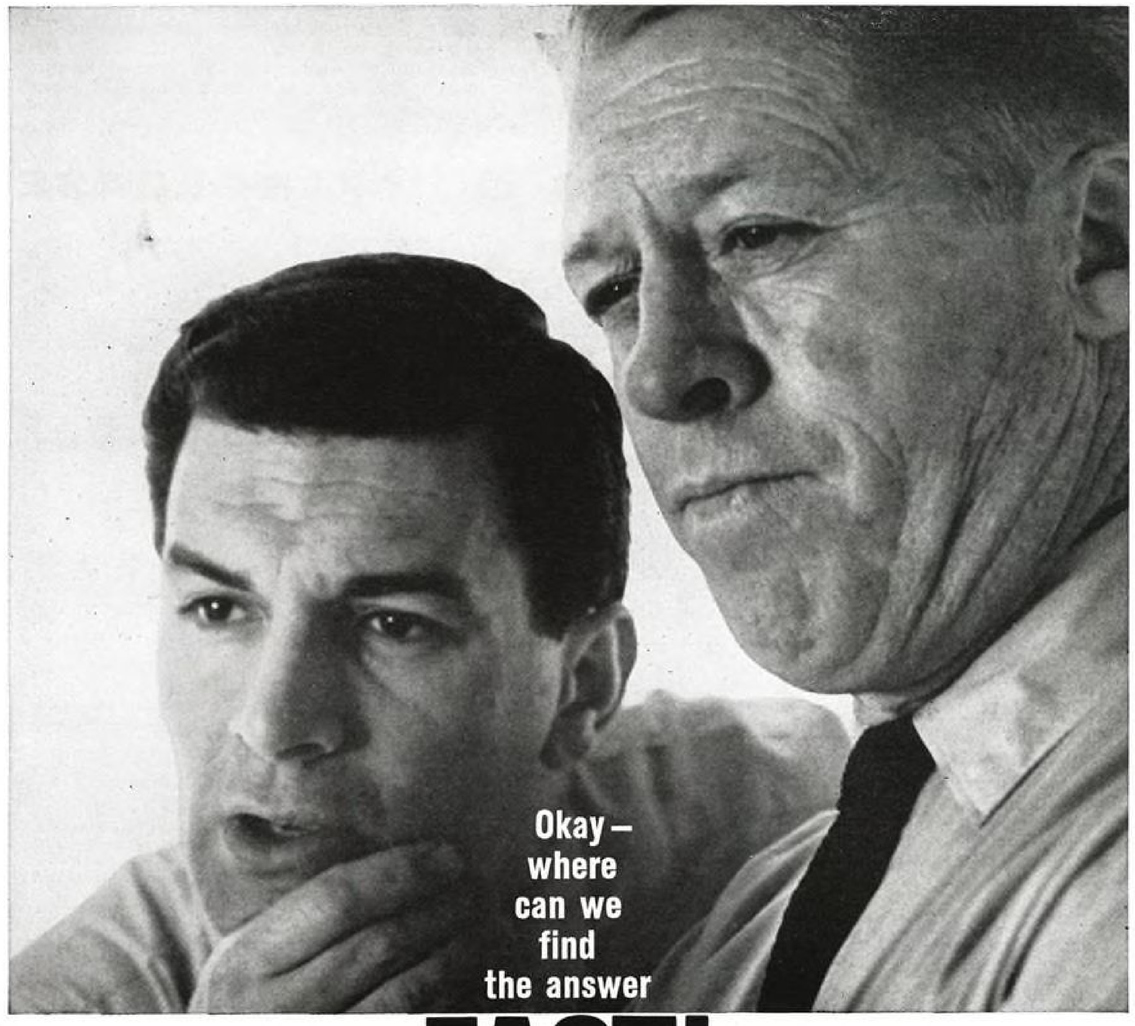
Packard aerospace cable has a first-class reputation for reliability, too, the result of our completely integrated production and exacting quality control.

For aerospace cable, it's a good idea to ask Packard Electric — first. Branch offices located in Detroit and Los Angeles make it very easy to do.

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"Live Wire" division of General Motors, Warren, Ohio

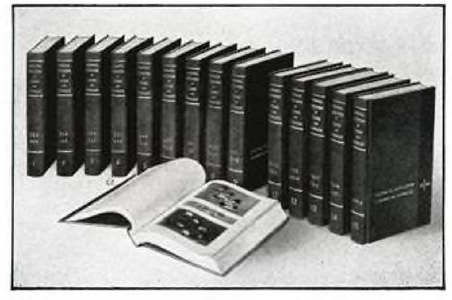
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AVDEL

Avdel Ball-Lok Pins insert easily, are positive-locking. Two types are available, single and double acting, in sizes from 3/16" diameter up. Different handle styles facilitate insertion and removal in difficult access areas. Made of 4130 aircraft quality chrome moly or stainless steels, to NAS standards. Many sizes available from stock, grip lengths in 10th inches.

POSITIVE-LOCKING QUICK-RELEASE

BALL-LOK® PINS

AVDEL DOUBLE ACTING PINS

Push-pull in operation, ideal for heavy loads requiring absolute safety. Three handle styles. Pins have built-in band for lanyard attachment. Standard pins available up to 1" diameter.



"R" RING HANDLE

Standard pins available up to 10" grip length, up to 1" diameter. Positive-locking.

Refer to catalog DWG 1127



"T" HANDLE

Push-pull to operate – easy to insert and remove. Positive-locking. Lanyard attachment.

Refer to catalog DWG 1126



"L" HANDLE

Fits in tight corners. Positive-locking. Standard pins up to 10" grip length and 1" diameter.

Refer to catalog DWG 1125

AVDEL SINGLE ACTING PINS

Simply push the button to insert... repeat the action to remove pin. Positive-locking until released. Five handle styles, with hook for lanyard attachment.



"B" BUTTON HANDLE

Fits snug in close quarters. Positive-locking until released. Aluminum or steel handle.

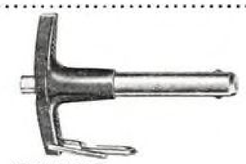
Refer to catalog DWG 1122



"L" HANDLE

Push button to insert and remove, instantly. Hook for lanyard attachment.

Refer to catalog DWG 1121



"T" HANDLE

Two-finger grip for instant removal. Standard pins up to 10" grip length and 1" diameter.

Refer to catalog DWG 1120



"R" RING HANDLE

Push button to insert, repeat to remove. Positive-locking for complete safety.

Refer to catalog DWG 1123



CAM LEVER HANDLE

Just pull handle with lanyard for instant release. Positive-locking until released.

Refer to catalog DWG 1124

AVDEL PIN RECEPTACLE

A receptacle for installations where flush surfaces are required. For use with standard single-acting pins. This pin-receptacle combination provides quick disconnect, with absolute safety in use.



SOLVES SPACE-WEIGHT PROBLEMS



AVDEL DETENT PIN

Solid steel shank, two-ball construction for security. Simply push to insert, pull to remove. For use where positive-locking is not required. Standard pins up to 10" grip and 1" diameter.

Refer to catalog DWG 1131



UP TO 3 INCH DIAMETER

GROUND EQUIPMENT PIN

A rugged positive-locking pin for heavy duty use. Two steel handle styles, L and T. Standard pins available to 10" grip length and 3" diameter. Mfg. to NAS standards.

Refer to catalog DWG 1128/30

AVDEL "SPECIAL" PINS are available for unique applications, including torque pins. Many "specials" use unusual release methods such as solenoid, hydraulic fluid, air, squib and others. Avdel expert engineers, in your area, can help you solve your fastener and release problems. We would like to hear from you.

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Nuclear experience . . . aero/space . . . marine . . . automotive . . . industrial! Harrison's engineering team brings to *your* job an unusual breadth of knowledge backed by unmatched experience in *every* field where temperature control is a problem. *This pool of experience is one reason Harrison can "engineer-in" performance characteristics matched precisely to each application* . . . why Harrison heat exchangers provide maximum reliability and efficiency through the full operational range! For assurance of lasting quality, complete product dependability . . . focus Harrison's "experience in breadth and depth" on your temperature control problems—aircraft, missile or space vehicle!

GM HARRISON — TEMPERATURES MADE TO ORDER

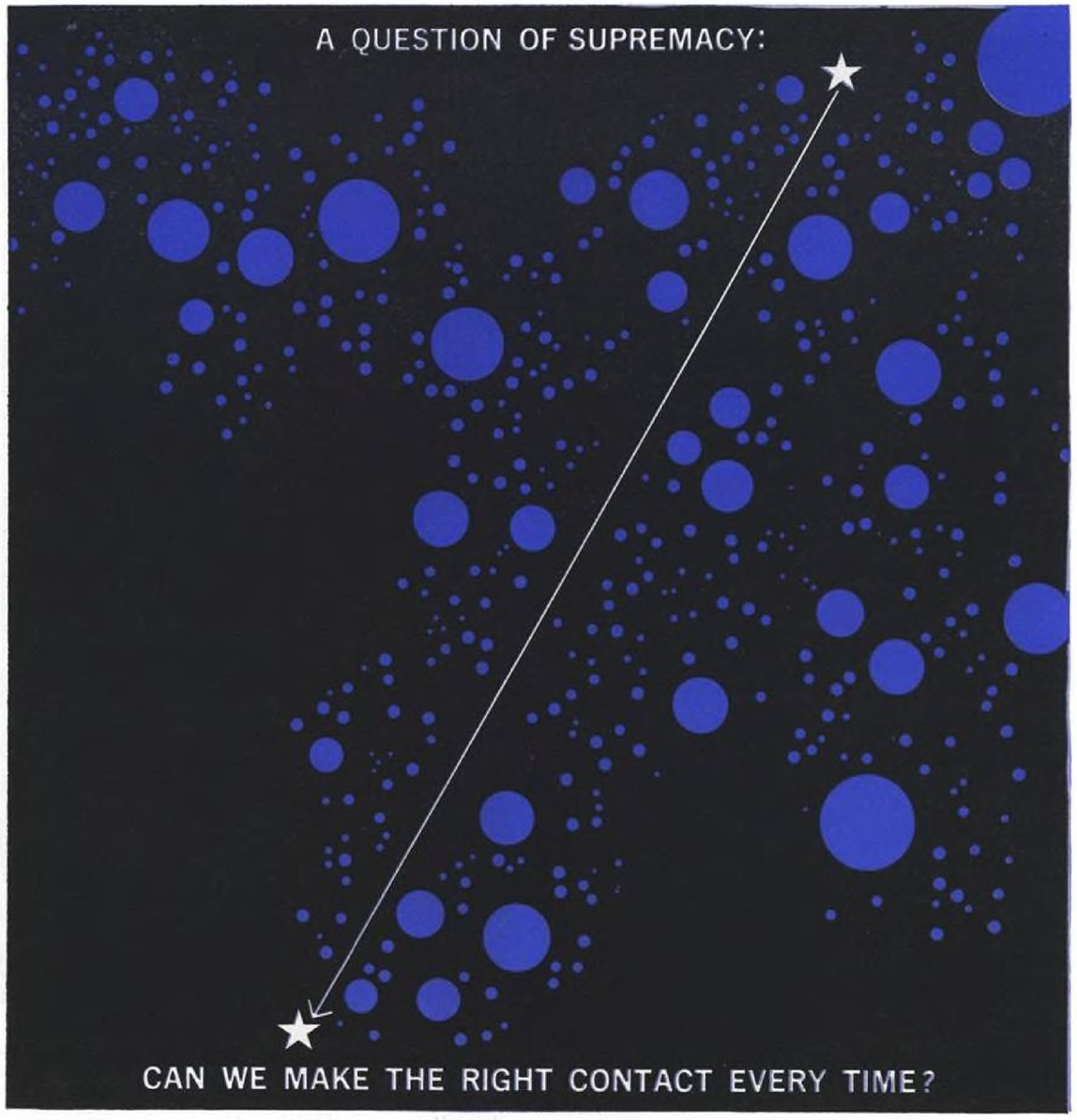
AIRCRAFT, AUTOMOTIVE, MARINE AND INDUSTRIAL HEAT EXCHANGERS

HARRISON RADIATOR DIVISION, GENERAL MOTORS CORPORATION, LOCKPORT, NEW YORK

Free For an informative 48-page brochure on the complete Harrison line . . . write to Department 902



Circle Number 39 on Reader-Service Card



You can lock onto any of 28,000 frequencies – from 2 to 30 megacycles – instantly and firmly, with the General Dynamics/Electronics – Rochester digitally tuned SC-900 series SSB equipment. ■ With these rugged, highly transistorized sets, General Dynamics/Electronics – Rochester has advanced the state-of-the-art in radio communications. This complement of Single Sideband equipment includes transmitters and transceivers, which speak with all the range and authority of 1000 watts PEP, yet occupy less than a 20 inch cube and weigh well under 200 pounds. ■ By simplifying both receiving and transmitting circuits, General Dynamics/Electronics – Rochester has achieved a significant advance in Single Sideband economy, reliability and ease of operation. Over 65 years of communications experience are built into the SC-900 series – a family of noteworthy SSB equipment developed by General Dynamics/Electronics – Rochester for all the branches of the Armed Forces. ■ Every product we make started with a question. We solicit yours. Write 1411 North Goodman Street, Rochester 1, New York.



GENERAL DYNAMICS | ELECTRONICS—ROCHESTER

Circle Number 40 on Reader-Service Card



J-M Microbestos and J-M Micro-Quartz Fiber used to reinforce high-temperature plastics

From Johns-Manville, manufacturer of Min-K and Thermoflex (the only thermal insulations used aboard the Mercury Spacecraft), come two equally important products . . . J-M Microbestos Paper and J-M Micro-Quartz Fiber. They are designed to provide reinforcement for high-temperature plastics such as exhaust nozzles, nose cones and aero-dynamically heated surfaces.

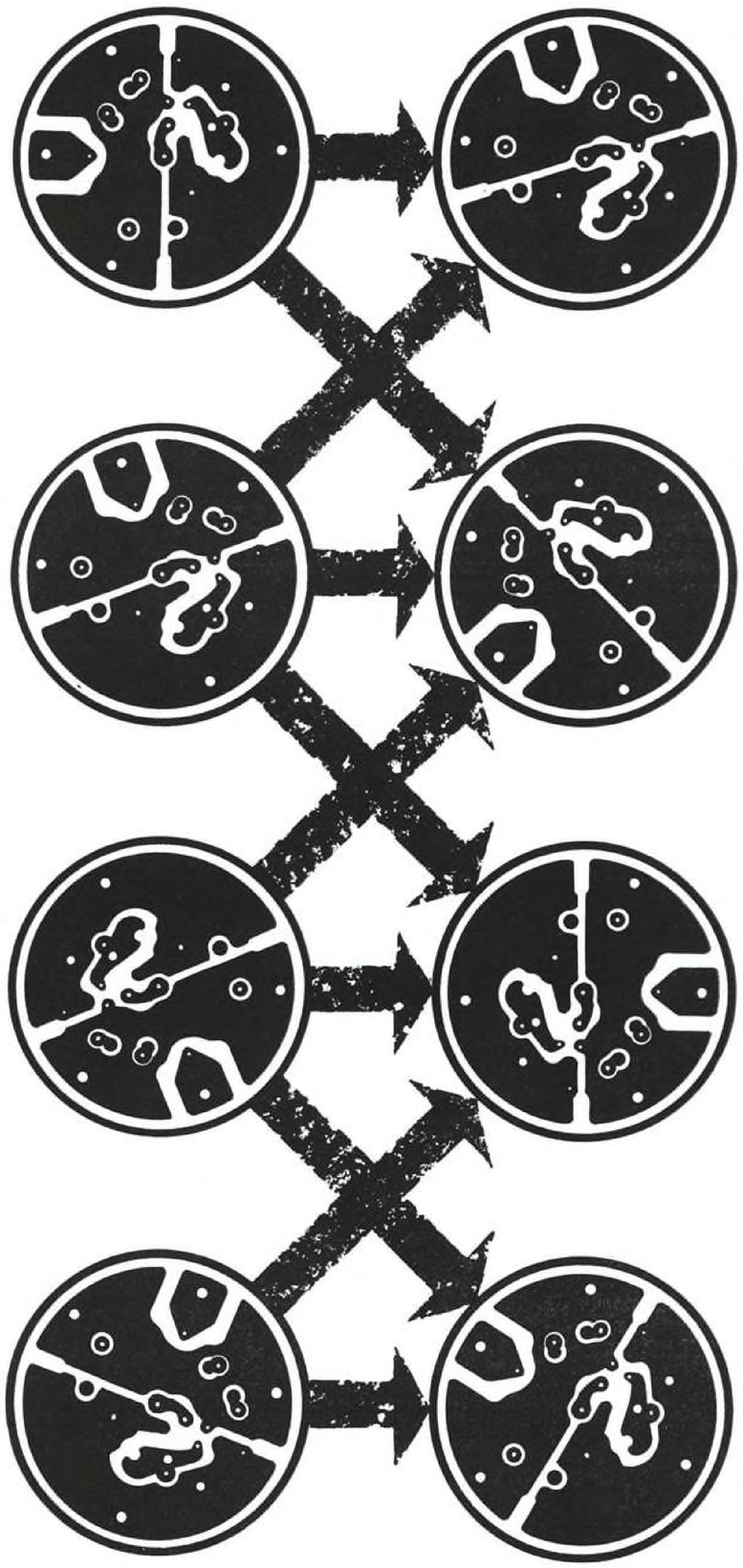
Microbestos Paper is a high-purity, high-bulk, uniform paper made of asbestos or asbestos in combination with other organic and inorganic fibers and fillers. It is capable of accepting up to 50% resin saturation. Microbestos-reinforced products saturated with various resin systems are available from leading manufacturers of laminating sheets, tapes, and molding compounds.

Micro-Quartz is made of the highest purity silica fiber with thermo-physical properties similar to those of pure silica. It is available in bulk form in various fiber diameters for use as a reinforcement for high-temperature and ablative plastics.

For full details on these and other J-M aerospace insulations, write to J. B. Jobe, Vice President, Johns-Manville, Box 14, New York 16, N. Y. In Canada: Port Credit, Ontario. Cable: Johnmanvil.

JOHNS-MANVILLE JM PRODUCTS

Circle Number 41 on Reader-Service Card



NEWS OF DEFENSE TECHNOLOGIES

DATA

To perform effectively, modern defense systems must continuously evaluate every dynamic influence within their environments. Data must be speedily collected, rapidly compared with voluminous memories, and be presented in an organized, accurate and lucid display — *in real time.* All this to assist human judgment, that unassailable prime factor of military strategy.

General Electric has played a major role in advancing the technologies of data utilization and display far beyond their early forms where manual computations of range and track data were accomplished at the plot board. In 1955, for example, General Electric introduced the AN/GPA-37 Radar Course Directing Group, the first mass produced equipment to perform semi-automatic tracking and automatic computation of the intercept problem. Later developments included the AN/FSA-12 Detector Tracking Group—the first equipment to demonstrate automatic detection and tracking of radar targets in all three dimensions—and the new Air Weapons Control System 412L, which provides the U. S. Air Force with the most modern aerospace management system available.

Today's accelerating progress in data technologies is evolving from leap-frog advances in logic and memory circuits and display techniques, and from an expanding scope of responsibility for the data processing and display functions. General Electric continues to make significant contributions to these technologies.



500 MEGACYCLE LOGIC SYSTEM, the first to take full advantage of the ultra high speed capabilities of the tunnel-diode, operates 50 times faster than present circuitry.



CRYOGENIC ASSOCIATIVE MEMORY enables computers to function like a human brain by instantaneously comparing and associating a new fact with all data in its memory.



THREE-DIMENSIONAL DISPLAY provides a realistic presentation of all spatial activity within its radar's range, in true perspective with scale references in all three dimensions.



CONTACT ANALOG DISPLAY for blind flying or flight simulation uses a digital computer to "paint" a moving TV picture of the ground analogous to the obscured real ground.



TDS-90 DATA SYSTEM transmits up to 62,500 characters a second via coaxial cable or microwave radio to link central processing equipment with remotely located computers.

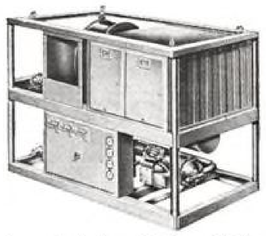
Progress Is Our Most Important Product

GENERAL ELECTRIC

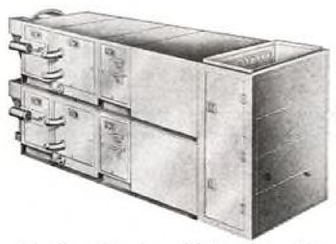
DEFENSE ELECTRONICS DIVISION

Circle Number 43 on Reader-Service Card

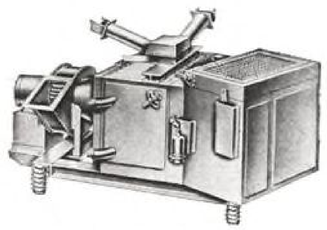
ONLY AAF OFFERS COMPREHENSIVE, ONE-SOURCE CAPABILITY IN ENGINEERED ENVIRONMENTAL SYSTEMS



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.



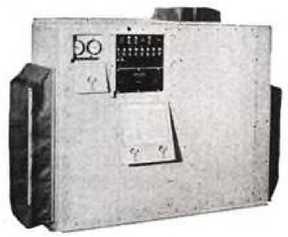
Air Conditioning Unit. Complete, modular constructed unit has supply fan, chilled brine supplied air cooling coil, air filter, automatic temp. control and alarm sensors. Fresh air filtration capable of removing 99.97% of all particulate matter over 0.3 microns in size.



Air Conditioning Unit. Complete, modular constructed unit contains supply fan, chilled brine supplied air cooling coil, air filter, air flow control dampers, automatic temp. control and alarm sensors. Designed to withstand shock load in any direction.



Emergency Cooling Unit. Contains DC-powered vaneaxial fan, DC-powered circulating pump, chilled water supplied air cooling coil, an AC-powered normal-service water circulating pump. Automatic controls for each component. Will withstand shock load in any direction.



Air Conditioner Unit. Provides fully modulated conditioned, filtered air supply with 3-stage cooling. 3-stage heating. Integral, finned, strip-type, electric resistance heaters. Cooling output: 42,000 BTU/hr., rated at + 125° F. Heating output: 51,000 BTU/hr.

YOUR PROBLEM

in engineered environmental control may be similar to problems we've already solved for others. Shown here are a few examples of specialized equipment AAF has designed and produced for such missile systems as Nike Zeus, Atlas, Minuteman and Pershing. Both in engineering knowledge and in research, testing, and production facilities we have proved capability to meet specifications such as MIL-R-27542, GM 07-59-2617A, S-133-2 and other stringent specifications.

Engineered Environmental Systems

HEATING
VENTILATING
AIR FILTERING
REFRIGERATION
HUMIDITY CONTROL

Write for Bulletin D-164



Air Conditioner CH-100A. Has both automatic and manual controls; integral and remote controls. Fully modulated conditioned air supply with 3-stage cooling, 3-stage heating. Cooling output: 30,000 BTU/hr. rated at + 125° F. Heating output: 51,000 BTU/hr.



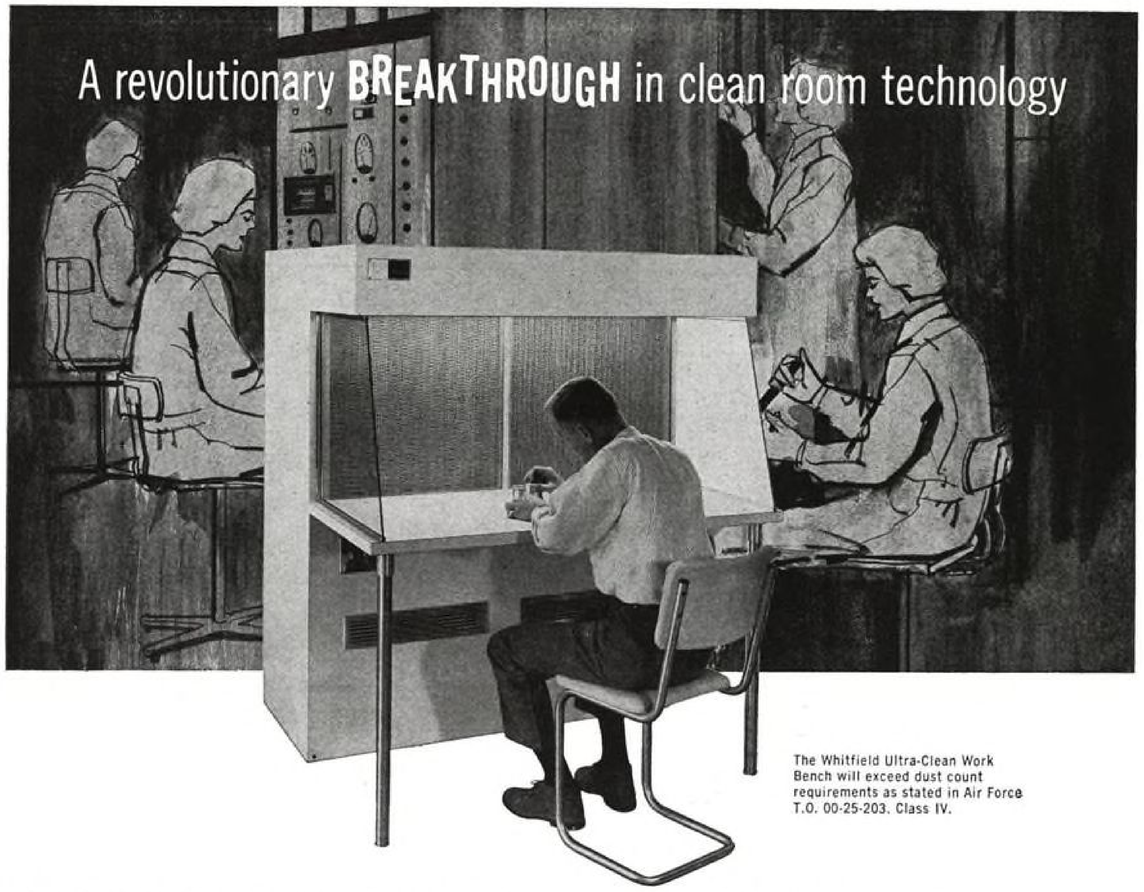
Explosion-proof Portable Heater. Designed to meet MIL-E-4970 Environmental and MIL-H-27507 performance. Delivers heated air while operating within hazardous atmosphere. Triple over-riding temperature limit controls. Unit grounded against static electrical build-up.

AAF

DEFENSE PRODUCTS DIVISION

AMERICAN AIR FILTER CO., INC., 310 Third St., Rock Island, Ill., Phone 788-9311

Circle Number 44 on Reader-Service Card



The Whitfield Ultra-Clean Work Bench will exceed dust count requirements as stated in Air Force T.O. 00-25-203, Class IV.

NEW WHITFIELD ULTRA-CLEAN WORK BENCH 500 TIMES CLEANER, PROVIDES FREE ACCESS, REQUIRES NO SPECIAL CLOTHING



ULTRA-CLEAN, ULTRA-CONVENIENT!
Clean air flow from the bench bathes work continually. Operator does not have to wear any special clothing, has free access to his work, and has absolutely the cleanest work area!

Now you can have an open, convenient, *literally ultra-clean* work area with *none* of the usual cleanroom restrictions! The Whitfield Ultra-Clean work bench continually bathes the work area with an ultra-clean air flow that carries particles away from the area before they can settle. Because the clean air flows *from* the bench, the dust count of the room and its personnel do not affect bench cleanliness. No gloves, special clothing, hoods or shields are necessary. *Personnel have completely free access to the work area, with a dust count of less than 1000 .3 to .5 micron particles per cubic foot maintained. This is 500 times cleaner than any other clean room or bench.* The Whitfield Ultra-Clean work bench provides a work area of 2′ x 2′ x 6′; it has a self-contained air supply and requires only 110 V.A.C. power. With the compact Whitfield design, continuous ultra-clean assembly lines can be had by simply adding benches. Get complete information on the new Whitfield Ultra-Clean work bench now by mailing the below coupon.

Please send me complete information and documentation on the Whitfield Ultra-Clean work bench.

AGNEW-HIGGINS, INC.

8402 Standustrial Street, Stanton, California
Telephone 714 JAsper 7-2251 CABLE—AH5301-U

NAME_____
TITLE_____
COMPANY_____
STREET_____
CITY_____ ZONE____ STATE_____

Circle Number 45 on Reader-Service Card







LET HEXCEL SUPPLY YOUR COMPLEX HONEYCOMB SHAPES



PROVEN CAPABILITIES READY NOW!

Curved, Carved, Contoured Parts To Your Specifications

12 years' experience in perfecting techniques for pre-curving, contouring, carving, edge-bonding and trimming honeycomb parts—in both aluminum and reinforced plastic materials. These are Hexcel's qualifications to help you achieve even the most complex combinations of cylindrical and spherically curved parts. You make no investment of time and money to train and tool-up, parts are shipped to you ready for bonding!

Typical Hexcel Pre-Curving Capabilities:

CYLINDRICAL RADII	Normal Expanded Honeycomb: 4x Thickness Over-Expanded: 1x Thickness
SPHERICAL RADII	8x Thickness in one-piece nose caps 4x Thickness over small areas of large pieces Segmented Assemblies: 1x Thickness

Finished Honeycomb Core Assemblies—including several of the above combinations, furnished edge-bonded, ready to use.

Engineering Consultation On Honeycomb Parts

Hexcel's pioneer role in development of honeycomb has resulted in design of special tooling for pre-curving and machining. Hexcel engineers will work with you in manufacturing your own forming equipment from Hexcel drawings, and stay in your plant till your own employees are trained in proven techniques for working honeycomb. Hexcel engineers can also consult with you on which combination of honeycomb material and forming techniques will best help attain your specific strength, temperature and cost requirements.

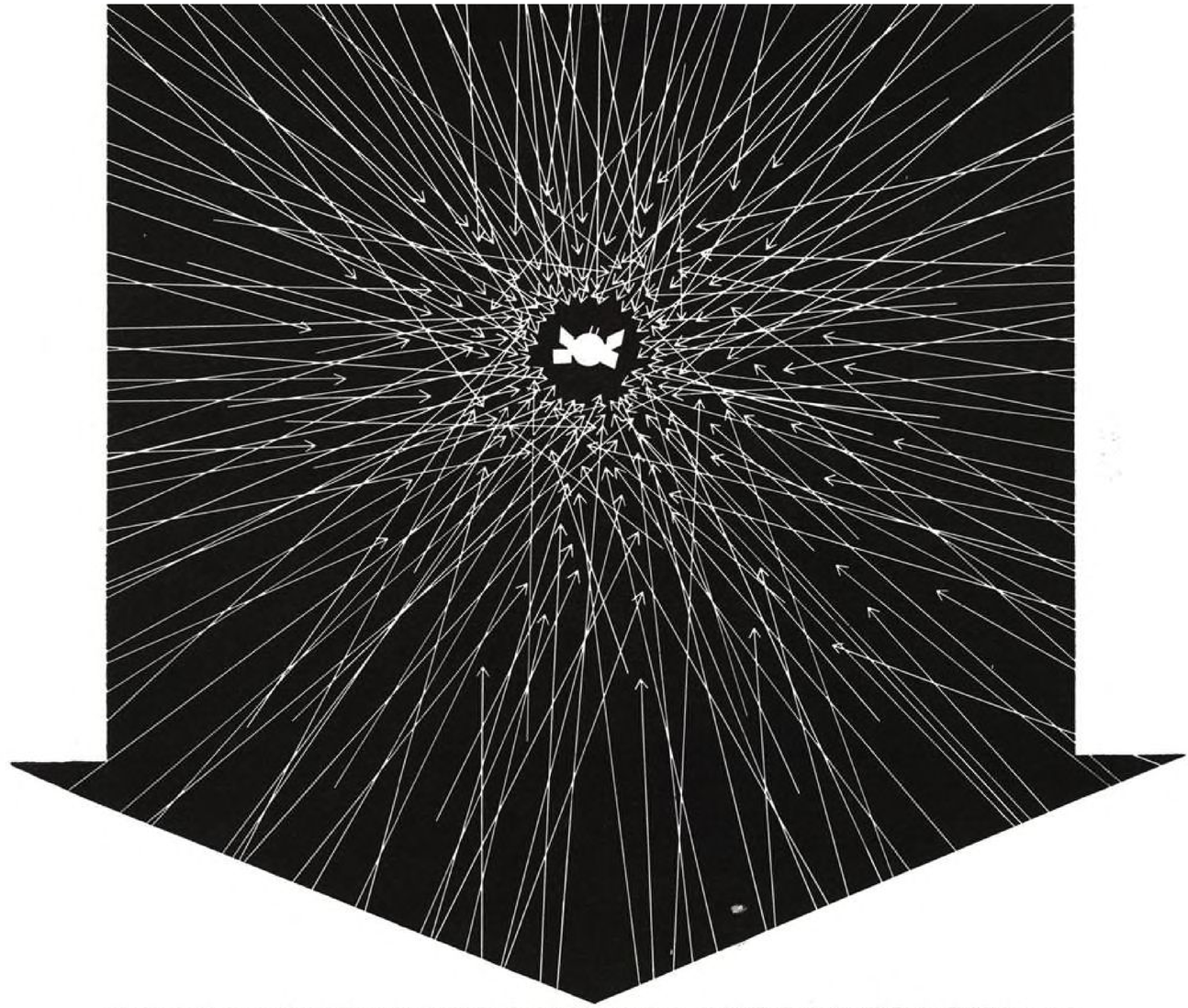
Hexcel Honeycomb Capabilities Proven In Major Projects

Pictured above are some of the major aerospace projects in which Hexcel has supplied pre-curved, contoured or carved parts. General Dynamics/Astronautics' Atlas-Centaur, NASA's Saturn and McDonnell's F4H are stronger, lighter, faster thanks to Hexcel Honeycomb technologies.

HEXCEL® PRODUCTS INC.
Strong, light, versatile honeycomb

EXECUTIVE OFFICES:
2332 Fourth St., Berkeley 10, Calif.
PLANTS:
Berkeley, Oakland, El Segundo, Calif.; Havre de Grace, Md.
SALES OFFICES:
Inglewood, Calif.; Fort Worth, Texas; New York, N. Y.; Havre de Grace, Md.

Circle Number 46 on Reader-Service Card





HOW TO LISTEN TO 160,000 SPACE MESSAGES—INSTANTANEOUSLY!

A satellite in orbit has a lot to tell. It sees the birth of a hurricane, feels the bombardment of radiation, peers into new space highways. Then it hurls this information to earth in the form of millions of electrical impulses. A Beckman system gathers and translates them to a common language, is capable of delivering 160,000 messages every second—without missing a one.

With a similar Beckman system you can check a prototype aircraft through its wind tunnel tests—improve on design long before actual flight. Or run continuous checks on a petroleum refinery—assure the quality of industrial output and the safety of workers. Other Beckman instruments analyze the mystic potions of a jungle witch doctor, balance the color in television receivers, and monitor the air in nuclear submarines. Beckman instruments, systems, and components are at work throughout the world in laboratories, production lines, and defense installations.

Remarkable what you—and a Beckman system can do.

If you have a problem in analysis, measurement, or control, write to our Director of Marketing.

Beckman® INSTRUMENTS, INC.
Fullerton, California

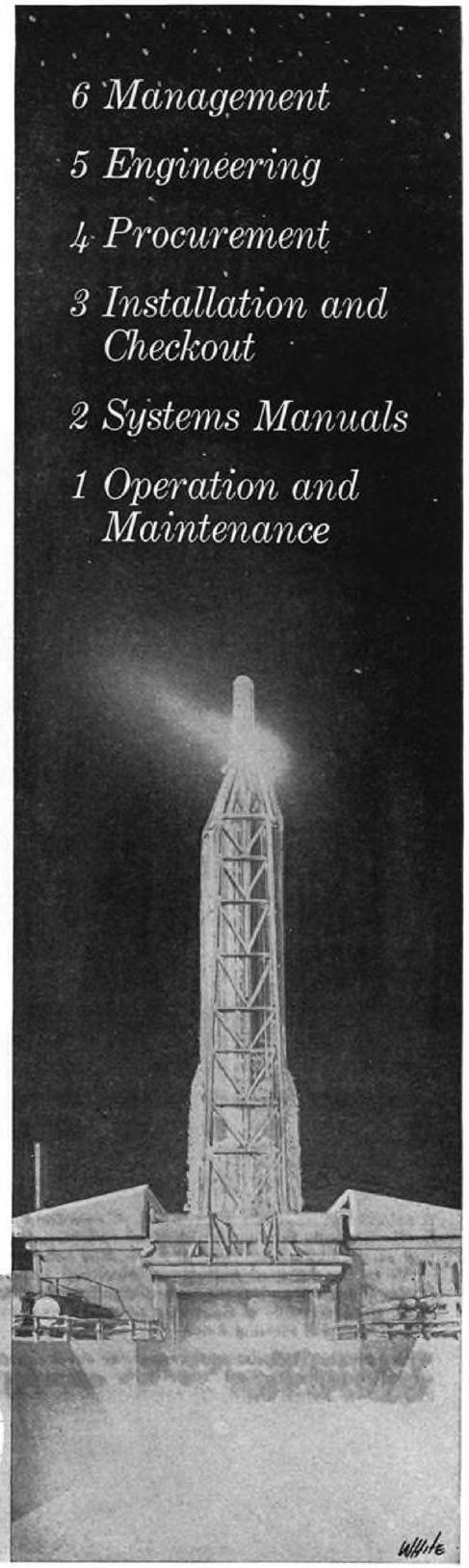
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COUNTDOWN ON RELIABILITY

Reliability typifies the Stearns-Roger staff of specialists in the fields of missile, cryogenic and nuclear facilities. Reliability requires the dedicated services of experienced and competent engineering personnel in the areas of criteria development, design, procurement, installation, check-out and operation.

Rely upon Stearns-Roger capability gained over the years in the Atlas, Titan, Minuteman, Saturn and associated programs.

With proven management and dependable, integrated engineering and construction staffs, Stearns-Roger can function under any contract to provide single responsibility for your requirements.



SINCE 1885

Stearns-Roger

660 BANNOCK / P. O. BOX 5888 / DENVER 17 / COLORADO

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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.

Circle Number 49 on Reader-Service Card

POWER CONVERSION when you need

for production, tests, labs, look to:

Motor Generator Corporation

Your guide to new uses of Motor Generators for–
• revising out-dated methods • new applications

FREQUENCY CHANGERS AND LINE ISOLATION
- 50 to 60 c.p.s. Induction or synchronous
- 60 to 50 c.p.s. Induction or synchronous
- 60 to 400 c.p.s. Induction, synchronous belted, or vari-speed to supply power to aircraft and missiles

ELECTROLYTIC SYSTEMS
- Disinfection
- Deionization
- Water treatment
- Saline water conversion
- Hypochlorinating

INDUCTION PRE-HEATING & STRESS RELIEF UNITS
- on a precise temperature and time cycle basis

CONVERTERS
- 60 or 50 cycle a.c. to 28.5 volt d.c. for piston-engine, turboprop or turbojet aircraft starting and checkout, also missile launching
- 60 or 50 cycle a.c. to 112 volt d.c. or other d.c. voltages (6-250)

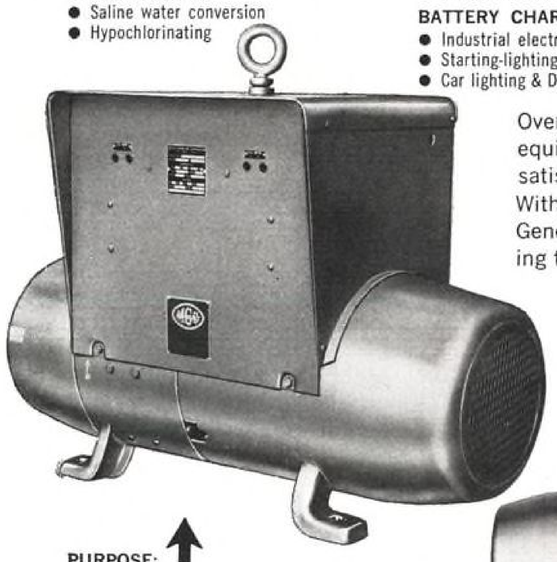
BATTERY CHARGING
- Industrial electric truck
- Starting-lighting-ignition
- Car lighting & Diesel locomotive

AIRCRAFT ENERGIZERS
- Engine driven 28.5 volt d.c. and 112 volt d.c. and 400 cycle for support of piston-engine, turboprop, and turbojet aircraft while on the ground
- 60 to 400 c.p.s. frequency changers for airport gate, ramp, hangar or shop use

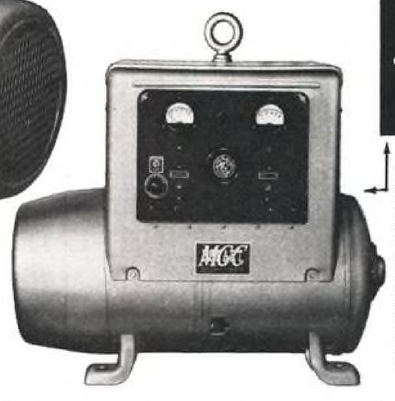
ELECTRIC STARTER ENERGIZER
- used in lieu of battery power for engines

ARC LAMP
- and other light simulator applications

Over fifty years experience in manufacturing electrical equipment qualifies us to offer you the guarantee of satisfaction in any service we may perform for you. Without reservation, we fully guarantee Hobart Motor-Generators to meet rigid quality standards incorporating the latest developments in materials and methods.



PURPOSE:
To test solar cells for life under the sun's intensity in outer space. Also for brilliant light generation for photography and military applications.



The picture at the left shows a 3-phase, a. c., 7½ HP, 220/440 volt, 60 cycle motor direct connected to a single-phase, 110/220 volt, 60 cycle, 6.25 KVA alternator. It is used where close control over the output voltage and complete isolation from the main power source is essential.

MGC's NEW DESIGNS CAN DO YOUR JOB FASTER WITH MORE RELIABILITY TO SAVE COSTS — INCREASE PROFITS

The above list gives a few typical applications for Hobart Motor Generators. If you have a specific power conversion problem why not let Hobart help you? There are many other applications calling for special power requirements. Write to address below for literature and quotation—all without obligation!

MOTOR GENERATOR CORPORATION, Box AV-72, TROY, OHIO, U.S.A. Phone 332-1223
(Hobart Brothers Affiliate)
CABLE - MOGEN

Circle Number 50 on Reader-Service Card



The Task: To Achieve the Ultimate in Mission Accomplishment for Aerospace Systems, with MAN "in the loop."

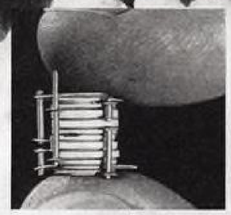
The Solution: Translation of Man/Machine Technology into Integrated Control and Display Systems through Refined Management Techniques.

Acquisition of technical information required for the development of space systems must be rapid and efficient. By analyzing the problems of a system at its inception, the most effective way of acquiring the necessary technology can be determined and implemented quickly. Deciding the needs for data display is equal in importance to the development of the methods of display. The capability of Lear to translate system requirements into operable control and display hardware is widely recognized. Lear experience includes the development of wholly integrated systems for supersonic aircraft and space vehicles, and Lear possesses exceptional ability to acquire, process and display technical information for the ultimate in mission management. We call it Control-Display Systems MANagement.



LEAR INSTRUMENT DIVISION • 110 IONIA AVE. N. W., GRAND RAPIDS, MICH. ID-7

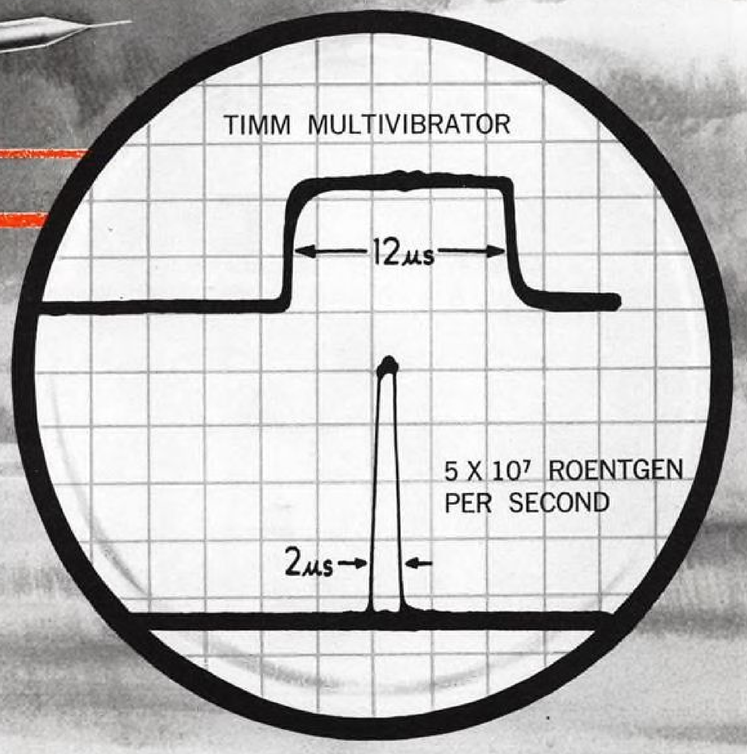
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NOW

electronic systems can be "hardened" against nuclear radiation with TIMM circuits

ELECTRONICS



TIMM OPERATION DURING
5 X 10^7 R/SEC RADIATION PULSE

High-intensity radiation pulses from a nuclear explosion can produce disrupting electrical transients in most of today's avionic equipment. With conventional circuitry, transient radiation can scramble the memory of a missile guidance computer . . . prematurely trigger a decision circuit . . . or block radio transmission from a satellite. It can cause equipment malfunction or total system destruction at distances once considered safe from nuclear heat and blast. To illustrate: A "small," one-megaton explosion in space will produce a crippling 10^7 R/sec. pulse *more than 110 miles away.*

TIMM Circuits will operate 97 miles closer to the blast, using the one-megaton example . . . and no shielding is required. Examine your system requirements in light of these exclusive TIMM features:

■ **Higher Radiation Tolerance (Transient and Steady-State).** TIMM circuits have an indicated capability of 10^9 R/sec. pulse-radiation tolerance and 10^{19} nvt fast neutron tolerance, without shielding. These are, respectively, 1000 and 10,000 times greater than the radiation tolerance of other microminiature approaches.

■ **Higher Temperature Tolerance.** TIMM circuits have an indicated long-term operation at 580°C. No cooling equipment is required.

■ **Wide Frequency Capability.** Fast switching action and high reliability are assured.

■ **Less Regulated Power Required.** Built-in bias and high-temperature operation reduce outside power requirements. Efficiency goes up as packaging density increases. Voltage regulators are eliminated.

■ **Practical Miniaturization.** System size is determined by circuitry rather than by cooling or shielding requirements. Operating-component densities to 1,000,000/ft.^{3}

■ **Rugged Construction.** High shock and vibration tolerance.

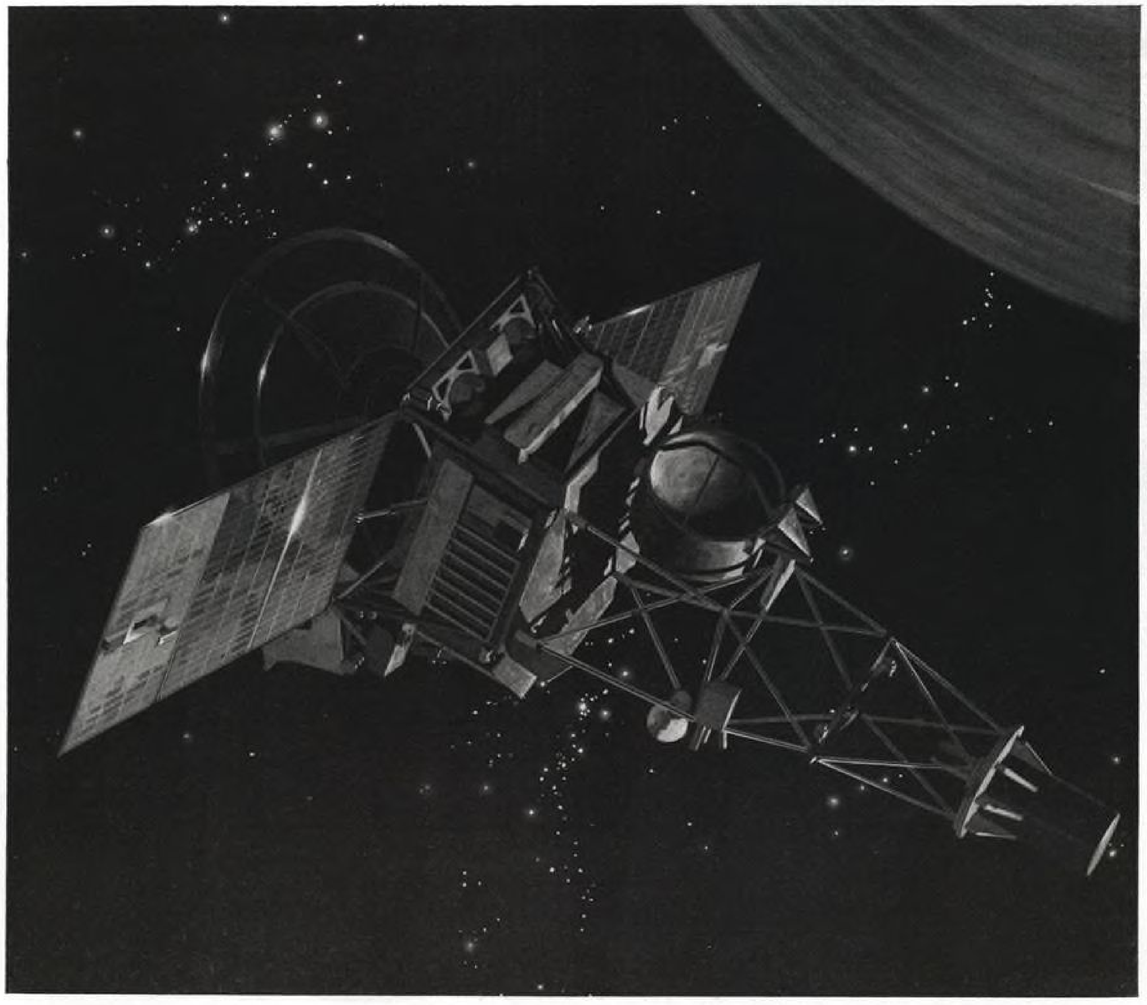
■ **TIMM Circuit Elements Now Available.** Individual elements (resistors, capacitors, diodes and triodes) are now available for breadboard experimentation.

A personalized presentation of the complete TIMM story can be arranged at your convenience and location. For more information, or TIMM literature, write to: General Electric Company, Receiving Tube Department, Room 1735, Owensboro, Kentucky.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle Number 53 on Reader-Service Card



How to power Venus-bound space probes?

Ryan Aerospace is producing lightweight solar panels which will support thousands of tiny photoelectric cells to harness the sun's energy in space. The cells will generate the electrical power needed for the controls, experimental and communications systems of Venus space probes and earth satellites.

With broad experience in systems management, Ryan engineers are developing power systems, communications systems, and advanced space structures to meet the requirements of space vehicle programs. These capabilities are geared to *fast reaction time* in keeping with the demands of planetary orbits and sudden shifts in program schedules.

Flexible, fast-moving Ryan is also making significant contributions in the areas of V/STOL aircraft, Doppler sensing and navigation systems, and Flex Wing applications. And Ryan is the world's largest producer of jet target systems for the Armed Services.

Your inquiry is invited concerning the total capability of Ryan Aerospace and Ryan Electronics in space age design, development and fabrication.

RYAN AERONAUTICAL COMPANY, SAN DIEGO, CALIFORNIA



HIGH-ALTITUDE *radar altimeters for the Saturn launch vehicle, lunar landing spacecraft, and high-speed hydrofoil ships are among the advanced electronic guidance and communications systems now being created by Ryan Electronics.*



FOLDING SOLAR MIRRORS *can provide a source of power for space vehicles. This model, 10 feet in diameter, was completely engineered and fabricated in just a few months by Ryan scientists, engineers and highly skilled metallurgists.*



MAGIC LINK *between space vehicles and earth is the Antenna which makes possible two-way communication. Ryan is developing lightweight, precision Space Antennae, capable of withstanding both launch and space environments.*

RYAN
AEROSPACE



MIDVAC STEELS OPEN NEW HORIZONS FOR DESIGN ENGINEERS

Where maximum reliability in high temperature ranges and minimum rejects are required . . . plus larger sizes for the new missiles, Midvac Steels have answered and are ready to solve the problems of many engineers. These ultra-clean steels are now available in ingots up to 60 inches in diameter, weighing 80,000 pounds.

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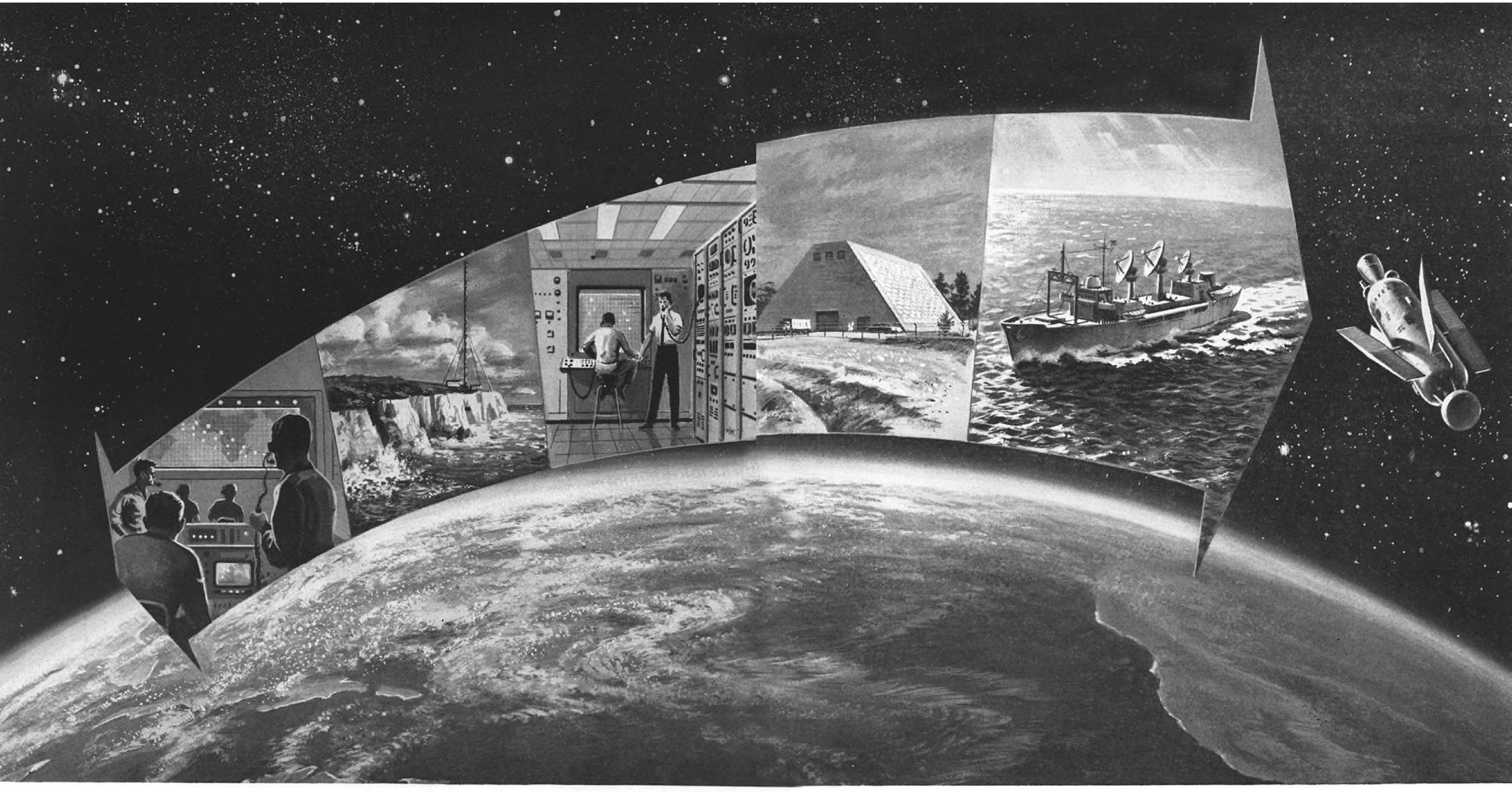
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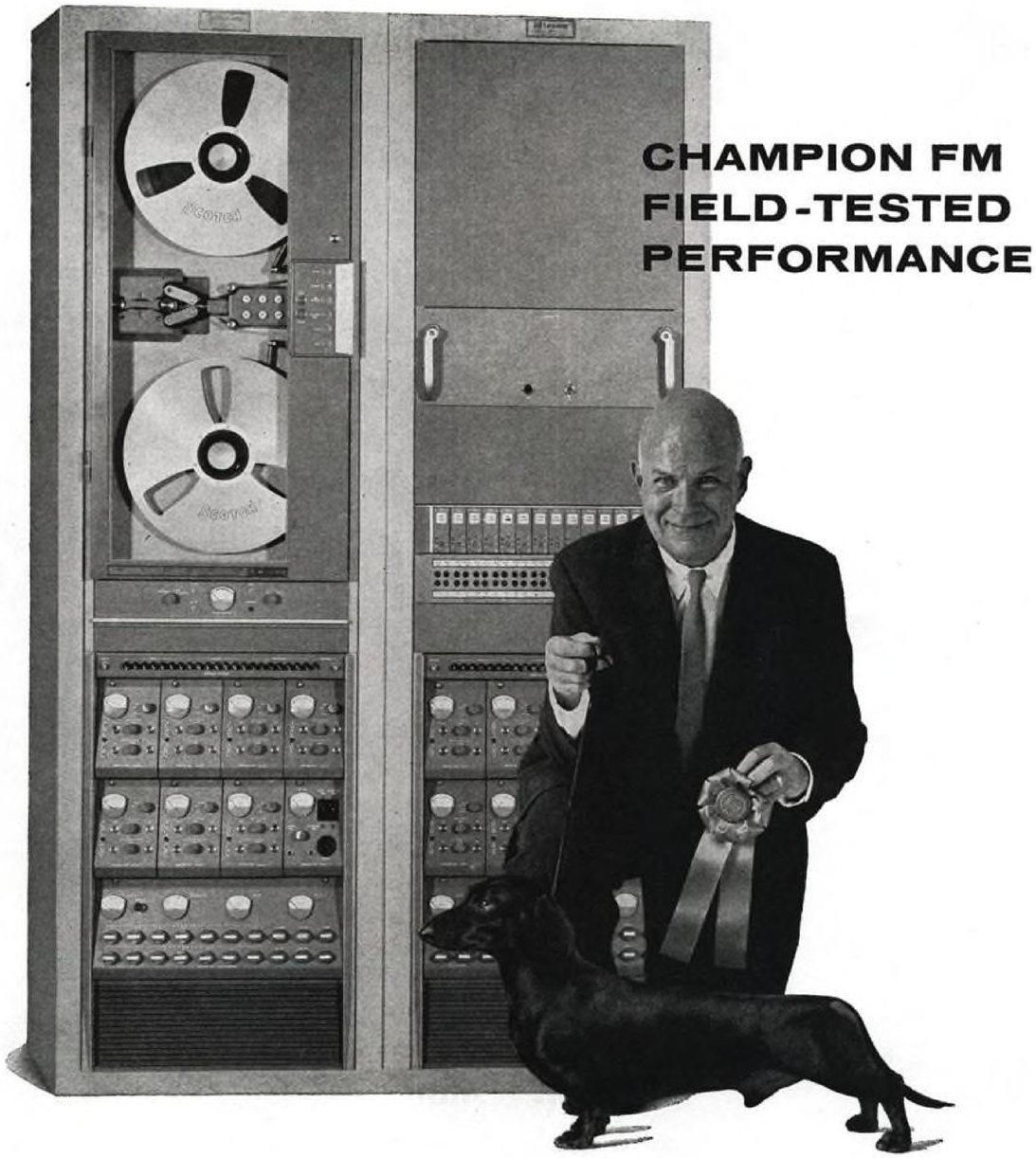
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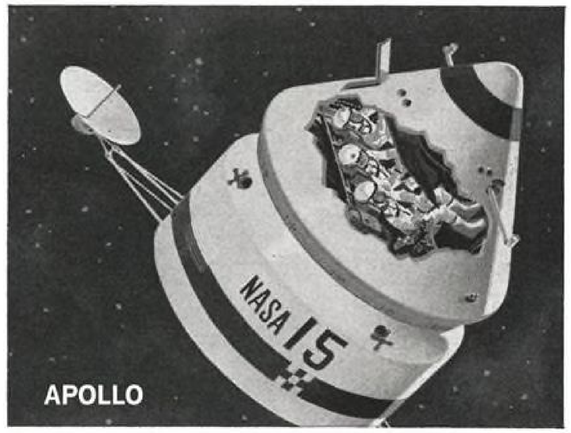
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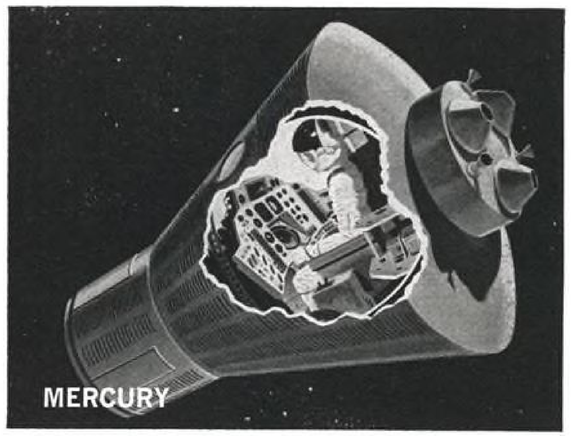
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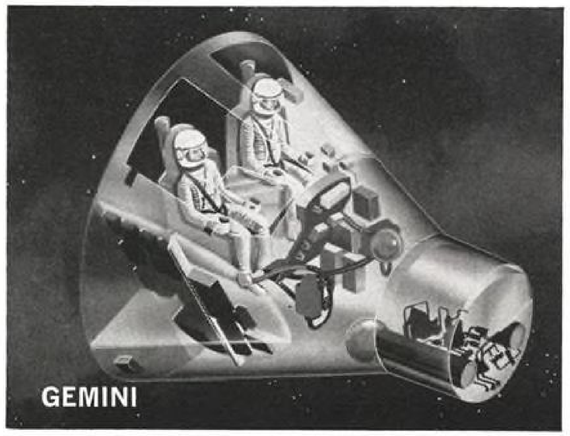
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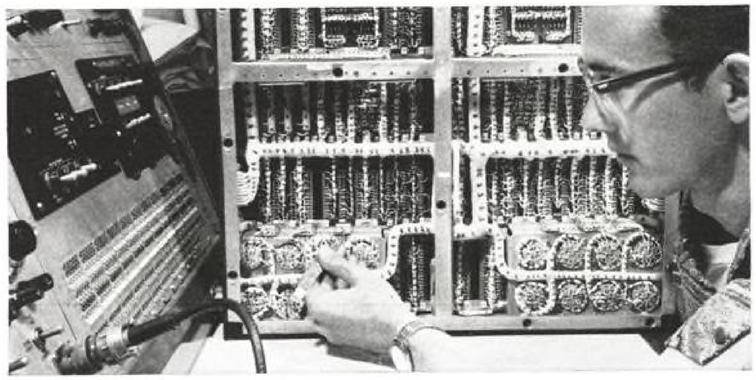
HONEYWELL SYSTEMS help U.S. astronauts control these vehicles through critical maneuvers in space.

When the multi-man Apollo spacecraft travels to the moon and back, Honeywell control, stabilization and display systems will be on board to help the astronauts perform the necessary critical space maneuvers along the way.

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Earlier steps in this series have included the pioneering NASA-USAF-Navy X-15 rocket-powered flights to the fringes of space and NASA's Mercury suborbital flights of astronauts Shepard and Grissom—and most recently, the three-orbit Mercury flight by John Glenn. Subsequent projects include the two-man NASA Gemini spacecraft for extended duration missions and orbital rendezvous tests, and the Apollo manned lunar spacecraft.

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Honeywell Mercury systems perform successfully on all shots

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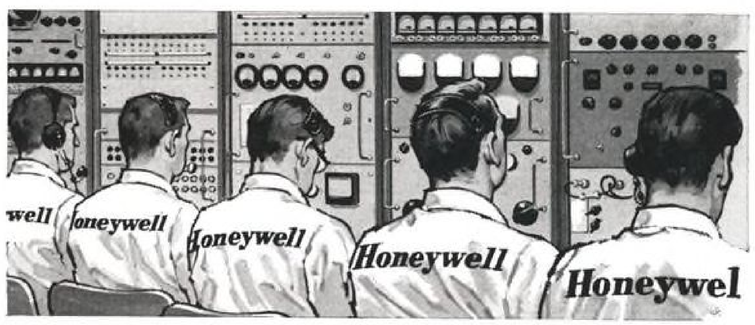
Honeywell support systems vital to mission success

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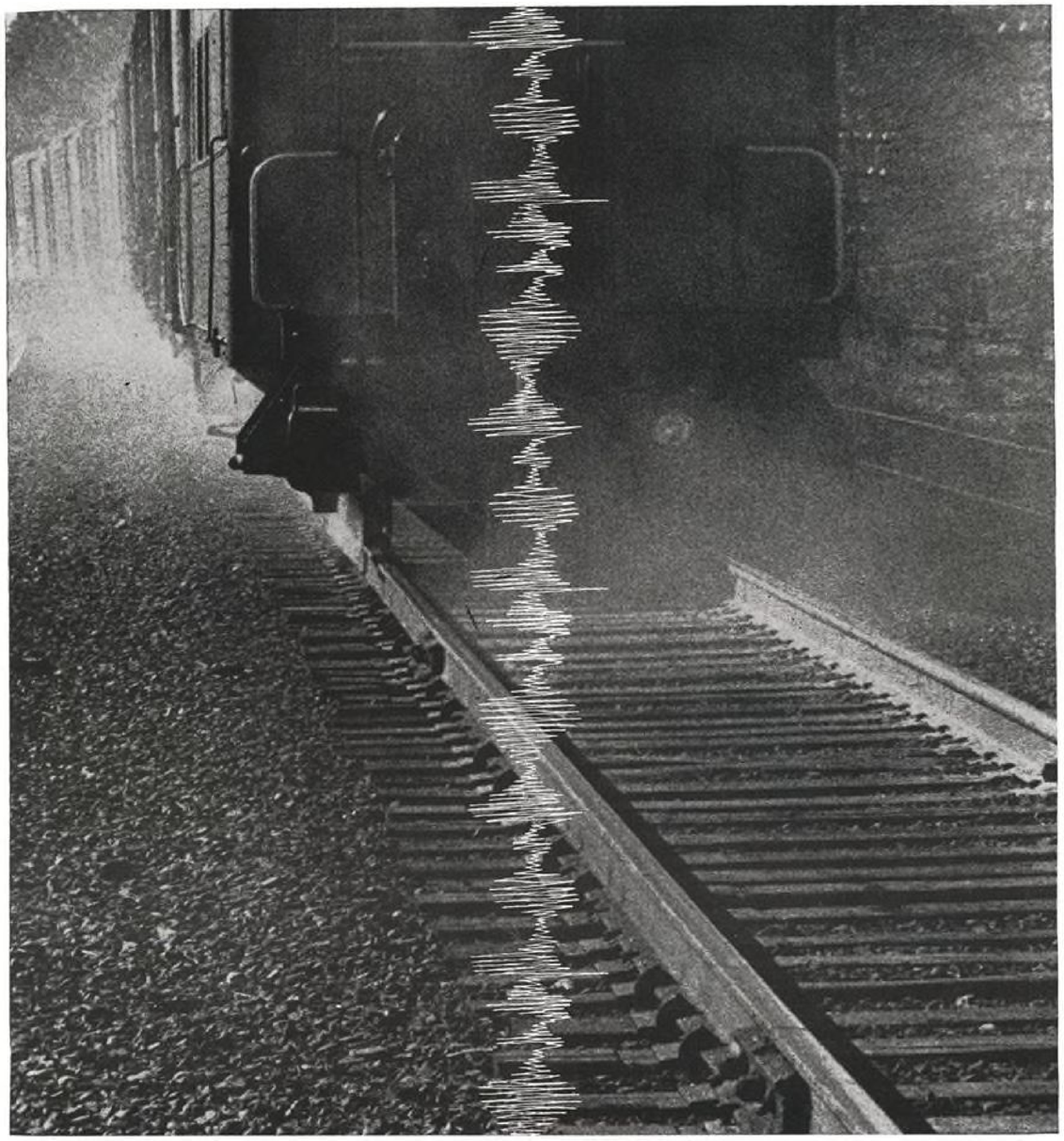
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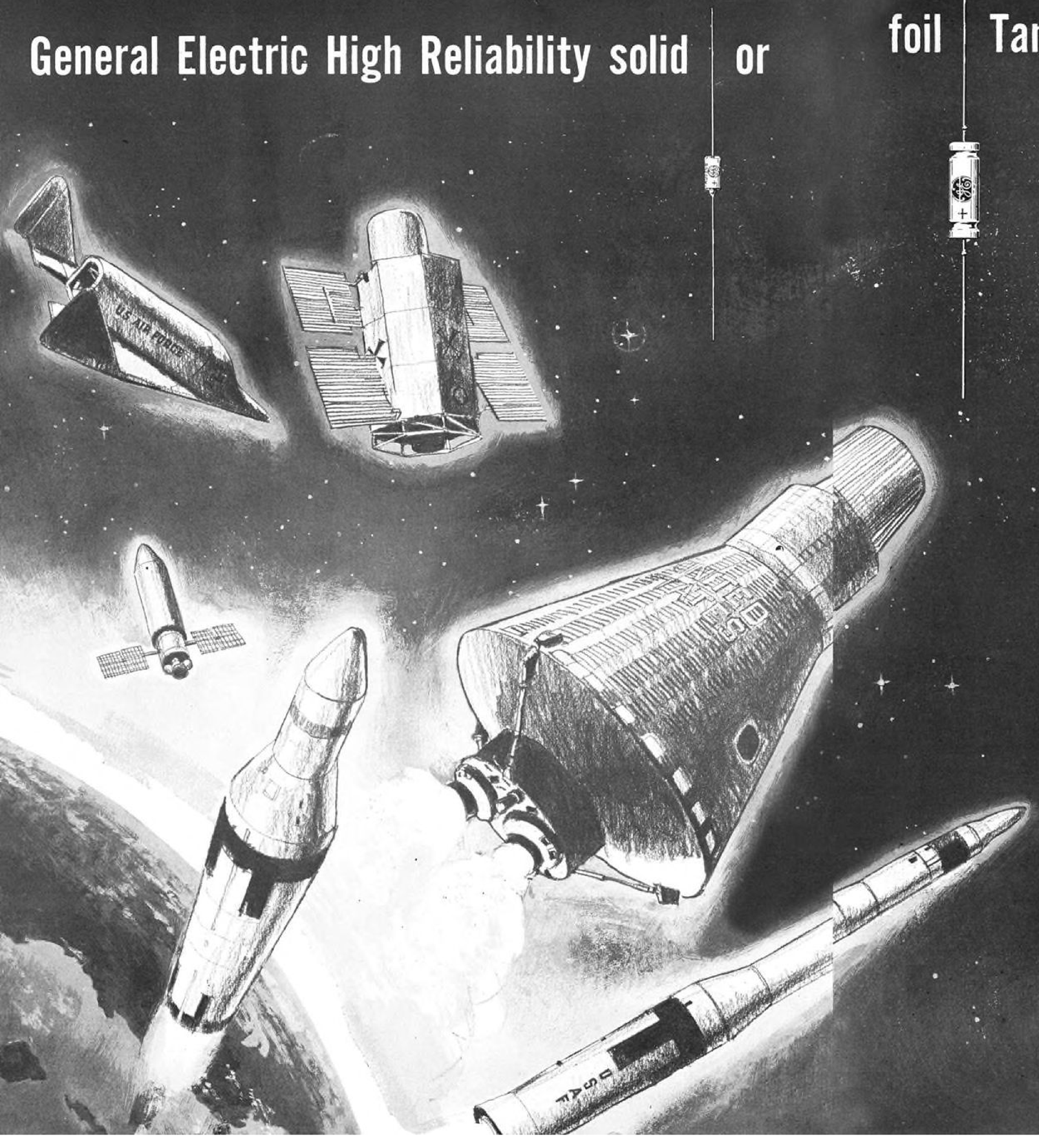
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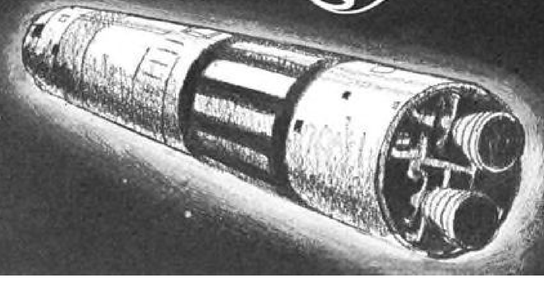
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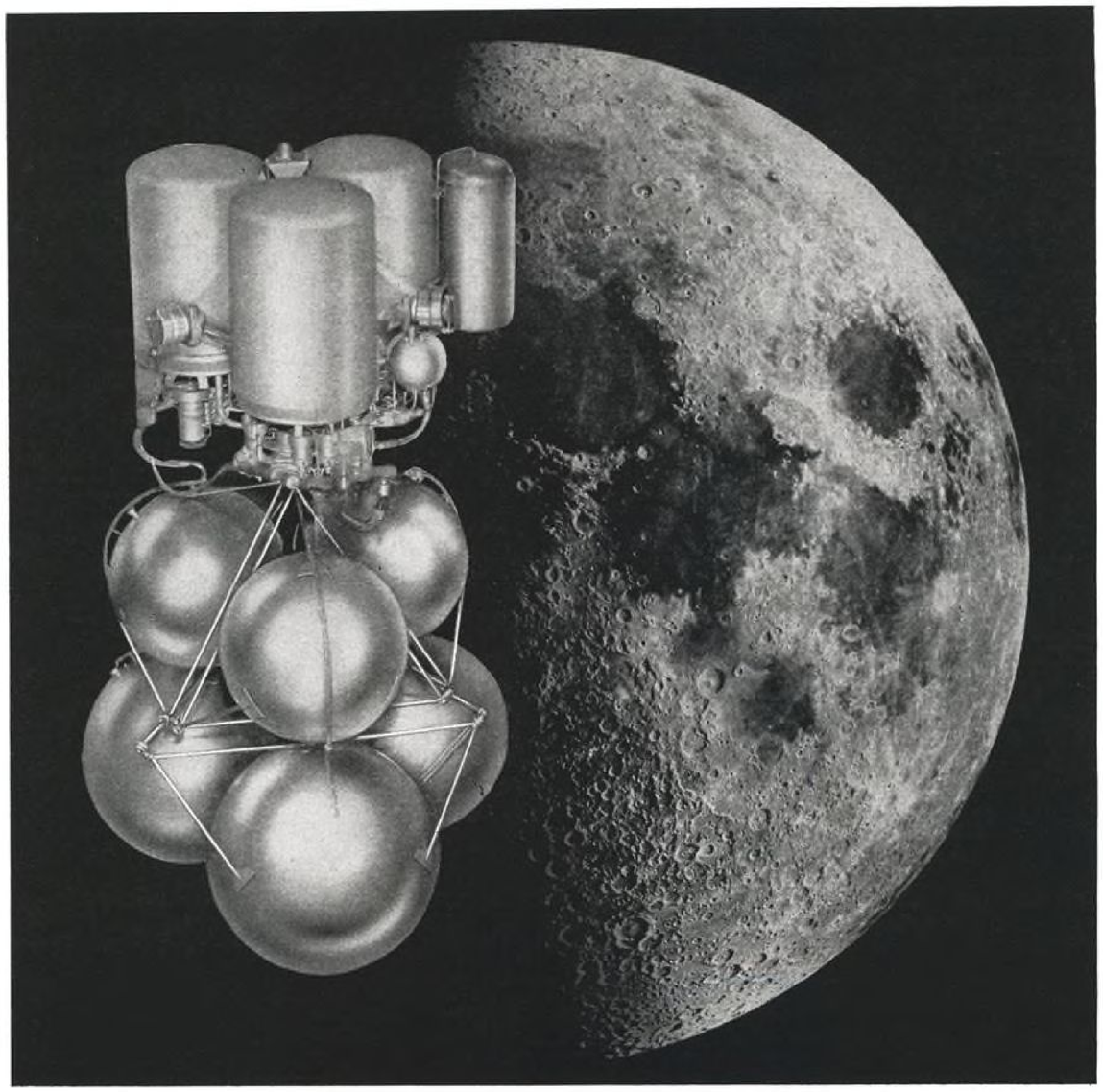
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The hydrogen-oxygen cell will supply power for environmental conditioning, communication, instrumentation, and scientific equipment. In addition to generating electricity, the fuel cell will provide water for Apollo's three-man crew.

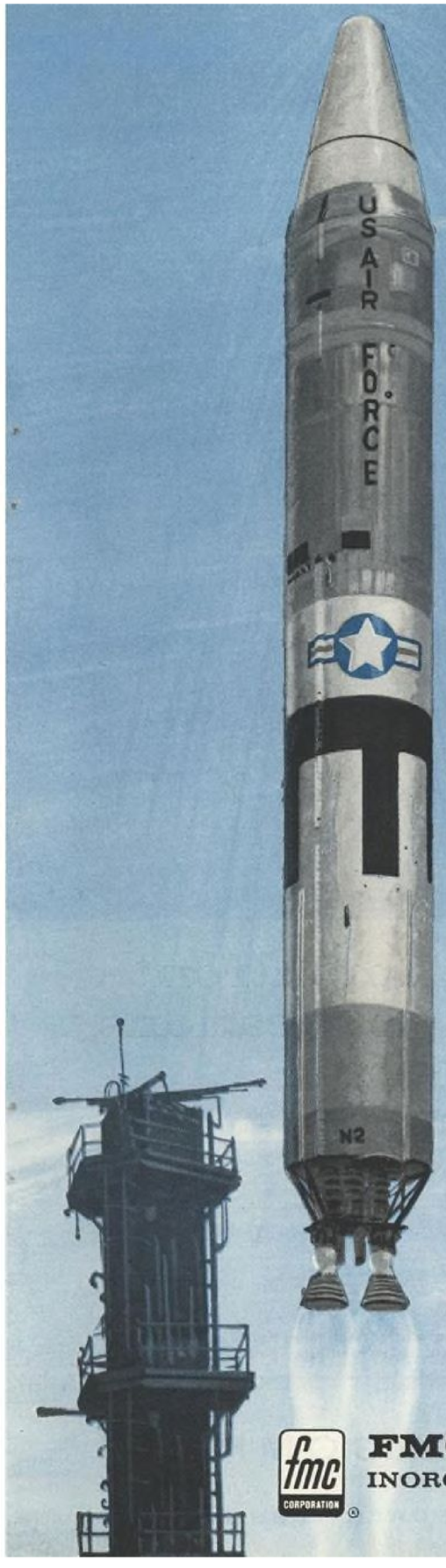
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Number 1

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July 2, 1962

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COVER: Base heating studies on Saturn model in Lewis Research Center tunnel

This special issue devoted to the vast expansion of the National Aeronautics and Space Administration's programs across the broad spectrum of space technology was written and edited by a special Aviation Week & Space Technology task force directed by Evert Clark, Washington Bureau Chief and AW&ST's first Space Technology Editor. The team consisted of David A. Anderton, Technical Editor; Irving Stone, West Coast Editor; Philip J. Klass and Barry Miller, Avionics Editors; Edward H. Kolcum and George Alexander, Space Technology Editors; assisted by William S. Reed, Arnold Sherman and Ann Dunphy with art direction by Lawrence J. Herb, Art Editor. All of the NASA field centers were visited by this task force in the preparation of this issue, in addition to extensive briefings at NASA headquarters in Washington, D. C.

Aviation Week & Space Technology

NASA's Spearhead to Space Creates New Capabilities, Markets

This country is now straining into space at a pace very close to the full capacity of its available resources. At the same time it has embarked on a massive program to create the basic new resources required to further accelerate the current pace during the next decade.

National Aeronautics and Space Administration is now the spearhead of the U. S. space technology program and bears the heaviest responsibility for its ultimate success, although NASA is still heavily dependent on the resources of the aerospace industry and the military services. NASA has come a long way from the fall of 1958, when it was created by an act of Congress and signed into being by President Eisenhower—just about a year after the Soviet Union's Sputnik 1 marked the dawn of the space age. At birth, NASA was a loose amalgamation of resources hastily gleaned from the research laboratories of the National Advisory Committee for Aeronautics, the Naval Research Laboratory's Vanguard team and the Army's Jet Propulsion Laboratory. It had an overly modest budget and little top-level governmental support for its tremendous task of trying to overtake the Soviet Union's then commanding lead in space technology.

By mid-1962 this infant of 44 months ago has already grown into a giant with technical resources, budget and national priority commensurate with its Gargantuan task. It also has a clear goal on which to focus its major energies:

Land men on the moon and return them safely to earth before the Soviets.

Despite the highest national priority for the manned lunar landing mission, this is not the sole goal of the national space technology program nor even the essential point of why this nation will probably devote more than $50 billion of its tax dollars to this task during the next decade. Because the requirements for the manned moon mission encompass almost every vital segment of technology that must be mastered by any sound space program, it provides an ideal focal point for this vast effort along with the essential stimulus of a clear-cut goal and tangible achievement. It also is the first point in the history of space exploration where it is technically possible for this country to overtake the Soviets and beat them to this goal.

Although NASA's space exploration program is now focused on the moon, the knowledge gained from this effort will be reflected primarily in a better life for man on earth.

What can the U. S. citizen who is supporting NASA's effort with his tax dollar eventually expect from his investment in space technology?

● **First, it is providing** a badly needed exercise in mobilizing national resources to achieve a basic national goal. This is a capability the U. S. has demonstrated previously only under the stress of a shooting war. But with the basic change in international conflict wrought by the thermonuclear threat, this direction of a nation's specialized resources to express an essential national purpose should not, and indeed cannot, await the obvious stimulus of armed conflict. Organization and successful operation of a national space program will be a significant exercise of the leadership and flexibility required for survival as an entity in the modern world.

● **Second, it will explore** a basic new scientific frontier that will produce a vast reservoir of new knowledge and technology that will have a profound and revolutionary impact on our economy, in much the same manner that the furious pace of research and development during the Second World War spawned the giant new industries that have sparked our economy through its amazing post-war growth.

● **Third, it can provide** an expression of national vigor and vitality measuring this nation's capability for international leadership at a time when this is sorely needed. From its inception, NASA has heavily emphasized the openness of its scientific program and diligently worked with scientists of all nations, not only in sharing the knowledge gleaned from its own experiments, but assisting them to organize their own space research experiments and pursue their own specialized lines of study. Despite the initial, universally acknowledged leadership of the Soviet Union in space, NASA's open-minded international cooperation program, in contrast to the USSR's medieval secrecy regarding its own technology, has already made a significant impact on the minds of the international scientific community. Nobody who attended the recent Cospar sessions in Washington could miss the growing significance of this aspect of NASA's program.

It is a sad historic fact that the Soviet Union led the world into the space age with Sputnik 1 and that this country truly organized its own space technology program only under the tremendous international pressure generated by the Soviets' initial successes. At the time NASA was organized, few knowledgeable persons in this country or anywhere else would have bet that the U. S. flag had anything but the tiniest chance of being hand-carried to the moon before the hammer and sickle.

Now we believe that this country has a better than even chance to win this laurel, and even if it does not, it can certainly become pre-eminent across the whole broad spectrum of space technology as long as the present scope and quality of its program continues to receive the current measure of public and governmental support.

President Kennedy established the manned lunar landing mission as the goal of a vastly expanded space technology program in May, 1961, little more than a year ago. Since then NASA has moved with a speed, vigor and imagination not usually found in government to organize, expand and enlist the necessary technical and industrial support to achieve the Apollo goal.

In mid-1962 it is possible to perceive the full pattern of these changes, the problems they present and the challenges they offer to science, industry and education. This is why AVIATION WEEK & SPACE TECHNOLOGY picked this particular time to assign a special editorial task force to a three-month study of the new NASA pattern and its portent for the aerospace industry, which is presented in this issue. Virtually all of the new NASA pattern is now complete and the outline of its major future problems clearly visible. The only piece still missing is the decision on which technical approach will get top priority as the major spearhead through space to the moon—lunar rendezvous or earth orbital rendezvous. Even this decision should be made before the end of July.

NASA has made remarkable progress in gearing its operations to the accelerated pace and expanded goals of the Apollo program, but it still faces many major problems in the years just ahead. These include:

● **Personnel.** NASA is successful in attracting recent college graduates with the bait of opportunity to complete advanced degrees while working on the latest technologies. It has also attracted some good men from industry with the lure of directing major new programs, but it is having trouble in getting the large quantity of experienced engineers and scientists in the ranges where industry salaries are much higher and NASA job challenges are not overriding considerations. NASA already has gone to industry to fill two key requirements originally scheduled for in-house capability in the Bellcomm systems planning contract and the General Electric Apollo systems integration and quality control contract.

● **Technical gaps.** Major technical gaps must be filled in various areas of the space technology spectrum such as high speed re-entry, orbital rendezvous, bioastronautics, radiation patterns, etc., before the full firm foundation for Apollo can be built. NASA faces the problems of filling these major technical gaps at the same time it is designing hardware for the lunar mission.

● **Military interface.** Few of the knotty problems of organizing and operating an effective NASA-military interface have been tackled yet, although increasing emphasis is being given to this area. Still unresolved is how much the military requirements in space will influence NASA's research and development programs and how much military support NASA can expect for its future efforts.

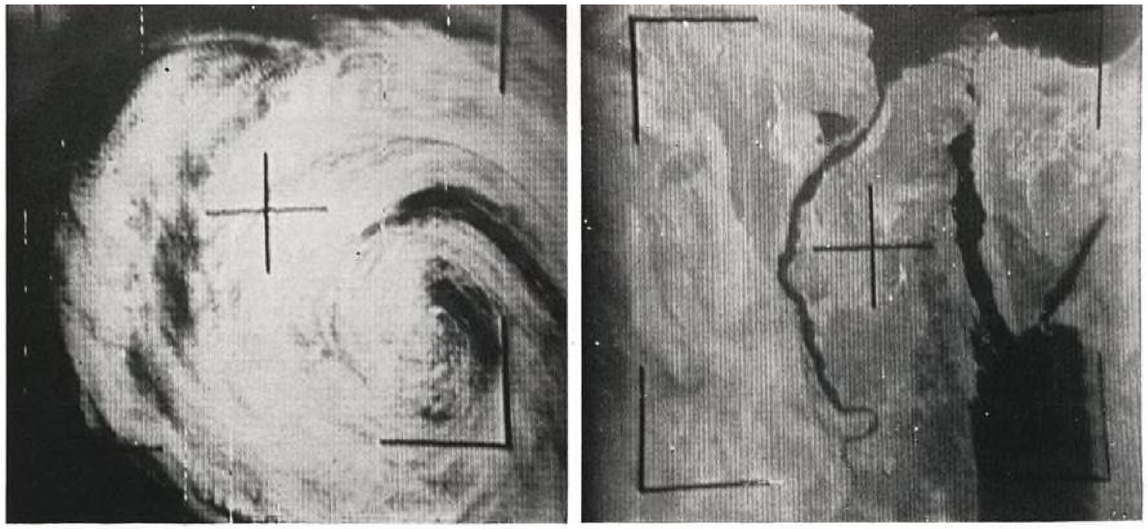
● **Public and congressional support.** Congress has supported the $3.7-billion NASA budget for Fiscal 1963 with an unprecedented unanimous vote in the House. Overwhelming endorsement of this budget is also expected later this month from the Senate. But as NASA programs progress, funding requirements inevitably will rise considerably above early estimates and it is likely that the agency will have to ask Congress for support in the $6-billion area for future years or face a significant reduction in its program operations. To get sustained support over the next decade from both Congress and the taxpaying public at this level will require both an unchallengeably superior performance by NASA, and a thorough understanding of its operations and achievements by the public.

For industry, the expanding NASA program offers new markets and presents many new challenges. It will require managements alert to the rapidly shifting tides of technology and technical capabilities to exploit them in a highly competitive environment. It will present managements with new ground rules in procurement, proprietary rights and profits and it will present industrial technology with new standards of reliability, design and production.

In looking over space technology in the summer of 1962, after visiting most of the NASA research, development and test centers and many of the great industrial complexes that support them, it appears that an ineffable spirit is stirring in the land. It is attracting the mentally adventurous and youthfully bold to this exploration of the universe in much the same spirit with which the ships of the late 15th Century mariners were crewed to explore the western oceans.

Like these ancient European mariners, who never achieved their goal of a shortcut to the Orient but opened the Americas instead, the space explorers of this generation may find their real achievements in areas that cannot be seen from this point in time on the earth's crust beneath its atmospheric sheath.

—Robert Hotz



CYCLONIC STORM area, left, photographed by Tiros 5 which was launched last June 19, demonstrates advanced state already reached by these experimental NASA meteorological satellites. Tiros 5 photo at right shows Nile River, Suez Canal, Red Sea.

Manned Lunar Program Reshapes NASA

Decision to push Apollo expands size and cost of agency's effort, strengthens its reliance on industry.

Washington—Mandate to attempt the greatest engineering feat ever undertaken by man—landing men on the moon and bringing them back to earth—has shaped and changed the National Aeronautics and Space Administration until it can almost be considered a new agency undertaking a new program.

Manned exploration of the moon and planets has been implicit in NASA's mission since it was created. But until the Apollo lunar project was announced by President Kennedy on May 25, 1961, NASA was not specifically committed to any manned space flights beyond Project Mercury.

The Apollo decision greatly expanded the size and cost of NASA's program, caused an internal reorganization, forced a strengthening of the agency's relationships with Defense Department and a broadening of its dependence on industry, cast its relationships with Congress in an entirely new light and sharpened an already keen sense of urgency.

Manned space flight now represents one-half to two-thirds of NASA's total effort. The civilian space program has many goals aside from the lunar mission. But Apollo is affecting even these, by forcing lunar scientific projects into more of a supporting than a purely exploratory role, for example.

Although change and growth are the norm in any dynamic situation, NASA's evolution in the past 13 months has made its earlier years seem peaceful.

NASA asked the Congress this year for $3.787 billion in Fiscal 1963 funds and a supplemental Fiscal 1962 appropriation of $156 million. The 1963 figure is more than double previous year's budget, which in turn was 16 times that of the last budget requested by the old National Advisory Committee for Aeronautics five years ago.

Requested increase in headquarters strength for the fiscal year that began July 1 was 494 people—almost the size of the entire NACA headquarters before NACA became the nucleus for the space agency. This increase, much of which is to support the manned lunar program, would bring headquarters strength to about 1,900 by the end of this fiscal year, nearly four times the size of NACA headquarters.

Basic Steps

The basic steps in putting together the Apollo program have been taken. A management structure has been created, with the help of formal and informal advice from government and industry. Although NASA intends to retain a flexibility on detailed methods —such as lunar vs. earth rendezvous and even rendezvous vs. direct ascent—the essential elements of hardware have been decided on and most have been contracted for.

NASA's problems now are to manage this vast undertaking, cover the many engineering and reliability hurdles implicit in the assignment, see that no other programs are slighted and continue to convince the Congress and the public, as successfully as it has in the past, that the over-all program merits support. The latter will be no small task, since the projected cost of the space program over the next 10 years is $35 billion, with about $20 billion earmarked for manned flight.

The tremendous cost and low production runs on launch vehicles, spacecraft and components—some of which must function so perfectly that men can rely on them for their lives at a distance of 240,000 mi. from the earth—have led NASA to institute a rigorous quality-assurance program that is requiring stringent inspection by NASA and extensive inspection and detailed reporting on reliability procedures by prime-contractors, subcontractors and suppliers (see p. 349).

NASA also must continue to look for flexibility and improvement in its management, something it has done continuously since it was created on Oct. 1, 1958. And it must satisfy the Congress, which it has not done yet, that it has solved all the many interface problems between the civilian and military space programs.

NASA research, development and operations work is carried out by eight major centers, the California Institute of Technology's Jet Propulsion Laboratory, and five smaller offices or installations (see p. 78). The organization has grown from about 8,000 NACA employes and a handful of Navy personnel from the Vanguard and upper air research groups in late 1958 to 21,880 at the end of Fiscal 1962 and is expected to increase by almost 4,400 in this fiscal year. These figures do not include JPL, which is a contractor.

About 32% of NASA's total employment in the recent past has been scientists and engineers, but the current goal is about 35%. The theory is that bringing more people with these skills into NASA will do more to conserve U.S. technical manpower than anything else, since NASA must manage such large technical projects with industry.

Last November, NASA began a recruiting drive for technical employes—chiefly engineers—that was to cover 31 cities. By early March, NASA had made 800 offers and 37% had accepted. Albert F. Siepert, NASA's director of administration, called this "an unheard of acceptance rate in view of industry experience." NASA is less concerned at this point about its own recruitment problems, in which it seeks about three-fourths engineers, as it is about the scientific area generally.

Associate Administrator Robert C. Seamans, Jr., told Congress his personal feeling was that "we are somewhat weak in the scientific area and I think if you look ahead we've got to make strenuous efforts in this country to augment the number of really capable scientists that we have." NASA attempts to help in this through space science programs with universities.

A great portion of the management of NASA's technical projects is handled by the centers themselves. Headquarters limits itself chiefly to the management of over-all programs, attempting to continue the NACA approach of decentralization.

NASA's Office of Manned Space Flight is an exception to this rule in some ways, and although the advent of Apollo was not the sole reason for the reorganization that created this office, it was the key one.

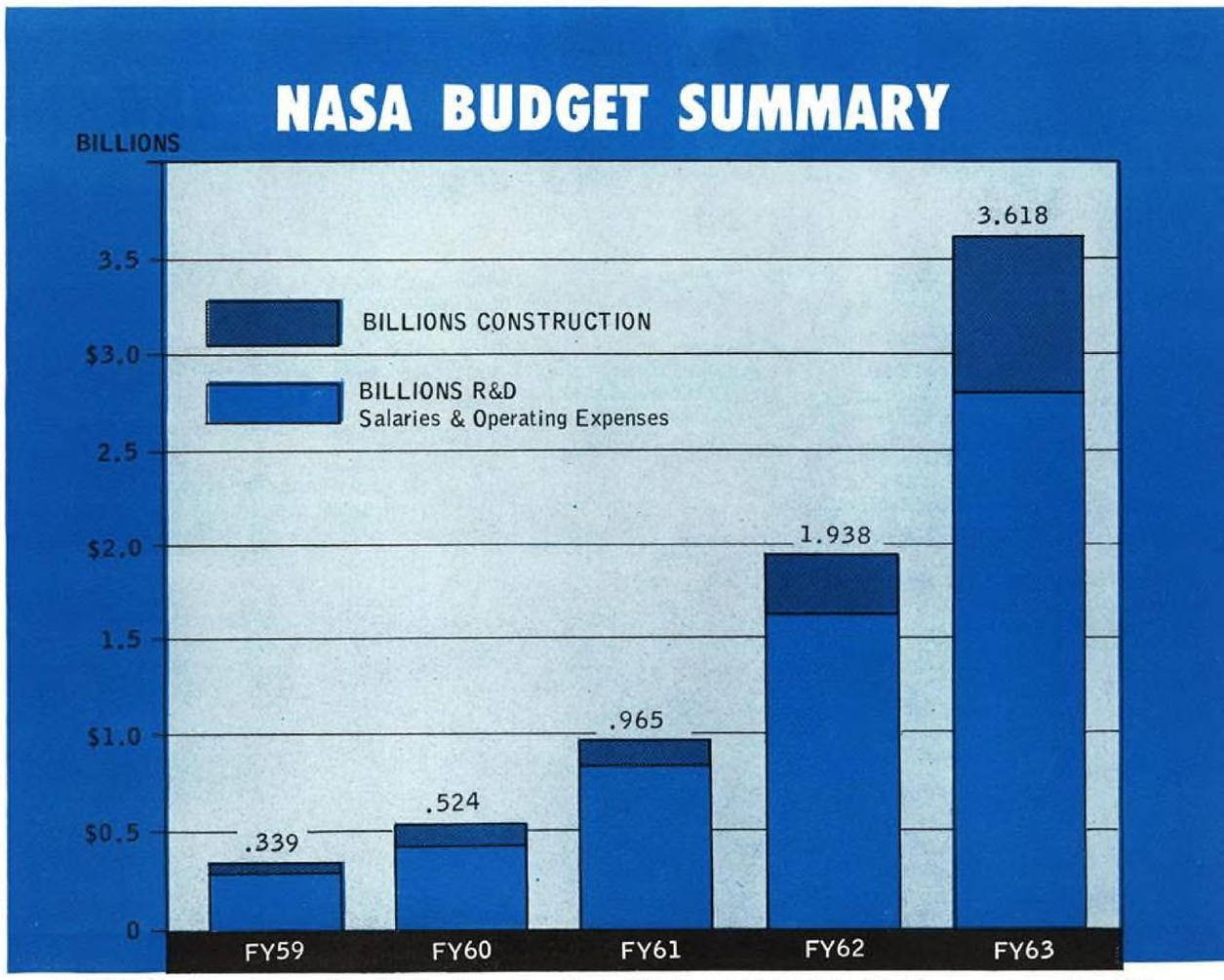
When President Kennedy took office early last year, all agencies were asked to re-examine their budgets, which had been formulated while the previous Administration was in power.

The space agency's response to this was to pose two major policy questions:

- **Since the U.S. was clearly** behind the Soviet Union in space propulsion, should it accelerate the development of large boosters? Estimated price tag for doing this was $100 million for the first year.
- **Did the new Administration** want to reaffirm the old Administration's decision not to go beyond Project Mercury, or reverse it?

The President asked NASA to turn these questions into recommendations. He accepted the first almost immediately and requested a supplemental appropriation for boosters late in March of last year. The second recommendation produced a great deal of discussion involving members of government, science and industry, and resolved itself into a question of when and where the U.S. could catch Russia in manned space flight.

The conclusion was that Russia al-



NASA BUDGET picture shows rapid growth since its creation. Fiscal 1963 figure is that authorized by House space committee. Full House voted $3.7 billion, Senate space committee has voted $3.8 billion. Appropriations committees have not acted.

NASA INSTALLATIONS

MINITRACK STATIONS

Blossom Point, Md.
Ft. Myers, Fla.
Quito, Ecuador
Lima, Peru
Antofagasta, Chile
Santiago, Chile
Woomera, Australia
Esselen Park, S. Afr.
San Diego, Calif.*
St. Johns, Newfoundland
E. Grand Forks, Minn.
Fairbanks, Alaska
Winkfield, England

*To be relocated to Goldstone, Calif.

MERCURY TRACKING STATIONS

Cape Canaveral, Fla.
Bermuda
Mid-Atlantic Ocean Ship
Grand Canary Island
Kano, Nigeria
Zanzibar
Indian Ocean Ship
Perth, Australia
Woomera, Australia
Canton Island
Hawaii
Pt. Arguello, Calif.
Guaymas, Mex.
White Sands, N.M.
Corpus Christi, Tex.
Eglin AFB, Fla.

MINITRACK STATION
East Grand Forks, Minn.

Wendover, Utah

Ely, Nevada

AMES RESEARCH CENTER
Moffett Field, Calif.

FLIGHT RESEARCH CENTER
Edwards, Calif.

HIGH RANGE TRACKING STATIONS

Beatty, Nevada

PACIFIC MISSILE RANGE
Pt. Arguello, Calif.

NUCLEAR ROCKET DEVELOPMENT STATION
Jackass Flats, Nev.
(NASA -- AEC)

WESTERN OPERATIONS OFFICE
Santa Monica, Calif.

GOLDSTONE TRACKING STATION
Goldstone, Calif.

JET PROPULSION LABORATORY
Pasadena, Calif.

MERCURY TRACKING STATION
White Sands, N.M.

DEEP SPACE INSTRUMENTATION FACILITY:

Goldstone, Calif.
Woomera, Australia
Johannesburg, S. Afr.

LEWIS RESEARCH CENTER
Cleveland, Ohio

PLUM BROOK RESEARCH STATION
Sandusky, Ohio

GODDARD SPACE FLIGHT CENTER
Greenbelt, Md.

NASA HEADQUARTERS
Washington, D.C.

MINITRACK STATION
Blossom Point, Md.

LANGLEY RESEARCH CENTER
Langley Station, Hampton, Va.

WALLOPS STATION
Wallops Island, Va.

DATA ACQUISITION FACILITY, Rosman, N.C.

MARSHALL SPACE FLIGHT CENTER, Huntsville, Ala.

MISSISSIPPI TEST FACILITY

MANNED SPACECRAFT CENTER, Houston, Tex.

MICHOUD PLANT
Michoud, La.

MERCURY TRACKING STATION
Eglin AFB, Fla.

LAUNCH OPERATIONS CENTER
ATLANTIC MISSILE RANGE
Cape Canaveral, Fla.

MERCURY TRACKING STATION
Corpus Christi, Tex.

MINITRACK STATION
Ft. Myers, Fla.

Washington
Oregon
California
Wyoming
Colorado
Kansas
Minnesota
Wisconsin
Iowa
Illinois
Missouri
Indiana
Kentucky
W.Virginia
Virginia
Pennsylvania
New York
Maine
Vt.
N.H.
Mass.
Conn.
N.J.
N.Carolina
S.Carolina
Georgia
Florida
Alabama
Louisiana
Arkansas
Oklahoma
Texas
New Mexico
Arizona



RANGER 4 DURING ASSEMBLY

most surely could orbit a manned space station before the U. S. and that it probably could also circumnavigate the moon earlier. This left the manned lunar landing as the most probable chance, and the result was Apollo.

Top NASA officials say the first Soviet manned space flight in April of last year and the suborbital flight of U. S. Astronaut Alan Shepard, Jr., both of which occurred while Apollo was being considered, had profound effects on the decision-making process.

Prior to the headquarters reorganization last Nov. 1, NASA centers reported to three program offices in headquarters. Four reported to the Office of Space Flight Programs; one—Marshall Space Flight Center at Huntsville, Ala.—to the Office of Launch Vehicles; and the three former NACA centers, Langley, Lewis and Ames, reported to advanced research. NASA also had a life science program office but no centers reported to it.

One key problem under this system was that NASA had no central place where it could take a look at the budget in terms of over-all resources and make judgments that justified the program of one office vs. that of another.

About a year ago, the agency created the Office of Programs, reporting directly to Associate Administrator Seamans and liberally staffed with technical people, to enable him to make program decisions based on a complete technical and financial picture.

Next came the problem of how to manage the rapidly expanding manned space flight program, which involved every center to some degree, without letting it completely overshadow space sciences, aeronautical research, etc. NASA talked informally and contracted formally with well-known government and industrial names in management—Raborn, Schriever, Dempsey, Mettler, Ramo, and the firms of Booz, Allen & Hamilton and John Diebold Associates—as it struggled with this question.

The job was considered to be too large for any single center to manage. It must be done in headquarters with a strong organization that could pull together all elements of the program, but without requiring centers to report to it so completely that Goddard, for example, which does only a fraction of its work in support of manned flight, would find its other programs adversely affected.

Centers report directly to Seamans for institutional matters, but to specific program offices on program and project problems.

The Office of Manned Space Flight was created with several major differences from the other headquarters program offices (see p. 87). One is the fact that it will manage the over-all Apollo project, including the systems engineering aspects, from headquarters—something which is not done with any other NASA project.

Another is reliance on industry for management help. The original plan was to recruit enough highly skilled technical management personnel from industry and from NASA itself to manage the program from within. But it soon became apparent that NASA could not recruit that much top talent in time—and probably not at all, on government salaries. Consequently, the agency turned to American Telephone & Telegraph and Western Electric for assistance in systems analysis and to General Electric for help in integration and checkout of a number of Saturn and Apollo subsystems and systems (AW Apr. 2, p. 38).

The Manned Space Flight Office is directed by Brainerd Holmes, who came to NASA from Radio Corp. of America, where he directed the creation of USAF's Ballistic Missile Early Warning network. His office ultimately will have a staff of 400 to 500 people. AT&T and Western Electric have formed Bellcomm as a wholly owned subsidiary to support Holmes' deputy for systems, Joseph F. Shea, by studying mission objectives and methods by which they can be reached, determining broad specifications and conceptual designs of major subsystems, establishing guidelines for subsystem interfaces, evaluating program technical status and making trade-off studies. Bellcomm, which will do most of its work in Washington, now has about 50 personnel. It expects to expand to 200 technical and 200 support personnel. Initial contract amount for Fiscal 1962 was about $500,000 and estimates for subsequent years range from $5 million a year upward.

GE will support Holmes' director of integration and checkout, James E. Sloan, by checking in detail the interfaces that exist between spacecraft and booster and between booster stages, and by gathering and processing reliability assessment data. Each stage of the Saturn and Nova launch vehicles is essentially a complete missile system, and unless each is wrung out completely for reliability, the laws of probability "are really working against you," Seamans points out.

GE has about 60 people assigned to this task now. Ultimate size of GE's operation and total cost of the contract are not known yet because parts of its mission still are being defined.

Holmes' office also has directorates for aerospace medicine, spacecraft and flight missions, launch vehicles and propulsion, and program review and resources management.

With the manned space flight management question resolved, NASA took this opportunity to solve other management problems by reorganizing more clearly along program lines. There is, for example, no launch vehicles office now. Vehicles supporting the manned space role are a part of that program; vehicles used chiefly for scientific satellites and probes now fall under a space science office.

The program offices other than manned space flight, and some of the considerations that went into their creation, are:

• **Space sciences.** NASA was concerned that it had not taken full advantage of the space science potential because of a preoccupation with technology. It pulled all the elements—vehicles, spacecraft, basic and applied research done by universities in support of the program—into one office, so that Director Homer E. Newell could deal directly with any center supporting any phase of his work. NASA also wanted to make greater use of university researchers, both for their competence and because universities are the training grounds for future scientists and engineers who will be needed in space fields.

• **Applications.** Earth satellites have reached a stage of practical usefulness more rapidly than many would have predicted in 1957. Although NASA is charged with a research and development responsibility rather than one of application, it has progressed sufficiently in meteorological and communications satellite work that it seemed necessary to give the applications satellites separate status. NASA now is studying, with Navy, commercial shippers, the Federal Aviation Agency, airline interests and the Maritime Commission, the feasibility of civilian navigation satellites that would be based largely on Navy's work in the Transit program.

• **Advanced research and technology.** The old advanced research office dealt only with the three former NACA laboratories. Since their work is so intertwined with advanced research in other NASA centers, in industry and at universities, the new office was given the responsibility for all advanced research work. Nuclear propulsion and auxiliary nuclear power work also fall under this office. Much of the effort in this program is not directly oriented to a specific mission, but some of it provides vital technological support for immediate problems. The lunar rendezvous scheme, for example, was a product of in-house research at Langley that was not originally mission-oriented.

• **Tracking and data acquisition.** This task of collecting and making sense of an ever-increasing amount of information gathered in an expanding space program had reached a complexity that demanded a central office for coordination of three NASA networks that involve civilian, DOD, industrial and foreign stations and personnel.

NASA does not consider this organization static. It has, in fact, made a number of lesser changes since last November, and the latest center to be created—the Launch Operations Center at Cape Canaveral, Fla.—only came into being on July 1. The group there formerly reported to the Marshall Space Flight Center as one of its directorates, but the bulk of the NASA-generated expansion at the Cape is directly related to manned flight. Consequently the new center will report to the Office of Manned Space Flight.

The agency does not rely primarily on informal suggestions and outside advice to determine what management changes it should make. It has created a Management Analysis Division under the Office of Administration whose job is to be concerned on a continuing basis with the over-all organizational structure, both internal and in relation to other government agencies.

Air Force Systems Command recently brought Maj. Gen. Osmond J. Ritland, former head of its Space Systems Division, into its headquarters at nearby Andrews AFB, Md., to be deputy commander for manned space flight and AFSC-NASA liaison chief. He will have six directorates corresponding to those in Holmes' office, in addition to other groups. Those corresponding to the NASA offices will handle the liaison that both agencies want and Congress insists they must have, but any specific program will be clearly assigned either to NASA or AFSC, rather than for them to have joint responsibility.

NASA still has not ironed out to the satisfaction of the Air Force nor some key congressional critics its relationship to the Defense Department in the field of bioastronautics. The new AFSC office also is expected to eliminate some of the friction in this area.

The House Science and Astronautics Committee has explored in some detail the questions of whether a larger military space program is needed, whether there is proper liaison between NASA and Defense, and whether NASA's program is responsive enough to present and future space needs of the services.

Most of this criticism—and a possible solution—seems to be summarized in a view expressed before this committee last spring by Dr. William O. Baker, vice president for research of the Bell Telephone Laboratories and a member of AFSC's board of visitors. Baker said NASA-Defense collaboration was "evolving in a very good pattern" and that he felt it was evident that the U. S. had "the capabilities, with the right kind of policy behind them, to make considerable progress, perhaps even satisfactory progress, by a parallel military effort along with the NASA one. I would submit that we do not have such policy, or such authority at the moment," Baker said.

The question of the hard-to-define military role in space, most of which seems to lie in the future, probably is a question for the National Aeronautics and Space Council and the White House to consider continuously and expand as necessary. But NASA probably can anticipate that future management changes will include some affected by the military question.

The council, chaired by Vice President Lyndon Johnson and including NASA Administrator James E. Webb, the secretaries of state and defense and the chairman of the Atomic Energy Commission, has played a vital role in problems affecting NASA—particularly Apollo and communication satellites—but it has not attempted to act as a board of directors overseeing each program and project.

Associate Administrator Seamans told Congress he did not know of any recommendation made by the space council "which has been at odds with the programs that we have been conducting. I know of no conflict."

With exceptionally good relations with Congress and the space council, and good if not perfect relations with Defense Department and industry, NASA's greatest task in the years ahead would seem to be to achieve all the goals set out for it.

NASA Budget Breakdown

Washington—National Aeronautics and Space Administration has asked Congress for $3.787 billion in Fiscal 1963 funds and $156 million in supplemental Fiscal 1962 funds. The money is requested in two categories—$2.968 billion for research, development and operations, and $818 million for construction. The former categories of research and development and salaries and expenses have been combined.

Congress has not yet completed work on the NASA budget, but the request for Fiscal 1963 breaks down by programs this way:

• Manned space flight—$2.26 billion, almost triple the $712 million appropriated last year. NASA estimates that 19,927 of its projected total of 26,273 total personnel at the end of Fiscal 1963 will be working in this area.

• Space sciences—$556 million, compared with $406 million appropriated last year. An estimated 3,082 personnel will work in this area.

• Advanced research and technology—$618.5 million, compared with $323.3 million last year. This area accounts for 9,671 employes.

• Applications — $139.7 million, compared with $106.5 million last year. This area will employ 706 people.

• Tracking and data acquisition—$213.1 million, compared with $124.3 million last year. Total personnel will be 1,887.

Western Operations Office

Santa Monica, Calif.—Western Operations Office administers $1.5 billion in National Aeronautics and Space Administration contracts with companies in the western states.

This office, which is considered an extension of NASA headquarters and reports to the Office of Administration there, also negotiates contracts and supports NASA's technical centers by providing a technical and quality assurance monitoring function.

Director Robert W. Kamm said the office currently issues vouchers totaling about $30 million per month to contractors. The office was established as the Western Coordinating Office in 1958, and had a staff of four. In August of 1959 it assumed its present name. The staff then totaled 10. It now stands at 130.

NASA recently established an office at North American's Space and Information Systems Division in Downey, Calif., to expedite decisions on the Apollo spacecraft and the Saturn S-2 upper stage. It is headed by John R. Biggs and is an element of Kamm's office here.

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ADMINISTRATOR
JAMES E. WEBB



INVENTIONS AND CONTRIBUTIONS BOARD
EXEC. SECRETARY
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GENERAL COUNSEL
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AEC-NASA SPACE NUCLEAR PROPULSION OFFICE
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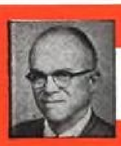
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R. P. YOUNG



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LAUNCH OPERATIONS CENTER
DIRECTOR
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GODDARD SPACE FLIGHT CENTER
DIRECTOR
HARRY J. GOETT

JET PROPULSION LABORATORY
(Cal. Tech. Contractor)
DIRECTOR
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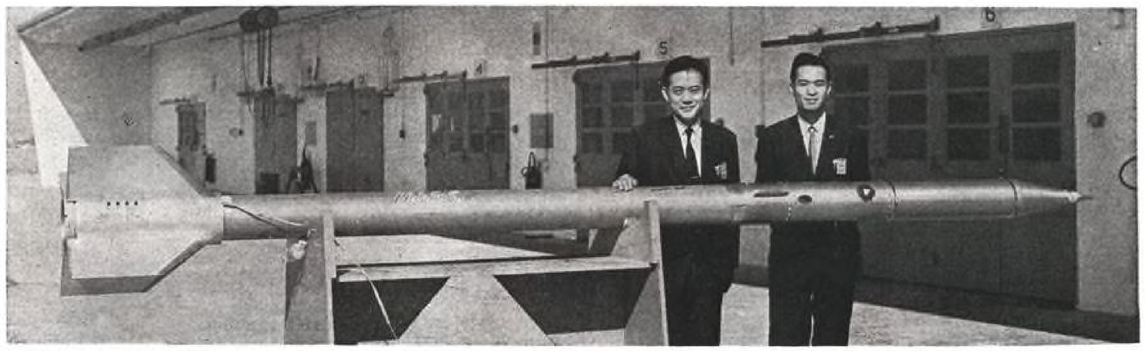
WALLOPS STATION
DIRECTOR
R. L. KRIEGER



LANGLEY RESEARCH CENTER
DIRECTOR
FLOYD L. THOMPSON



MANNED SPACECRAFT CENTER
DIRECTOR
ROBERT R. GILRUTH



DR. KUNIO HIRAO, left, chief scientist of Radio Research Laboratory, and Toshio Muraoka of Yokohawa Electric Co. participated in joint Japanese-U. S. firing of Nike-Cajun sounding rockets from NASA's Wallops Station, Wallops Island, Va.

NASA Spurs International Space Efforts

Washington—Broad but highly selective program of international cooperation involving more than 55 nations is rapidly and quietly spreading the scientific benefits of space research and proving the openness of the U. S. civilian space program to the free world.

Even the Soviet Union has shown an inclination in recent weeks to consider cooperative projects, after almost four years of refusing to deal with anyone including the Communist satellite nations.

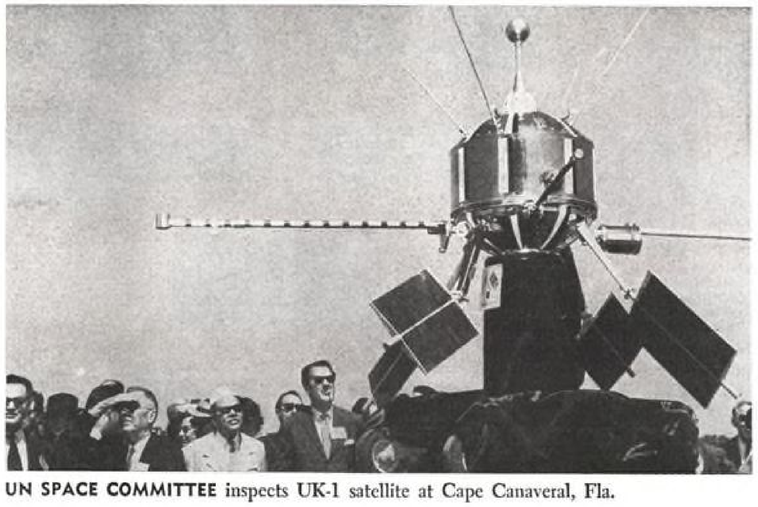
There is a strong belief in the National Aeronautics and Space Administration that the change in Russia's attitude is a direct result of the highly successful program NASA has built for the U. S., which has included participation by the same Communist nations that Russia rebuffs.

Neither the extent of U. S. space ventures with other nations nor the hard-headed practicality of the program is appreciated widely in this country, NASA believes. Nor has the aerospace industry fully realized the scope of the potential market that broad participation by less technically advanced nations represents.

More than 46 nations are directly involved in cooperative projects such as satellite and sounding rocket launchings, ground-based meteorological observations related to U. S. weather satellite flights, and communication satellite experiments.

Forty-five or so are involved in operational support for Minitrack, Mercury and deep space tracking networks—with some countries paying for and manning the stations themselves and sharing data with the U. S. About 30 countries are engaged in NASA-sponsored educational and training programs, which include a year of study in the U. S.

More than 1,000 scientists and government officials from more than 40 countries visited NASA installations last year, and this program is growing as participation expands.



UN SPACE COMMITTEE inspects UK-1 satellite at Cape Canaveral, Fla.

This year, for the first time, members of the United Nations Committee on the Peaceful Uses of Outer Space visited Cape Canaveral. They were invited as guests of NASA and the U. S. to witness the world's first cooperative satellite launching of the project—the U. S.-United Kingdom Ariel radiation satellite.

Delegates to the third annual meeting of the Committee on Outer Space Research (Cospar) of the International Council of Scientific Unions—including some delegates from Iron Curtain countries—took advantage of the Washington meeting site to visit NASA's nearby Goddard Space Flight Center and the Wallops Station at Wallops Island, Va., where NASA and joint-project sounding rockets are launched.

More important than the breadth of this cooperative program is its insistence on quality. The decision to enter a joint project through an agreement with NASA's Office of International Programs must be the other country's, and the ground rules are strict:

• **No dollars exchanged.** NASA does not insist on equal expenditure of dollars, but each side must finance its own contribution.

"This is much more meaningful than if we subsidized the whole program," Marvin W. Robinson, deputy director of the international office, said. "First of all, the other country should know it has to be able to afford what it's getting into and second, it can make its likes or dislikes known this way, so that it is a truly cooperative program."

• **Experiments must hold promise** of producing a meaningful scientific contribution and must be of mutual interest. "We are not interested in just supplying rockets," Robinson said. This does not mean that NASA rejects a country automatically if its space technology is not as advanced as that of the U. S.—that would defeat the purpose of the international program.

In Pakistan's case, for example, initial talks between U. S. and Pakistani scientists indicated that Pakistan was not yet technically ready for a joint experiment. NASA trained Pakistan scientists and technicians at Goddard, Wallops and two universities. Then it sent a technician to Pakistan to help select a launching site, and provided a Nike-Cajun sounding rocket for a sodium vapor experiment. The Pakistanis installed the equipment, manned the range, etc., and last June 7 the Nike-Cajun—renamed Rehbar 1—made the first Pakistan space flight from a site near Karachi. Several more experiments in the joint project are due over the next few months.

"This is cooperation in depth," Robinson said, "not just an exchange of hardware."

• **Joint projects are** completely open. All U. S. agreements are with civilian agencies, designated by the other country's government so that NASA does not become entangled in domestic disputes between rival space organizations, and the data gathered must be made available to the scientific community. All agreements so far have been between NASA and a single government organization with the exception of Telespazio, a part-government and part-private organization created in Italy for participation in communication satellite experiments.

"NASA is not trying to sell or push this down anyone else's throat," Robinson said. "The impetus has to be theirs. We point out that there is no sense in doing one experiment and quitting. We are trying to attract but we are not subsidizing."

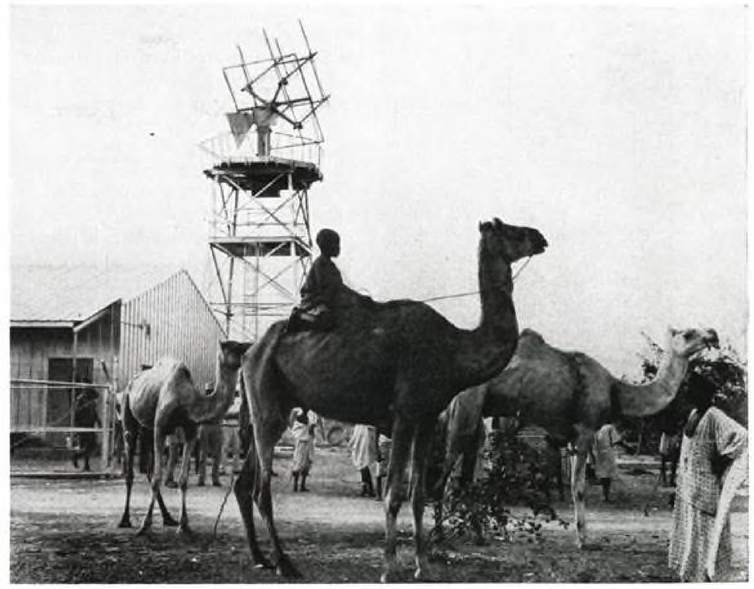
Word on the joint program is exchanged through visits of U. S. scientists to meetings abroad and vice versa, through U. S. information channels, and so on. U. S. embassies are provided with details on the fellowship program, "but with careful instructions that no one is to beat the drums," Robinson said.

"There is no need to get involved with countries that cannot afford a project or haven't the scientific competence —and yet we have the great number of participants that we do, and the number is growing."

Industry Interest

Increasing interest by U. S. aerospace firms in recent months has led NASA to believe that the industry is just beginning to appreciate the magnitude of the international program.

The potential market for rocket and satellite hardware, electronic flight and ground equipment, range instrumentation, propellants, etc., is a large one. Even if other countries intend to do their own manufacturing, which many have indicated they do, they are often interested in the possibility of cross-licensing agreements.



MERCURY tracking station at Kano, Nigeria, typifies NASA's cooperative projects.

NASA can offer little specific assistance beyond informing industry what countries are involved in programs and explaining what its own role is, since other government agencies handle such problems as export licensing. But the International Programs Office is receiving about one visit a week from firms that are ready to send sales representatives abroad to explore the market potential, and Robinson recently was asked to speak to an Aerospace Industries Assn. group about the scope of the cooperative program.

Practical Advantages

NASA recognizes the obvious political advantages that running a completely open program brings to the country and to an organization created as a civilian agency for the peaceful exploration of space. Fortunately both the Eisenhower and Kennedy administrations have recognized that the program is only worthwhile—even from the political point of view—if real scientific contributions are made.

"We can never be accused of running a cooperative program for purely political gain," Robinson said. "When a scientist from a cooperating country gets up at a meeting abroad to report to a scientific body, it is pretty easy for fellow scientists to ascertain whether the experiment has been a useful one. We would do a disservice to both countries if we ran meaningless programs."

There are practical reasons other than political for joint operations:

• **"No nation has a monopoly** on brainpower, and the problems and questions to be answered are tremendous," Robinson said. "We want to have as many people as possible involved, especially if what is learned is to have any application beyond basic science."

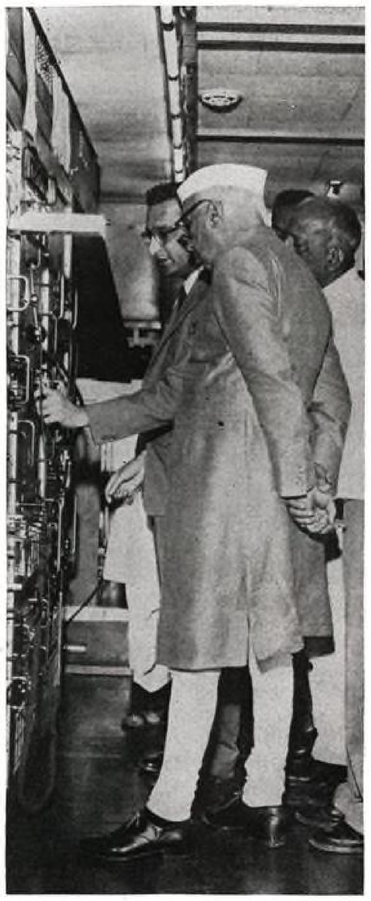
Through an agreement with Sweden, NASA will provide four Nike-Cajuns for four shots from the Vidsel Range late this summer that will sample noctilucent clouds. Origin of these very high, faintly luminous clouds is unknown. They occur only for a short period of the year and only in certain regions of the auroral zone.

Last Apr. 26, the first of three Nike-Cajuns was launched from Wallops Island in a joint U. S.-Japanese test of a Japanese-developed radio-frequency resonance probe that may permit measurement of electron density and temperature simultaneously with only one instrument, and at a faster rate than before.

Experiments such as these obviously give the U. S. geographic or scientific advantages that it would not have without joint programs.

• **Savings to the U. S. taxpayer.** The best example of this lies in the communication satellite field. The U. S. would like to conduct transatlantic experiments with the NASA-American Telephone & Telegraph Telstar satellite and its own Relay satellite. It undoubtedly could have obtained permission to build foreign stations. But the interest in other countries is as high as it is here. France is building its own $12 million station and England is building one at a cost of $3-to-$4 million. Their agreements with NASA call only for cooperation in research and development, with no commitments regarding an eventual operational system.

Through such agreements, England,



INDIA'S Prime Minister Nehru visits data acquisition station at Ahmedabad, India.

France and Brazil probably will be ready for the first experiments this summer; Germany is building a sending and receiving station; Italy is constructing a receiving station and NASA is discussing joint ventures with other countries. A great number of countries are interested, if for no other reason than the revenue that such systems are expected to produce. But cost and such technical limitations as the coverage the satellite will give, and the power supply it can carry, will hold down the number of participants.

Satellite Workshops

NASA and other government agencies recently sponsored an international communications satellite workshop, similar to the successful international meteorological workshop that attracted representatives of 27 nations to Washington last fall. The space agency paid no travel expenses, but representatives of some 30 countries attended.

In addition to training foreign scientists and technicians at its research centers for specific projects such as the Pakistani experiment, NASA has two programs administered for it by the National Academy of Sciences:

• **International fellowship program,** in which other countries select young graduate students to attend one of 18 leading U.S. universities engaged in space-related research. Applicants' qualifications are reviewed by both the academy and the universities. The other country provides travel to the U.S. and subsistence for a year—again the program is not a U.S. subsidy—and NASA pays tuition and inland travel costs for visits to NASA centers. The pilot program so far has included seven fellows from six countries and has been so successful that it will be expanded next fall. The European Space Research Organization (ESRO) already has set aside 15 fellowships to be used in this program.

• **Resident research program.** Under this plan, carefully selected senior scientists from both the U.S. and abroad work for one year on either theory or experiments at Goddard or Goddard's Institute for Space Studies in New York City. In this case, NASA provides, through the academy, a stipend consistent with the scientist's senior status.

NASA also is responsive to invitations for U.S. scientists to go abroad for lectures, seminars or possibly even stays of a full semester at foreign universities. It also is sponsoring a six-week summer institute in space sciences at Columbia University for outstanding undergraduates, in which about 20 foreign students will participate.

Program Administration

All aspects of the international program are administered by NASA's relatively tiny Office of International Programs, under Director Arnold W. Frutkin. The office consists of only 19 people, including secretaries. It draws legal and technical help from other NASA offices and centers, and most of the actual operation involved in joint agreements takes place at the field level—chiefly at Goddard and Wallops. This office also coordinates with State Department, the Weather Bureau, the academy and other organizations.

ESRO, which has a membership of 10 European countries and is the first example of regional cooperation in space research, has sent groups to the U.S. to study NASA's methods. NASA can deal with ESRO as it would with a single country, but it retains the privilege of bilateral agreements with member nations just as member nations of ESRO retain the privilege of conducting their own national programs.

NASA expects this regional cooperative approach to grow—possibly in South America next — and expects greater participation from member nations of the U.N. space committee.

Joint satellite launching agreements so far have been completed only with the United Kingdom and Canada—chiefly because cost and competence are formidable barriers. But the appearance of the large observatory satellites (see p. 183), which can carry a number of experiments, may permit other countries to send up single experiments. They would be subject to the same selection process used to select experiments by NASA, university and industry experimenters now.

Participation in NASA's space work has included Czechoslovakia, Hungary and Poland. All three have made correlated ground observations of Tiros weather satellites at the invitation of NASA and the Weather Bureau.

"Some time ago there was a rash of propaganda that Tiros was a spy satellite," one NASA official said. "The value of the openness of the program is that everyone recognizes its benefits and sees from what it does that it is not a spy satellite. Had we been secretive, they would still be calling it a spy, but foreigners have actually sat here and seen the read-outs."

Soviet Situation

Recent talks in Geneva between Soviet Academician A. A. Blagonravov and NASA's deputy administrator, Dr. Hugh Dryden, produced some hope that Russia may eventually cooperate in space research.

A joint communique issued by Dryden and Blagonravov said that recommendations had been forwarded to both governments for cooperation in meteorology, a world magnetic survey and satellite telecommunications, "looking toward eventual coordinated launchings of meteorological satellites" and probable coordinated launchings of satellites by each country for the magnetic project.

Frutkin pointed out in a speech some time ago that the International Geophysical Year, often cited as an example of world-wide scientific cooperation, was in fact a collection of national programs loosely coordinated by a nongovernmental mechanism; that it did not solve any political problems; that "Soviet intransigence greatly restricted the IGY agreements for exchange of information" in space research, and that Russia "has effectively blocked a purely scientific symposium on space research under UN auspices in order to exact a political price which would give it a veto over the activities of other nations in meeting the problems of outer space."

But the Geneva talks—follow-ups to exchanges of views by President Kennedy and Premier Khrushchev—have at least raised the possibility that Russia has learned a lesson. If it has, some NASA officials are certain that the U.S. international program was the teacher.

NASA Seeks to Enlarge Space Benefits

Washington—National Aeronautics and Space Administration has moved beyond its communication and meteorological satellite research (see p. 293 and 300) to begin a modest program of exploring less tangible ways to apply the benefits of space technology to the national economy.

President Kennedy told the Congress last January that "all of us in the United States and in all nations can derive many benefits from the peaceful application of space technology. The impact of this new science will be felt in our daily lives.

"It can bring all people closer together through improved communications," the President said. "It can help control the climate around us. We can safely predict that the impact of the space age will have a far-ranging effect within industry and in our labor force, on medical research, education and many other areas of national concern."

NASA has formalized its approach to this by creating a directorate of future applications under its headquarters Office of Applications, which is headed by Morton J. Stoller.

One program now in the planning stage calls for study of civil applications of the Navy-developed Transit navigation satellite, including the feasibility of its use by civil aircraft and ships. Stoller emphasizes that NASA has no intention of duplicating current Navy efforts, nor does it see the need for a separate civil navigation satellite. The Navy already has under development a reduced-accuracy, lower cost receiver for use with the Transit which the space agency hopes to evaluate for civil applications.

Another possible satellite application under consideration is a general purpose data collection spacecraft that might be used to obtain data from a variety of different terrestrial sensors. For example, the Navy might be interested in placing self-powered buoys at key points in the ocean to measure the sea state, while the Weather Bureau might be interested in small unattended weather stations placed at remote sites in the Arctic and Antarctic whose measurements could be telemetered to a general purpose data collection satellite for subsequent transmission to data collection stations.

Applying Knowledge

The principal product coming out of NASA's programs will be new knowledge—knowledge of the space environment, the solar system and the earth itself. While this will be exciting and extremely valuable to the world's scientists, its impact on the peoples of the world probably will be limited, at least initially.

But the new technologies and inventions, sparked by the needs of NASA's space programs, are certain to have a more dramatic impact on industry, and through its products, on society as a whole.

Since any new invention or advance in the state of the art usually is a product of knowledge gained from many streams of activities, it will not be easy to pinpoint those which result solely from NASA's efforts and programs, particularly since much of the technology which NASA uses today is a direct outgrowth of earlier research and development.

A few examples of such advances, whose lineage is difficult to trace but whose impact on non-military, nonspace activities appears promising, include:

• **Hydrazine,** developed in the early 1950s for use in rocket fuels, has spawned a family of drugs for mental illness, for treatment of angina pectoris and tuberculosis.

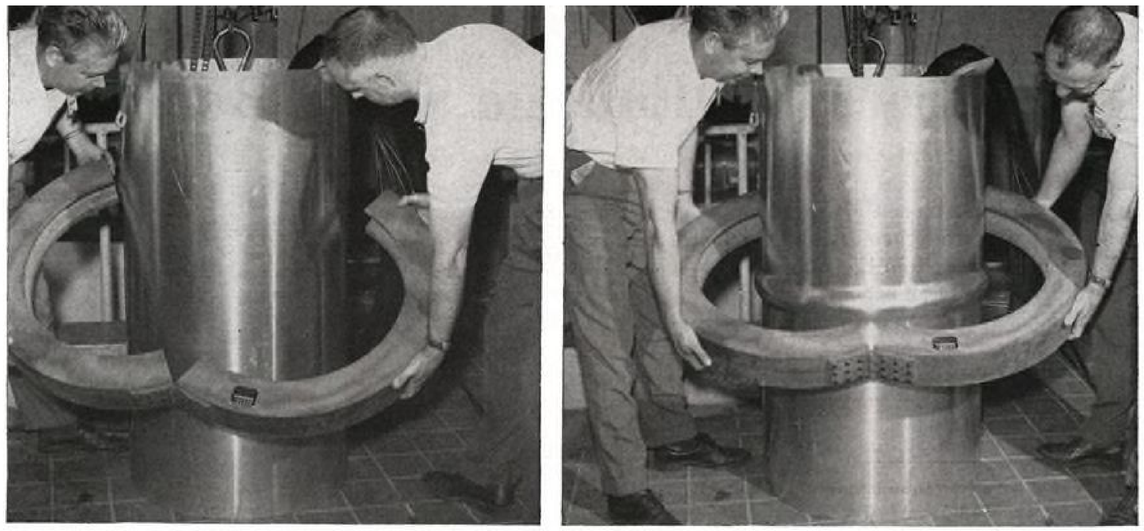
• **Fluoro-ethylene propylene coatings,** first applied by Jet Propulsion Laboratory to the mandrel core used in casting solid-propellant rocket motors to enable the mandrel to be withdrawn later without sticking and without contamination of the propellant material, is now being applied as a release mechanism in presses used to laminate plywood, to furniture gluing clamps and to rubber gasket molds, according to Louis B. C. Fong, chief of industrial applications in the office of applications.

• **Magnetic pulse forming,** employed in fabrication of the Saturn launch vehicle at the Marshall Space Flight Center, makes use of strong magnetic fields to shape metal. Electrical energy equivalent to 5,000 - 10,000 ft.-lb., stored in banks of capacitors, is dumped into an induction coil in less than one millionth of a second, generating a tremendous





MAGNETIC PULSE forming technique being perfected at Marshall shapes metals by dumping extremely strong electrical charge into induction coil. Magnetic field pushes metal against die. Parts for Saturn booster are being formed this way.



MARSHALL TECHNICIANS place die around segment of propellant line for Saturn, left, remove it after metal is formed by magnetic field.

magnetic field which pushes metal against a forming die.

• **Stirred-arc gas heater,** a new heating device developed by NASA's Ames Research Center, may find a variety of industrial uses where chemical reactions must be carried out at extremely high temperatures. The heater has two doughnut-shaped, water-cooled copper electrodes which are caused to spin at 400 rpm. by the application of an external magnetic field while a high intensity arc is drawn between the two spinning electrodes. The spinning prevents electrode burning and the energy of the arc is transferred to the gas or mixture in which they spin. Operating at pressures up to 2,000 psi., the heater can heat gasses up to 5,000 deg. and provide enthalpies up to 2,000 Btu./lb.

Speedy Application

Such new techniques and developments generally find speedy application throughout the aerospace industry, Stoller says, as a result of trade publications and technical conferences. But a major objective of the NASA future applications program is to devise effective means for bringing these new techniques to the attention of companies outside the aerospace field, for application to industrial and consumer products.

NASA recently has formed a small group at each of its research and development centers whose assignments are to familiarize themselves with new techniques, processes, materials and devices being developed or applied in their respective facilities.

This will involve close liaison with branch chiefs and individual engineers and scientists as well as with NASA's patent lawyers. Stoller says that ideas which are not patentable may nevertheless have sufficient novelty to offer benefits to industry users.

The applications group at each center will file periodic reports on new ideas and techniques to NASA headquarters, where they will be stored and disseminated by the Office of Technical and Scientific Information. The first center reports are now beginning to come in, Stoller says.

Stoller said NASA is attempting to work out plans whereby its outside contractors would also be required to file reports on new techniques.

The problem of how best to disseminate such information to companies outside the aerospace field is under investigation. NASA has contracted with the Midwest Research Institute, which serves industry in the Kansas City area, to conduct a pilot effort to transfer new techniques coming out of the aerospace field to Midwest companies operating in other fields.

The institute first had its scientists visit major NASA centers and compile a list of about 50 comparatively new techniques not generally known or applied outside the aerospace field. For the past several months, MRI has been visiting major cities in the Midwest, holding seminars to brief local firms on these techniques.

As a result of such seminars, one hat manufacturer who was experiencing difficulty in separating blocking molds from hats because the felt stuck to the mold, learned of the use of Teflon to prevent mandrel sticking in molding solid rocket cores. The company now coats the blocking mold with Teflon and thereby eliminates its previous troubles.

The institute will check later with other individual manufacturers to see how many are applying ideas learned at its seminars.

But NASA is not overlooking the need for the effective interchange of new technical information among its own scientists and within the aerospace industry itself.

The space agency recently awarded a $1.2-million contract to Documentation, Inc., Bethesda, Md., for the creation and first year's operation of an integrated technical information center to disseminate information to NASA scientists, its prime contractors and to other designated organizations and scientists.

The new scientific and technical information facility is expected to receive, catalog and file in miniature photographic form more than 25,000 reports a year from NASA centers and contractors. The facility will use an IBM 1401 for automatic location and retrieval of information.

Biweekly Publication

All documents registered at the new facility will be abstracted,, and the abstracts will be published in a biweekly journal, "Technical Publications Announcements," to be prepared by Documentation, Inc. and issued by NASA. Quarterly, semi-annual and annual cumulative indexes will be published.

The new facility is intended primarily for use by NASA's scientists and its contractors. While the cataloging will be centralized at the site near Washington, the facility will supply duplicate computer tapes of its catalog to each NASA center and to individual organizations participating in NASA programs, so that location of desired references can be carried out on a decentralized basis.

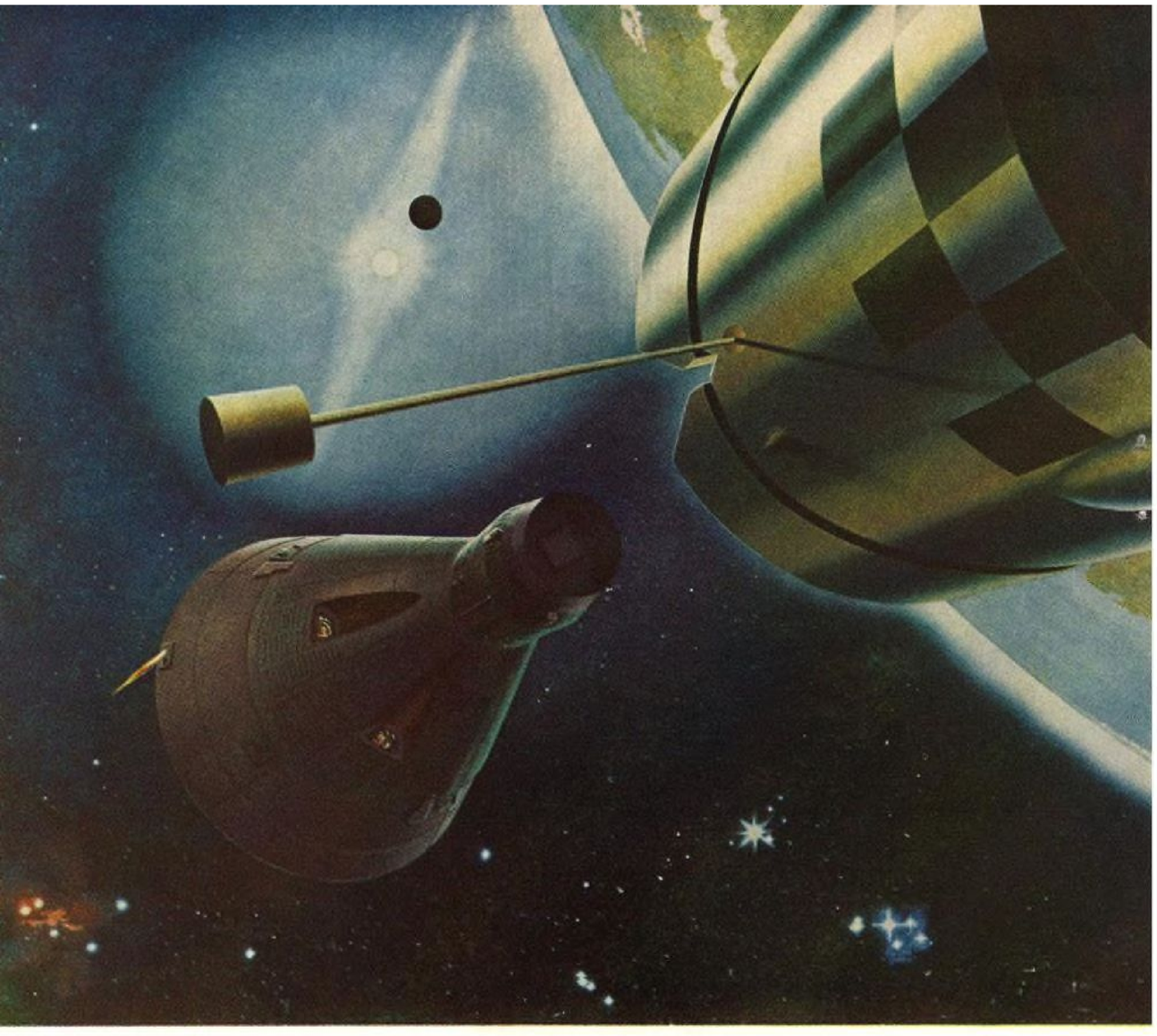
Copies of all reports received by the new facility will be sent to each NASA center and to participating contractors either in original printed form or on 5 x 8 in. transparencies which can be used either in optical viewers or to make photo reproductions.

The new facility is operating under the direction of NASA's Office of Scientific and Technical Information, headed by Melvin S. Day.



Apollo command module and escape tower mounted in Ames Research Center tunnel

Manned Space Flight



RENDEZVOUS CONTROL: By Astronaut

Primary control responsibilities during Gemini rendezvous and docking operations will be assigned to the Astronauts. Man, with his ability to see, analyze, reason and judge, will be fully utilized for this important phase of America's first spacecraft rendezvous operation.

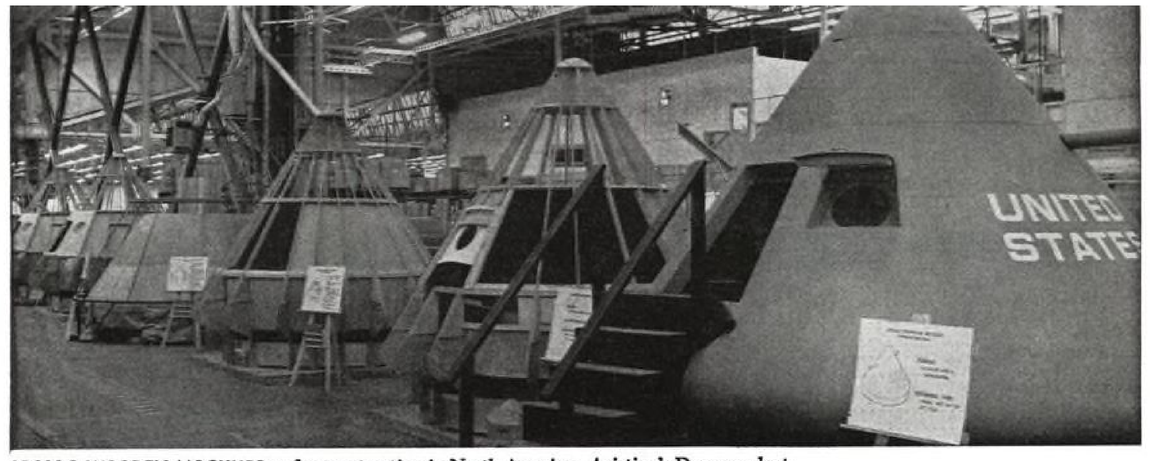
Gemini is a two man, extended mission, orbital rendezvous and docking spacecraft now being designed and built for the National Aeronautics and Space Administration by McDonnell.

Rendezvous in space can have several applications in speeding America's space exploration efforts. Rendezvous will permit launching of multiple payloads with two or more smaller boosters rather than one large vehicle. With such techniques it will be possible to assemble large space stations, ferry space crews and supplies, refuel and/or assemble chemical upper stages for deep space missions, and refuel re-usable nuclear upper stages for deeper space explorations.

Space Rendezvous, the key to a quickened pace in manned space exploration, is another facet of manned space flight being pioneered by McDonnell.

MCDONNELL *F4H and F-110A Fighter and Attack Aircraft • RF-110 Reconnaissance Aircraft • Mercury, Gemini, Asset and Aeroballistic Spacecraft • Talos and Typhon Missile Airframes and Engines • Electronic Systems • Automation*

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APOLLO WOODEN MOCKUPS under construction in North American Aviation's Downey plant.

NASA, Industry Facing Apollo Challenge

Nation gears management and technical resources; most complex peacetime job has $20 billion estimate.

Washington—Awesome task of landing a man on the moon and returning him to earth is the most challenging peacetime undertaking in the history of the U. S.

Project is complicated by the pressures of a tight timetable that will tax the ingenuity and resourcefulness of much of the nation. At this point in its development, organizing to manage the program is as difficult as the technical complexities which the program itself faces.

Project Apollo, and Mercury and Gemini as its precursors, have become the focal point for a significant portion of the country's scientific and technical effort. An estimated 100,000 top government, industry and Defense Department personnel must be marshaled into a single team to assure success of the manned space flight program.

Manned Probes

Despite its anticipated $20 billion cost and the unprecedented effort it demands, Apollo is only a start in man's exploration of space; it is certain to be followed by manned probes into deep space and planetary exploration.

Effective management of the program demands precise planning and the capability for immediate response by the decision-maker. Without this, the waste in dollars and talent will be monumental, because nothing is inexpensive in manned space flight. But the potential fallout from the program is monumental, too. This facet of space exploration has become the primary point of competition between the U. S. and Soviet Russia, and it is an area in which the U. S. can demonstrate its full capability.

National Aeronautics and Space Administration has drawn heavily on industry to establish the framework for its manned space flight management responsibility, both in managers and in organization. Brainerd Holmes, director of Manned Space Flight, came to NASA from Radio Corp. of America, where he directed the Ballistic Missile Early Warning System program, and his office follows closely the concepts evolved in the BMEWS work.

At its heart is a systems engineering organization whose task it is to take a critical look at every aspect of the flight mission. Once the mission has been defined, the emphasis shifts to an interpretation of its effect on hardware.

For the past several months, the complete effort of the Systems Engineering Office has been to define the basic Apollo transit mode, according to Dr. Joseph F. Shea, Holmes' deputy director for systems. This sizable effort has involved compilation and analysis of studies and theories which will contribute to a decision being made by Holmes and NASA on the fundamental approach to the Apollo mission—whether it will be by lunar orbit rendezvous or earth orbit rendezvous.

Dr. Shea emphasized that responsibility for implementation of Apollo plans remains with the various centers. In its relationship with the Manned Spacecraft Center in Houston, for example, headquarters is represented by George M. Low, director of Spacecraft and Flight Missions. Low said he spends about 99 percent of his time in partnership with Houston, and about 1 percent directing the Houston center, under Robert R. Gilruth, to do things differently. It is his job to be fully informed on center-level aspects of the program by working closely day to day with Gilruth and his team.

The in-house management philosophy, according to Shea, is that "Washington draws the roap map; Gilruth drives the car."

Milton W. Rosen, director of Launch Vehicles and Propulsion, performs the same function in headquarters' relationships with Marshall

Funding Requests

Washington—National Aeronautics and Space Administration has requested $2.2 billion to conduct the manned space flight program in Fiscal 1963, which includes $1.6 billion for research and development of spacecraft and launch vehicles, and $615 million for construction of production, test and launch facilities.

Of the total NASA personnel roster of 26,144 requested for Fiscal 1963, 11,627 are assigned directly to spacecraft and launch vehicle projects for manned space flight.

The funding breakdown shows:

- Manned spacecraft: Mercury, $13.3 million; one-day Mercury capsules, $12.2 million; Gemini, $203.2 million; Apollo with launch vehicles, $617.2 million. Total, $832.5 million.
- Launch vehicles: Saturn C-1, $249.2 million; Saturn C-5, $335.2 million; Nova, $163.6 million.
- New construction: Atlantic Missile Range, $360 million; Mississippi Test Facility, $92.5 million; manufacturing engine facilities and control center, $79.8 million; Marshall Space Flight Center, $33.4 million; Manned Spacecraft Center, $30.7 million, and Michoud manufacturing plant, $18.4 million.

NASA Manned Spacecraft

Project	Spacecraft Contractor	Launch Vehicle	Spacecraft Weight	Re-entry Vehicle Dimensions (in.) Dia.	Height	First Flight
Mercury	MAC	Atlas D (GD/A)				
Three-orbit			4,265	72	82	2/20/62
Six-orbit			4,265	72	82	Fall 62
One-day			4,200	72	82	Early 63
Gemini	MAC	Titan 2 (Martin)				
Rendezvous			7,700	84	120	Early 64
Long-duration			6,600	84	120	Early 64
Apollo	NAA					
Earth-orbit		Saturn C-1	20,000	154	154	1965
Circumlunar		Saturn C-5	40,000	154	154	1966
Lunar landing						
Direct		Nova	150,000	154	154	1969
Lunar-orbit		Saturn C-5	90,000	154	154	1967
Earth-orbit		2 Saturn C-5s	400,000	154	154	1967

Abbreviations: MAC, McDonnell Aircraft Co.; NAA, North American Aircraft Space & Information Systems Division; GD/A, General Dynamics/ Astronautics.



ONE-EIGHTH SCALE MODEL of the two-man Gemini spacecraft with its adapter section shows modular concept which is dictating the design of this second-generation capsule. Twelve Gemini vehicles will be built by McDonnell Aircraft Corp. to test rendezvous techniques and to study ability of man to function after being weightless as long as 14 days. Access doors around the capsule will permit easy pad checkout and parts replacement.

Space Flight Center and the Launch Operations Center at the Atlantic Missile Range.

Holmes' management organization also includes an Aerospace Medicine directorate, headed by USAF Brig. Gen. Charles H. Roadman; directorate of Integration and Checkout, headed by James E. Sloan, and directorate of Program Review and Resources Management, headed by William E. Lilly.

Detailed policies and technical decisions to conduct the manned space flight program are formulated by Holmes, his six directors, and by Gilruth and Walter C. Williams of the Manned Spacecraft Center; Wernher von Braun and Eberhard Rees of Marshall Space Flight Center, and Kurt Debus of the Launch Operations Center. Together, they form a Management Council which meets monthly to discuss and resolve interface problems between spacecraft and launch vehicle and their systems.

Practical Consideration

This decision-making structure is being complemented by industry under contract because of a practical consideration: NASA was unable to recruit the types and numbers of people it wanted in the face of the schedule which has been dictated for the program. A combine of Bell Telephone Laboratories and Western Electric, called Bellcom, is furnishing systems integration support for Dr. Shea, and General Electric will support Sloan in checkout, integration and reliability assessment.

It is within this framework that the vital management decisions are being made in mission philosophy for manned space flight; in contractor relationships being established for spacecraft and launch vehicles, and in developing facilities for the manufacture, test and launch of the vehicles to transport man to the moon and planets.

Houston Center Builds Broad Competence

New facilities to be completed in 1964 for central management, testing of manned spacecraft systems.

Houston—Development and operation of manned space vehicles is the responsibility of National Aeronautics and Space Administration's Manned Spacecraft Center, which is being built here as one of the first space development centers to have facilities completely compatible with its mission at the outset.

The center does not face the same difficult period of adjustment experienced by other NASA laboratory complexes when the agency's emphasis shifted from aeronautics to space. When construction is completed in mid-1964, the U.S. will have a new competence to solve the specialized spacecraft problems of manned flight to the moon and planets.

During the period the center is under construction on a 1,600-acre tract 20 mi. from downtown Houston, technical and administrative functions are being carried on by a staff of 1,640 from eight buildings around the city.

The organization to develop spacecraft is being built around project offices, one for each of the spacecraft projects—Mercury, Gemini and Apollo. Operations responsibility is a division function, with branches performing tasks in pre-flight operations, flight operations, and flight crew training and preparation.

Research and Development Division gives the center a capability to support the three projects directly and to explore the field ahead for development of future spacecraft. Engineering Support Division will provide instrumentation and data systems for spacecraft boiler-plates and models, data computation and reduction, shop services and engineering and design services.

The Administration Division provides the standard management, financial and facilities services, with one exception. The center will develop into NASA's largest contracting element in terms of dollars obligated. The Fiscal 1963 total will be $800 million, and it will grow to more than $1 billion in Fiscal 1964.

Manned Spacecraft

Houston—Manned Spacecraft Center being built here has requested an operating budget of $39.9 million for Fiscal 1963, and an increase of 1,060 employes to bring the total to 2,700. While the center is under construction on a 1,620-acre site adjacent to Clear Lake 25 mi. southeast of here, employes occupy quarters in eight downtown Houston office buildings.

The center was authorized in Fiscal 1962, and requests during the first two years for facilities will give it a plant value of $90.8 million.

Major portion of facilities being constructed here will support the Research and Development Division, headed by Maxime A. Faget, and the Operations Division directed by Walter C. Williams. Mercury, Gemini and Apollo projects will be located in a project management building, essentially an office building designed to house 300 people who will be directly concerned with spacecraft development management.

Project Offices

Because all but the future function aspect of Houston operations directly supports current projects, base of activity at the new center will be the project offices. The four divisions will feed the following data into the projects:

- **Research and development:** spacecraft systems, life systems and physics technology, and systems test and evaluation.
- **Operations:** preparation of the spacecraft, including modifications, individual systems tests, altitude chamber tests, simulated flights, battery installation, pyrotechnic buildup, rocket alignment and weight and balance checkout.

Flight operations are divided into four distinct phases: final checkout, countdown and launch; flight control, trajectory assessment, systems and medical monitoring, voice communications, re-entry and abort; network tracking, communications and data acquisition, and recovery, search and location.

Paul E. Purser, special assistant to Robert R. Gilruth, director of the center, explained that crew preparation for Gemini and Apollo missions will be about as self-sufficient within NASA as it is for Mercury. Training will be keyed to a 40g centrifuge and procedures trainers to be installed at the Houston complex, and a mission control center, which NASA wants to locate at Houston for both mission simulation and mission operations.

- **Engineering support:** instrumentation, computing and data systems and shop services.
- **Administration:** costs, contracting and procurement, and personnel.

Purser said the philosophy is not to duplicate existing simulators, but to build new ones only after technology reaches the point where their value is assured. Existing planetariums, for example, will be utilized wherever they are available. Simulators for rendezvous, docking and lunar landing will be constructed, but only after prototypes have been developed at Langley and Ames Research Centers.

Training Ground

Faget characterized his Research and Development Division as a training ground for engineers and scientists who will be assigned to projects. He feels one of his most essential tasks is to create a pool of people who recognize problems, and who are able to isolate long lead-time items. Within the context of the Manned Spacecraft Center mission, however, R&D is not abtract: it is totally oriented toward specific objectives. This is shown by major tasks being performed within the division:

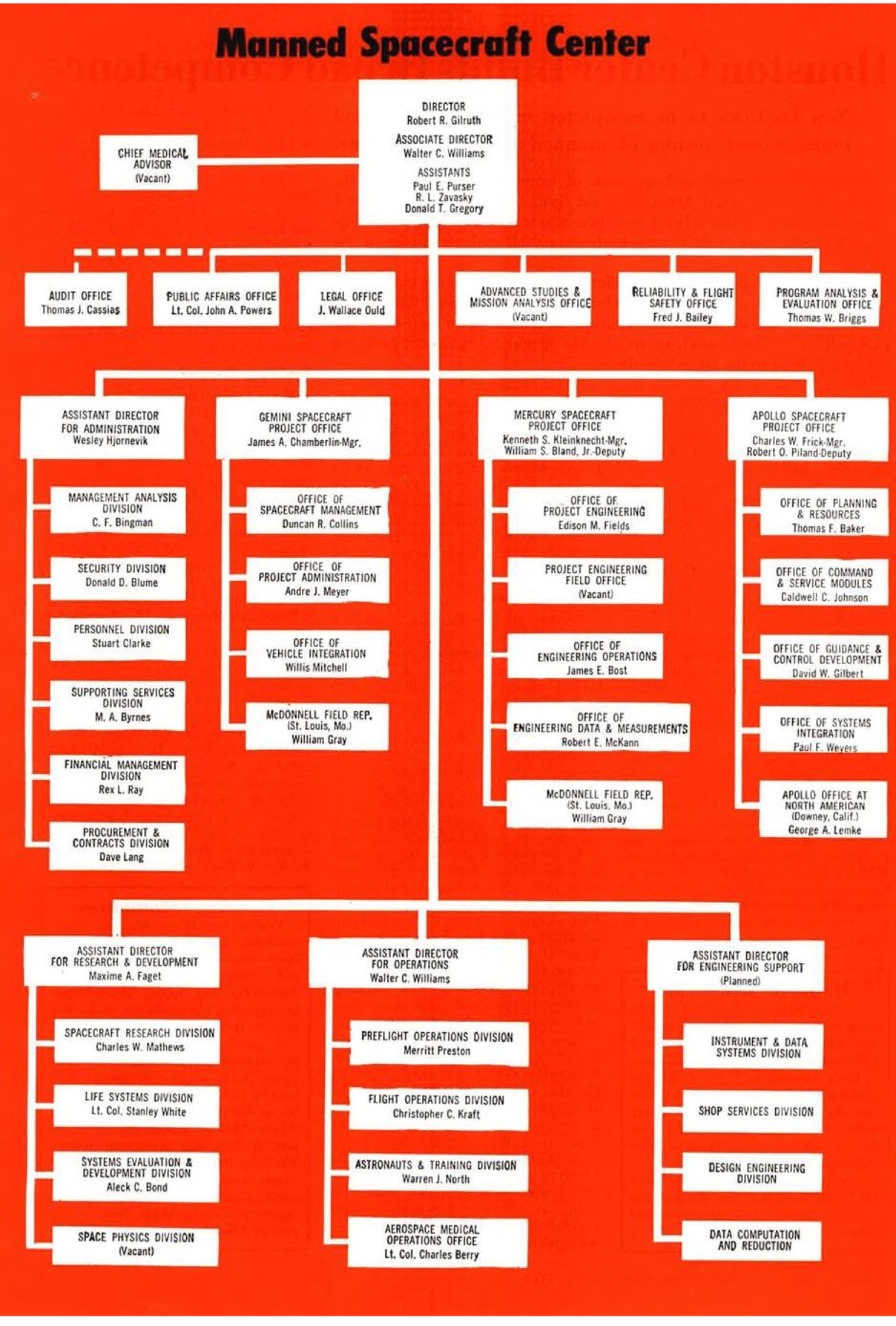
- **Spacecraft Research:** This branch has the general assignment of writing a manned spacecraft design manual. The assignment involves an all-inclusive compilation of existing engineering knowledge in such fields as structures and loads; flying qualities, reasonable safety margins and procedures for rationalizing trade-offs. In support of Gemini and Apollo projects, this branch analytically considers the spacecraft as a whole to determine how best the system should be configured. This involves detailed analysis of weights, flight dynamics and structural analysis.
- **Life Systems:** The central consult-

Landing Simulators

Washington—Three dynamic flight simulators and a number of ground-based simulators for advanced research and training are planned by National Aeronautics and Space Administration for exploring the problems of landing men on the moon.

A prototype landing simulator is under construction at Langley Research Center using a tethered capsule. The Langley facility will generate technology for an operational simulator to be built at the Manned Spacecraft Center for pilot training and component testing. The third landing simulator, a free flight system, would be used at the Flight Research Center at Edwards, Calif., to explore piloting problems, from an altitude of 5,000 ft.

Manned Spacecraft Center





GENERAL ELECTRIC CO. engineers read data from a test of the company's fuel cell, to be incorporated in the Gemini spacecraft for power and drinking water. A cell unit is in the background with a heating element around it. The Gemini system will consist of two sections each with three stacks of cells. A stack contains 31 membrane cells fueled by hydrogen and oxygen.

ant for project offices in aeromedicine, and development manager for pressure suits. Like the Spacecraft Research Branch, this element has the task of establishing tolerance criteria across a broad front to assure that no artificial physiological restrictions will hamper the program.

• **Systems Evaluation and Development:** This is the key reliability element of the Houston center. Its function will be to assess existing and follow-on components. At this time its major task has been the creation of facilities to be used for evaluating. Among facilities under design are large vacuum chambers, heating rigs and loads instruments.

• **Space Physics:** Clearing house for experiments to be conducted with Gemini and Apollo spacecraft.

In addition, Faget's division has a general responsibility to "get better components for future spacecraft," and the division sponsors advanced technical development work in the general area of product improvement. Preliminary design studies for the future presently emphasize advanced heat shield technology, nuclear and solar power supplies, on-board propulsion system improvement, pressure suits and the over-all crew equipment problem.

To perform its functions, the division is obtaining a comprehensive inventory of laboratories and development facilities. Now under construction or in design are a spacecraft research building, structural test laboratory, electrical, electronics and optics laboratory, materials and mechanical systems laboratory, spacecraft environmental test chamber, simulation facilities, flight acceleration centrifuge and thermochemical test facilities.

Manned Spacecraft Center is establishing extensive communication lines to insure that effective liaison exists with other NASA installations, and also with its principle contractors. Sizable liaison activity exists with Marshall Space Flight Center in the Apollo program, because Marshall is responsible for the Saturn vehicles which will launch the Apollo spacecraft. There are joint panels in all operational and mechanical interface areas, and in quality assurance and checkout.

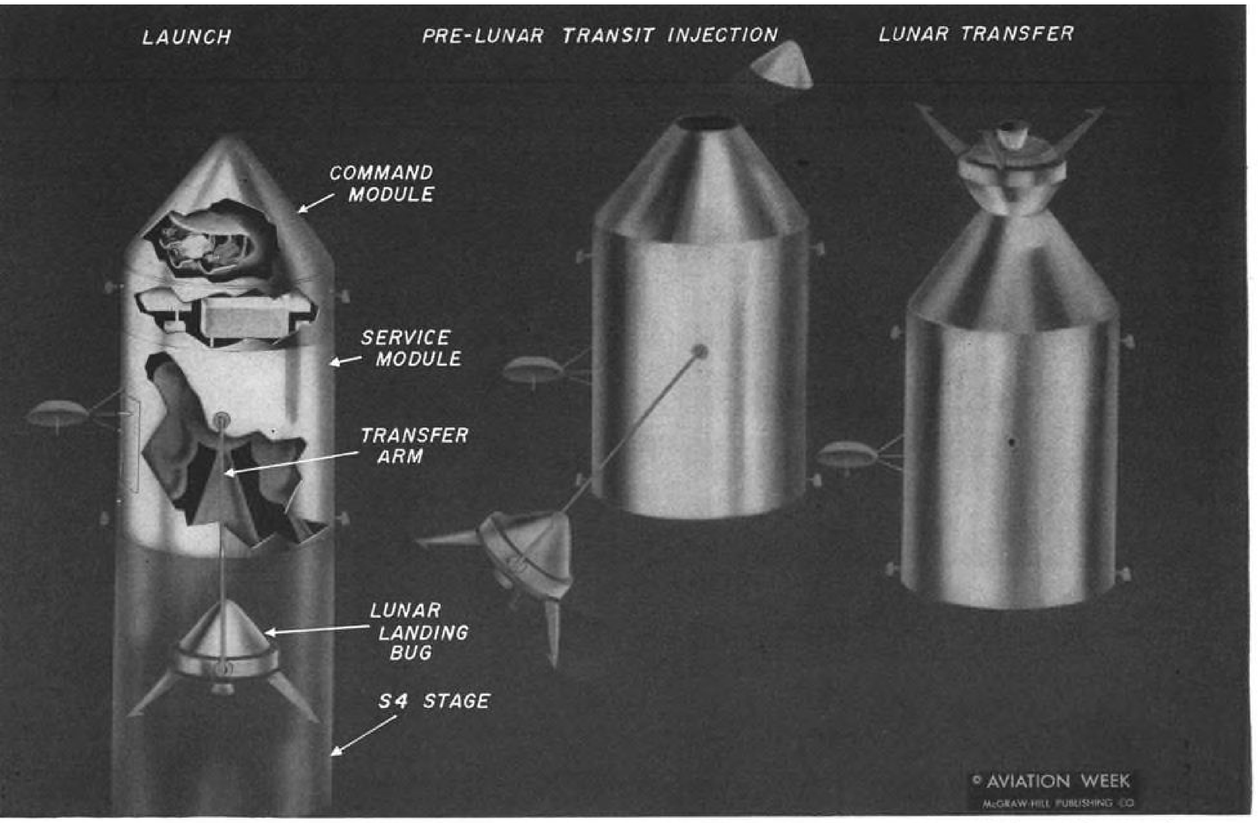
Langley Research Center, which does a considerable amount of general research in manned space flight, has appointed Axel Mattson as a permanent representative at Houston.

Liaison with headquarters is on a day-to-day basis through George M. Low, director of Spacecraft and Flight Missions, who in practice is Houston's Washington representative, and Washington's Houston representative.

NASA Launch Vehicles

Manned Spaceflight Launch Vehicles	Vehicle Contractor	No. Stages	Liftoff Thrust	Dimensions (Ft.) Dia.	Height	Applications
Nova	——	3	12 million	50	280	Direct manned flight to moon—Apollo
Saturn C-5	[1]	3	7.5 million	33	270	Manned circumlunar and rendezvous—Apollo
Saturn C-1	[1]	2	1.5 million	21.6	125	Manned earth orbit; lunar logistics—Apollo
Titan 2	Martin	2	430,000	10	98.5	Rendezvous and 14 day missions—Gemini
Atlas D	GD/A	1	360,000	10	67.3	Mercury 3, 6, 18 orbits; Agena B launcher for Gemini
Little Joe 2	GD/C	1	300,000-700,000[2]	12.8	40	Development of Apollo spacecraft
Satellite and Probe Launch Vehicles						
Centaur	GD/A	2	367,000	10	100	Lunar, planetry spacecraft; synchronously orbiting payloads
Atlas Agena B	GD/A	3	367,000	10	91	Astronomical, geophysical observatories, Ranger, Mariner, Rebound
Thor Agena B	Douglas	2	165,000	8	76	Geophysical observatory, topside sounder, Nimbus, Echo 2
Thor Delta	Douglas	3	165,000	8	90	Workhorse vehicle for payloads up to 500 lb.
Scout	Chance Vought	4	115,000	3.3	62	Lightweight (150 lb.) payload carrier

Notes: [1] Vehicle contractors not selected; Boeing is C-5 booster contractor; Chrysler is C-1 booster contractor. [2] Thrust varies with mission.
Abbreviations: GD/A, General Dynamics/Astronautics; GD/C, General Dynamics/Convair



LUNAR ORBIT rendezvous method of landing men on the moon may involve this sequence. Two-man bug would be transferred to the command module nose so that service module propulsion could operate for midcourse maneuvers and deceleration for lunar orbit.

Apollo Management Is Focused in Houston

Houston—Fundamental decisions relating to the evolution of the three-man Apollo spacecraft are being made daily in three key locations across the country, with the focal point at the Manned Spacecraft Center here, which has the responsibility for the development of all hardware from the translunar injection point through the completion of the manned lunar landing mission.

Over-all management of the Apollo system emanates from National Aeronautics and Space Administration Headquarters in Washington. The third key location in the network is Downey, Calif., where North American Aviation is building the spacecraft under technical and quality criteria unsurpassed in previous manufacturing history.

Apollo is essentially the first program NASA is conducting under the systems concept, the philosophy aimed at tying in all parts of the Apollo program into a single, integrated effort. Responsibilities for the major system elements are clear-cut, and interface problems are quickly brought to the attention of the decision-makers—Brainerd Holmes, director of Manned Space Flight, and Dr. Joseph F. Shea, Holmes' deputy for systems.

Charles A. Frick, Apollo project manager, is responsible for the day-to-day development of the capsule and its flight mission. His management office here, and his plant office in Downey consist of a random mixture of former industry and government technical executives. He has been given a relatively free hand to build the most talented management-technical team he can find, and his office, now totaling 85, will gradually expand to 200 during the next 12 months.

Frick's deputy is Robert O. Piland, who directed the Apollo program through its conceptual stages when the project was an advanced study in the Space Task Group at Langley Field. Frick considers himself the "outside man," handling all phases of the program conducted away from the Manned Spacecraft Center. Piland's task is management of the NASA activities conducted here, which includes elements to monitor command and service module, guidance and control, systems integration, flight safety and quality assurance.

In addition, Piland is acting chief of the lunar lander module program office. The lunar lander is a braking stage which will decelerate the Apollo spacecraft so that it can enter into a lunar orbit, and then further brake it to a velocity of about 750 fps. for a lunar letdown. North American's service module will perform the actual touchdown braking maneuver.

Lunar lander will be a part of the Apollo system if the earth-orbit launch mode is selected for the Apollo mission. If the lunar orbit mode is selected, the lunar landing module will be eliminated.

Houston Group

Frick's Houston organization is structured this way:

• **Spacecraft modules,** directed by C. C. Johnson, with one key branch chief monitoring each major subsystem, and others responsible for crew, power, mechanical systems and electrical circuitry, and ground support equipment. Branch chiefs are industry's direct contacts with the project.

• **Planning and resources,** headed by Thomas Baker. This group develops schedules, budgets, facilities and cost control, the last function an analysis of what is being spent, and where it is being spent. Program Evaluation and Review Technique (PERT) is a critical part of Baker's procedure. Daniel Sword, a member of the center administrative staff, is the contract representative in this office.

• **Guidance and control,** David Gilbert, who is the Massachusetts Institute of Technology contact for this system.

• **Systems integration,** headed by Dr. Paul Weyers, whose functions are spacecraft checkout, integration of spacecraft and launch vehicle in conjunction with the Marshall Space Flight Center, mission engineering, ground operational support system requirements, and reliability.

General Electric, which will assist NASA with checkout and reliability in the Apollo project, will have representatives in Houston who will work through Dr. Weyers. Frick pointed out that in no case will GE resolve conflicts, rather the company will study systems integration problems as a staff instead of a line contractor. In reliability, GE will analyze such problems as crew survivability, mission success probability, mean-time-to-failure, spares required and optimum redundant systems.

In the operations area, Robert R. Gilruth, center director, Walter C. Williams, his associate director, and C. C. Kraft and Merritt Preston, key operations managers, frequently institute campaigns to inject operational requirements into technical spacecraft criteria.

Apollo Design

Design and mission characteristics which have been made firm for Project Apollo include:

• Command module, to have a 154-in. base dia. with a 33-deg. side wall slope. It will weigh approximately 10,000 lb.

• Service module, also to have a 154-in. dia. to match the command module. Length has not been fixed because the precise amount of propellant has not been established. Weight will be about 40,000 lb.

• Maneuverability will be obtained by offsetting the center of gravity 6 to 9 in. from the centerline. In-flight lift/drag ratio will be 0.5, and subsonic lift/drag ratio will be 0.7. Potential landing footprint at re-entry will be an area 500 mi. either side of the centerline, and 3,000 mi. downrange. Re-entry angle of attack will be 30 deg.

• Recovery will be on land. Present plan is for letdown to be accomplished by a cluster of three 85-ft. parachutes, any two of which will assure a safe landing. If the paraglider system is proved in Gemini, the Apollo spacecraft will be fitted with this system.

Frick's executive assistant is Thomas Markley, and R. C. Seabold is a consultant on Apollo manufacturing.

Resident project manager in Downey is George Lemke, whose primary functions are engineering, quality assurance and reliability, and business administration. He is functionally responsible to Johnson in Houston, and is structuring his organization in the same way Johnson's command and service module division is organized.

Lemke defined his operation as "insurance" in confidence and maximum system reliability. He will have about 30 technical people on his staff—divided among the engineering disciplines, and quality control-design experts.

Daily contacts between NASA and North American on specific problems are supplemented by formal bi-weekly sessions, and by monthly design review meetings. NASA and NAA have established working groups which are presently active in eight specialty areas. These working groups may well splinter off to isolate specific problems, and others could be formed to attack new problems. Working groups currently are active in vehicle design and integration, vehicle dynamics and control, vehicle instrumentation, vehicle electronic systems design and integration, vehicle assembly, system checkout and preflight testing, launch operations and flight evaluation.

North American is in high gear on the Apollo program, and is looking toward 1963 for delivery of boilerplate and mockup Apollo models.

John Paup, NAA vice president for Apollo, expects his company to acquire orders for 16-18 boilerplate models, to be built to various degrees of sophistication. First boilerplates will be used for impact tests at the Downey site and for aircraft drops. Later models consisting of both command and service modules will be flown on Little Joe 2 vehicles on ballistic trajectories to verify design criteria and to qualify the rocket escape system.

North American also will build several procedures trainers, which will be duplicates of the command module and these trainers will be linked to computers for mission profile simulation.

Many command module wooden mockups are under construction in a plant area North American calls "teepee village," because the capsule looks like an Indian teepee. Paup explained that boilerplates will be used "to find things out; mockups will be used to learn where to put things."

Placement and coloring of instruments, compatibility of electronics, handling and servicing, interior lighting and egress are among the design problems mockups will help solve.

Reflecting NASA's demand for quality assurance, North American is using Apollo flight hardware quality control procedures to build wooden mockups. This allows the company to train its manufacturing people in advanced quality assurance techniques, and to use the techniques as early as possible. Philosophy is to manufacture a spacecraft with the same certification as a commercial airliner.

Pending decision on whether earth or lunar orbit rendezvous will be selected for the Apollo mission mode does not slow North American's work, according to John Disher of headquarters Apollo office.

Disher said the external configuration of the command module has been fixed (see box) to the point where the company has been able to start work on the design of the prototype command module.

He pointed out that nothing in the Apollo design is beyond the existing state of the art, although the fuel cell system—to generate power and drinking water—probably goes farthest in technology. Disher feels the major technical problems exist in:

• **Reliability of the subsystems,** particularly in service module and attitude controls, guidance, navigation, electrical power supply, environmental control.

• **Development of operational** techniques and displays and controls for rendezvous, lunar touchdown and the checkout and countdown for lunar takeoff.

Apollo Subcontractors

Houston—Subcontractor estimates for major Apollo spacecraft systems total $231 million, and the prime contract for spacecraft will have a value estimated at $1 billion.

Negotiations are still being conducted with North American Aviation's Space and Information Systems Division for the spacecraft, with formal contracts to be let in phases. First phase will carry work through the engineering mockup, and the second increment will be through delivery of the prototype.

Associate contractor, Massachusetts Institute of Technology, has received contracts totaling $40 million for development and production of the Apollo guidance system. Top tier subcontractors and estimated value of awards, are:

• Minneapolis-Honeywell, $66 million for the stability and control system.

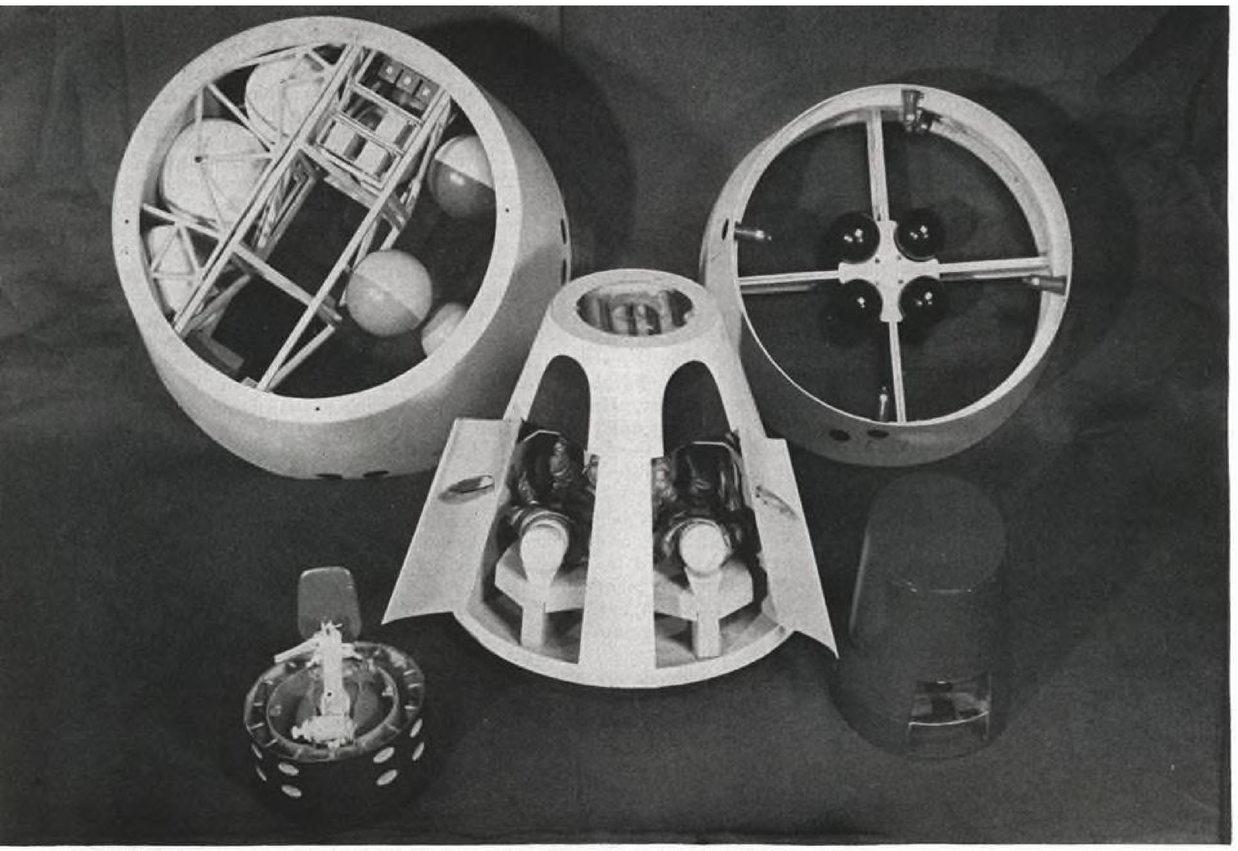
• Collins Radio, $50 million for telecommunication system.

• AiResearch, $24 million for development of environmental control system.

• Marquardt, $12.4 million for the reaction control system.

• Avco, $11.7 million for heat shielding.

• Pratt & Whitney, $10 million for the fuel cell system.



MODULAR structures of the Gemini capsule surround the pilots' compartment in this scale model.

Gemini to Be Testbed for New Techniques

Houston—Role of Gemini as the first truly operational U. S. manned space vehicle has been overshadowed by current Mercury flights and the more ambitious Apollo program, but Gemini is expected to become the flexible testbed for new techniques and systems for both scientific and military space flight.

The two-man Gemini will permit long duration flights for assessment of the effects of space environment on crewmen and components, test and demonstrate rendezvous techniques, rectify design shortcomings that have become obvious through the Mercury program, and it will place increased reliance on the astronaut as a pilot and controller.

With its flexibility, Gemini will be a true second-generation spacecraft rather than a simple adaptation of Mercury. The only valid similarity between the two vehicles, both of which are being built by McDonnell Aircraft Corp., will be in external configuration. Even the fundamental design philosophy has been altered.

Rapid Development

Gemini is being designed under the modular concept, with major systems located outside the pressure vessel, quickly available for replacement or servicing through access doors. Mercury has a layer-cake design, with systems piled one on another inside the pressure vessel.

Gemini was approved as a project only eight months ago, but final design criteria will be frozen before the end of this summer and the first flight is scheduled in 14 months. The unprecedented development speed for a flight vehicle has been made possible because National Aeronautics and Space Administration's Manned Spacecraft Center decided to establish firm capabilities for the spacecraft, and then to stick to them, rather than to try to add improvements continually. Advances and sophistications in spacecraft will await development of the third-generation vehicle, the Apollo A three-man, earth-orbiter.

This extreme scheduling pressure is not arbitrary. NASA urgently needs the information Gemini will supply in order to make intelligent mission plans for Apollo, and the Gemini capabilities are not proving restrictive by any standards. They will permit a two-day rendezvous mission with a 6,600-lb. payload or a 14-day orbital mission with a 7,700-lb. spacecraft.

The rendezvous configuration will permit slight changes in orbital plane and passive approach to a target vehicle.

The long-duration vehicle will have the flexibility for a two-man crew or a pilot and a menagerie of experimental animals.

Key features of the Gemini system serve to illustrate its considerable advance over the existing Mercury capsule, and to demonstrate the critical value of Mercury in development of the second-generation spacecraft.

Role of Adapter

Externally, Gemini will look like an enlarged Mercury capsule with an adapter section, 90 in. high and 10 ft. in dia. attached to the blunt end. The adapter will carry reaction control fuel and 104 lb. of oxygen and will have the added function of a space radiator to cool the crew compartment. Stringers in the adapter structure will be hollow, and a liquid similar to hydraulic fluid will be circulated through them as a coolant.

The adapter also will house eight maneuver control thrust chambers and six of the 24 attitude control jets. The maneuver control system consists of eight 100-lb. thrust units, two of which fire aft or down, two forward, and four in the direction of displacement.

Attitude control jets have a 25-lb. thrust. Sixteen attitude jets are located in the neck of the capsule, a section called the re-entry attitude control module; two are located in the re-entry module, and six are in the adapter structure.

The adapter will remain a part of the Gemini spacecraft in both rendezvous and long-duration configurations until completion of the mission. At that time, the spacecraft will be oriented to a 24-deg. re-entry attitude and the adapter will be jettisoned by a shaped charge between the re-entry module and the adapter.

Reaction control jets for both maneuvering and controlling attitude will be fueled by bi-propellant hypergolics. Fuel will be monomethyl hydrazine, and the oxidizer will consist of mixed oxides of nitrogen. This combination will provide a specific impulse of more than 280 sec.

Propellants will be stored in bladders sealed with a metal disk which will be pierced automatically after the vehicle is inserted into orbit. Thrust chambers will be fixed, and will use ablation-cooled nozzles. Solenoid valve controls will eliminate tailoff and permit extremely short thrust pulses—as low as 15-20 milliseconds.

Re-entry Vehicle

The re-entry vehicle, with a base diameter of 90 in., houses the pressure vessel-crew compartment and the electronics and major systems, which are located between the pressure vessel and the spaceframe. Primary spacecraft power system will be supplied by a system of six-module fuel cells, based on an ion-exchange membrane to produce both electricity and drinking water through chemical reaction of hydrogen and oxygen. Two separate silver zinc battery supplies will be provided, one for arming and safety and to fire squibs and pyrotechnics, and the other as a backup and for use during re-entry.

The fuel cell system will deliver a cruise power level of 1,600-1,700 watts against an average predicted requirement of 600 watts.

The only major system located within the Gemini pressure vessel will be environmental control, which will furnish pure oxygen and maintain a 5.1 psia. cabin environment. This system will vent overboard and will have the same major features as in the Mercury system. Carbon dioxide will be controlled by charcoal absorption and suit temperature will be controlled by oxygen changing to water through a heat exchanger. Humidity is controlled by water removal downstream from the heat exchanger.

Oxygen for use in orbit and oxygen for use in re-entry will come from two independent systems, the orbital system tanked in the adapter and the re-entry system in the re-entry module.

Pressure suits of both astronauts will be connected in parallel in a single closed loop system, which means the pilots must agree on a temperature environment.

The re-entry module will have large access doors for servicing and replacing equipment without the need to tear the entire capsule down. This will solve one of the major problems found in Mercury. When a system fails to check out, it will be replaced on the pad. On several occasions, the Mercury capsule had to be removed from the launch vehicle and generally disassembled to remove a system found faulty during countdown.

Gemini pilot seats will be universal, but astronauts will have individually molded couches from the buttocks up. Abort can be initiated by either crewman. Each will have a D-ring actuator which will eject both in a single operation.

Immediately forward of the re-entry module is the re-entry reaction control system structure, and forward of this section is the paraglider stowage compartment and rendezvous radar system.

Incorporation of maneuvering controls, a displaced center of gravity and the paraglider system are the main features which combine to make Gemini an operational spacecraft, capable of positive pilot control in orbit, during re-entry and after re-entry.

Homer Dotts, Gemini structures chief explained that the center of gravity is offset 3 in. from the spacecraft centerline, and by re-entering the atmosphere with a 16 deg. tilt, a lift/drag ratio of 0.25 can be obtained. This results in a controlled roll, which allows the spacecraft to be headed in the generally desired direction, with a landing "footprint" 500 mi. long and 200 mi. wide at the beginning of re-entry.

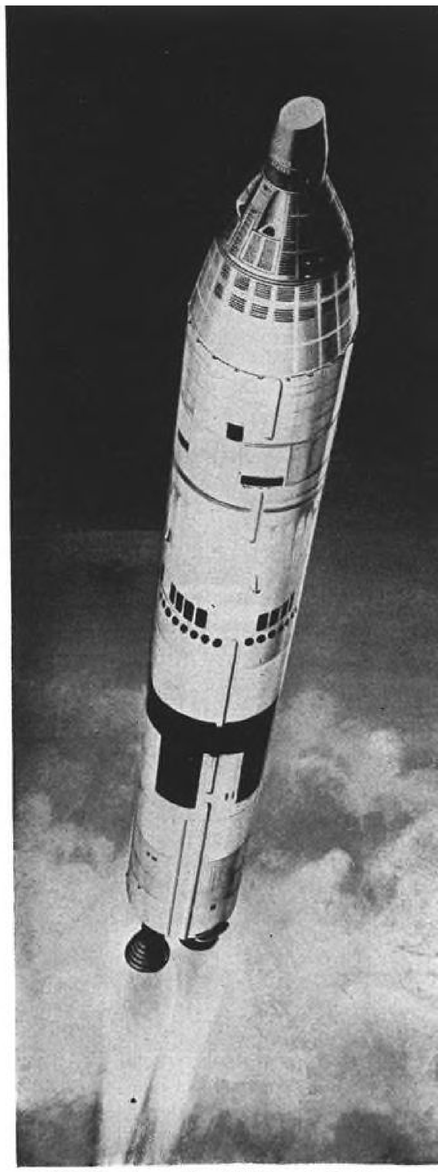
Lifting angle to be induced during re-entry will lengthen the peak heat pulses, and this necessitates a somewhat different structural heat protection approach than is used in Mercury. The heat shield will be a combination of glass fibers and phenolic resin, but it will not be uniform in thickness. Hot spots and corners will be built up, and similar ablative materials will be in-

Gemini Contracting

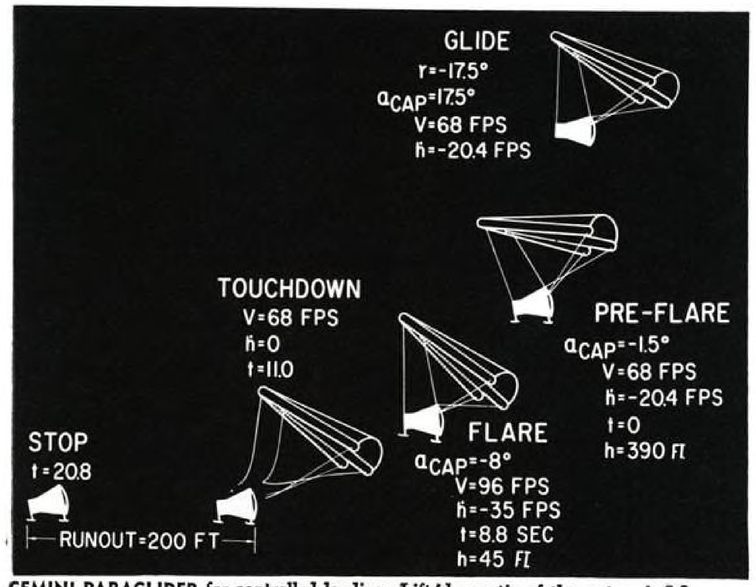
Houston—Direct contract obligations for the 12 Gemini two-man spacecraft on order total $308.6 million, including an estimated $250 million to McDonnell Aircraft Co. for production of the capsules. The McDonnell contract is still under negotiation.

Major subsystem contracts have been signed with:

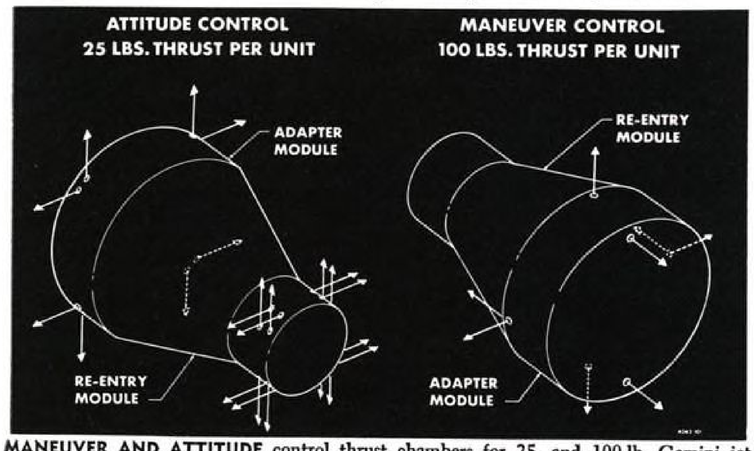
- International Business Machines, $24 million for inertial guidance.
- Rocketdyne, $14.4 million for orbit attitude and maneuvering reaction control systems.
- Minneapolis-Honeywell, $8 million for the inertial measuring unit.
- Garret Corp.'s AiResearch, $6.4 million for the environmental control system.
- General Electric, $5.8 million for the fuel cell system.



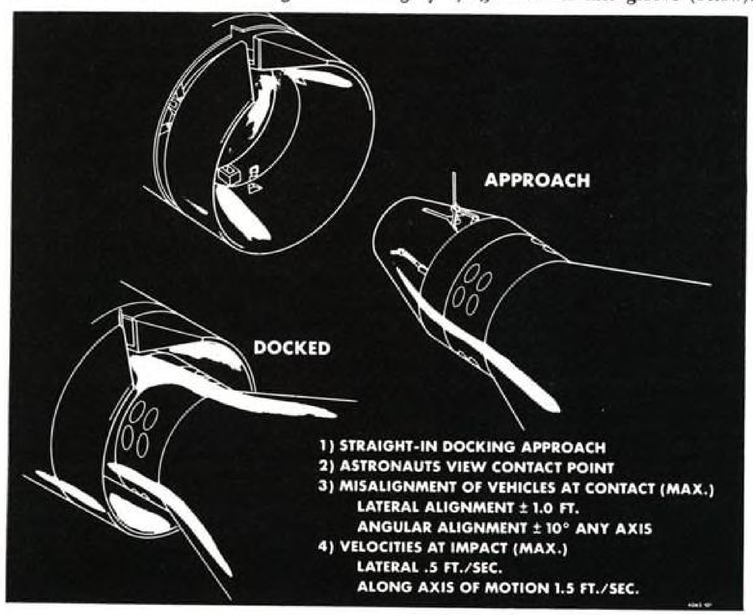
DRAWING shows Gemini-Titan 2 during boost. Abort escape will be accomplished with ejection seats.



GEMINI PARAGLIDER for controlled landing. Lift/drag ratio of the system is 3.2.



MANEUVER AND ATTITUDE control thrust chambers for 25- and 100-lb. Gemini jet (above). Pilot controls Gemini-Agena B docking by flying index bar into groove (below).



stalled around the reaction control recovery module at the spacecraft neck, which is subjected to intense heating loads during re-entry.

The neck section of the Mercury capsule is protected with beryllium plates, but they are too heavy for the Gemini system.

The paraglider is designed to make possible a point landing anywhere within the footprint and to compensate for errors introduced during re-entry.

The paraglider, which weighs 510 lb., is stowed in a 10-cu. ft. compartment. Deployment will begin at an altitude of 50,000 ft., and is completed at 40,000 ft. at the start of the glide maneuver.

When the glider is fully deployed, Gemini has a 3.2 lift/drag ratio, and the capability to maneuver 25 mi. downwind, or 15 mi. upwind.

The capsule is flown into a landing by the pilot, who uses a hand controller to actuate gas-operated cable reels, two in order to vary pitch and two for roll. A fifth cable is fixed. The point landing system is accomplished in four steps:

- **Glide, from 40,000 ft.** to 390-ft. altitude at an angle of 17.5 deg., forward velocity of 68 fps., and sink rate of 20.4 fps.
- **Pre-flare, from 390 ft.** to 45 ft., actually a dive to increase forward velocity to 96 fps. and sink rate to 35 fps. Spacecraft angle is dropped to −1.5 deg.
- **Flare, from 45 ft.** to impact, with capsule angle increase to − 8 deg. and forward velocity slowing to 68 fps.
- **Touchdown,** which is made at a maximum vertical velocity of 5 fps. and a horizontal velocity of 68 fps. Approximate runout distance has been computed to be 200 ft.

Nitrogen or another cold gas will be used to operate the cable reels, and landing skids will be made of a heat-treated steel.

Origin of Concept

The Gemini concept began in April, 1961, with James Chamberlin as a scheme for redesigning Mercury to make it easier to perform an 18-orbit mission for one man. Chamberlin, now Gemini project manager, believed that the modular design philosophy, the paraglider and ejection seats could quickly be incorporated into the Mercury design. Ejection seats will replace the abort tower used in the Mercury system. Although the tower concept is probably the most reliable abort technique, the weight makes it incompatible with the Gemini's Martin Titan 2 launch vehicle capability, and there is no off-the-shelf rocket presently available for a Gemini escape system. The seat also provides a capability for ejection after re-entry, which the tower would not.

Chamberlin's initial ideas have matured into the present Gemini system. Although the first Gemini mission will terminate in parachute recovery, it is the only unmanned mission planned in the 12-flight program. An extensive paraglider development program will begin within 60 days. In the first phase, 20 unmanned boilerplate Gemini models will be dropped from Lockheed C-130 aircraft to make radio-controlled landings. Phase 2 calls for North American Aviation test pilots to demonstrate the system in C-130 drops, and the third phase is for NASA astronauts to make controlled landings after drops.

NASA is considering using the spent Titan 2 launch vehicle second stage as the target in early development flights if Pad 14 at the Atlantic Missile Range is not free in time for these flights. Pad 14 is the only pad available for Project Mercury launches, and NASA will use it for both 6-orbit and 18-orbit Mercury flights. When these missions are completed, it will be adapted to accommodate Atlas Agena B vehicles for the Gemini mission.

Tests have indicated that an ejection abort using seats will subject the pilots to a g-load of 12-15, not as severe as ejecting from high performance aircraft. Maximum dynamic pressure for the Titan 2-Gemini combination will be 800 lb./sq. ft. as compared with 982 with the Atlas-Mercury combination.

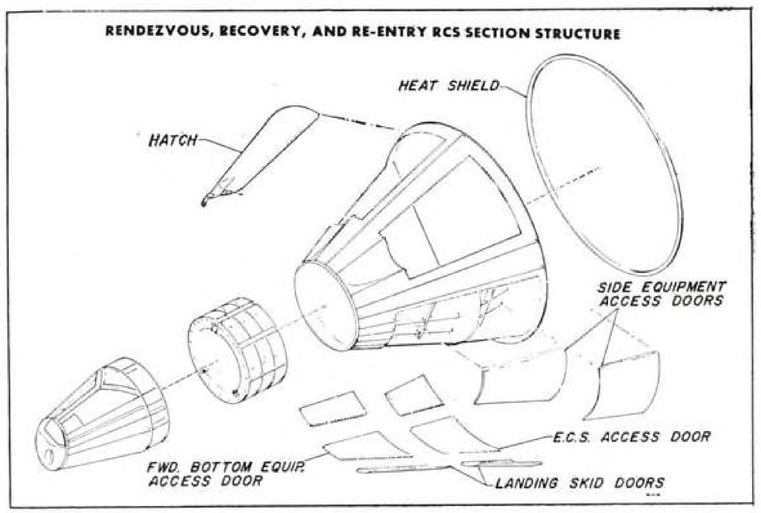
Gemini's Titan Booster

Titan 2 launch vehicle which will boost the Gemini spacecraft into orbit is essentially a copy of the Titan 2 missile, and component parts already are being delivered to Martin Co.'s Baltimore plant, where the vehicle will be assembled.

Main differences between the missile and the Gemini launch vehicle are the addition of a malfunction detection system (MDS) and some supporting trusses, and the switch to a radio guidance system instead of an inertial guidance system. MDS sensors will be located at critical points to sense tank and thrust chamber pressures and rates.

Attempts to increase reliability in the Gemini launcher have been instituted by Martin in two main ways—incorporating redundancy into some of the critical systems, and use of a critical component program which requires more component testing for Martin and its vendors.

Two-stage Titan 2, with a constant dia. of 10 ft., has a booster thrust of 430,000 lb. and a second-stage thrust of 100,000 lb. It uses hypergolic, storable propellants. First stage is 746 in. high, and the second stage is 435-in. high. The Gemini spacecraft is 103-in. high, giving the launch configuration a height of 107 ft.



MAJOR STRUCTURAL components of the Gemini spacecraft indicate the modular design of the capsule. The 510-lb. paraglider will be stowed in the section at the left. Immediately aft is the module which houses re-entry Reaction Control System (RCS). Doors provide access to equipment and to environmental system. Unlike the Mercury capsule, Gemini will have few components inside the pressure vessel.

In a typical rendezvous mission, the Agena B target will be launched first into a 150-mi. circular orbit. The Gemini spacecraft then will be launched in the same orbital plane into a slightly elliptical orbit, ranging from 87-150 mi. Because of the difference in velocity, Gemini will approach the target at an angular rate of 5.3 deg. per revolution, and this process can be speeded by changing the orbital path of Agena to slow it down.

When the two vehicles are 250 mi. apart, the rendezvous radar on the small end of the Gemini spacecraft locks on the transponder located around the Agena B adapter. This system provides angles, ranges and range rates for rendezvous guidance, and range and range rate for docking.

Range Decreased

When the range has decreased to 50 mi., the technique switches to semi-optical, using both an electromagnetic scanner in Gemini and a high-intensity flashing light in the target. The crew actually flies Gemini into the Agena B adapter section visually, using an index bar to line up with a groove in the adapter.

The present concept is to use a straight-in docking approach. This calls for precise pilot control, with only one foot lateral and 10 deg. angular misalignment.

Lateral docking impact is estimated at 0.5 fps. and 1.5 fps. along the axis of motion.

The Agena B adapter section will have three hard points, or seats. When Gemini connects with the seats, the adapter will be cinched solidly to the target to form a single rigid vehicle. Disconnect will be made by reversing the process.

The pilot will have four manual and two automatic attitude controls, which will include foot pedals, recommended by the Project Mercury astronauts, to control yaw. Direct pilot controls will be fly-by-wire, single pulse for fine adjustment, proportional rate command, and rate command for attitude hold.

Automatic Systems

Automatic systems will be provided in attitude hold, and in what will be called the orbit mode. The latter system uses sensors to pick up the horizon and will maintain constant roll and pitch, allowing the crew to rest even though their spacecraft will drift in yaw.

Special Gemini Tests

Houston—Experiment which would permit one of the two crewmen to leave the spacecraft while it is in orbit is being considered for Project Gemini. A snubbing device is being developed that will hold the door open so an astronaut, attached to the capsule by an umbilical tube, would be able to operate outside his vehicle.

Environmental needs would be provided either through the umbilical or by means of a self-contained satchel or back-pack.

Another advanced experiment under consideration is the use of the spacecraft to dock with an unspecified propulsion stage, larger than the Agena B.

Mercury Provides Data for Apollo, Gemini

Hampton, Va.—Project Mercury, conceived under tremendous pressure four years ago in the face of Soviet space successes, has evolved into a valuable building block in the U.S. manned space flight program, and before it is completed, it will provide much of the fundamental knowledge for the Apollo manned lunar landing mission.

Mercury had a single objective at the outset—to verify the ability of man to function in the space environment. This objective was met last Feb. 20 with the three-orbit flight of Marine Lt. Col. John H. Glenn, Jr. It was confirmed last May 24 when Navy Lt. Cdr. Scott Carpenter flew a second three-orbit mission.

Because the pressure to advance has been on Mercury since its inception, the three-orbit mission will grow to day-long missions about six months from now.

There has been a tendency to identify Project Mercury with the capsule and its pilots, but they are only aspects of what has become an extensive proving ground for the Gemini and Apollo programs.

Full Mercury system consists of a government-industry team that has given the U. S. the means to design, engineer and manufacture a manned space vehicle, which was qualified and flown by man 17 months after the prime contract was let.

The system has provided a world-wide tracking network with the capability to handle data on a real-time basis; it has given controllers the opportunity to devise realistic flight and recovery procedures.

The Mercury system evolved during a time when U. S. international prestige was foundering from diplomatic setbacks and Soviet triumphs in space. The successes of Navy Cdr. Alan B. Shepard, Jr., and USAF Capt. Virgil I. Grissom in ballistic flights, and Glenn and Carpenter on orbital missions, have had a marked national impact because they became a focus for renewed national pride. The impact was beyond the expectations of even top Administration leaders, and it has led to the operating philosophy behind future manned space flight programs.

New scientific knowledge that Mercury provides is one of its most important characteristics. Another is the role it has played in publicizing the need for a vigorous manned space flight program.

Sustained Backing

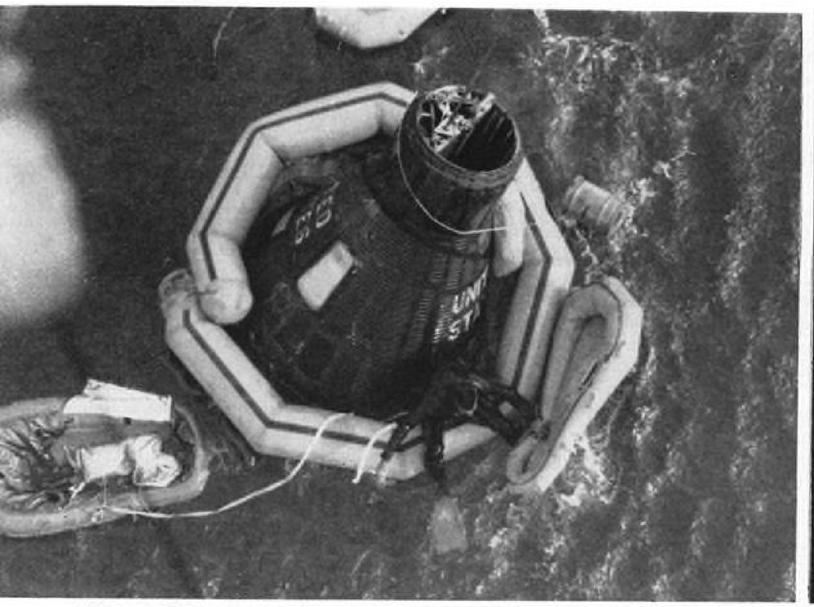
Sustained backing is predicated largely on continued solid achievements, which the National Aeronautics and Space Administration is programing on what it considers to be a logical, step-by-step schedule. Orbital flights by Glenn and Carpenter provided an excellent base from which to proceed in extending the Mercury profile to six orbits and then to a full day of orbital flight.

There is a plan under consideration to fly two six-orbit missions and two or three one-day missions. This plan will carry the manned space flight program forward until the fall of 1963. At that time, launch facilities enter the schedule as a major pacing item.

Pad 14 at the Atlantic Missile Range is the only Mercury launch complex. It is also the facility from which the Agena B stage will be launched for the Gemini rendezvous mission. If Gemini missions are to start in early 1964, Pad 14 must be available early next fall for modification to handle the Atlas Agena B launch vehicle.

Fundamental purpose of six-orbit missions is to provide baseline aeromedical data on the effects of prolonged weightlessness. Six orbits is considered the limit of the capability of the existing Mercury configuration under the payload limitations of the Atlas launch vehicle. NASA has established a turnaround time—actually a launch schedule—of 60-90 days for each mission, and the expanded Mercury program now conceived will not delay the schedule.

NASA is satisfied from the Glenn and Carpenter flights that a properly trained, experienced test pilot will not be hampered by extended weightless flight. But the agency wants to verify this, in view of the nausea experienced by Soviet Maj. Gherman Titov after five orbits of his 17-orbit mission. Although a six-orbit assignment was a relatively recent consideration in the Mercury program, it can provide the opportunity for detailed aeromedical monitoring during more than 500 min. of weightlessness without significant capsule modification.





AURORA 7 flight capsule of Lt. Cdr. Scott Carpenter is shown during retrieval operations following its flight last May 24. Flotation collar was installed around listing capsule by scuba divers, one of whom is resting on collar at left.

Six-orbit plan calls for an absence of positive pilot attitude control during a significant portion of the flight. The pilot will exert control during the first two orbits while precise orbital elements are being calculated. At the start of the third orbit, a decision will be made whether to continue the flight for six orbits, or to end it after three. If the decision is to continue, the automatic reaction control system will be made inoperative to conserve fuel, and many of the power-consuming components will be switched off to save battery power.

Capsule will then drift as far as attitude is concerned for the third, fourth and part of the fifth orbits. About midway through the fifth orbit, systems will be energized for the final orbit and re-entry.

Recovery Area

Recovery area after six orbits will be near Midway Island in the Pacific Ocean. The tracking ship Rose Knot, now being modified to give it command capability, will be stationed near The Philippines. It served as the Project Mercury Atlantic Ocean Ship through the Glenn flight.

Modifications in the six-orbit capsule configuration can be utilized in the one-day capsule, according to Charles McGuire of NASA's Mercury office in Washington. He said that as a result of a general weight-reduction program and removal of some redundant components, the one-day capsule will weigh nearly 100 lb. less than the existing Mercury capsule, which has a liftoff weight of 4,265 lb.

Among components to be removed are the 74-lb. periscope and the complete rate stabilization and control system (RSCS). NASA also is considering removal of the backup telemetry system.

RSCS is one of the four attitude control systems in the Mercury capsule, and neither Glenn nor Carpenter used it. The one-day capsule will retain the automatic stabilization and control system (ASCS), fly-by-wire and manual proportional system. The latter two systems are manual, providing control when the pilot moves a control stick. The automatic system reacts to inputs from a horizon scanner link.

Consumable stores to be increased for the one-day mission will be oxygen for the environmental control system, water for cabin and suit cooling, and battery power.

The one-day mission has essentially the same objectives as the six-orbit mission, in that it will extend man's weightless flight experience and provide an opportunity to assess the effects of g-loading after prolonged zero gravity flight.

Glenn and Carpenter contributed significantly to the decision to advance Mercury beyond three orbits, since their performances resulted in consideration of the pilot as an active part of the capsule system. After Glenn's flight, Robert R. Gilruth, director of the Manned Spacecraft Center, said, "The presence of the human crew should lead to design criteria (for spacecraft) more similar to manned aircraft than to ballistic missiles.

"Since man has now demonstrated his ability to operate in the space environment," Gilruth said, "vehicle design for manned space flight can now consider full utilization of human crew capabilities. This utilization of crew should lead to increased reliability in terms of both flight safety and mission success."

Mercury was developed without verification that man could perform in space. It had added requirements of complete redundancy even though it was limited to the weight capable of being orbited by the Atlas launch vehicle. Because of the exigencies of time, it was designed as a layer cake, with systems and components placed one on the other inside the small pressure vessel. These shortcomings themselves are exerting a strong influence on the advanced Gemini and Apollo flight programs, both of which will benefit from knowledge of them.

This means essentially that in future programs man's full skills and abilities will be used: design will be modular with easy access to components; functional, integrated test under conditions similar to those experienced in flight will be made mandatory.

Wisdom of selecting experienced test pilots as crewmen and training them with a heavy reliance on flight simulators was proved by the excellent performances of Glenn and Carpenter in their orbital missions, and Shepard and Grissom in ballistic flights. Not quite so apparent is the fact that the training and simulation applies equally to launch and flight operational crews to the extent that the launch team, flight controllers, trackers and computer personnel have evolved the basic procedures for subsequent manned space flight missions.

Sound Program

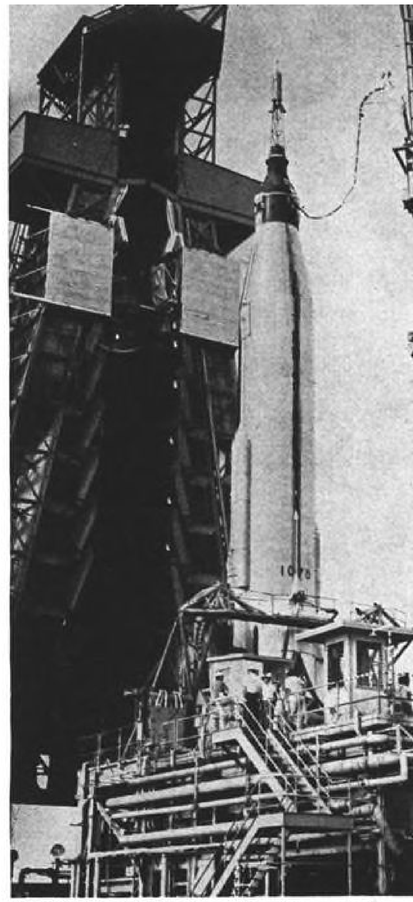
Operational shortcomings in Mercury flights, with some few exceptions, have been traced to technique rather than to any fundamental fault in a system. With the experience of 20 ballistic and orbital flights, the Mercury system has proven to be a sound one. But its most important significance lies in the fact that, as the first U. S. step in manned space exploration, it has proved to be strong and sure.

Mercury Contracts

Hampton, Va.—Project Mercury will have a total cost slightly in excess of $400 million through its four-year funding lifetime which will end during Fiscal 1963.

McDonnell Aircraft Corp., prime capsule contractor, has received approximately $160 million for production of 20 capsules, two procedures trainers, an environmental trainer and ground support equipment. This figure includes $12 million to modify four capsules for one-day missions.

Other major capsule contractors are Collins Radio, telecommunications; Ai-Research, environmental system; Cincinnati Testing Laboratory, heat shields; Northrop Ventura, recovery; Minneapolis-Honeywell, navigation; Bell Aerosystems, reaction controls, and Lockheed Propulsion, escape rocket.



MERCURY ATLAS-7 configuration used General Dynamics/Astronautics Atlas 107D.

Marshall Directing Vehicle Development

NASA's largest center uses flexible tools to manage in-house and contractor production of large boosters.

Huntsville, Ala.—Launch vehicles are the business of the George C. Marshall Space Flight Center and all work here—from experiments with liquid hydrogen to the study of various rendezvous techniques—eventually is applied to moving a payload from a point on earth to a point in space.

Under the direction of Dr. Wernher von Braun, former director of development for the Army Ballistic Missile Agency and rocket scientist at Peenemunde during World War 2, the center now is involved in:

- **Development and flight-testing** of the Saturn C-1 launch vehicle.
- **Detailed engineering design** of the Advanced Saturn, or C-5.
- **Detailed preliminary design** of the Nova vehicle.
- **Development of rendezvous operations**, including the lunar-orbit and earth-orbit modes.
- **Procurement and adaptation** of Thor Agena, Atlas Agena and Atlas Centaur launch vehicles.
- **Studies of future requirements**, ranging from post-Nova launch vehicles to the storability of propellants on the moon.

Divisions, Project Offices

Marshall is organized into nine support divisions—aeroballistics, astrionics, computation, manufacturing engineering, propulsion and vehicle engineering, quality assurance, research projects, and test and launch vehicle operations—and three project offices—Saturn Systems, Light and Medium Vehicles, and Future Projects. Some Marshall officials consider the Michoud plant a tenth support division.

The project offices do not have the depth of the support divisions in either personnel or facilities. This deliberate apportionment of strength, a carry-over from ABMA where von Braun had essentially the same management structure, is designed to provide each project office with pools of talent that can be tapped as needed.

As a project—such as Saturn—grows, Director of Saturn Systems Oswald H. Lange can draw engineers from any division to apply their particular abilities to the vehicle. As Saturn approaches an operational status several years from now, Lange will return these engineers to their divisions, where they will be re-assigned to other projects.

This flexible arrangement allows project directors to gear the size of their offices to the bell-shaped curve of a project's life cycle and economizes manpower utilization. It also avoids having too many engineers personally involved in, or oriented to, one project and makes for a minimum of reorganization and re-assignment as one project phases out and a new one phases in.

Management Tools

Marshall uses three basic tools to manage its programs—working groups, coordination panels and the technical board meeting.

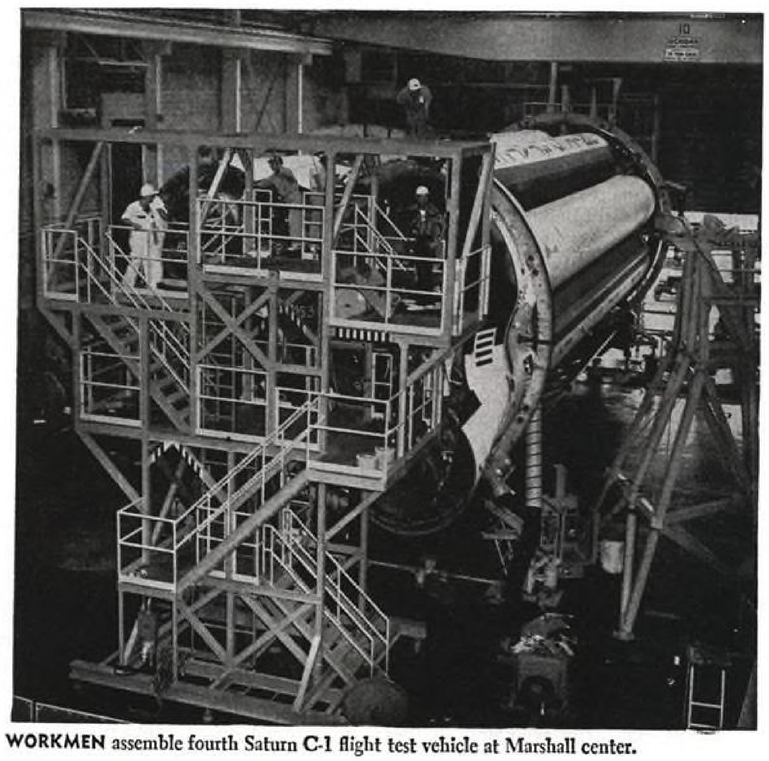
Working groups are in-house units which supplement the project office in the development of a system—whether hardware or feasibility study—by concentrating the best technical personnel available from the support divisions on specific problems or critical areas in the system. Each group is led by a Marshall branch chief or division director and includes representatives from other NASA centers, Department of Defense and the contractors.

Meetings are scheduled as necessary either by the group chairman or the office for which the group is working. Solutions or recommendations are presented to the project office for approval. Decisions of the working group are not binding upon the project office, but since the group is formed to aid the office in a particular sphere of competence, its suggestions invariably are followed.

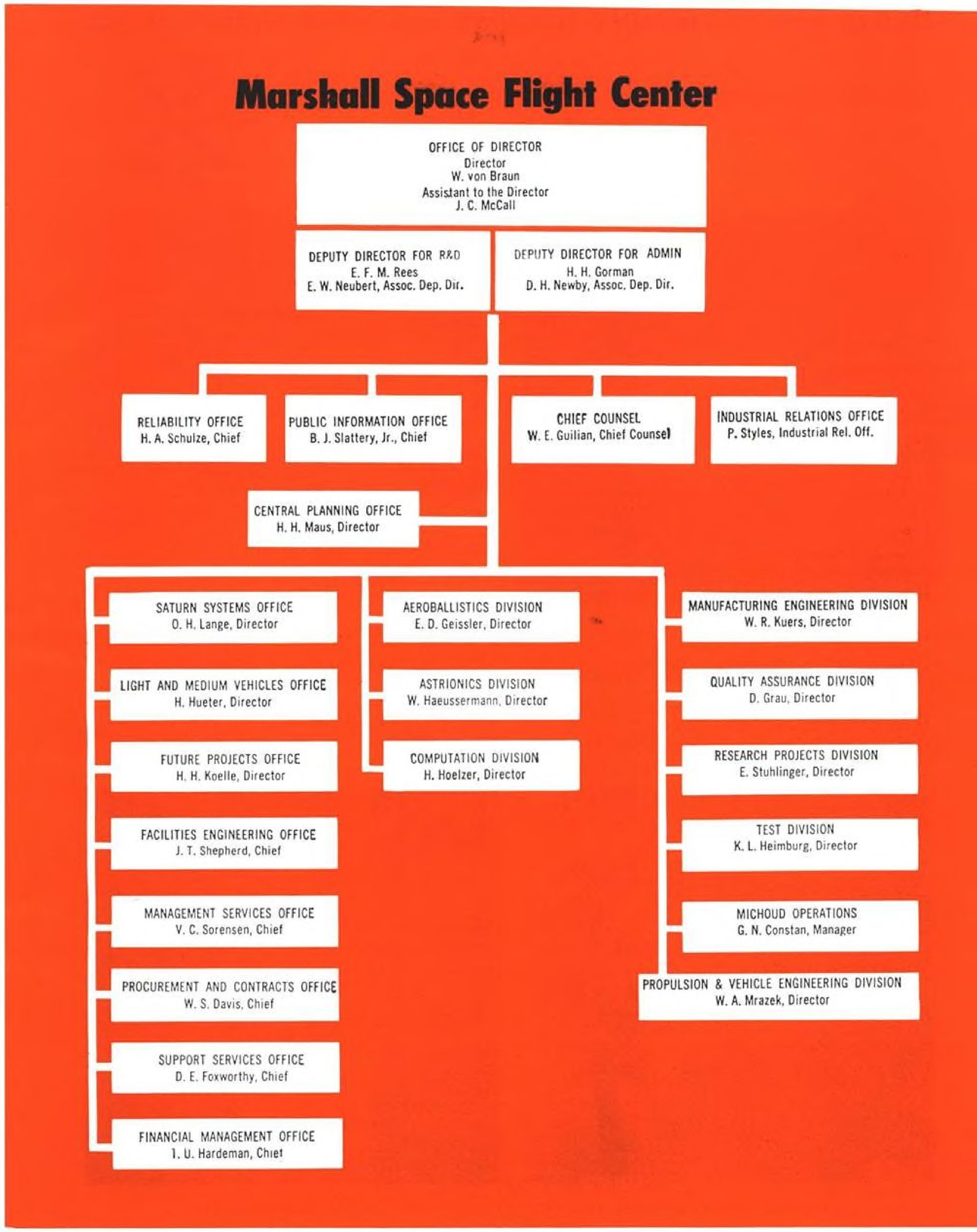
Robert E. Lindstrom, vehicle manager of the C-1 project within Saturn Systems, has eight working groups covering various areas for his office.

These groups typify the support drawn from the divisions by the project offices:

- **Vehicle Mechanical Design Integration**, under Hans Palaoro, whose regular assignment is chief of the vehicle systems integration branch in the Propulsion and Vehicle Engineering Division.
- **Vehicle Dynamics and Control**, under Dr. Ernst D. Geissler, director of the Aeroballistics Division.
- **Vehicle Instrumentation**, under Otto A. Hoberg, chief of the instrumentation development branch in the Astrionics Division.
- **Electrical Systems Design Integration**, under Hans Fichtner, chief of the electrical systems integration branch in the Astrionics Division.
- **Vehicle Assembly**, under Hans Maus, director of the Central Planning Office.
- **System Checkout and Pre-flight Test-**



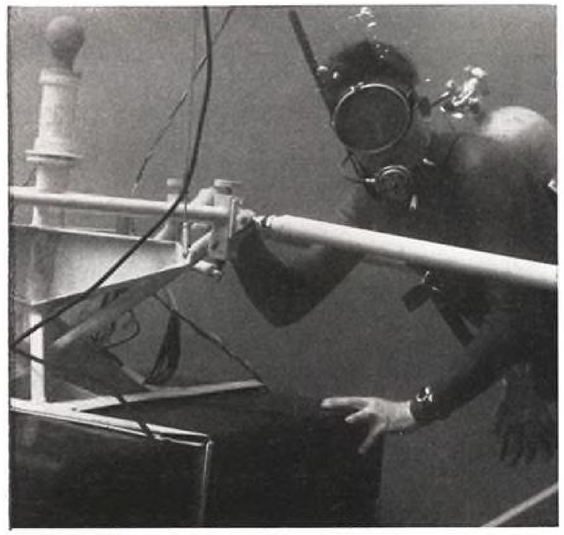
WORKMEN assemble fourth Saturn C-1 flight test vehicle at Marshall center.



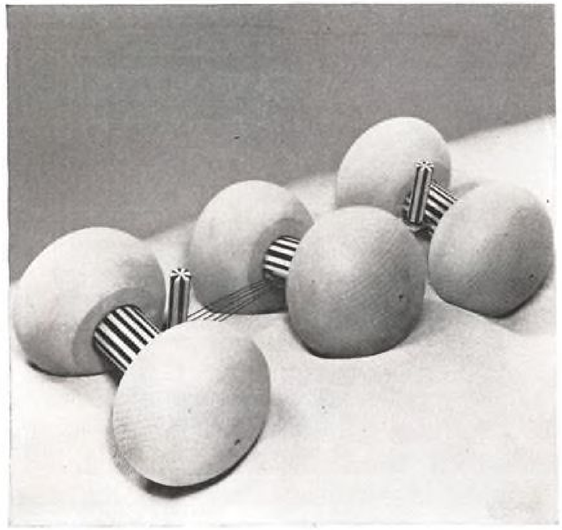
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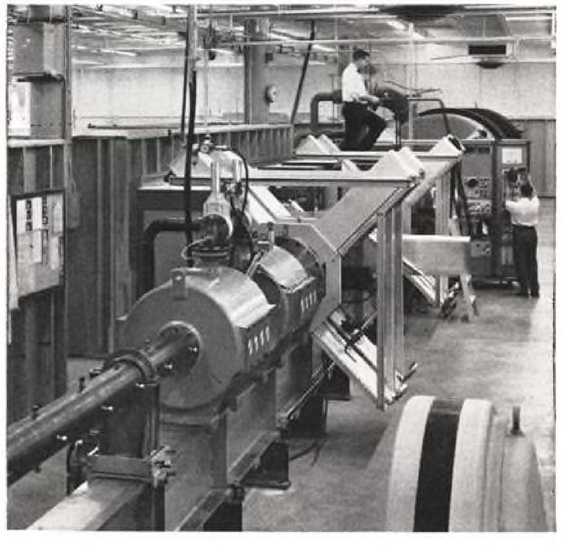


SEA OPERATIONS: Today, top-flight scientists at GM/DRL are at work in, on, and under the sea, prying out the ocean's secrets. From their studies can come detailed knowledge pointing the way to more precise methods of underwater tracking, navigation, undersea charting and marine vehicle mobility.



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ing, under Dieter Grau, director of the Quality Assurance Division.

• **Launch Operations,** under Dr. Kurt Debus, director of the new Launch Operations Center at AMR.

• **Flight Evaluation,** under Dr. F. Speer, chief of the flight evaluation branch in the Aeroballistics Division.

C-5 also has eight working groups, covering the same areas as C-1 groups, and ad-hoc groups are appointed as needed to explore problems falling outside the areas of the regular working groups. Working groups are not management committees, because only the chairman has authority to make decisions and he must assume responsibility for the group's actions. Centaur program has four working groups.

The Manned Spacecraft Center (MSC) at Houston, Tex., also uses working groups in developing the Apollo capsule. They correspond functionally to the Saturn groups at Huntsville. Von Braun and his staff had urged MSC, when it was still the Space Task Group at Langley Station, Hampton, Va., to adopt a management structure similar to Marshall's after it transferred to Texas earlier this year, and MSC agreed.

Working groups of the two centers meet in coordination panels, which are patterned after the joint units formed by the centers for the Mercury-Redstone program. These panels cover the same areas as the in-house groups to assure that development of booster and spacecraft proceed in lock-step. As far as possible, panel members are drawn from the corresponding working groups of Marshall and MSC. Panel membership usually does not exceed 12.

Dr. Joachim P. Kuettner supervises Huntsville panel participation; his Houston counterpart is Dr. Paul Weyers.

Panels presently constituted are: launch operations; mechanical design integration; electrical systems integration; on-board instrumentation and communications; flight mechanics, dynamics and control; and quality assurance and checkout. Additional panels are being considered for flight evaluation and man-rating. Like the working groups at Marshall and MSC, representatives from other NASA centers, DOD and industry contractors are invited to join panel sessions.

Bulk of the panel's work is done through informal meetings and discussions between the working groups here and at Houston; the panel meetings frequently serve to work out details of agreements already reached, as well as to probe problems which either has isolated.

Results of panel meetings are forwarded through Kuettner and Weyers to the Saturn Systems and Apollo project offices. From there, the panel reports go through von Braun and Robert R. Gilruth, MSC director, to Brainerd Holmes, director of NASA's Office of Manned Space Flight, and his Management Council.

Disagreements that cannot be resolved within a panel are referred to a joint Huntsville-Houston Review Board, composed of von Braun; Deputy Director for Research and Development Eberhard Rees; Saturn Director Oswald Lange and four division directors from Marshall; Gilruth, his Associate Director Walter Williams; Apollo Project Director Charles Frick and four office directors from MSC. So far, the board has yet to be called upon to resolve a panel dispute.

Marshall intends to keep its in-house manufacturing capability, built up during its Army Ordnance days, and will continue to assemble the initial units of any new stage before turning it over to a contractor for production.

Von Braun defends retention of this capability on two grounds:

• **Managerial competence** is maintained at a level which permits Marshall to make authoritative judgments on the contractor's production. By building one or several units itself, Marshall feels it is in a better position to supervise the contractor's work and to assess problems that the company might encounter. Marshall is building 11 Saturn C-1 development vehicles, and will build at least one Saturn C-5 prototype.

• **Training and development** of young Marshall engineers so they can effectively discharge this managerial responsibility. It also is an attraction for recently graduated engineers who find the prospects of working on a hardware program more interesting than shuffling contract papers at a desk, and who might otherwise go to industry.

Von Braun and his assistants also are anxious to see that the experience gained in one program is applied to similar projects. For example, Marshall would like to save Douglas Aircraft Co. and Rocketdyne Division of North American Aviation, Inc., stage and engine builder respectively of the hydrogen-fueled S-4 stage, from some of the problems encountered by General Dynamics/Astronautics and Pratt & Whitney Division of United Aircraft Corp. in the development of the Centaur upper stage. Primary means of achieving this cross-fertilization, Marshall feels, is through its working groups.

Huntsville Budget

Huntsville, Ala.—Marshall Space Flight Center, largest of National Aeronautics and Space Administration's facilities in terms of employes and operating cost, is located on a 1,617-acre tract under permit from the Army at Redstone Arsenal. Fiscal 1963 operating budget request is $101.7 million, and employment, 6,480. Budget increase over Fiscal 1962 is about $14 million, and employment increase totals 490.

Plant value of Marshall is $99.2 million, and the center has requested a $33.4 million facilities expansion program for Fiscal 1963.

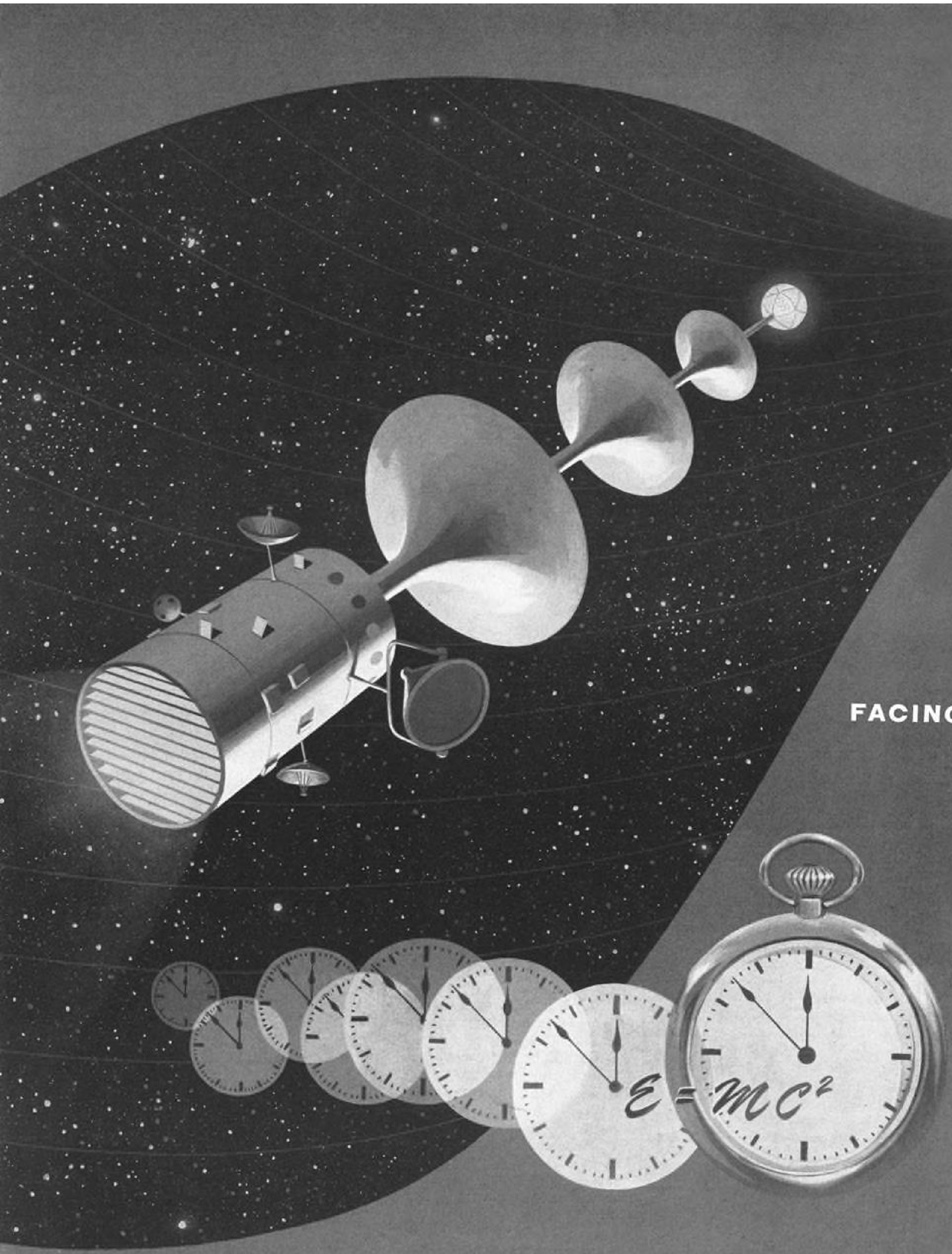
Marshall also manages the Michoud Plant near New Orleans, manufacturing site for S-1 and S-1C boosters. Michoud operating cost is included in the Marshall budget. This facility will have 6,759 employes by July, 1964, most of them industrial workers from Chrysler and Boeing, who will build the booster stages.

Michoud is located on an 825-acre tract, and has a Fiscal 1963 expansion program request totaling $34.5 million.

Closely tied to the Michoud manufacturing facility is the Mississippi test site, 50 mi. east of New Orleans, where NASA will occupy 141,950 acres to static-test Saturn and Nova class vehicles. Request has been made to construct facilities valued at $92.5 million during Fiscal 1963.



REACTOR In-Flight Test (RIFT) vehicle project will be managed from Huntsville.



FACING THE FOURTH DIMENSION IN PROPULSION DEVELOPMENT

Whether the universe has a "saddle shape," or any shape at all, is a matter of interesting conjecture. The matter of space travel, however, is the subject of intense experimentation. A nuclear/thermionic/ionic propulsion system, currently being studied at Lockheed Missiles & Space Company, might well become the power source for space vehicles.

Its design incorporates a nuclear reactor only one foot in diameter, generating heat at a temperature of 1850°K. This is transmitted to banks of thermionic generators, converting the heat directly into electrical energy for the ion beam motor which uses cesium vapor as a fuel. The entire system is designed without any moving parts, minimizing the possibility of failure.

Lockheed's investigation of propulsion covers a number of potential systems. They include: plasma, ionic, nuclear, unique concepts in chemical systems involving high-energy solid and liquid propellents, combined solid-liquid chemical systems. The fundamentals of magnetohydrodynamics, as they might eventually apply to propulsion systems, are also being examined. Just as thoroughly, Lockheed probes all missile and space disciplines in depth. The extensive facilities of the research and development laboratories—together with the opportunity of working with men who are acknowledged leaders in their fields—make association with Lockheed truly rewarding and satisfying.

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Rendezvous to Slash Apollo Target Time

Huntsville, Ala.—Rendezvous in space, which was not even an element of the U. S. space program a year ago, now is being counted on to help accomplish the Apollo lunar landing mission at least one year earlier than it could be done by direct ascent.

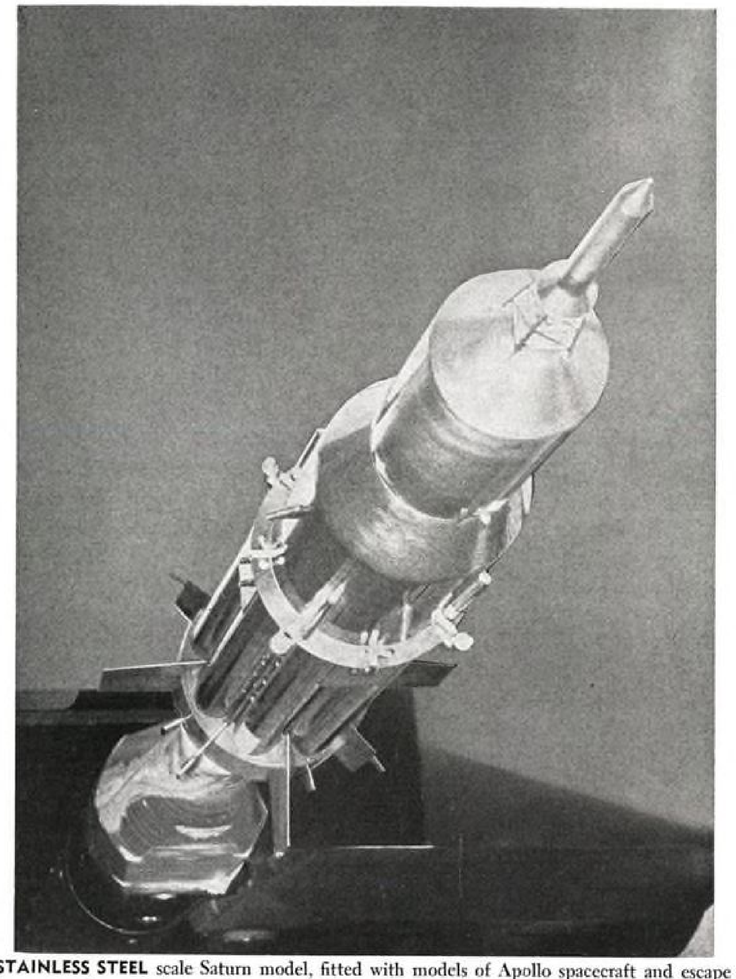
Rendezvous is considered an essential technique for the manned exploration of space, even if a direct ascent vehicle were available for the first lunar landings. It was first examined in great detail and advocated strongly for practical use in National Aeronautics and Space Administration programs by the Marshall Space Flight Center here.

Marshall first advocated—and still prefers—rendezvous in an orbit a few hundred miles above the earth for the Apollo mission. As rendezvous in a lunar orbit gained favor in recent months, Marshall—like other NASA centers and a number of companies—thoroughly explored this approach, modifying and adapting its initial ideas on vehicles and techniques as necessary.

Of several earth-orbit possibilities, Marshall most recently proposed the use of a tanker which would transfer propellant to the Apollo propulsion module in orbit prior to translunar flight.

Use of the earth-orbit method would permit checkout of the entire Apollo vehicle in near space before it was committed to the lunar flight. Lunar rendezvous, favored by the Manned Spacecraft Center, calls for use of a small two-man "bug" to descend from the Apollo, land on the moon, and rejoin the Apollo in orbit around the moon. It would shave some time—perhaps a year—off the timetable at the cost of landing two men instead of three.

Critics say the lunar method sacrifices some reliability by eliminating the checkout in orbit and requiring rendezvous 240,000 mi. away from earth. Proponents say it might be more reliable because it is in many ways less complex, requiring one launching from earth instead of two and giving the pilot a simpler spacecraft and greater control at the lunar end of his mission.



STAINLESS STEEL scale Saturn model, fitted with models of Apollo spacecraft and escape tower, has been wind tunnel-tested at Chance Vought to determine longitudinal stability from Mach 0.5 through Mach 5.

Earth-Orbit Method

In the tanking version of earth-orbit rendezvous, the Apollo vehicle would have this configuration:

- **R-1 first stage,** the "R" designating rendezvous, would propel the entire vehicle from earth-orbit into its lunar trajectory and be jettisoned after burnout. R-1 basically would be an S-4B upper stage modified with a male-type conical connector over its base for docking operations. It would be powered by one 200,000-lb.-thrust Rocketdyne J-2 liquid oxygen-liquid hydrogen engine.
- **R-2 second stage** would inject the Apollo into lunar orbit and then lower the spacecraft to the lunar surface. No contractor has been selected for this unit as yet.
- **R-3 third stage,** or service module, would contain both the lunar-take-off and earth-return propulsion system—now under development by the Aerojet-General Corp.—and some spacecraft subsystems.
- **Apollo command module,** carrying the three-man crew, now under development by North American Aviation, Inc.

R-1, about 80 ft. long and 220 in. in diameter, will go into orbit with a full load of liquid hydrogen and a nearly empty liquid oxygen tank. A small amount of liquid oxygen will be carried in the R-1's oxidizer tank to keep important plumbing at the proper chill level. Once in orbit, the R-1 would fill up its oxygen tank from the orbiting tanker.

The tanker, designated T-1, probably would be a spherical 220-in.-dia. bladder within a well-insulated conical airframe with a 33-ft.-dia. base. Design emphasis would be on storability of a cryogenic liquid. Base of the T-1 would be a female-type cavity to accept the R-1 docking mechanism and would mount small liquid-propellant engines for final velocity control and attitude positioning during the terminal rendezvous maneuver.

T-1 would be placed into an orbit of about 140 mi. by a two-stage (S-1C and S-2) Saturn C-5. After its orbital plot had been determined precisely, the Apollo vehicle (including the R-1, R-2 and R-3 stages) would be launched into a 261-mi.-high orbit, whose plane coincides at the moment of launch with the tanker's orbital plane. The Apollo would stay in this orbit until the difference between the orbital velocities of the two vehicles brought the tanker below; then the tanker's independent-hypergolic engines would be started to push the T-1 upward on an elliptic trajectory that would intercept the Apollo's path.

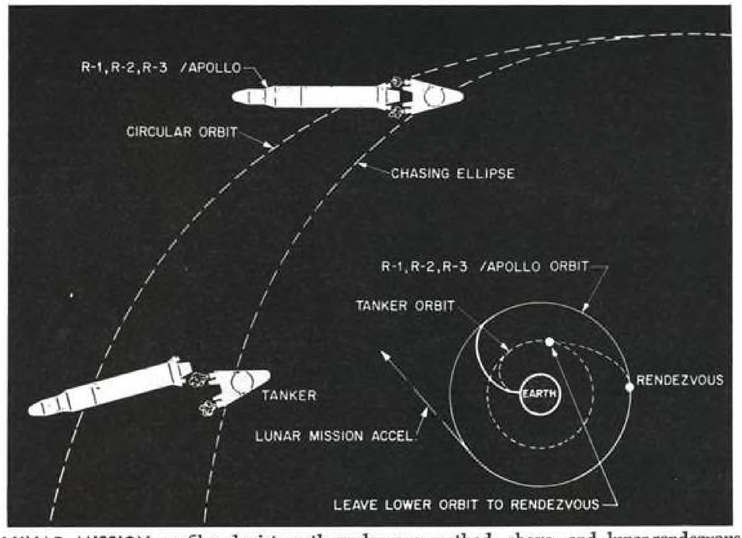
Final acquisition of the tanker, controlled by the Apollo crew, would begin at a distance of 25 to 50 mi. at an initial relative rate of about 200 fps. Terminal closure rate would be less than 1 fps., with the Apollo crew visually driving the R-1 into the tanker either by use of a periscope on the command module or a television camera mounted on the R-1 base.

The docking maneuver would join feed-lines between the R-1 and T-1 tanks; valves then would be opened and the liquid-oxygen expelled by high-pressure helium from the T-1's bladder tanks into the R-1.

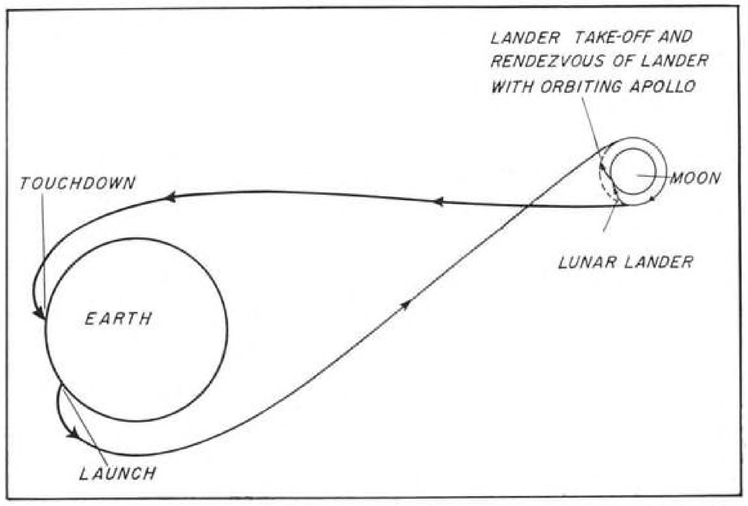
After propellant transfer had been completed, the entire docking structure —including that portion on the R-1— and the empty tanker would be jettisoned and kicked into a ballistic trajectory toward earth to burn in the atmosphere.

The Apollo, primed for translunar flight, would wait for the launch window—the optimum relative positions of earth and moon—and ignite its J-2 engine for the flight across space.

Rendezvous in earth-orbit, docking and propellant transfer would require development testing before it could be used operationally. Marshall has considered test flights using a Saturn C-1B vehicle. Tests would be concurrent with flight testing of the Saturn C-5 and development and training flights of the Apollo spacecraft.



LUNAR MISSION profiles depict earth-rendezvous method, above, and lunar-rendezvous technique, below, using Apollo manned spacecraft in each method.



Saturn C-1B

Saturn C-1B is envisioned as an intermediate vehicle between the C-1 and C-5; its configuration would be a Block-2 S-1 first stage and a S-4B second stage. Saturn C-1 uses either Block-1 or Block-2 S-1 first stages plus an S-4 second stage.

Test flights of the earth-orbit rendezvous and tanking mode, using C-1B vehicles, would approximate operational flights of C-5s, with these differences:

- **T-1 tanker would not be fully fueled,** but would carry only enough liquid oxygen to test the propellant transfer technique.
- **R-2 stage,** the lunar retro and descent module, would not be carried aboard the C-1B. Configuration of the Apollo, in this test program, would be an R-1 first stage, R-3 or service module as the second stage and the Apollo command module.
- **Flight plan,** after propellant transfer, would call for the R-1 to ignite and burn only for a short time, then shut down and separate from the R-3. R-3 then would be started, burn briefly, then shut down and separate. The Apollo vehicle would return to earth.

Marshall scientists estimate that four trials would be necessary to test the propellant transfer technique and to train Apollo crewmen.

S-1 booster should be man-rated by the time this test program would begin several years from now, but the S-4B would have to be certified as reliable for manned flight. Four flights now are being considered for man-rating the S-4B, as well as several missions that could be carried as bonus payloads aboard these unmanned flights—earth satellites, interplanetary probes or, by orbiting the entire S-4B with propellants still aboard, study of the thermodynamics of cryogenic liquids in space.

Initial order for C-1Bs could be 14—eight for the tests of the propellant transfer technique, plus two back-up vehicles, and four additional units for man-rating flights of the S-4B.

Tanking version of earth-orbit rendezvous, despite the complexities of propellant transfer, has been determined to be preferable to the connecting—or straight assembly—version. This latter method, one of the first types of rendezvous to be studied in detail, would orbit the fully-fueled R-1 stage as the payload of one Saturn C-5 and the combined R-2 and R-3 stages with the Apollo capsule as the payload of a sec-



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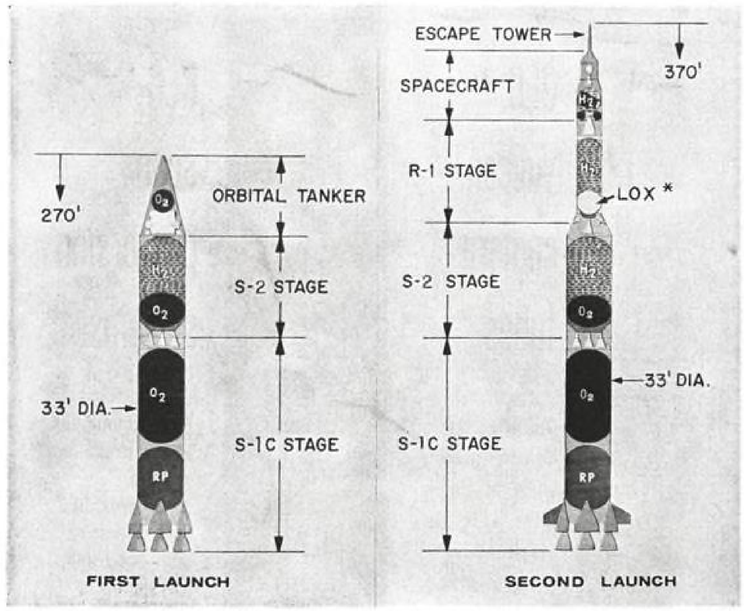
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ond C-5. The vehicles would then rendezvous, dock and assemble, preparatory to lunar flight.

But intensive study revealed the connecting version of rendezvous had some serious drawbacks:

• **Docking structure** between the R-1 and R-2 stages could not be jettisoned after the two payloads had been joined together. It would be a dead weight that would add nothing to performance. The docking structure also would have to be strong enough to take the thrust of the R-1's J-2 engine.

• **R-1 could not be insulated** as well as an orbital tanker designed specifically for that purpose and a considerable amount of liquid oxygen and hydrogen could be lost by evaporation if there was a lapse of several days between launches of the R-1 and the Apollo.

• **Weight limitations** imposed by the payload capacity of the Saturn C-5 would dictate modification of the R-1 and R-2 stages. The combined weight of the R-2 and R-3 stages, fully fueled, and the Apollo spacecraft now is estimated at around 150,000 lb.—well within the C-5's 200,000 lb. capability. Since the R-1 cannot exceed 200,000 lb. thrust, it could not push 150,000 lb. on an escape trajectory to the moon.

The R-2 stage could be enlarged, bringing the total weight of the R-2, R-3 and the manned spacecraft up to 200,000 lb., and could be ignited to give the vehicle the necessary escape velocity to the moon. It then would be shut down until the Apollo reached the vicinity of the moon, where it would be re-started to brake the vehicle's velocity down to the speed needed to sustain lunar orbit.

But some critics are leary of counting on seals in the R-2's propulsion system to last during the long shutdown period between engine starts, and they fear that the Apollo might arrive at the moon only to find that all propellants in the retro module had leaked out during the flight.

For these reasons, the tanking version appeared to offer fewer problems and it was selected over straight assembly.

Lunar-Orbit Method

Lunar-orbit mode of rendezvous would fly an Apollo vehicle from earth directly to the moon's vicinity aboard a single Saturn C-5. There the spacecraft would go into lunar orbit.

Lunar-orbiting vehicle would consist of a three-man Apollo capsule, a service module or R-3 stage and a two-man "bug," or lunar descent vehicle. The bug would be the only part of the entire system actually to land on the moon.

The bug would contain its own descent and takeoff propulsion system and, having no heat shield, could be designed with a helicopter-type bubble cockpit that would give the descending pilot a clear, direct view of the lunar landing area. Mercury pilots prefer this approach.

After exploring the moon, the pilot would re-board the bug and launch his small craft into an orbit coplanar with that of the mother spacecraft. He would rendezvous with the larger Apollo spacecraft and dock with the mother ship in one of two ways:

• **Hard docking**, in which the lunar descent vehicle would mechanically

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couple to the airlock at the top of the Apollo capsule. The pilot would return to the Apollo vehicle through the airlock, the bug would be jettisoned and the engines in the service module started for the flight back to earth.

• **Soft docking,** in which the bug would fly alongside the Apollo and a line would be thrown from one to the other. The pilot then would leave the lunar descent vehicle and, using the line, pull himself back to the mother craft.

Advantage of the lunar-orbit mode of rendezvous is a significant saving, in weight—total spacecraft weight, including the bug and the propulsion module, would run between 52,000 lb. and 70,000 lb. in growth forms.

Weight savings come in several areas. The bug would not have to carry the heavy Apollo heat shield, needed for earth re-entry, down to the moon and then lift it off again. This eliminates weight of a considerably larger propulsion system.

The mother craft's propulsion system would have an inertial velocity of 6,000 mph. with which to begin the return flight to earth, and therefore would require less weight for placing the Apollo spacecraft on the proper return trajectory.

Lunar Descent Vehicle

Marshall had suggested to the Manned Spacecraft Center that consideration be given to a lunar descent vehicle almost identical to the Apollo spacecraft, but lacking a heat shield. This big lunar descent vehicle would be abandoned on the moon after the landing had been achieved and the crew would return to earth in a small, rather cramped re-entry vehicle.

This concept was based on a liquid oxygen-liquid hydrogen propulsion system for earth-return flight, and for this very reason, Houston did not find the idea appealing. Manned Spacecraft Center wants immediate full-thrust response from the service module engines, because they serve a dual function: lunar takeoff and abort escape. This requirement is not compatible with a liquid oxygen-hydrogen system and so Houston favored pressurized, earth-storable hypergolic propellants.

Lunar-orbit rendezvous has the disadvantage of operating in a remote and inaccessible region, where little assistance can be rendered in the event of trouble.

In earth-orbit rendezvous, by way of contrast, the entire vehicle could be checked out prior to commitment to flight and, if difficulties appear, the crew would either return to earth or a support crew in another Apollo capsule could be launched into orbit to provide aid.

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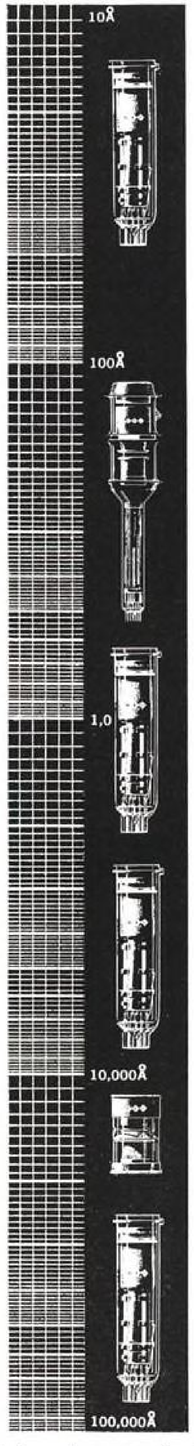


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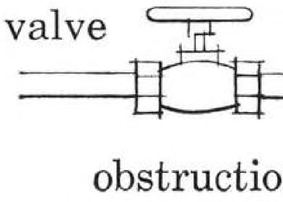


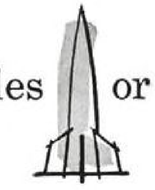
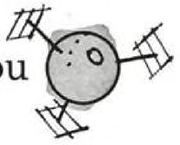
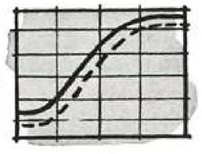
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Marshall Supervises Booster Development

Marshall develops or buys launch vehicles ranging in size from Thor-Agena to Saturns and Novas.

Huntsville, Ala.—Marshall Space Flight Center is responsible for the transport of most National Aeronautics and Space Administration payloads into space. It develops or buys a pool of launch vehicles ranging from light vehicles such as Thor-Agena to giant space trucks such as Saturn and Nova to fulfill this mission.

Cross-section of Marshall's work today shows the major emphasis being given to the development of the two Saturns—C-1 and C-5—and the Centaur upper stage. Nova, the super booster, and the nuclear-powered Rift stage, still are in the early design phases. Purchase and modification of already developed vehicles such as Thor-Agena and Atlas-Agena, is a continuing task.

C-1, which has been flight-tested twice to date, is the early model Saturn and will consist of an S-1 booster and S-4 second stage. Advanced Saturn, called the C-5, will have an S-1C first stage, S-2 second stage and S-4B third stage. An intermediate vehicle, the C-1B, now is under consideration (see p. 106). It would consist of an S-1 booster and S-4B second stage.

Engines for these stages also are being developed under Marshall's supervision. They are:

• **Liquid oxygen-kerosene burning** H-1 and F-1, built by Rocketdyne Division of North American Aviation, Inc. H-1s for the Block-1 S-1 boosters have 165,000 lb. thrust. For Block-2 S-1s, it is uprated to 188,000 lb. The F-1 generates 1.5 million lb. thrust and will drive the S-1C stage.

• **Liquid oxygen-liquid hydrogen burning** RL-10-A3, built by Pratt & Whitney, and J-2, built by Rocketdyne. RL-10-A3, the first liquid hydrogen engine developed in the U.S., generates 15,000 lb. thrust and will be used on the Centaur, S-4 and S-5 stages. J-2 is rated at 200,000 lb. thrust and is scheduled for the S-2, S-4B and R-1.

S-1C stage is to be built by the Boeing Co. under a five-year, $240 million contract and will be the first stage of the three-stage Saturn C-5 vehicle. Initial order calls for Boeing to deliver 24 flyable boosters, plus several ground test units, and probably will be amended to assign Boeing the role of C-5 system manager. Additional S-1C boosters undoubtedly will be ordered for the post-1966 period, but Boeing has no guarantee that it will receive the follow-on contract.

The S-1C, which Boeing will build at the NASA-owned plant in Michoud, La., will stand about 140 ft. tall and have a 33 ft. diameter. Construction will be of the longeron-and-stringer variety, with the horizontal rings protruding into the tanks to act as anti-slosh baffles. Unlike its 9-tank S-1 predecessor, the S-1C will have two integral tanks, one each for liquid oxygen and RP-1. Airframe skin will be chemically milled from 0.5-in. aluminum alloy stock to 0.25-in. or 0.125-in. thicknesses, depending on location.

Marshall Space Flight Center recently decided to cut back the S-1C's propellant capacity from 4.6 million lb. to 4.4 million lb. and to raise the capacities of the S-2 and S-4B stages by 30,000 lb. each. Idea was to add more punch to the upper stages. Given two launch vehicles of the same general configuration and approximate lift-off weight, the vehicle with the more powerful upper stages will deliver a greater payload in space.

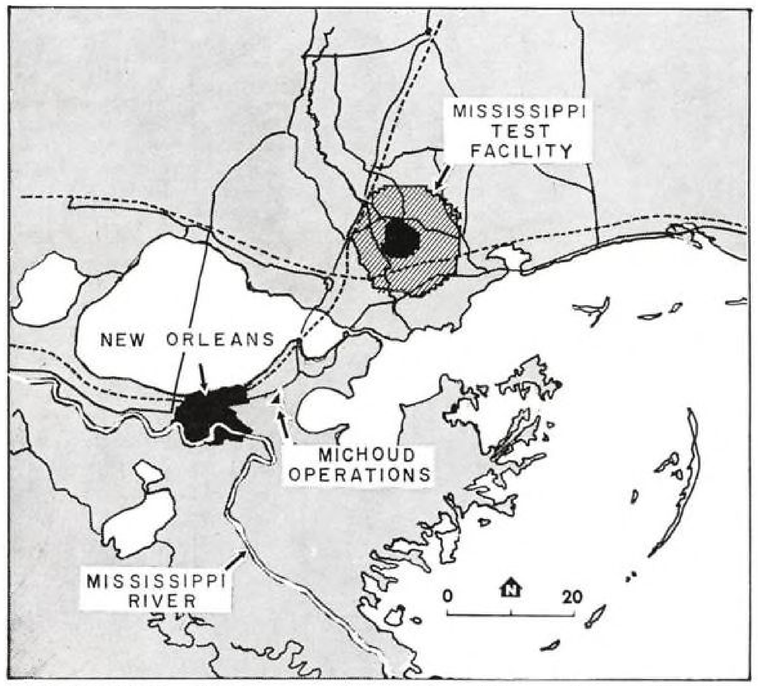
Boeing now has about 1,000 engineers and technicians, under George H. Stoner, working alongside Matthew W. Urlaub, chief of the S-1C stage office within the C-5 project office at MSFC, and his Marshall personnel on detailed engineering design. This work is near completion.

This month Marshall will begin building a 40- to 45-ft. tall mockup of the booster's boat-tail that can be checked against design work for interference among different lines and piping around base of booster.

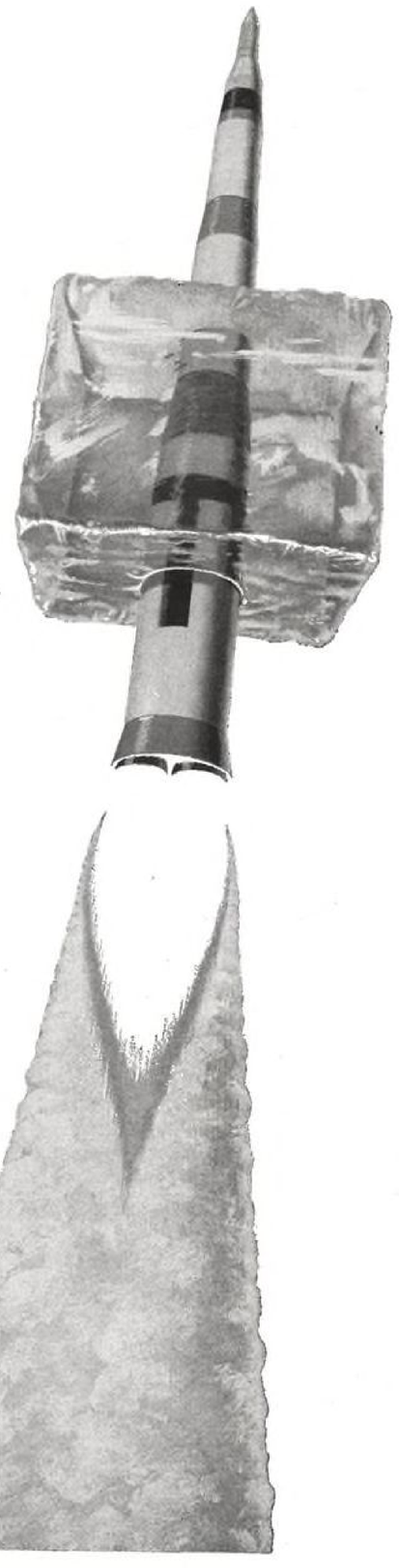
Using blueprints of the flight design and its own in-house manufacturing capability Marshall will build a non-flyable S-1C at Huntsville. It will be used as a static test firing unit and also provide Marshall with the experience of actually building an S-1C. It is expected to be as useful as the SA-T static test model of the S-1 stage, which has been fired here 23 times since April, 1960 for a total of 1,331 sec.

By using soft tooling and omitting some unnecessary items—such as stage separation rockets and perhaps fins—Saturn project officers expect to build this static test model six to nine months before Boeing rolls out its first booster from Michoud in 1963 or early 1964.

The first Boeing-made S-1C also will be a non-flyable booster. It will be used as a dynamic test model to determine



SATURN LAUNCH vehicles for manned lunar missions will be assembled at Michoud, La., near New Orleans and static tested at Mississippi site.



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Future Projects Office Pushes Nova

Huntsville, Ala.—Conversion of the Nova launch vehicle from a perennial study exercise to an actual hardware program is indicative of U. S. intentions to follow up the manned lunar landing project with a broad-gaged space exploration program.

Nova, soon to enter the detailed preliminary design phase of development with hardware contracts expected by the end of the year, will have a payload capability of about 200 tons in earth orbit and 90 to 100 tons on escape missions, approximately twice that of the Saturn C-5. NASA and Marshall Space Flight Center plan to use Nova's weight-lifting abilities after the first several manned lunar landings to haul materials and supplies to the moon in the buildup of a base there. Plans also are being made to make maximum use of Nova's abilities in earth-orbit rendezvous operations.

First stage of Nova, designated N-1, will be about 115 ft. tall and 50 ft. in diameter. It will be powered by eight Rocketdyne F-1 engines, for a total stage thrust of 12 million lb. Second stage, N-2, also will be about 115 ft. tall, but will have a 40-ft. dia. The N-2 will be powered by four M-1 engines, the new liquid oxygen-liquid hydrogen 1.2 million lb. thrust powerplant to be developed by Aerojet-General Corp. Stage thrust of the N-2 will be 4.8 million lb. Third stage, N-3, will be 82 ft. tall and 22 ft. in diameter and will be driven by a single J-2 engine of 200,000-lb. thrust.

All of the work done to date on Nova has been accomplished by MSFC's Future Projects Office, using in-house working groups and contractors.

Future Projects, under Director Herman Koelle, primarily is responsible for the development and evaluation of concepts leading to advanced systems and future launch vehicles—from a non-rotating space laboratory and orbital launch facility to a super booster, tentatively labeled Orion, with a 1,000-ton payload capability.

The office carries an idea, whether generated within MSFC or by some outside agency, through the phases of feasibility and preliminary design down to the point of seeing the concept become a hardware project office. Frequently, those Future Projects personnel who have been closest to the development of the concept leave that office to establish a project office when the idea becomes an approved program. Francis L. Williams, deputy director of Future Projects, has been directing the Nova studies for several years now and is expected to become director of the Nova project office.

But for every MSFC in-house study, there are four contracted efforts with industry. During Fiscal 1963, Future Projects expects to award between 20 and 25 study contracts from a list of about 40 identified areas of interest, ranging from vehicle subsystems (such as a design manual for electronic systems of advanced launch vehicles) through future launch vehicles (such as the Orion) to lunar base concepts (such as a shelter for the first Apollo crew).

Funds to be spent this year by Future Projects probably will run between $5-$8 million. Only about 5% of this money will be spent for hardware and that for experimental verification of a particular idea or technique.

Studies are an essential element of the work of the project offices and support divisions and are centrally handled by the Research Projects Division under Dr. Ernst Stuhlinger. Engineers in projects and divisions are asked at the beginning of each calendar year to identify the items they feel require research—of an applied, not basic, nature. On a standard form, an engineer describes the work he would like to have done, estimates the cost and suggests one or more contractors capable of doing the study.

This research request is screened by the initiator's immediate superior and then passed up to the project director division chief. If the request survives this screening, it is then forwarded to Research Projects, which makes another review, comparing it with known research efforts going on in other NASA centers or government agencies. Research Projects then either approves the request or returns it to the initiator's office with appropriate comments or suggestions.

All MSFC research requests are compiled in a book with a total dollar figure and then forwarded to NASA headquarters for inclusion in the NASA budget request for the next fiscal year. Whatever money Congress allots to NASA is returned to Marshall and Research Projects apportions funds to as many requests as possible, using priorities jointly accorded the requests by Research Projects and the project office or division concerned.

Bids then are solicited, a competition held and an award made, based on standard NASA procurement policies. Originator of a request is responsible for the technical management of a study contract based on his request.

This year, Research Projects asked for about $20 million for 350 research requests. Last year, the division asked for about the same amount of money but received only $10 million in the NASA authorization. It is felt that the pattern will repeat itself this year.

Chief of the Physics and Astrophysics Branch in Research Projects Division, Dr. Charles A. Lundquist, last year initiated Project Highwater—a study of the ionosphere through its effects on a large quantity of water deposited in it.

On the flight of Saturn SA-2 last April, the 95 tons of water carried in the dummy S-4 and S-5 upper stages as ballast were explosively released at an altitude of about 65 mi. Purpose of the experiment was to see how quickly a patch of the ionosphere built up after disruption, what the wind characteristics and diffusion rates are at that altitude and the effect of the water—which quickly turned to ice—on the region's radio reflectivity. Data derived from this experiment still is being processed and analyzed.

Research Projects plans to repeat Highwater on another Saturn flight, probably SA-3, which is scheduled to fly later this year. Consideration now is being given to the addition of chemicals in the water so as to either enhance or sharply reduce ionization levels between 100 and 150 km. altitude.

bending moments and vibration modes. It also will be a dry run for Boeing's production line and, according to Marshall engineers, a test of the company's manufacturing and quality control processes.

S-1C will use five F-1 engines for first stage thrust of 7.5 million lb. Four gimbaled engines will be located 90 deg. apart around the circumference of the base. The fifth, at the center, will be rigidly mounted.

S-1C will have four fins around its base, like the Block-2 S-1 stage, for aerodynamic stability. Short, airfoil-shaped fairings between the fins will house liquid hydrogen dump lines from the upper stages. To preclude the possibility of liquid hydrogen boil-off running down the side of the launch vehicle and perhaps mixing explosively with the frost formed around LOX tanks, the hydrogen will be piped down along the outside of the C-5 and ported at an angle away from the S-1C's base.

Chrysler Corp. won a $200 million contract last November from MSFC to build 20 S-1 stages at the Michoud plant. Company also is expected to become system manager for C-1 launch vehicle, as Boeing may for C-5.

S-1 consists of a central 105-in. dia. tank containing liquid oxygen and eight outer tanks, each 70-in. in diameter, alternately holding LOX and RP-1. The five liquid oxygen tanks are pressurized by gaseous oxygen and the fuel tanks by high-pressure nitrogen. All tanks are interconnected so that equal amounts of fuel and oxidant are consumed if one engine fails.

Marshall is building the first eight



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Rift System to Be Mated on Launch Stand

Huntsville, Ala.—Airframe and engine of the Rift (reactor in-flight test) system will be mated for the first time on a launch stand—and not on a production line as is conventional—as these two major elements of the first U.S. nuclear-powered stage follow physically separate and distinct development programs.

Marshall is responsible for all parts of the Rift stage except the engine. Lockheed Missiles and Space Co. holds a first-phase $6.5-million contract from MSFC for design of Rift and, next May, will begin fabrication, development and testing of Rift vehicles under what is expected to be a $180 million program. Rift will be powered by the Nerva (nuclear engine for rocket vehicle application) engine.

Col. Scott Fellows, USAF officer on loan to NASA, is the director of MSFC's Nuclear Vehicle Project Office within the Propulsion and Vehicle Engineering Division. This office may become an independent project office—like Saturn Systems or Light and Medium Vehicles—especially since consideration now is being given to using an operational Rift stage on Nova as well as on Saturn C-5. Rift is scheduled to make its first flight around 1966-1967 as the third stage of a C-5 vehicle.

Lockheed will build separate production lines of flight and ground-test Rift stages. Eleven of the approximately 85 ft. long, 33 ft. diameter stages are planned under the present contract:

- Three battleship models, with one of these shipped to Aerojet for engine tests.
- Three static and one dynamic test models for use at the Nuclear Rocket Development Station at Jackass Flats, Nev.
- Four flight test vehicles, to be flown from Cape Canaveral, Fla.

First flight of Rift will be made with an inert Nerva engine. Second flight will be the first powered flight of Rift, with a live nuclear reactor flown into Cape Canaveral and mated to the airframe in a vertical assembly building. This first flyable Rift will be flown line-of-sight from the Cape in an almost straight-up and straight-down trajectory to provide the maximum telemetry time—about 10 min.

Rift will not be built at the present NASA-owned Michoud, La., plant because the S-1 and S-1C production lines will utilize all existent space. Plans now are being considered to add another high-bay area to the Michoud facility to accommodate Rift production or to build a completely new plant to house Rift and Nova stages.

S-1s, designated SA-1 through SA-8, at Huntsville. Chrysler will build SA-9 as a dry-run test of its manufacturing procedures and then Marshall will construct the last research-and-development booster, SA-10. Chrysler then will build the 20 units called for in its contract.

First two Saturn boosters—SA-1 and SA-2—flew successfully last Oct. 27 and Apr. 25, respectively. Both were three-stage vehicles, as SA-3 and SA-4 also will be, but the second and third stages—S-4 and S-5—were and will be dummy stages filled with water for ballast.

Block-2 models of the S-1 booster will be introduced into the flight test program starting with SA-5. Block-2 version of the S-1 differs from Block-1 model, used on SA-1 through SA-4, in the following ways:

- **Up-rating of the H-1** engine from 165,000 lb. thrust to 188,000 lb.
- **Increased engine gimbal capability** from Block-1's ±7 deg. to ±10 deg. on Block-2.
- **Increased propellant capacity** from 750,000 lb. on Block-1 to 850,000 lb. on Block-2.
- **Addition of stabilizing fins** to the Block-2 booster.

Also starting with SA-5, the Saturn C-1 will change to a two-stage configuration, using the S-1 (Block-2) booster and the Douglas S-4 second stage. SA-5 will be the first powered flight test of the S-4, and will be the critical test of the guidance and control system which is based on components drawn from the Army-Martin Pershing ballistic missile.

SA-5 will carry the first unmanned Apollo spacecraft and flights SA-6 through SA-10 will continue to test both the Saturn booster and the three-man spacecraft in earth-orbit flights.

North American's Space and Information Systems Division was selected last September to build 10 S-2 stages under an initial contract totalling $140 million.

Originally, the S-2 was conceived as a 21.5-ft. dia., 74-ft. long stage to be powered by four J-2 engines, for a total stage thrust of 800,000 lb.

But when Marshall and NASA decided last January to use five F-1 engines in the advanced Saturn booster, the S-2 was modified to make it more compatible with the first stage. Diameter was increased to 33 ft., same as the S-1C. Length was stretched to 80 ft. and a fifth J-2 engine was added to provide a total stage thrust of 1 million lb. The S-2 has a propellant capacity of 930,000 lb.

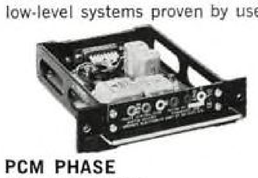
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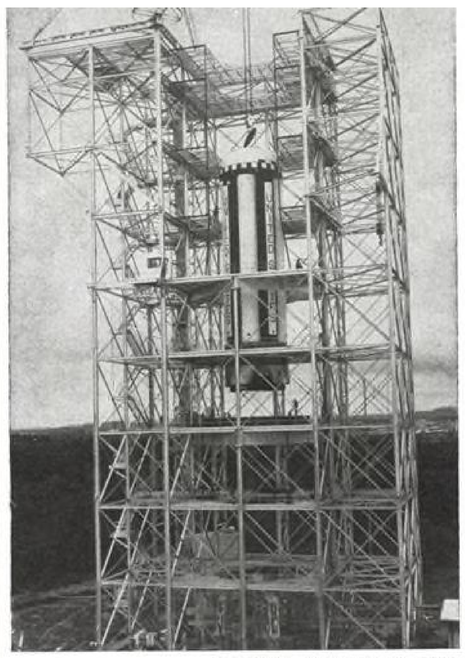
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SATURN DYNAMICS TEST

will be constructed in vertical jigs at North American's Seal Beach, Calif., facility. The company now is making structural modifications to the plant to allow it to accept the 80 ft. high stage.

S-4 and S-4B Stages

Contract for 10 S-4 stages was awarded to Douglas Aircraft Co. in May, 1960. The S-4B—for which Douglas is expected to receive a contract shortly—grew out of a six-month feasibility study done by Douglas as a task assignment under the S-4 contract.

Both S-4 and S-4B have a 220-in. diameter, but the S-4B is about twice as long as the 41-ft. S-4. The S-4 will be the second stage of the C-1 Saturn; the S-4B will be third stage of the C-5.

Originally, the S-4 was to have been powered by four LR-119 liquid oxygen-liquid hydrogen engines, rated at 17,500 lb. thrust each, for a total stage thrust of 70,000 lb.

In March of 1961, NASA and Marshall decided to substitute six 15,000 lb. thrust RL 10 A3 engines for the proposed uprated units. Total stage thrust now is 90,000 lb. Propellant capacity is about 100,000 lb.

The S-4B will be powered by a single J-2, producing 200,000 lb. thrust. Propellant capacity is about 230,000 lb.

Marshall had considered using a third stage—the S-5—on the Apollo Saturn C-1, but decided against it when studies showed the stage would not add enough to over-all vehicle performance to compensate for its weight. S-5 is a Centaur stage modified for use aboard Saturn. It may see service several years from now on a three-stage Saturn C-1

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A look over the transom at General Electric

FUEL CELLS

JULY, 1962

ABOUT THIS SERIES. Things are happening with G-E fuel cells. Looking back on our half-dozen years of developing these power sources that generate electricity directly from a chemical reaction, the progress is enormous. We could write books—(in fact there are two of a progress report flavor already available; yours for the asking*)—but fuel cells are such a new and promising technology that this is hardly the stage at which to tell all. That's why, for now, we'd rather limit the world to monitored glances through our laboratory transom. But we'll be appearing regularly with newsworthy highlights, and hope you'll tolerate an occasional note of enthusiasm that may enliven our technical talk.

■ A MILESTONE AND WHAT'S BEHIND IT

In fuel cell R&D, as in any fastmoving technology, success is checkered with the kind of building blocks that many of us like to call milestones. We had one recently, when a G-E ion-exchange membrane cell logged its 2000th hour of continuous 100-amp/ft² operation at 0.7 volt. It was a gratifying moment and, just for fun, we used it as an excuse to spot-inventory the six years of work that led up to it. Here are some of the things we catalogued. We counted up having worked with:

50 cell construction designs
30 ion exchange electrolytes
100 experimental electrode designs
6 classes of fuel compounds
12 cell assembly methods, and
15 operating hardware designs

And other engineering almanacs showed, with a little computation, that

385,000 hours of engineering hardware test are now behind us, including 200,000-plus cell-hours of life test.

Now obviously the sum total of all this is far, far greater than the mere success of a 100-amp/ft² test cell. (Our Progress Report GEA-7538 has eight pages about other milestones. Copies, unlike fuel cells, are available "off-the-shelf" if you'd like to drop us a card.) Among other landmarks, for example, we have found ways of packaging the ion membrane fuel cell to provide impressively high power density per unit *volume*. The 100-amp/ft² cell represents an output of over two kilowatts per cubic foot, a respectable yield in any man's language. But we find especial reassurance in the 100-amp cell for another reason. Together with its 150-amp/ft² (more than 3 KW/ft³) offspring that's now undergoing early tests, it conclusively dispels any of the old doubts that ion membrane cells, even though compact and uncomplicated, could escape their suspected handicap of low power density.

As to why this success . . . well, we suspect our competitors tend to read magazines too. So for the moment details of the "whys" (as well as of some additional "whats" that we've frankly yet to learn) will have to remain behind closed doors. However, we will say this: it's done with new ion membranes. May we leave it at that for now?

■ WATTS WITH FUEL CELLS FOR GEMINI

Optimism and workload are both at a high level since our recent selection by McDonnell Aircraft Corporation to furnish fuel cell power for NASA's Gemini spacecraft. The Gemini project was welcomed into our fold with measured modesty, because this purports to become history's first truly functional application of a fuel cell.

The G-E system will weigh less than an astronaut, and will deliver a peak output of almost two kilowatts while the two-man spacecraft is in orbit.

Gemini's ion-exchange membrane fuel cell battery, (about which we'll have more to say later in this series), will provide all electrical power for the spacecraft as well as potable drinking water needed for the astronauts' projected two-week trip.

Meanwhile, via the USAF Project HOPE program, we have initiated space-environment ground tests on a generally similar 50-watt system that we will soon see into extended orbit to confirm the concept.

■ ENLISTING HYDROCARBON COOPERATION

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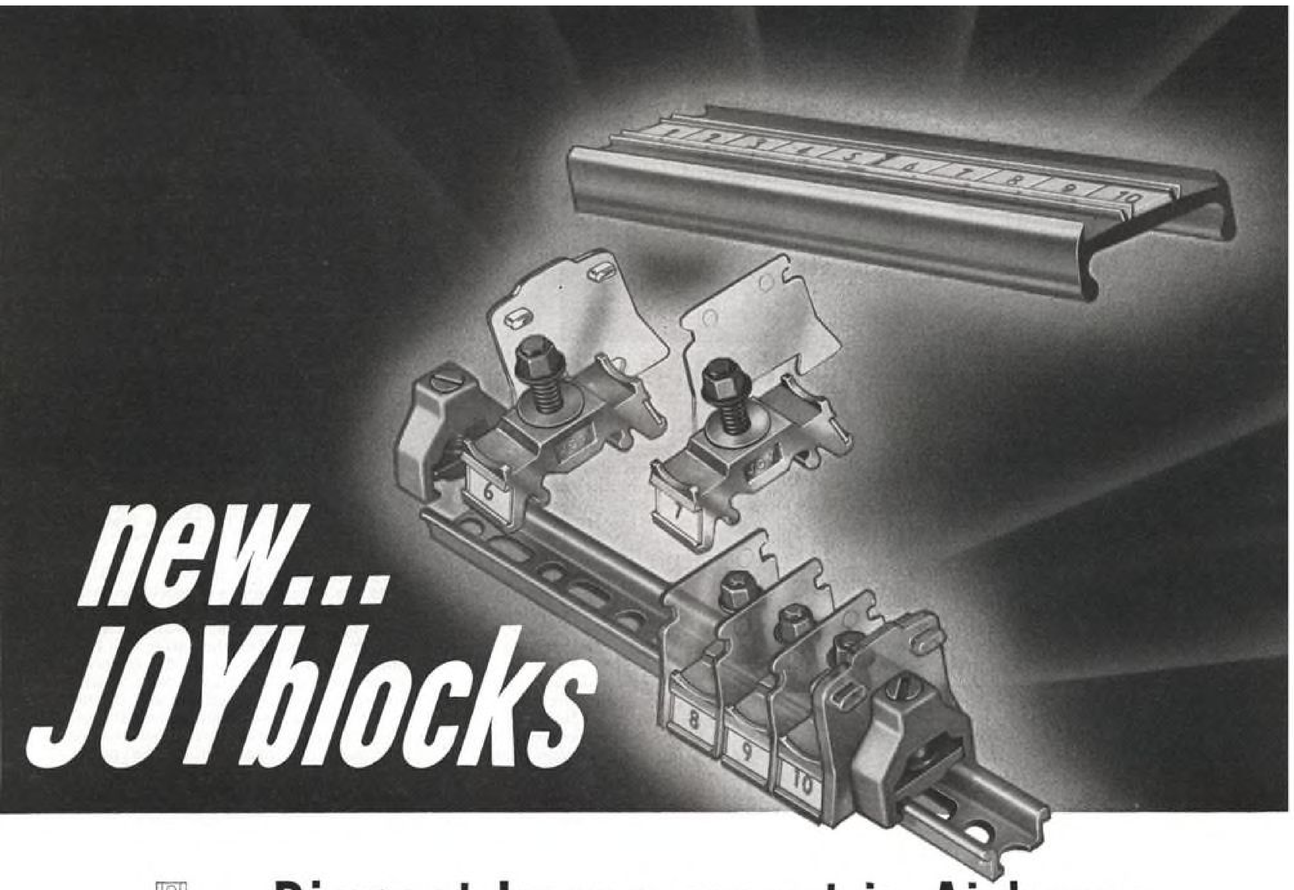
The plan of attack is a complex one: an ambitious mix of solid state theorizing and practical investigation of highly active electrode structures. We have eight PhD's on it full time. Their tools-of-trade are platinum plated.

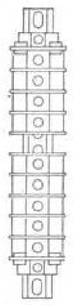
* Bulletins GED-4111B (Some Plain Talk About Fuel Cells), and GEA-7538 (Fuel Cell Development Progress at General Electric). For copies, drop us a line at General Electric Company, Section B183-08, Direct Energy Conversion Operation, 950 Western Ave., Lynn, Mass.

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for some unmanned satellite and interplanetary probe missions.

NASA and Marshall inherited the Centaur program from USAF with something less than wild enthusiasm. Despite development problems and a first-flight failure last March which have added 18 to 24 months to its original schedule, Centaur appears to be coming out of the development woods, and Marshall officials—including Wernher von Braun—have publicly defended it.

Hans Hueter, director of light and medium vehicles project office, says that present Centaur problems do not look any more serious than those encountered in other new programs.

Hueter has established a series of working groups—in such areas as structures, guidance and control, propulsion and launch countdown procedures—with personnel drawn from Hueter's own project office, from Marshall support divisions and the two prime contractors—General Dynamics/Astronautics for the stage and Pratt & Whitney for the engines.

Agena-D

Unlike Centaur, where Marshall deals directly with General Dynamics, Marshall's prime contractor for its Agena program is USAF's Systems Command and the actual builder of the stage—Lockheed Missile and Space Co.—technically is a subcontractor to USAF. All changes desired by Marshall in the basic Agena are passed to USAF, which in turn directs Lockheed to make the changes.

Marshall is looking forward to the Agena-D, which will have the same configuration and propulsion system as Agena-B, but a sharper separation of carrier vehicle and payload. The B, developed primarily for USAF's Midas and Samos programs, has different mission systems and subsystems scattered throughout the stage and these must be modified before NASA payloads can be mounted effectively.

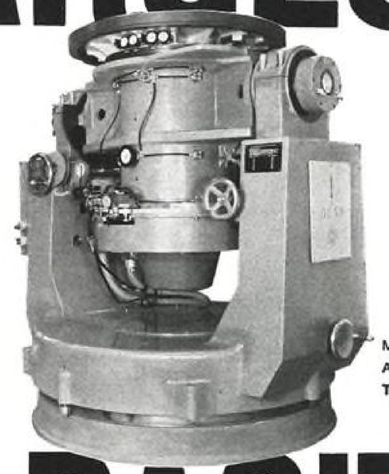
All electronics on Agena-D are the latest modifications of B equipment and are more accessibly located on the stage's basic structure. For example, the guidance system now is modularized and can be reached through a single panel. These changes have added some weight to Agena-D, but the vehicle project office feels that the cleaner layout of systems and greater accessibility more than compensate for it.

NASA has firm plans to use both the B and D models through at least 1965.

Marshall, in conjunction with USAF, presently is looking for an inexpensive, standardized upper stage for small payloads that would be available around 1965-1966. Whether it will be a modi-

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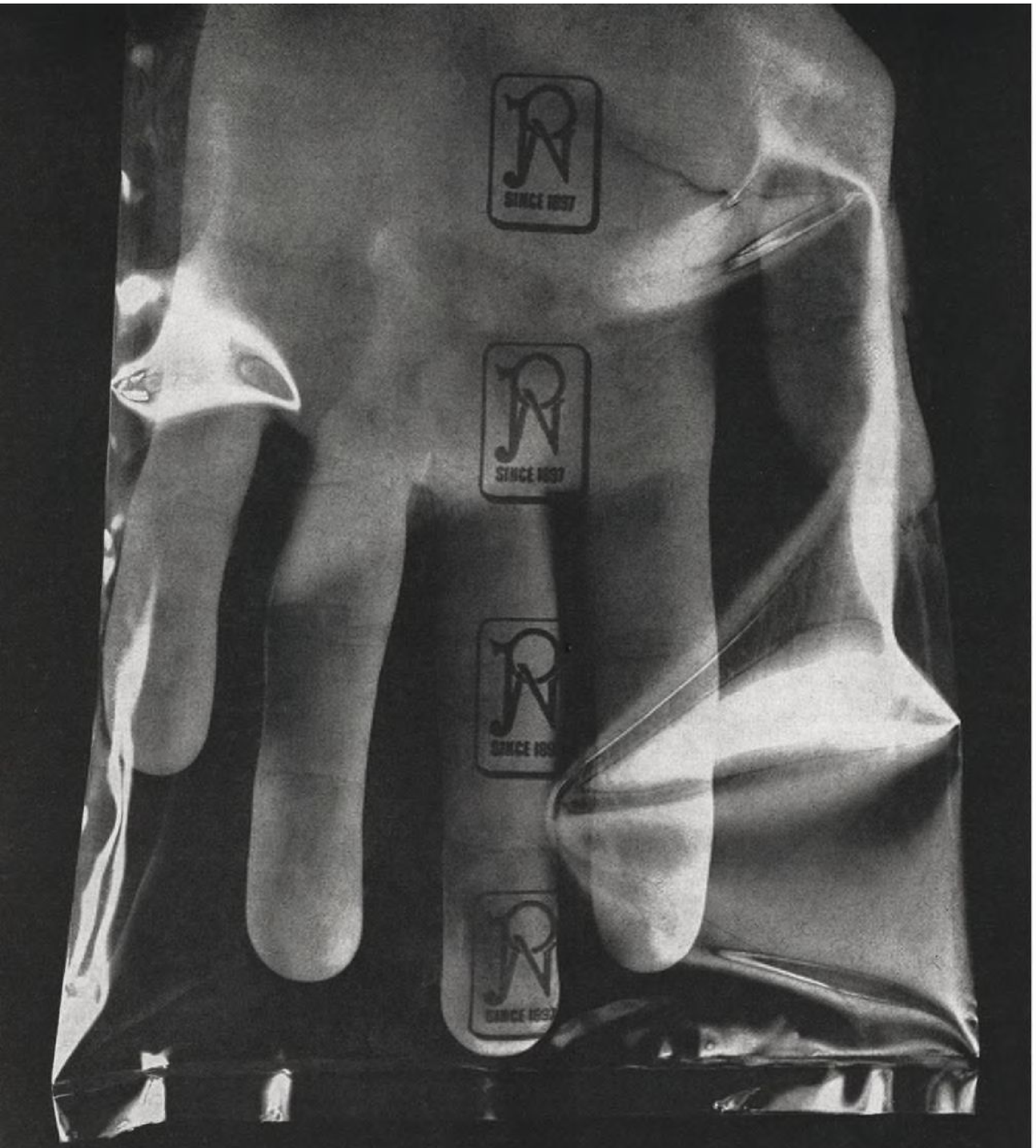
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fied Agena or a Centaur atop an Atlas or a Titan, Marshall feels strongly that there is a requirement for a more economical vehicle in the years to come.

All NASA centers have been laying stringent reliability requirements on contractors during the past year and Marshall has been no exception. Unlike military booster programs, where a reliability figure of 75 to 80% might be acceptable, Marshall is seeking almost a 100% guarantee that a launch vehicle will work when called upon. Hardware is getting too big and too expensive to afford failures.

Marshall's director, Wernher von Braun, says that reliability has three major components:

- **Inherently reliable design.**
- **Constant striving** on all levels of the contractor's organization to achieve perfection. Past performance in this area will be a critical element in the awarding of future contracts.
- **Establishment of manufacturing** procedures and development of checkout equipment.

Marshall has a Quality Assurance Division whose job it is to design automated checkout systems and to analyze all electrical, pneumatic, hydraulic and mechanical systems intended for any booster. The center also has a Reliability Office, which ties in closely with the Saturn Systems and Light and Medium Vehicles Project Offices.

Saturn Guidance

Guidance and control systems for the Saturn C-1 and C-5 will be made chiefly by Marshall, using components drawn from the Jupiter and Pershing ballistic missile systems.

The Astrionics (formerly Guidance and Control) Division presently is developing two all-inertial systems, including sensors and flight controls, for the following:

- **Saturn C-1**, for the first five or six flights of the Block-1 S-1 booster—SA-1 through SA-5 or SA-6. This system employs components taken from the Jupiter missile and mounted on a modified platform.
- **Block-2 Saturn C-1** and Saturn C-5. This system, intended to be the guidance and control unit of operational Saturn vehicles, is based on accelerometers, gyros and leveling pendulums drawn from the Pershing weapon system. These will be mounted on a four-gimbal platform with 360 deg. freedom in all planes; it is being built by Eclipse-Pioneer Division of Bendix Corp. Platform's full-circle freedom is designed to give Saturn a maneuvering capability for rendezvous operations.

Pershing components will be flight-tested on an open-loop basis aboard Saturns SA-3 through SA-6, but—if proved successful by SA-5—may be assembled into the complete unit to re-

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3. Pour Point†	-160°F.
4. Viscosity-Temperature Coefficient*	0.54
5. Specific heat	0.34 cal/g.
6. Coefficient of Expansion** (average, 25-75°C.)	11.1 x 10⁻⁴
7. Specific gravity (25°C/25°C)	0.961
8. Volatility (2 g. sample—24 hrs. in air at 150°C.)	5.6 wt-%
9. Flash Point (COC)	345°F.
10. Dielectric Strength (KV with 0.1" gap)	38
11. Dielectric Constant @ 25°C. (ASTM D-924-49) 10³-10⁶ cycles	2.75
12. Dissipation Factor @ 25°C. (ASTM D-924-49) 10³-10⁶ cycles	0.0001-0.0003
13. Volume Resistivity (ohm-cm) (ASTM D-1169-54T) 25°C. at 500 v.d.c.	1.2 x 10¹³

†Modified ASTM test **cc/cc/°C.

*V.T.C. = $\left(1 - \frac{\text{V @ 210°F.}}{\text{V @ 100°F.}}\right)$

QUALITY—ALWAYS!

A fluid of this nature is called for in heat exchange devices, electrical systems, hydraulic systems, liquid springs, and other devices that must operate between -50°F and -100°F. *And* UNION CARBIDE *low viscosity L-45 Silicone Fluids are the best fluids of this nature.* They are fluid at these temperatures, and therefore pumpable; they have low volatility, and therefore are useful at higher temperatures, too; and they are uniform in their properties. UNION CARBIDE is the quality leader in silicones, and high reproducibility of properties is one reason why. This reflects the extreme quality control measures which have made, for instance, our organo-silicone surfactants the standard of the polyurethane foam industry, and our transistor-grade trichlorosilane the optimum basis for producing ultra-pure silicon. Here, it is demonstrated by the fact that 7 cstk. L-45 silicone fluid is the first of this viscosity to be considered for certain critical military applications where reliability is essential!

Another such application is as a heat-exchange medium for an electronic counter-measure device in the B-52 bomber. The UNION CARBIDE fluid is pumpable at the low temperatures encountered at high altitudes, and stable in contact with the heat of the device. The plane's safety depends upon the counter-measure device; the reliability of the device depends upon the fluid. The fluid is UNION CARBIDE L-45, 20 cstk., which has a flash point of greater than 400°F. and a pour point of about -100°F.



Remarkably stable silicone fluids enable planes and electronic equipment to operate successfully in the Antarctic despite sub-zero temperatures.

ELECTRICAL GRADE? ALL OF IT

In the early days of silicone manufacture, a special electrical grade fluid had to be produced. But UNION CARBIDE has found it no longer necessary to market a special product. Instead, all L-45 fluids are now electrical grade, with the result that recently a large manufacturer of electronic equipment found, after his own exhaustive testing, that our regular fluid was significantly freer of impurities than specially prepared "electrical grades" of other manufacturers. This holds true, also, for these low-temperature, low-viscosity fluids. The outstanding electrical properties of L-45 silicone fluids make them ideal as insulating and cooling mediums in capacitors, small transformers, circuit breakers, and other electrical devices. And at very low temperatures, a low viscosity silicone fluid is absolutely essential. The data in the accompanying table give the actual facts and figures.

SEE YOUR SILICONES MAN

UNION CARBIDE is the leading innovator in silicones technology. Breakthroughs such as these consistent and reproducible low-temperature fluids are constantly developing. One reason for this is the great resource of technical capacities available within UNION CARBIDE CORPORATION—in this case, the world's finest low-temperature laboratories and scientists made their contributions. To find out what's being done in silicones today (and tomorrow), contact your Silicones Man. He represents thousands of scientists and their coordinated abilities. Send in the coupon below for further information.

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Michoud Plant, Mississippi Test Facility

National Aeronautics and Space Administration's Michoud, La., manufacturing plant and the Mississippi Test Facility are extensions of the Marshall Space Flight Center and key installations in the development program for large launch vehicles.

At Michoud, about 15 mi. north and east of New Orleans, Boeing will build the S-1C booster for the Saturn C-5 vehicle and Chrysler Corp. the S-1 first stage for the Saturn C-1—both under the same roof. Support services for the plant, which has about 1.8 million sq. ft. of manufacturing space and a clear working height of 40 ft., will be provided Marshall, Boeing and Chrysler by the Mason-Rust Co. S-1C will be built vertically and the plant will have to be modified to accept the stage's 140-ft. height.

The plant is expected to have a capacity of one booster per month. It stands on 825 government-owned acres. There is a possibility that an additional high-bay structure will be built for construction of the Rift (reactor in-flight test) nuclear-powered stage. The plant has a 5,500 ft. long airstrip and a canal link to the Mississippi River-Gulf outlet. S-1C and S-1 stages will be barged from Michoud to the Mississippi Test Facility and Cape Canaveral.

Marshall now has a resident staff of 35 people, under Dr. George Constan, stationed at Michoud with about another 25 scheduled to be assigned there by the end of this year. Boeing, Chrysler and Mason-Rust personnel are expected to reach close to 7,000 by mid-1963.

NASA has stipulated that the stages of launch vehicles be built at government-owned plants so that the agency can evict a poor-quality contractor and bring in a replacement with minimal interruption in production schedules. No contractor—Boeing for the S-1C, Chrysler for the S-1, North American for the S-2 and Douglas for the S-4 and S-4B—has an iron-clad guarantee that he will receive a follow-on contract for additional units of the stage he is building now. Future work, Marshall has made clear to contractors, depends on present performance.

Mississippi Test Facility is an adjunct to Michoud. Present plans are to construct these stands initially:

- Two acceptance stands for the S-1C booster. These stands will closely approximate the propellant loading, pressurization and other systems to be found in the future Saturn C-5 launch stands at Cape Canaveral.
- Two acceptance stands for the S-2 second stage.

Future planning now envisions the addition of these stands:

- One acceptance and one research-and-development stand for the N-1 booster of Nova.
- One acceptance and one research-and-development stand for the N-2 second stage of Nova.
- One F-1 and one M-1 single-engine stand located, respectively, near the N-1 and N-2 stage stands. These engine stands will allow the stage contractor to check various elements of his stage design using only one engine instead of eight (the number of F-1s in N-1) or four (number of M-1s in N-2).

Consideration also is being given to construction of a cold-flow stand for the Rift stage and the conceptual S-1B booster—an S-1 stage with one F-1 engine replacing the cluster of eight H-1 powerplants.

Stands will be located in the middle of the NASA-owned 13,550-acre reservation and exhausts probably will be deflected toward the northeast where the surrounding area is least inhabited and the noise problem should be less. Encircling the approximately 5-sq.-mi. test area is an easement area of about 128,400 acres. Area is in the southwestern-most corner of Mississippi, about 50 mi. from Michoud.

Within the test area, there will be a considerable support area, including offices, warehouses, shops, etc. Firm of Sverdrup & Parcel holds a contract from Marshall for studies of rail access, propellant requirements, industrial water supplies, canal utilization, data processing and transmission and safety.

place the Jupiter system as the primary guidance unit on SA-6. It will control all Saturn C-1 and C-5 flights thereafter.

In addition to the platform, the Pershing system adapted for Saturn substitutes an International Business Machines (IBM) digital computer for the weapon system's analog unit. Almost identical to the one built by IBM for USAF's Titan 2 ICBM, the computer has a 4.5 in. diameter magnetic drum memory with a 100,000 bit capacity. It will fly for the first time aboard SA-5.

Entire guidance system, along with telemetry and communications equipment, will be contained within an instrument unit 220 or 260 in. in diameter and about 5 ft. deep. This unit will be inserted between the top upper stage (S-4 on C-1 flights; S-4B on C-5 vehicles) and the payload.

Autopilot Function

Autopilot function of the system will be derived from attitude sensors, a small analog control computer and the gimbal-actuators of the engines. Sensors are resolvers mounted on the gimbal rings of the gyro-stabilized platform and provide pitch, roll and yaw data. Resolver outputs are fed through the computer to the engine actuators of whatever stage is burning at the time.

On SA-4, the instrument section will mount infrared horizon scanners which will be flown open-loop. Performance of these sensors will be compared to that of the resolvers and, if they should prove to be more accurate the IR units will be used instead of the resolvers to align the platform along a local vertical during coast periods.

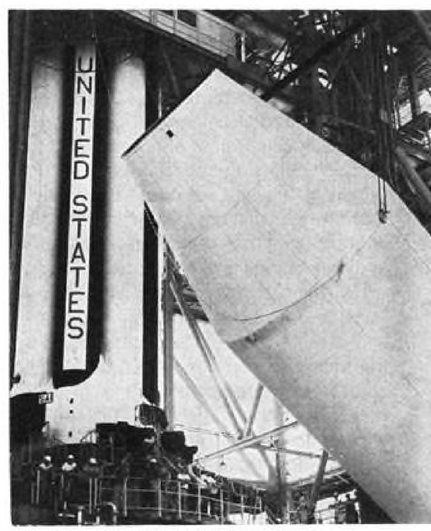
Resolvers also are used to check drift of the gyros stabilizing the platform; the IR sensors will be compared with the accuracy of the resolvers in this function, too, with an eye toward possible replacement.

Body-Fixed Accelerometers

In addition to the three mutually-perpendicular accelerometers on the stabilized platform, the guidance and control system will include two body-fixed accelerometers to monitor forces in two perpendicular directions—such as wind gusts and thrust variations.

A radio-command link will allow ground trackers to send overriding signals to the guidance system—if necessary—and will be used to shut down the engines of the last stage when correct velocity has been achieved. System is being designed for an accuracy of 10 fps.

Astrionics Division also is considering what modifications would have to be made to the Pershing-component system to adapt it to the Nova vehicle.



SATURN/DUMMY STAGE MATED



This research specialist is subjecting a military power package to programmed torture. Purpose . . . establishing design and hardware reliability. This type of practical research was applied to the development of a 700 HP aluminum compression ignition engine weighing about four pounds per HP.

A standard procedure at Caterpillar, testing of this type is used regularly with new components, engines and vehicles. A new facility has been completed which will expedite these engine testing programs through the built-in fuel, water, exhaust, control and instrument systems.

A six-winged building of 164,000 sq. ft., the new Engine Research and Development Laboratory houses a complex of 72 testing cells where a wide variety of engines can be tested.

Each cell is air conditioned to 75° Fahrenheit and is maintained at a slight vacuum. Each has its own inertia block to eliminate the transfer of vibration from one test zone to another. Each is completely soundproof. The researcher and the engine are separated by thick pane glass panels.

During testing, an automatic console control permits the researcher to subject the engine to any of the many stresses and strains it could encounter during its work life. With the flick of a switch or the turn of a dial, the specialist can adjust the water temperature of the cooling system, the horsepower, the oil and fuel pressure, the RPM, the load and torque, or many other conditions.

The effect these changing conditions have on the engine's performance is accurately measured at the console. Test results are correlated—and often predicted—by digital and analog computers. The analysis of these results is combined with the findings of a physical examination of individual parts for ways to provide maximum reliability.

Another building soon to be ready at the Technical Center is the Gas Turbine Engine Laboratory. Here will be housed facilities for the research group which has been exploring this exciting new engine concept for the past five years.

When the Center is completed it will consist of six buildings. It will house 1400 engineers, physicists, applied mathematicians, chemists, metallurgists, instrumentation specialists and laboratory technicians who are part of the Caterpillar research and development team.

It will provide needed additional space and facilities for the intensive research currently going on in metal fatigue, high-speed rotational phenomena, fluid mechanics, fuels and lubricants, special studies in basic materials, and dozens of other projects.

This type of research helps assure you of effective performance, with minimum maintenance, from specialized vehicles such as the AUET and eight-ton GOER vehicles, and new-concept power packages such as the LDS-750 and LVDS-1100 aluminum engines.

For more information about how Caterpillar's expanding R & D facilities can contribute to the solution of your ground mobility problems, write Defense Products Department, Caterpillar Tractor Co., Peoria, Illinois.

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New NASA Center Expands Cape Mission

Launch Operations Center will have increasing role in design, application of advanced launch vehicles.

Cape Canaveral—Newly-established Launch Operations Center will join the Marshall Space Flight and Manned Spacecraft centers this year as a full partner in the manned lunar landing program and also will have an increasingly greater voice in the design and use of new launch vehicles.

Starting with the present Saturn C-1 program, facilities are becoming as essential an element in a launch system as the flight vehicle itself. As future vehicles, such as Saturn C-5 or Nova, grow in size and complexity, so will the facilities and the requirement to extract the maximum use from each launch complex.

These considerations of vehicle size, launch frequency, number of launch stands, time and money and conducting the launchings themselves are the components of the mission assigned to the center and its director, Dr. Kurt H. Debus. They might be summed up this way—How is NASA to launch more vehicles more frequently from the least amount of land at the most economical cost?

This question applies equally to all programs brought to LOC here at the Atlantic Missile Range, whether they are today's research and development projects, such as Saturn, or tomorrow's operational systems, such as Apollo-Saturn is expected to become by 1967-1970.

Anticipating a near-future time when its activities at Cape Canaveral will take on more of an operational color and less of a research-and-development shade, NASA decided earlier this year to separate the Launch Operations Directorate from Marshall and establish it as an independent center. This separation was scheduled to become effective July 1.

Lunar Landing Program

Interfaces between the center and Huntsville and Houston now are being defined. This will fix the Launch Operations Center's precise spheres of responsibility in the manned lunar landing program. Manned Spacecraft Center is charged with development of the Apollo spacecraft and Marshall with the development of the Saturn C-5 launch vehicle.

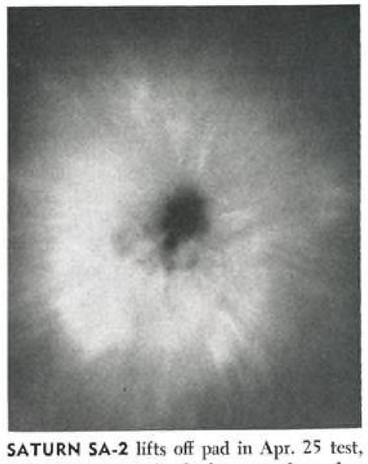
To Debus' center probably will go the task of assembling the complete Apollo-Saturn vehicle and then launching it—at least through the powered flight of the three-stage Saturn—as well as scheduling launch windows with the Atlantic Missile Range and coordinating all NASA support requirements to be asked of the range. The center here will report directly to Brainerd Holmes' Office of Manned Space Flight at NASA headquarters.

Debus presently is building his organizational structure. It is expected to resemble that of Huntsville and Houston with support offices in two broad areas—facilities and ground support equipment—and two systems offices—heavy and medium space vehicles—plus the usual administrative and financial offices.

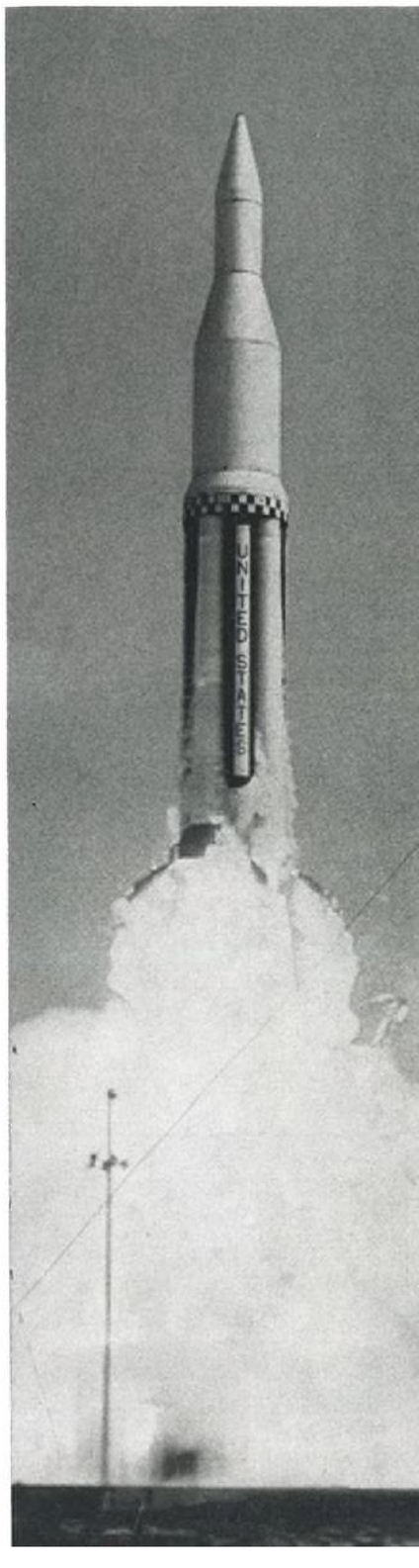
There also will be a technical staff of specialists in such areas as pad safety, nuclear systems and sound and explosive damage, reporting directly to Debus. A reliability office and an industrial relations office also are strong possibilities.

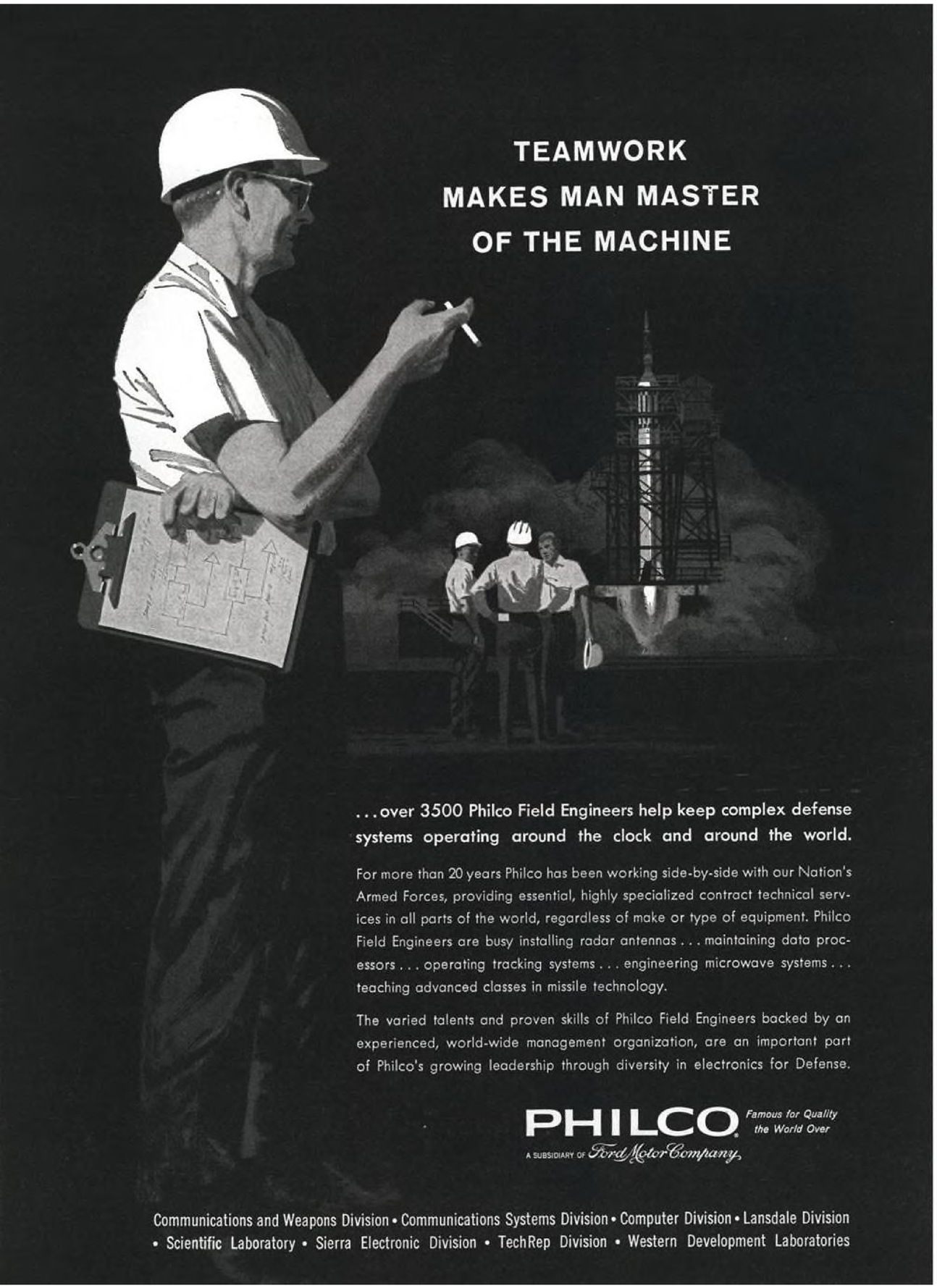
Field Office

Debus expects to have a field office of about 80 personnel, under Theodor Poppel, stationed at Huntsville to see that operational launch requirements are incorporated into the design of new launch vehicle systems and that vehicle design parameters are met by the ground support equipment planned for installation at the Cape. Marshall will have a field office attached to the center here, essentially for the same purposes as the launch center's office at



SATURN SA-2 lifts off pad in Apr. 25 test, right. Ice crystal cloud, above was formed at 65 mi. altitude by dumping water ballast. S-2 was deliberately destroyed.





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Pacific Launch Operations Office

Seven Nimbus meteorological satellites and seven scientific payloads are planned for launch into polar orbit by the National Aeronautics and Space Administration over the next two years from the Pacific Missile Range.

Pacific Launch Operations Office has been established by NASA at Pt. Arguello, Calif., to coordinate the agency's requirements at PMR with Navy and USAF. Office has the use of four Thor-Agena B launch stands at Vandenberg AFB and two Atlas-Agena B stands at nearby Pt. Arguello. NASA has its own Scout launch complex at Pt. Arguello.

Pacific office, which reports to the director of the Office of Space Sciences, is staffed presently with about 15 people. There are field offices of Goddard Space Flight Center (seven people), Marshall Space Flight Center (six) and Langley Research Center (five) attached to the office.

Navy made available half of a missile assembly building at Pt. Arguello for a NASA spacecraft laboratory. There, with 4,000 sq. ft. of laboratory space and 10,000 sq. ft. high-bay area, satellites are checked out, telemetry tested and missions simulated to the extent of the ground support equipment provided by the contractor or payload developer.

Pacific office has one floor in a building adjacent to the laboratory and there, in addition to administrative offices, it is building a mission operations center. The mission director—drawn from the center responsible for the payload—will control the flight of his spacecraft from this center through data displayed on plotting boards and consoles.

A 450 ft. tall antenna tower is being built alongside the spacecraft laboratory to allow direct communications between the mission operations center and spacecraft sitting on stands at Vandenberg; a 350 ft. tall ridge presently separates the two sites.

Huntsville and also to monitor the condition of stages shipped to the Cape from Marshall-supervised production plants.

Facilities office of the launch Center will be responsible for the brick-and-mortar construction of launch complexes, support structures, launch control centers and the vertical assembly building. It will work closely with the Army Corps of Engineers, the actual construction agent. Ground support equipment office will be charged with integration of computers and checkout equipment in the different vehicle handling and assembly buildings, propellant storage and transfer systems, the launch table—including support and hold-down arms, and display equipment in launch control center and blockhouse.

In the systems offices, the heavy vehicle branch will assemble, check out and launch the Saturn C-1 and C-5, Nova and Rift vehicles. The Saturn C-5 with a Rift third stage aboard is called a Saturn D. Medium vehicles office will be assigned to handle Thor Agena, Atlas Agena and Atlas Centaur boosters.

Debus' center deals with Air Force Missile Test Center, proprietor of the Atlantic Missile Range, through a Test Support Office under USAF Col. Asa B. Gibbs, who is on loan to NASA. Test Support Office gathers the requirements of all NASA units on the Cape, ranging from new roads to scheduling proposed launch dates to tracking and presents these needs to AFMTC as a unified package. Conflicts among the different NASA centers are ironed out before requests are laid on AFMTC.

AFMTC is responsible for a build-up of the range in general, NASA for facilities needed for specific missions. All AFMTC support is reimbursable.

Forecasting of future needs in utili-



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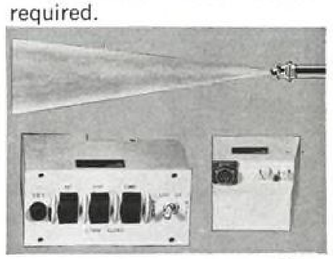
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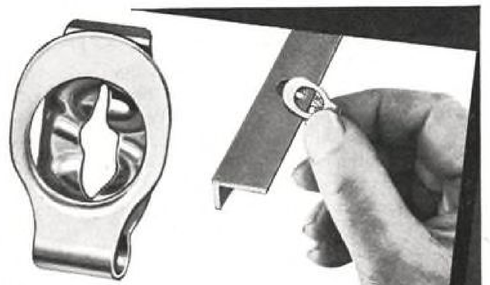
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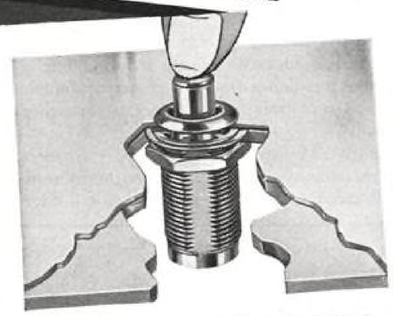
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ties, roads, sites, communications and instrumentation, telemetry and tracking is accomplished in a Master Planning Board, which includes representatives from AFMTC and other military agencies, the Launch Operations Center and Pan American, contract operator of the range. Originator of a request tries to cite the actual equipment or facility he will require and the date, and AFMTC then cranks this requirement into its future plans. Planning Board is perhaps the most important of several joint USAF - NASA - contractor working groups.

To preclude the growth of large, separate NASA launch crews for each launch vehicle system, the launch center intends to grant more and more preflight and launch responsibility to vehicle contractors. As a vehicle leaves research and development and approaches operational status, center launch specialists gradually will taper off that vehicle and transfer to a new vehicle just beginning its flight test program.

The contractor, probably the vehicle's system manager, gradually will be phased into the operation and be thoroughly trained in the center's procedures, philosophies and policies. Eventually, when a vehicle has reached operational status, its launch complex will be staffed about 99% by contractor personnel. The center will retain control and authority of the vehicle, and the NASA center providing the payload for the vehicle may direct the mission—but the launch and powered flight of the booster will be executed by the contractor.

Launch Operations Center presently has about 600 personnel, of which some 200 are engineers or technicians. Debus hopes to add another 180 to 200 slots to his center this fiscal year, bringing total strength up to around 800 by next summer.

Attached to the center's organization, but not line members of it, are the

AMR Center

Cape Canaveral, Fla.—National Aeronautics and Space Administration's operating element here recently was raised to a center and is called Launch Operations Center. NASA is acquiring 80,000 acres here for Saturn and Nova launch complex sites, and uses other Atlantic Missile Range facilities jointly with the Air Force.

The center has an operating budget request of $12.5 million for Fiscal 1963, with employment totaling 713, which is 210 more than last year. Budget increase is about $3 million.

NASA has asked for $360 million to construct new launch facilities here during Fiscal 1963.

BRINGING OUTER SPACE "DOWN TO EARTH"



(Or: Reliability revisited)

Norm Froomkin (pronounce it as though there were only one "o") tells a story that sticks in the mind. A short while ago, Norm, who heads up Test Facilities Engineering at Budd Electronics, was discussing with an Air Force General the various and sundry inputs required for reliability testing of spacecraft. The General suddenly stopped, looked at Norm, and said, "You know what we really need to build? *An acre of the moon!*"

With due regard for the General's inspired cogitation, we're sure there are many others who long for a slice of lunar environment here on terra firma. What makes the idea so memorable is that it pretty well sums up the whole problem of getting our spacecraft . . . and our spacemen . . . to their destinations *with nothing less than 100% reliability.*

The problem basically is one of getting enough operational failure mode data.* (Is there ever enough?) Getting it from actual launchings is too costly and too slow . . . and, in the case of manned craft, unthinkable. Some of it we can get from single-force testing of materials and subsystems. But statistical extrapolation . . . from system elements under single forces to subsystems and complete vehicles in omniforce spatial environments . . . is not going to assure us 100% package reliability. We may have a good idea of the type and magnitude of the space force envelope, but what about the complex interacting and intermodulating stresses it produces on spacecraft? The solution . . . it becomes clearer every day . . . has got to come down to total simulation of space environments.

There's nothing new about the idea of simulative force testing as a means of assuring performance reliability . . . at least not here at Budd. It's been a way of life with us for nearly 50 years, put into practice on our own products in our own testing facilities. To this experience, Budd Test Facilities Engineering adds a thorough familiarity with force environments and their simulation . . . stress interactions and their analysis . . . and test facility design, construction and instrumentation. And that's giving you the story at Mach 5. It's actually conservative to say that every scientific and engineering discipline has to come into play in building what we call a Dynamic Omniforce Testing Facility.

We supply such facilities . . . as well as those for more conventional testing . . . on a turnkey basis, from force system analysis to final checkout. We also supply individual test modules for specific jobs, and consulting services on testing programs. If we've whetted your appetite, your letter or phone call will bring you more information or a provocative discussion of your needs. Test Facilities Engineering, Budd Electronics, 43-22 Queens St., Long Island City 1, New York.

*R & D terminology for "Why didn't it work *this* time?"

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Field Projects Branch Office of Goddard Space Flight Center, Preflight Operations Division of Manned Spacecraft Center, Jet Propulsion Laboratory field office and Launch Operations Division field office of Marshall.

Goddard has 24 people stationed at the Cape under Robert H. Gray and their job is to prepare both launch vehicles and complex for the flight of an ambitious number of satellite programs. The Delta launch vehicle is bought directly from Douglas, the vehicle system manager, by Goddard.

Goddard has 27 Deltas ordered, 10 of which have been used already, for programs extending through Fiscal 1963—Tiros, Telstar, Big Shot, Relay, Syncom and several scientific satellites.

First 12 Deltas have the 150,000 lb. thrust Rocketdyne engine in the Thor stage; starting with Delta 13, the uprated 165,000 lb. engine will be substituted instead. Delta 15 will see the introduction of an improved second stage; designated AJ-10-118-A, it will be 36 in. longer than its predecessor and use inhibited red—instead of white—fuming nitric acid (IRFNA) as oxidant. Deltas 13 and 14 will be a mixture of new first stage and old second and third stages.

Goddard's Field Projects Branch has been sharing Complex 17 with USAF's Space Systems Division. There are two stands at Complex 17, A and B, with Goddard using A for the first 10 Deltas and USAF using B for the Thor-Able-star booster and Transit, Anna, Courier and Composite payloads. Because of the heavy launch schedule facing it this year Goddard will be allowed to use 17-B whenever it is needed and whenever USAF can make it available—starting with Delta 11. Launch crews are mostly Douglas personnel, with Field Projects Branch Chief Robert Gray directing the launch and a Greenbelt man supervising the mission.

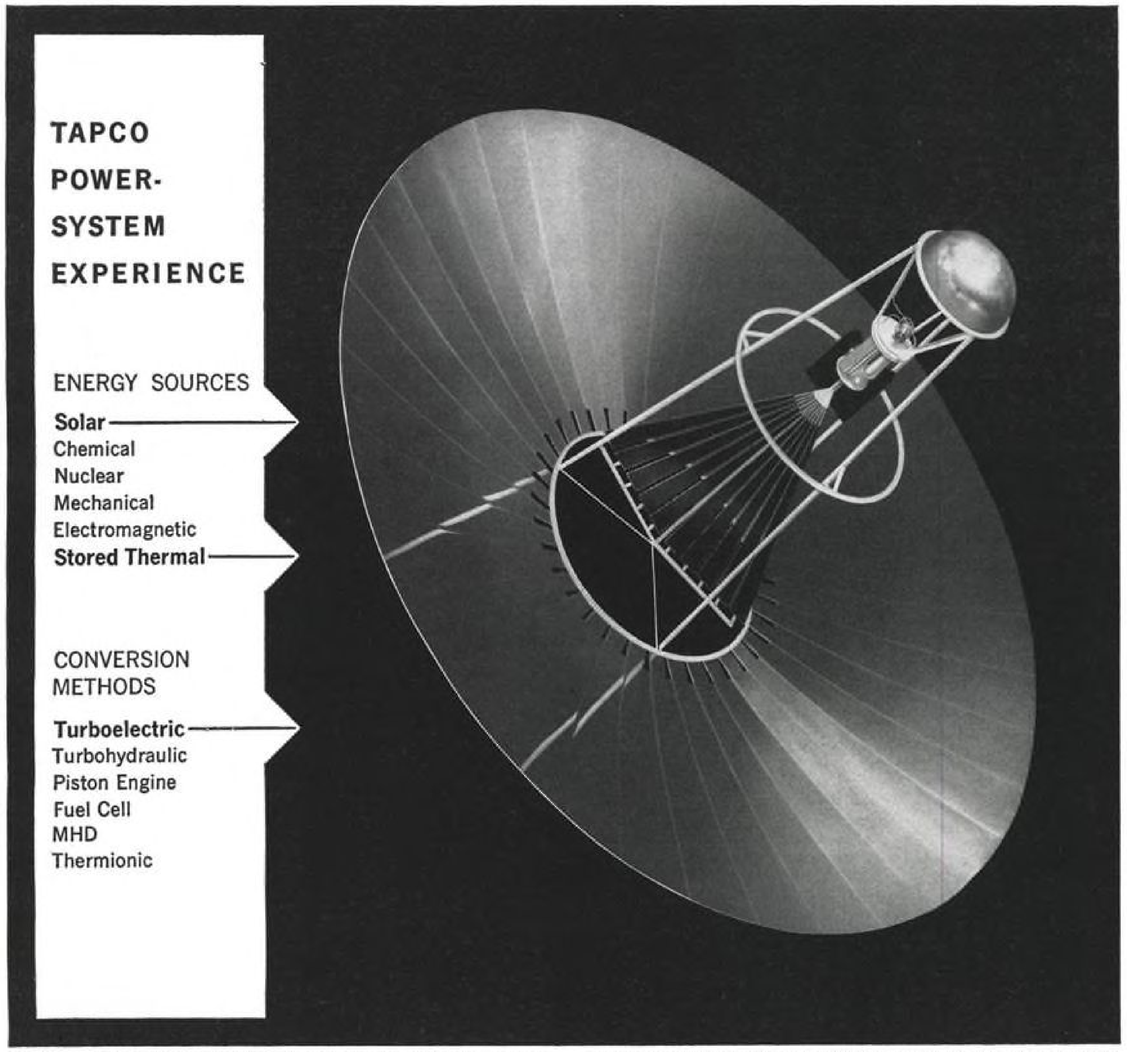
When Goddard's Eccentric Geophysical Observatory (EGO) and Orbiting Astronomical Observatory (OAO) come along, Field Projects will use Atlas-Agena vehicles instead of the Delta. There also are some vague plans to use Atlas-Centaur and possibly even Saturn for some scientific satellites.

Jet Propulsion Laboratory has a small office here to check out their payloads and integrate them aboard Marshall-provided launch vehicles. At the time of a launch, JPL acts as the mission director with a launch center man—frequently Debus—serving as test director and General Dynamics/Astronautics and USAF personnel as test conductors.

Houston's Preflight Operation Division, as the title implies, is responsible for preparation of man-rated booster and manned spacecraft before flight operations.

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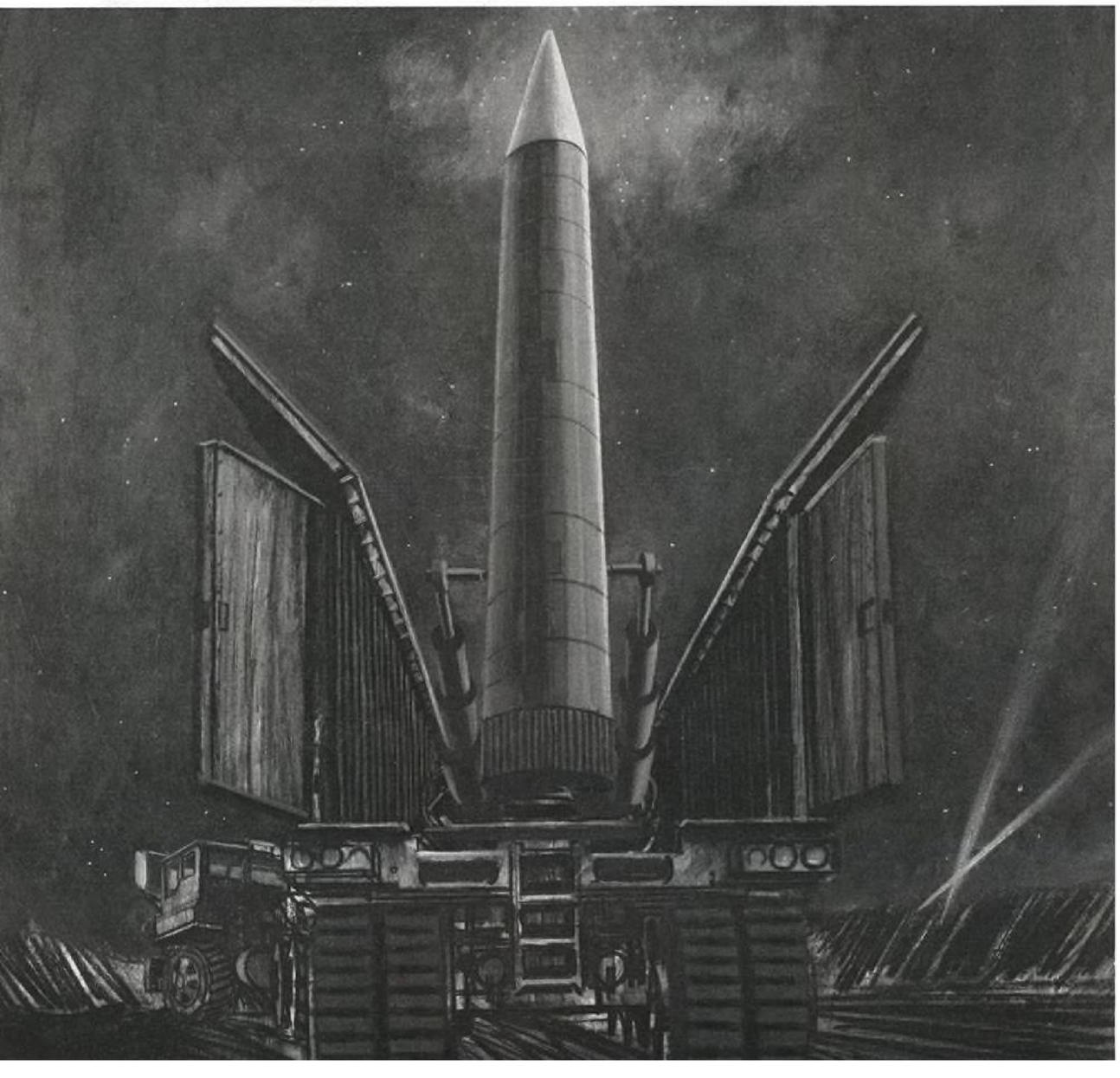
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NASA Building Flexible Cape Facilities

Cape Canaveral—Facilities being planned here for the Advanced Saturn, Rift and Nova vehicles reflect the National Aeronautics and Space Administration's intention to base the future exploration of space on a flexible and quick-response earth launch capability.

Launch complexes for the Saturn C-5 and Nova are being designed as integral parts of the complete launch system and will make maximum use of the experience gained from design and construction of the first Saturn facilities—Complexes 34 and 37—for the C-1 vehicle.

Three Saturn launch complexes are now planned for the Atlantic Missile Range:

- **Complex 39,** with four stands for the Saturn C-5 vehicle.
- **Complex 37,** with two stands for the Block-2 model of Saturn C-1.
- **Complex 34,** with one stand for the four Block-1 Saturn C-1 vehicles. It will be converted for Block-2 Saturn C-1s.

Nova launch facilities are still in a very fluid study phase and are dependent on final vehicle configuration and intended operational uses.

NASA's launch complexes presently planned or building at AMR include, from south to north: Gemini-Titan 2 at Complex 19; Complex 34; Complex 37, about 3,800 ft. north of 34; and Complex 39, about 20,000 ft. north of 37. Nova sites are being investigated and probably will be several miles further north of Complex 39. USAF, which manages the Air Force Missile Test Center, presently plans to build three Titan 3 launch stands between Complexes 37 and 39. Little Joe 2, a solid-propellant booster to fly Apollo on suborbital trajectories, may be launched at the Cape or at White Sands, N. M.

Nerve center of Complex 39 will be vertical assembly building, where the three stages of Saturn C-5, the Apollo spacecraft and its modules will be vertically assembled prior to movement out to a launch stand. The 400-450 ft. tall building presently is envisioned as a series of modularized high-bay areas which can be built in steps. It is likely that only four bays will be built at first. Two more bays, with higher ceilings than the first four, probably will be built later for growth versions of the C-5, such as an Advanced Saturn with a nuclear third stage.

Four initial bays will be built in-line and each will open either on a barge canal or road—depending on the type of transporter-launcher selected. Extra-high bays would be added to the end of the building facing the launch stands.

At the far end of the building will be a launch control center, which will direct all activities in the complex area, and a low-bay area for barge-delivery of the S-1C, S-2 and S-4B stages. Stages are to be delivered in a flight-readiness condition and, after an acceptance check and pre-assembly preparation in the low-bay area, will be moved by overhead crane into a high bay for assembly with other stages. Design criteria of the vertical assembly building are expected to be completed by this fall and a competition held for an architectural and engineering contractor.

At the base of each bay will be a transporter-launcher, a mobile platform upon which the Saturn C-5 will be assembled, moved to the launch area and fired.

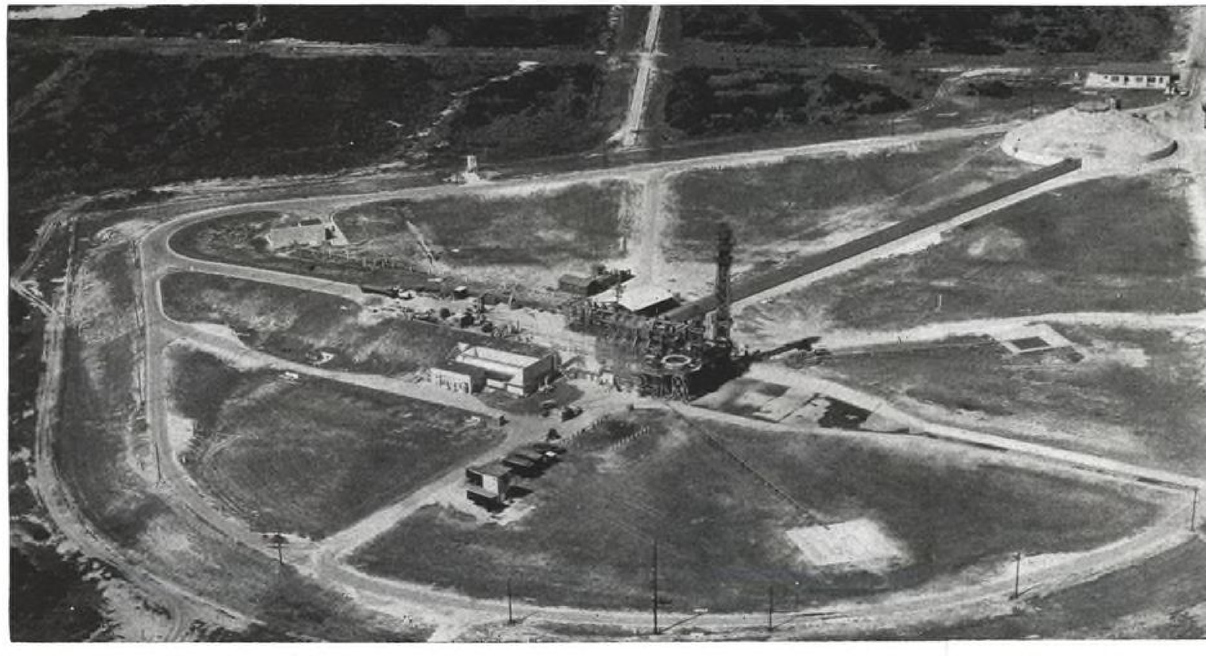
Each launch stand, upon which the transporter will rest, will have its own liquid oxygen and liquid hydrogen storage tanks. Studies now are being made of the best way to bring propellants from the central storage area to the launch area—barge, pipeline or railroad car.

The stand will include a dry-launch flame deflector, but not a launch pedestal; this will be one of the two functions of the transporter-launcher.

Three types of transporter-launchers are under consideration and are favored in this order:

- **Crawler.** As studied for Launch Operations Center by the Bucyrus-Erie

TITAN 2 Complex 19 at the Atlantic Missile Range is now being modified to accommodate the two-man Gemini spacecraft payload.



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Titan 2 for Gemini

Provision of the Titan 2 booster for the two-man Gemini spacecraft will follow procedures similar to those used by National Aeronautics and Space Administration and Air Force for procurement of the Atlas vehicle in the Mercury program.

USAF's Ballistic Systems Division will be funded by NASA's Manned Spacecraft Center for fabrication, assembly and preparation for flight of the Martin Titan 2 missile. Tankage will be built at Martin's Denver, Colo., factory but assembled at the Baltimore, Md., plant. USAF also will be responsible for erection of Titan 2 on the launch stand, countdown, launch and powered flight of the vehicle, under NASA's direction.

Manned Spacecraft Center will assign a permanent plant representative to Martin-Baltimore to monitor assembly of Titan 2 boosters and a representative, who will travel between Houston, Denver, Baltimore, Los Angeles and Cape Canaveral. He will keep the spacecraft center appraised of vehicle status and keep USAF, Aerospace Corp. and Martin current on NASA's thinking.

Two weeks before scheduled delivery of a Titan 2 to the spacecraft center's Preflight Operations Division at the Cape, an engineer from the Cape division will travel to Baltimore, review the history of the particular vehicle to be delivered and stay with it until it actually flies. This engineer is expected to become thoroughly familiar with his booster's individual characteristics.

Gemini program also will seek a continuation of two management groups established for Mercury:

- Booster working group, convened by USAF's 6555th Test Wing at the Cape, will include major Titan contractors (Martin, Aerojet-General, AC Spark Plug and IBM) and NASA representatives. This group primarily is concerned with booster and launch complex readiness.
- Mission working group, convened by the spacecraft center at the Cape, will comprise Preflight Operations personnel, Houston project people, USAF representatives, both from BSD and Atlantic Missile Range, and a senior engineer from Martin and Aerospace. Meetings will be concerned with such matters as spacecraft-booster mating procedures, major test procedures, detailed scheduling of tasks and resolution of particular hardware problems, i.e., incompatibilities between Titan 2 and Gemini capsule or between ground support equipment and the complete vehicle.

Only significant difference between handling of Titan 2 and Atlas at the Cape will be the formalization of Preflight Operations Division's technical capability to monitor booster development.

Under Mercury, USAF officially was completely responsible for all booster work and presented only the results of its work to NASA for approval. In reality, there was much informal cross-talk between USAF representatives and NASA engineers from different preflight offices and proposed modifications to the launch system were discussed thoroughly before the proposal actually moved through USAF-NASA channels.

For Gemini, these preflight engineers will be formalized into functional groups so that Titan 2 development can be expedited. USAF still will be responsible for initiation of booster improvements and will continue to channel proposals up through BSD-headquarters to Manned Spacecraft Center headquarters at Houston, but will have the benefit of NASA inputs at the working level.

Co., the crawler was conceived as a two-part vehicle—an assembly and launch table mounted on a tracked-drive flat-bed locomotor. When the Apollo-Saturn was ready to roll to the launch stand, the crawler would raise several 80-in.-dia hydraulic pistons to clear the launch pallet and then move out of the bay area onto a concrete road for the 2-2.5 mi. trip at a speed of about 1 mph. At the launch stand, the crawler would retract its supporting pistons and lower the launch table onto the stand. It then would drive out from beneath the pallet and return to the assembly building. Total weight of the crawler system, including the empty Saturn vehicle, is estimated at 8 million lb.

- **Barge.** A series of canals would connect the vertical assembly building to the launch stands in this concept, and the Apollo-Saturn would be built on, moved by and launched from a barge approximately 180 ft. long, 130 ft. wide and 25 ft. deep. The completely-assembled vehicle would be moved through the canals to a launch stand, which would essentially be a lock. Once the barge was properly positioned, the lock would be closed, the water pumped out and the barge allowed to settle on the stand supports. Weight of this system, including the empty launch vehicle, is estimated at slightly more than 8 million lb.
- **Rail.** This system would be similar to the crawler concept, but would use rails instead of a road. Weight is estimated to be around 10 million lb.

NASA Operations Center personnel feel the rail technique has limited growth potential in addition to its greater weight. Barge plan causes some apprehension because of the very fluid nature on which the system must move. Crawler presently seems the most attractive approach because it offers a solid medium on which to move and the ability to remove the locomotor from the damaging effect of the Saturn's exhaust.

Regardless of the system chosen, the center has decided that the transporter-launcher will contain three essential elements:

- **Digital computer system** carried in the base of the transporter and used as the primary item of checkout equipment for the launch vehicle. This system will begin an automatic checkout of the vehicle, stage-by-stage, as each stage of the Saturn C-5 is brought into the bay and assembled. Once the transporter begins movement of the vehicle from the assembly building to the launch area, one of two launch control computers in the Launch Control Center will assume remote control of the vehicle and respond to data provided by the transporter's computer system over a digital link. Transporter computer system will continue to monitor the vehicle through the countdown and —being heat-protected and shock-isolated—during the three-second hold-down after ignition of the five F-1 engines. Computers in the transporter will be almost identical with those in Launch Control Center.
- **Umbilical tower,** about 350 ft. tall, will be located about 40 ft. away from the vehicle on the transporter. Tower will contain an elevator for personnel and flexible swing arms to each stage and the spacecraft. Arms will hold personnel cat-walks and lines for propellant loading, electrical power, and gas lines for purging, heating and cooling. Hydrogen boil-off from the S-2 and S-4B stages will be piped off the vehicles across these swing arms, carried down the tower and dumped away from the launch area. Inter-stage structures will be big enough to allow maintenance men to enter and work on stage systems, if necessary. Personnel platforms within interstage structures will be removed through access doors prior to final preparation of the vehicle for launch.
- **Support and hold-down arms** will be built into the launch table. Present Launch Operations Center-Marshall thinking leans to four of each for Saturn C-5, with the support arms re-



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An ordnance tower will be located midway between the vertical assembly building and the launch areas and the transporter will stop there to allow the escape tower to be added to the Apollo spacecraft and all other pyrotechnic devices to be installed.

Using the vertical assembly method, the center expects to cut the time spent by the launch vehicle on a stand waiting for flight from C-1's present figure or two or three months to less than a week. Assembly time for the C-5 in the vertical facility also should be considerably less than assembly time for C-1 on the pad because of the sheltered environment and extensive use of automated checkout equipment.

Vertical assembly building plus four launch stands will provide NASA with considerable flexibility in scheduling the manned lunar landing program. For the earth-orbit mode of rendezvous, for example, the orbital tanker could be set up on Stand 1 and two manned Apollo vehicles prepared on Stands 3 and 4, with Stand 2 held in reserve as a back-up stand for either the tanker or a manned vehicle. Should any of the three prime vehicles be unable to proceed with the mission, it could be rolled out of the launch area and a new vehicle brought in from the vertical assembly building. Distance between each stand is expected to be 8,000-11,000 ft.

For lunar rendezvous, where only one C-5 vehicle would be required, launch-window restrictions would be eased markedly. One or two back-up vehicles could be prepared for possible replacement of the primary Apollo-Saturn.

Only limiting factor in the launch frequency rate of Complex 39 would be the turn-around time of range tracking and instrumentation. Theoretically, two Saturn C-5s could be launched within minutes of each other. Actually, it would require several hours.

Block-2 models of the Saturn C-1 will be flown from two fixed launch tables—A and B at Complex 37. A and B stands are separated by 1,200 ft. Only one vehicle will be on either stand at a time to preclude the loss of two Saturns if an explosive failure should occur.

Vehicles will be assembled by a rail-mounted service tower, which will be able to roll back and forth between 37A and 37B. Tower will have a swing-open coffin that can encase a complete Saturn C-1 so that work may go on under any weather conditions. After erecting a launch vehicle on 37A (or B), the tower will be rolled back to the other stand to minimize damage in the event of a failure at launch.

The first facility built to launch a Saturn vehicle, Complex 34 will fire two more Block-1 models of the C-1 vehicle, SA-3 and SA-4 As SA-5, the first of the Block-2 vehicles, and SA-6 fly from Complex 37, the older complex will be modified to take Block-2 vehicles.

Modifications to Complex 34 include the construction and installation of a liquid hydrogen ground storage tank for the 4S stage, an increased high-pressure gas capacity and construction of a 240-ft. tall umbilical tower with swing arms for the first and second stages and the Apollo spacecraft. Launch pedestal also will be modified by the replacement of the four support arms used for the Block-1 C-1 with eight arms used for Block-2 vehicles. Umbilical tower will be ready by the time SA-3 flies later this year and the hydrogen ground storage tanks will be begun soon.

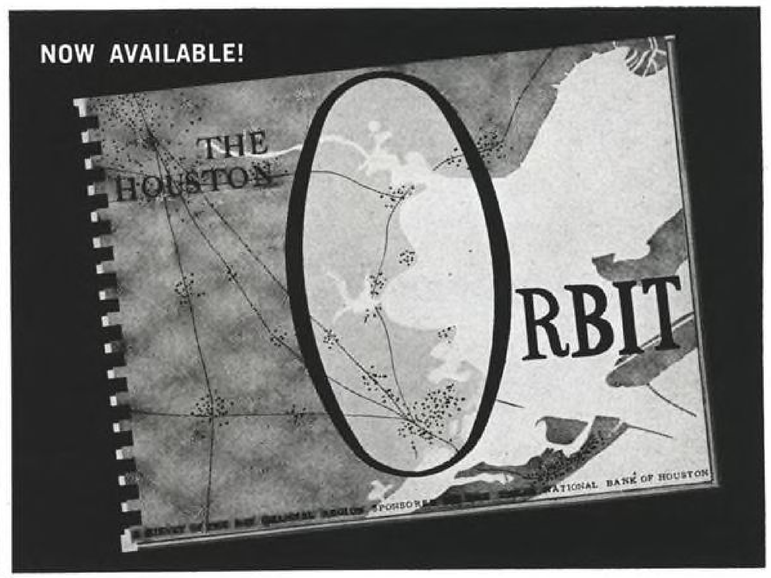
Conservative estimates of the launch rates are four per year for Complex 34 and six per year for Complex 37. First flight of a Block-2 C-1 from Complex 37 will occur early in 1963.

Part of the 72,644 acres adjacent to the present Cape area to be acquired by NASA (AW Feb. 12, p. 31) will be used for an industrial area on the northern end of Merritt Island. A spacecraft preparation building is to be constructed there by the Manned Spacecraft Center and another building by its side will be used by the Launch Operations and Marshall center and contractors. Both will be combined office and laboratory structures. The area also will include storage warehouses, a pyrotechnic building, dispensary and cafeteria. NASA expects to authorize Corps of Engineers to seek an architectural and engineering firm for design soon.

Consideration is being given to the installation of some low-altitude tracking facilities on Merritt Island, but plans are not yet definite. Sites would house infrared and scintillation counters for a precise track during the first several hundred feet of powered flight.

NASA does not plan to build a liquid hydrogen plant at the Cape, believing it will be cheaper to buy bulk lots and have it trucked into storage areas. The liquid oxygen plant now at the Cape will be expanded significantly.

NASA has acquired all the beach land for about 20 mi. north of the Cape's present northern boundary. This will be used for Saturn C-5 and Nova sites and was considered first in priority for acquisition. NASA Administrator James E. Webb recently announced the agency's intention to acquire another 14,800 acres beyond this 20 mi. zone, since the construction of Titan 3 launch stands will demand a little more room on either side of the USAF facility and push Saturn C-5 and Nova areas still farther north. The Cape reservation now will extend from Brevard to Volusia counties.



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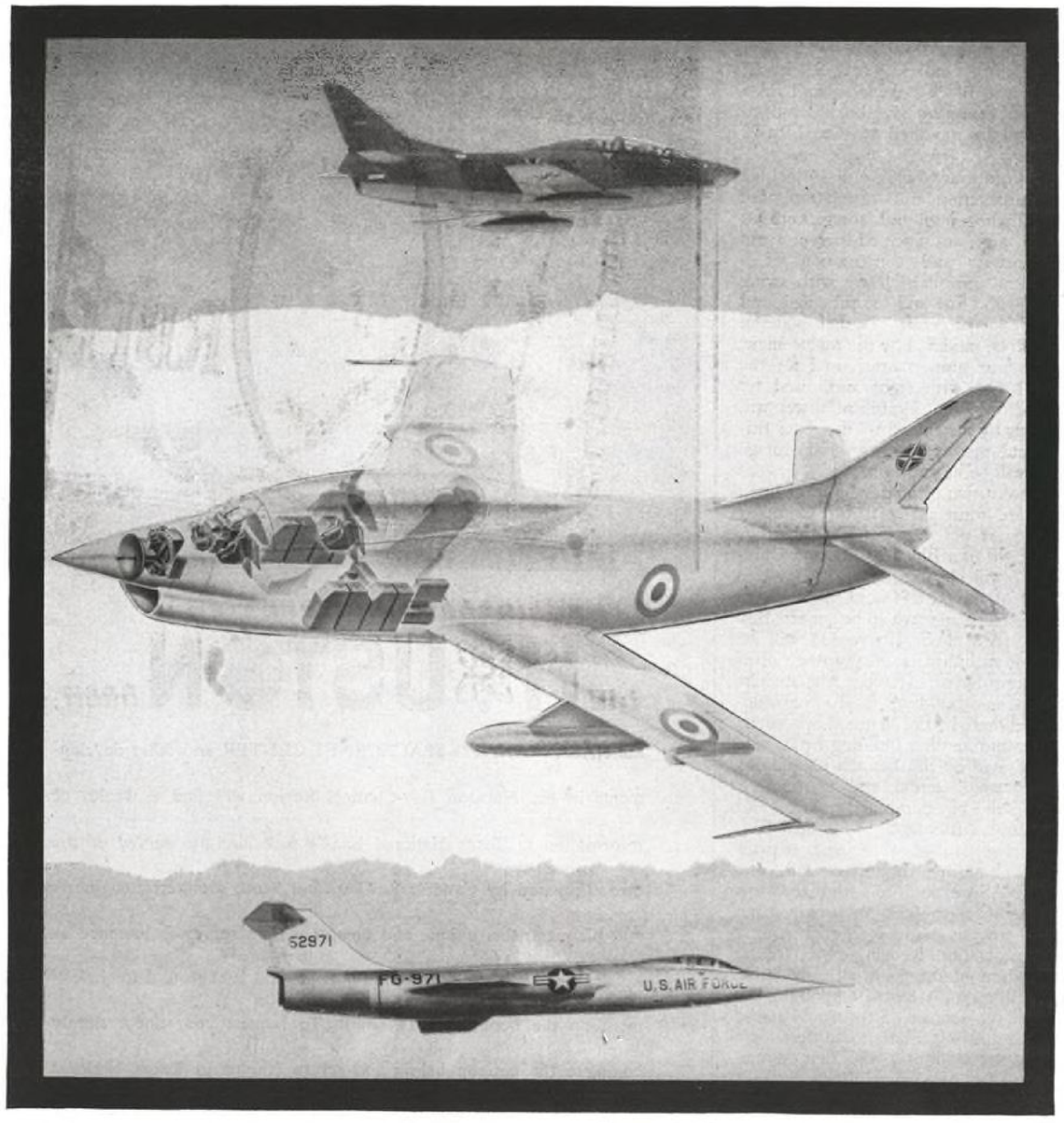
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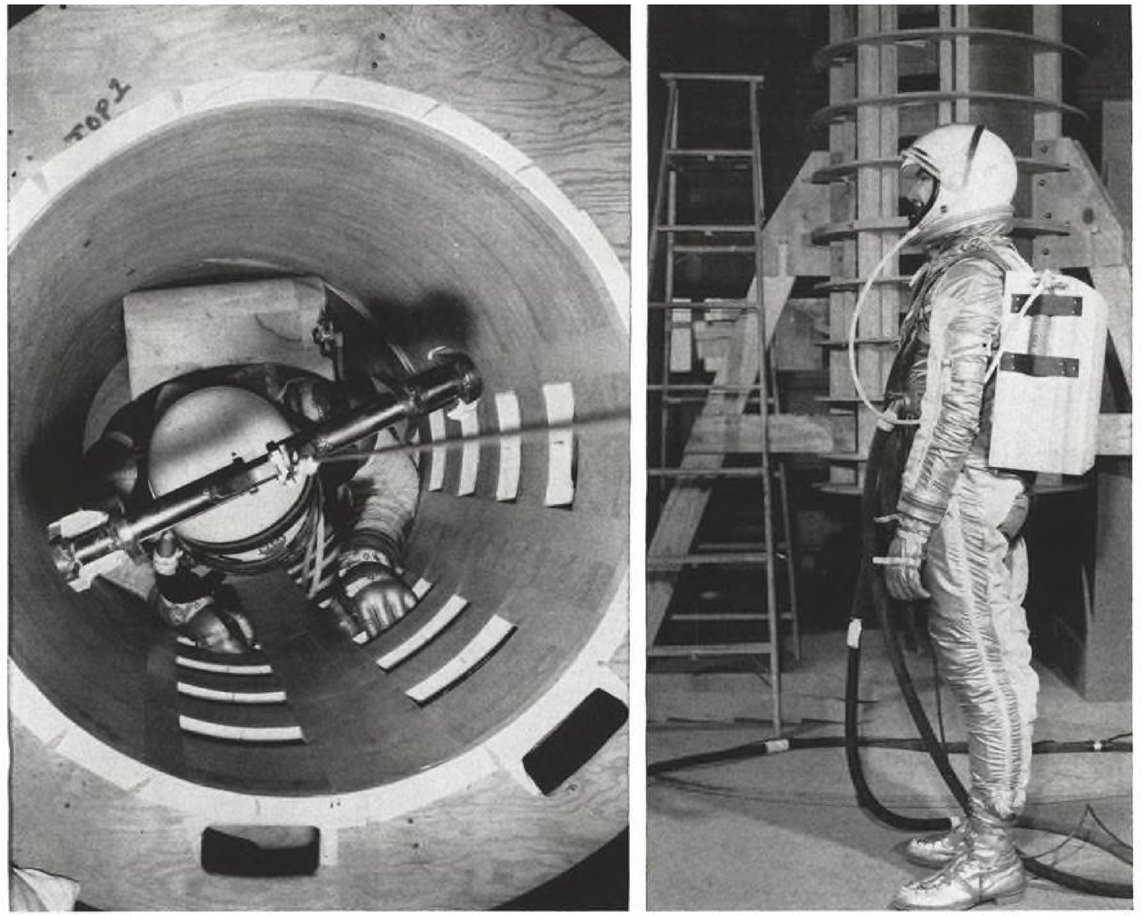
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MANNED SPACECRAFT CENTER engineer, wearing a spacesuit with a mockup environmental control unit on his back, tests ease of movement within a wooden tube simulating the airlock in the Apollo capsule. These tests at the Manned Spacecraft Center are designed to provide data on optimum sizes of the control unit and the airlock.

NASA Bioastronautics Role Still Unclear

National Aeronautics and Space Administration and Department of Defense so far have failed to reach agreement on the extent of bioastronautic support to be provided by the latter for civilian manned space flight programs and the resultant impasse probably will go now to top Administration officials for resolution.

There is no doubt that Defense's bioastronautic capabilities are to be used in Gemini and Apollo. The question is—how? NASA would like to make maximum use of Defense facilities and personnel on a task-by-task basis. Although Defense presently is accepting task assignments from NASA, it claims that continuation will fragment the bioastronautic structure that has been built up over the years.

Defense has been urging NASA to assign package responsibility for bioastronautic support of manned space flight to the military and to use total USAF-Navy-Army resources and personnel as an entity—as if it were another NASA division.

NASA has rejected this on the ground that NASA must have some of its own capability in this field, since bioastronautics is as essential an element of mission success as spacecraft or booster development.

NASA's position was most clearly stated by Deputy Administrator Hugh L. Dryden before the House Committee on Science and Astronautics: "Some capabilities must be provided within NASA itself. It would be foolhardy for any organization to accept responsibility for the manned exploration of space without the acquisition of some competence in one of the main fields on which success depends.

"It is not possible to delegate complete responsibility for an entire technical field to some other group, although it is possible and desirable to delegate the largest part of the execution of the program to other agencies, including industry, universities and other government agencies as appropriate."

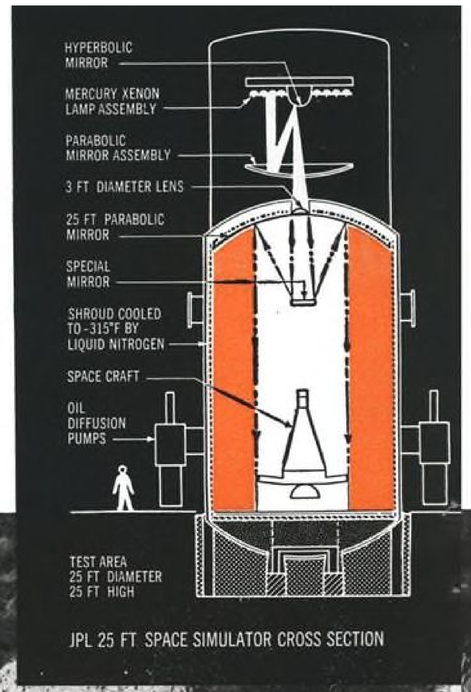
Dryden also said: "I do not think the complete responsibility of bioastronautics can be assigned to the Department of Defense any more than any branch of any weapon system support could be or would be assigned by Defense to some other agency."

Underlying this disagreement on spheres of managerial responsibility are two major factors—expansion of bioastronautic facilities and USAF's manned space program.

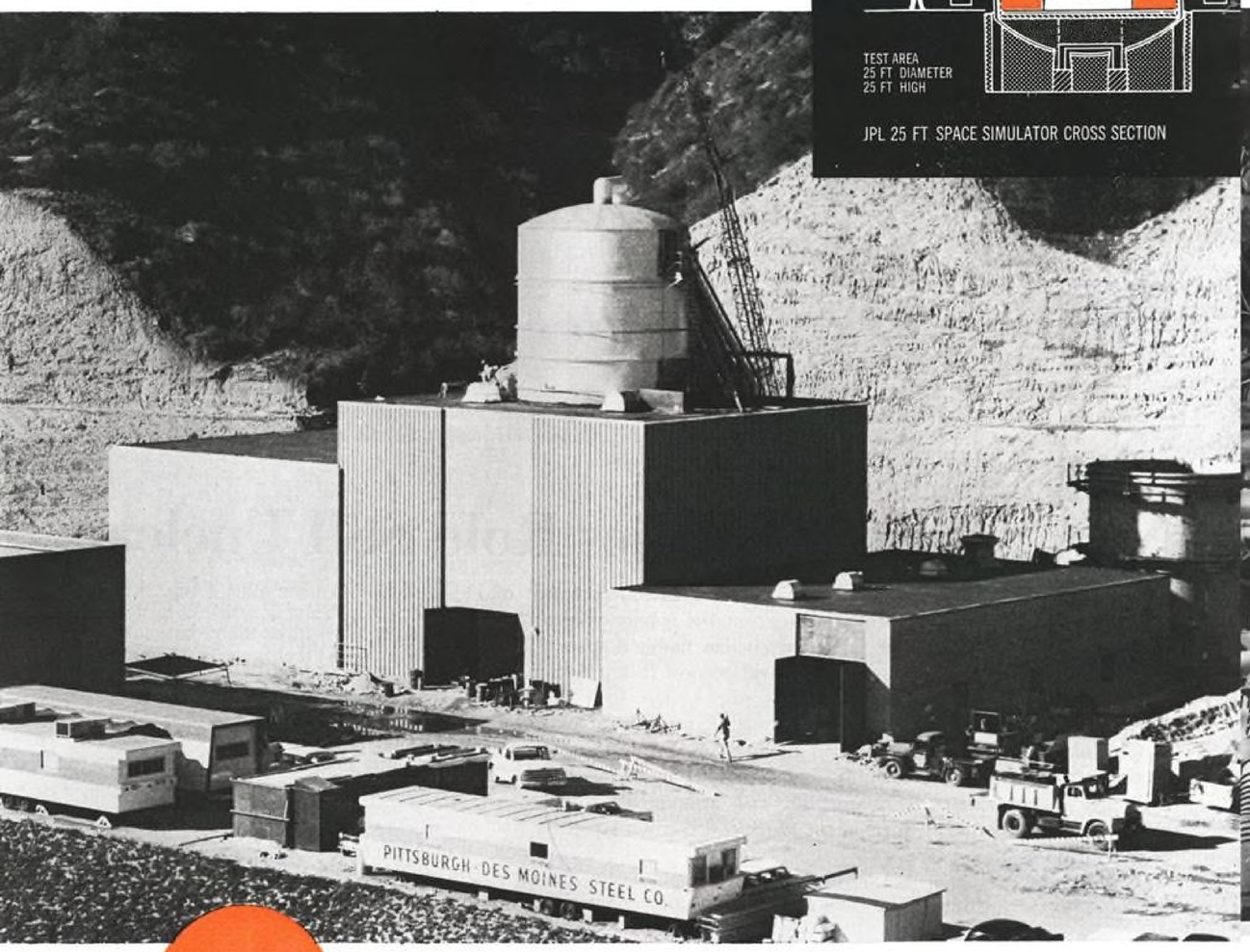
NASA has long contended that Defense's present facilities are not large enough to cope with the bioastronautic work that will be required for Gemini and Apollo and that considerable expansion will be necessary. Defense has agreed that growth is required, but argues that it should be built

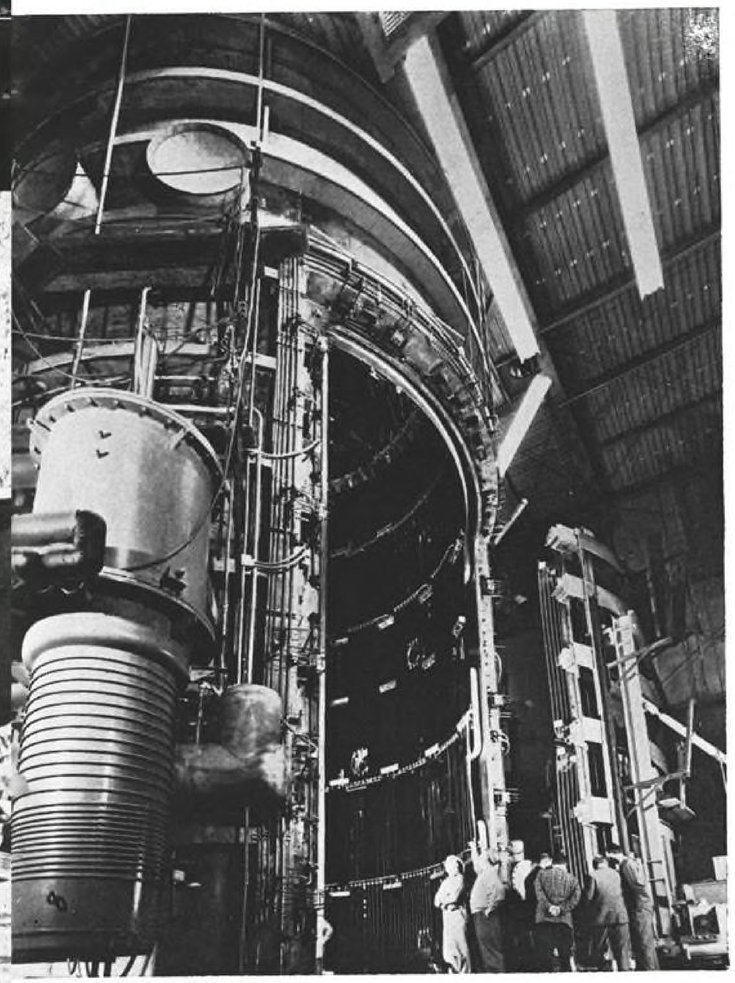
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around existing nuclei to save time and money.

NASA is chary of providing Defense with funds to accomplish this, for fear that this would only strengthen USAF's drive for complete management responsibility.

On this matter, Dr. Dryden told the committee: "We have taken the position that some of these [expanded] facilities must be within NASA, that some probably will be at existing laboratories of the Department of Defense. And, in any case, we are firmly agreed that the existing facilities should be used to the fullest extent possible. Our only questions relate to the necessary expansion of this effort and to questions of management. . . ."

Defense, on the other hand, is hesitant to expand facilities without guarantee that they will be used fully and efficiently. Promise of a series of tasks through the years is no such guarantee, Defense feels.

USAF appears to have two primary manned space flight goals at present: The manned Saint vehicle (AW June 4, p. 34) and Project MOSS, for Manned Orbital Space Station. Both programs, if they win approval, will absorb Defense's bioastronautic capabilities to such an extent that the only support for NASA's programs would be on a task-by-task basis. But these programs are not yet firm and their impact has yet to be determined.

Many bioastronautic observers, within both NASA and Defense, think it ironic that, while the top levels of the two agencies disagree, the laboratory levels of each organization often work together in harmony.

NASA Bioastronautics

NASA's bioastronautic work today is divided among three separate offices:

- **Aerospace Medicine,** under the direction of Brig. Gen. Charles H. Roadman, USAF officer on loan to the agency, in the Office of Manned Space Flight.
- **Bioscience Programs,** under Dr. Orr E. Reynolds, in the Office of Space Sciences.
- **Bioresearch and Technology,** to be located in the Office of Advanced Research and Technology. Director's position has been vacant since Alfred M. Mayo resigned from NASA late in May. Mayo had been appointed to organize the office.

Manned Spacecraft Center at Houston has two important bioastronautic groups: the Life Systems Division, under Lt. Col. Stanley C. White, USAF physician loaned to NASA, in the Directorate of Research and Development; and the Aerospace Medical Operations Office, under Lt. Col. Charles A. Berry, another USAF medical officer detailed to NASA, in the Operations



NASA has selected Raytheon's Missile and Space Division to produce the digital guidance computer for the APOLLO manned lunar exploration program. This computer, located in the spacecraft, will serve as the mission nerve center during the entire APOLLO flight. It will receive the outputs of each of the guidance system's sensors.

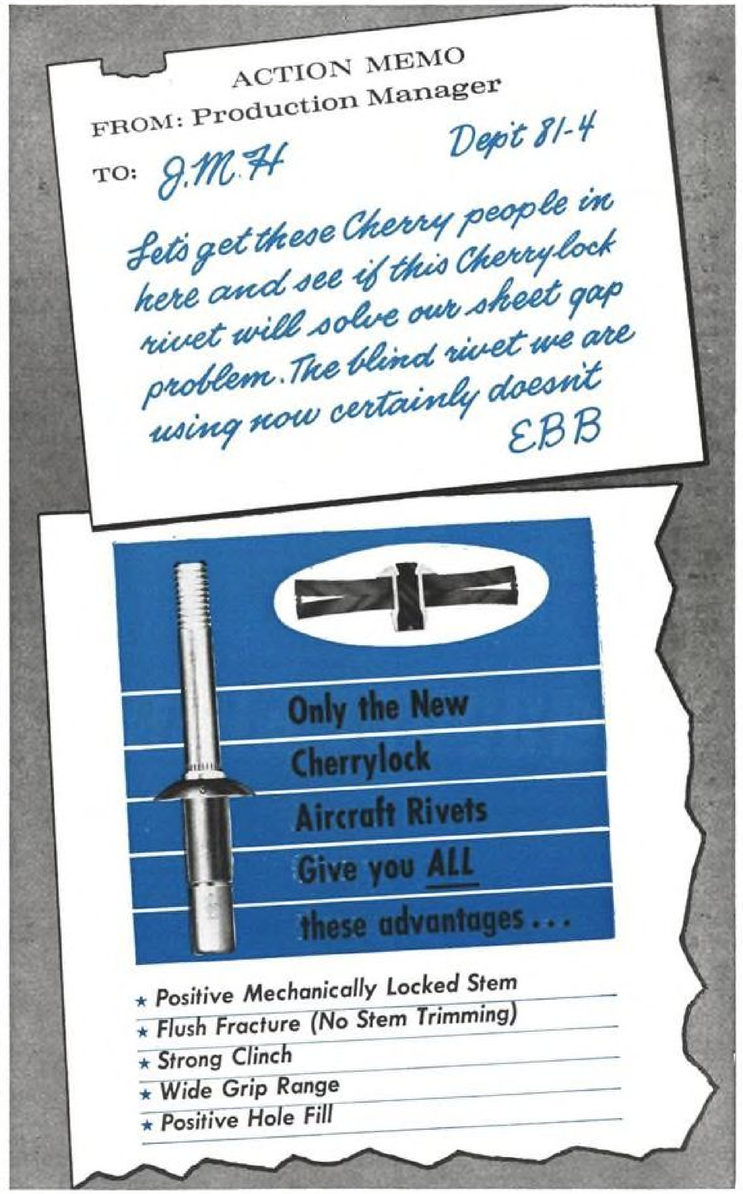
Data will be processed by the computer for automatic control of certain flight functions and for presentation to the crew to permit the optimum exercise of human intelligence during the mission. The computer will be used for all phases of the APOLLO mission.

Under its NASA contract, Raytheon will provide engineering support on the computer design to the M.I.T. Instrumentation Laboratory, which has design responsibility for the complete APOLLO guidance system. In addition, Raytheon will produce the computers which will be used on APOLLO flights.

The selection of Raytheon for this key role in the APOLLO program is but one indication of Raytheon's rapidly expanding space program and demonstrates that in the space age, as in the past, Raytheon means Excellence in Electronics.

Engineers or scientists interested in a challenging career in Raytheon's space and missile programs are invited to contact Mr. W. F. O'Melia, Raytheon Company, Missile and Space Division, Bedford, Massachusetts.

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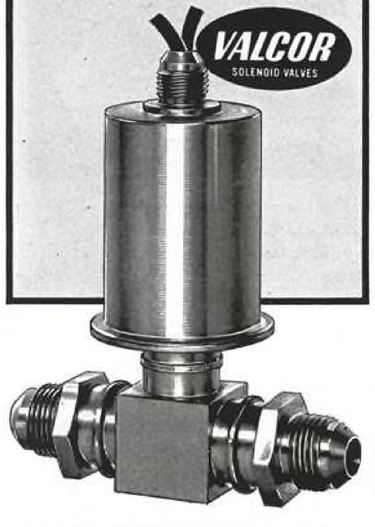
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Directorate. Both groups report through Houston to Roadman's office.

Ames Research Center primarily supports and executes the programs of the Bioresearch and Technology office.

White House-appointed panel which reviewed the nation's bioastronautic capability last year was critical of the fact that there is no central office in NASA to coordinate all its life science efforts. Associate Administrator Robert C. Seamans, Jr., performs this function along with all the other responsibilities, but some feel a top-level man should be assigned to the task full-time.

Gen. Roadman's office is responsible for all aerospace medical support of the Mercury, Gemini and Apollo programs, and any future NASA manned space flight programs. There are two major components of this mission:

• **Research and development,** test and evaluation of all life support systems—environment control, space suits and restraint, nutrition, respiration, waste removal and radiation protection—that go into a manned spacecraft. This work, as well as the determination of biological criteria for future pilots and validation of pilot selections, is executed by Dr. White's division at Houston.

• **Operational support** of existing programs, to be done by Dr. Berry's group, will include medical selection and care of pilots, preparation and insertion of pilots into spacecraft, world-wide medical monitoring of pilots in flight medical aspects of recovery, and data reduction and analysis of biomedical data taken during a flight.

Dr. White has about 100 personnel —nine of whom are physicians and more than 50 with engineering or medically-allied degrees—in four branches—biomedical; technical services systems support; crew equipment and human engineering.

Biomedical branch is used primarily to develop criteria for various elements of space flight—pilot psychology and physiology, safe radiation dosage rates, amount and nature of radiation shielding, tolerable acceleration forces, gas pressures and compositions and nutrition.

This branch is doing considerable research into radiation hazards with the Atomic Energy Commission and USAF's School of Aviation Medicine. Projects include an integrating dosimeter, which would show the total amount of radiation absorbed by a pilot during flight; effects of ionized radiation on different structural materials and anti-radiation drugs. A particle accelerator will be used for the structural radiation tests.

Crew equipment branch is concerned with spacecraft environmental control systems and escape, restraint and personnel equipment. Much of this unit's work is stimulated by requirements identified by the biomedical branch.

The crew equipment branch is heavily engaged in development of spacesuits for Gemini, Apollo and extra-vehicular missions. Gemini suit, being developed by B. F. Goodrich Co., will consist of three sections—torso, arms and legs. Arms, legs and helmet will be quick-disconnect units. Unlike Mercury, where the spacecraft was considered the primary pressure vessel and the pilot's suit a back-up, Gemini suits will be the prime pressure container. Cabin pressure will be dumped if one pilot leaves the craft in flight to test movement and working conditions in free space.

For Apollo, present NASA thinking tends toward a coverall that would be worn inside the capsule during flight and an extra-vehicular garment that would replace the coverall before a pilot left the spacecraft. A back-pack would provide the pilot with oxygen, water and communications for exploration of the lunar surface.

For Apollo, the crew equipment branch is planning a capsule atmosphere of 50% oxygen and 50% nitrogen at approximately one-half atmospheric pressure. Studies of different gas compositions and pressures are planned, as well as the effects on the human body of pure oxygen inhalation during high-g experience.

Human Engineering

Human engineering group takes the work of its sister branches and tries to determine if equipment has met the criteria successfully and whether all equipment lends itself to harmonious integration. Technical services branch is a pool of technicians assigned as needed to the other branches.

One of the more important and immediate jobs facing Dr. Berry and his present group of five is the medical selection of 10 new pilots for the Gemini and Apollo programs. The pilots are expected to be selected in September and Dr. Berry believes they generally will be younger by 5 to 10 years than the Mercury pilots because of program lead times. There is a strong possibility that a physician or medical specialist may be included in this group. Consideration also is being given to the flight-training of an astrologer or geologist for far-future flights.

Unlike Mercury, where pilots were tested first for basic biomedical data and trained later, these new pilots will undergo testing and training simultaneously.

Dr. Berry's Aerospace Medical Operations Office also will be responsible for the training of flight medical monitors, two of whom will be stationed at each tracking station and ship around the world during a flight.

Dr. Berry's office will have two branches—an astronaut care and training field element at Cape Canaveral and a future plans section at Houston. Cape field office, now headed by Capt. Howard Minners, USAF physician, will have at least three doctors as a sort of group practice for pilots undergoing training there. Field office also will check out life support systems of a spacecraft after delivery to the Cape and make tests of critical elements.

In supervising these two operations, Gen. Roadman's office attempts to make certain that not only are all critical bioastronautic areas covered by White or Berry, but that they are covered in depth.

To Gen. Roadman's office also has fallen the assignment of coordination with Defense Department on a joint bioastronautic program that will support Gemini, Apollo and Dyna-Soar. Defense suggested a list of 89 tasks applicable to all three programs. After a series of joint discussions, it reduced the list to 56 items. Defense will pursue these tasks using NASA funds.

Only two items proved to be controversial. Defense wanted to fly some animals at higher orbital altitudes before inserting men in the spacecraft, but NASA refused to participate. Defense also proposed to fly some instrumented satellites to determine the amount of spacecraft shielding required for radiation protection, but NASA insisted this data could be obtained on the ground, using a particle accelerator. Thirty-one tasks were dropped when NASA's plan for Fiscal 1963 revealed that the civilian agency intended to perform those jobs itself or contract them directly with industry.

Although these 56 tasks have been agreed to at NASA-USAF working levels, lack of precise definition of managerial responsibilities—the core of the NASA-Defense conflict—is holding up initiation of the work.

Bioresearch and Technology Office, established within the last several months, is concerned not only with manned space flight but with man in a space environment, such as crew members in a permanent space station or at a lunar base. The office is not oriented toward any particular project, but tries to identify and develop future life support items.

This fiscal year, Bioresearch and Technology plans to spend about $20 million through the Ames, Langley, Houston, Marshall and Edwards centers in these major areas:

• **Effects of space flight** on the human organism. Acceleration, sensory deprivation, heat, noise, radiation, zero-g, nutrition and atmosphere will be studied singly and in combination to determine man's performance and how it can be improved.

• **Life support systems** and the relation of such things as communications, displays, food, drugs, etc., to man's performance capability and their alteration or modification to improve that capability.

• **Manned systems integration,** to answer such questions as how does man receive and assimilate information? How does he use this data in the course of his flight to make his machinery respond to his wishes? These studies will attempt to optimize design of spacecraft systems from a pilot's point of view.

• **Applied physiology** and behavioral psychology.

Through these studies, Bioresearch and Technology will attempt to lay the groundwork for long-duration manned flight times of one to six months, considering both the man and the man-machine as entities.

Search for extra-terrestrial life and basic research into the effects of space and planetary environments on living organisms are the two basic goals of the bioscience office in the Office of Space Sciences. Biosciences director is Dr. Orr E. Reynolds. The Biosciences office has four branches:

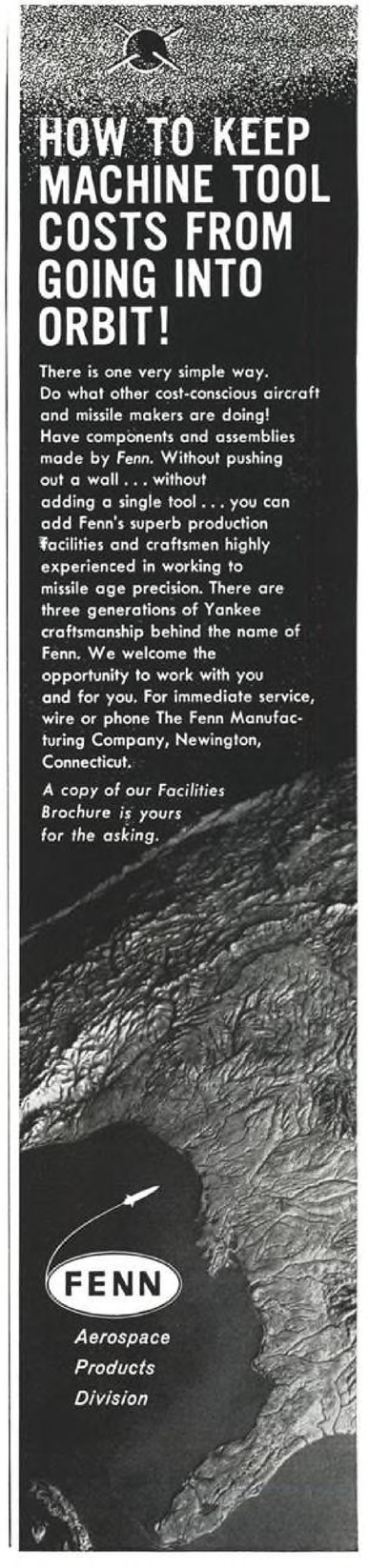
• **Exobiology,** under Dr. Freeman H. Quimby, is concerned with the identification of extra-terrestrial life forms, the study of the origin of earth-based life through biochemistry, the sterilization of spacecraft, search for microbes in the upper atmosphere through balloon-borne experiments, infrared spectroscopic investigation of Venus and Mars by a 36-in. telescope carried onboard a balloon and life detection devices to be flown onboard Mariner B and Voyager spacecraft in 1964 and 1966, respectively.

• **Environmental biology,** under Dr. Dale W. Jenkins, is interested in the effects of space environment on all living matter and types of earth life that could exist in other atmospheres.

• **Physical biology,** under Dr. George J. Jacobs, is concerned with new concepts and devices in bio-instrumentation so that accurate measurements of such parameters as blood samples, hormone flows and urinalysis can be made directly and simply in space. It also is concerned with fundamentals of respiration, cardiovascular system and the central nervous system.

• **Behavioral biology,** presently vacant, will study the reaction of organisms to different environments and the navigational, time-telling and communicative capabilities of various birds, mammals and insects leading to possible application to manned systems.

Last year the bioscience office issued about 50 study contracts, split about evenly between industry and universities, with a worth of about $2.5 million. Contracts and total dollar figure are expected to double this year.







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NASA—Wallops Island, Virginia

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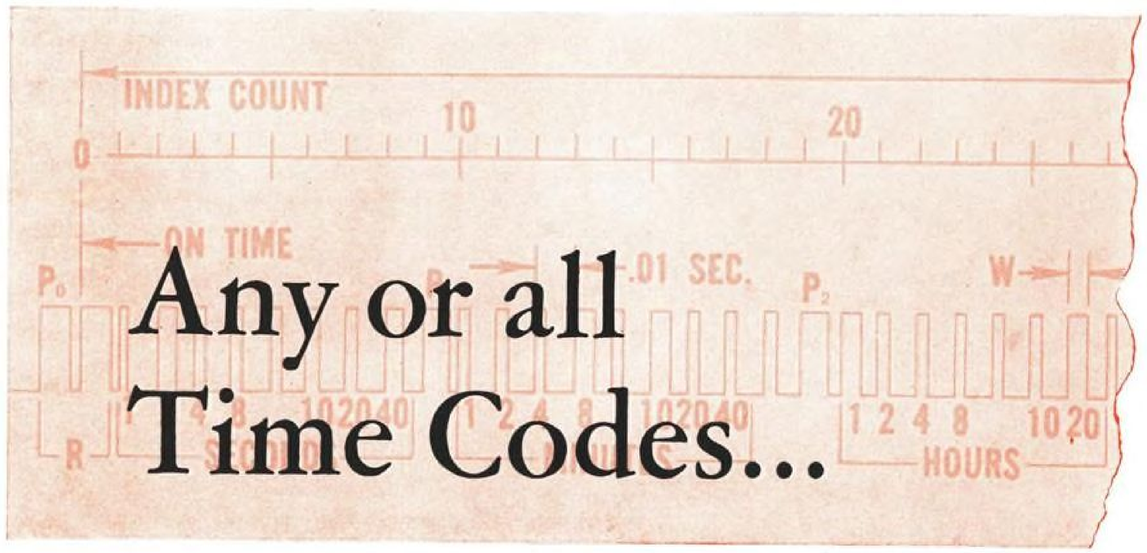
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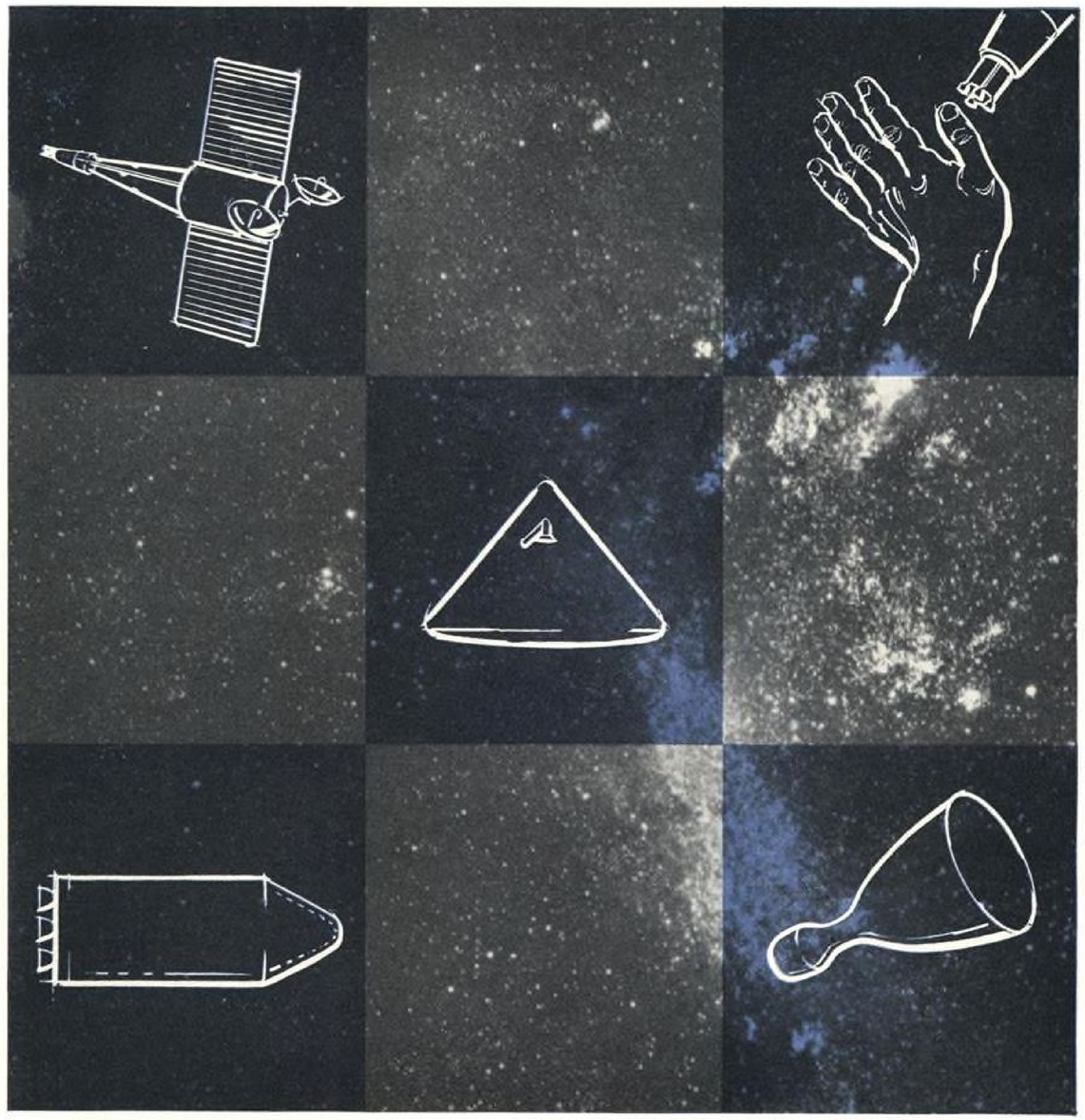
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Space Science Probes Secrets of Universe

NASA work ranges from gathering of basic physical data to supporting research for manned exploration.

Washington—Gathering of fundamental physical knowledge of the universe and man's relation to it continues to climb the steeply accelerating curve made possible by the first sounding rockets 17 years ago and the advent of artificial earth satellites in 1957.

This direct measurement of the planetary and interplanetary environment is entering a new phase through the use of complex orbiting observatories and the first of the probes that will take relatively close looks at Venus and Mars.

Space science is true basic research, embracing all the scientific disciplines and such elemental but exciting questions as the origin of life and the origin of the universe.

But its findings can be immediately and vitally applicable—discovery of the hostile radiation belts, prediction of solar flares that might prohibit manned flight to the moon or at the least require heavy shielding that must be considered early in the design and development of the spacecraft that will carry man.

Scientific curiosity provided the impetus for the space effort in the first place, and the National Aeronautics and Space Administration drew a key part of its operational program from the work of existing sounding rocket and satellite teams when it was formed late in 1958.

NASA's space science activity is directed by Dr. Homer E. Newell, a veteran of Navy rocket work and the first U.S. satellite program, begun for the International Geophysical Year.

Status Raised

In the major reorganization of NASA headquarters last November, set off by the addition of manned lunar landings to the NASA missions, the agency raised the status of space sciences to that of a major office equal to those for manned flight, applications, advanced research and technology and tracking and data acquisition.

Associate Director Robert C. Seamans, Jr., said NASA felt that in its first two years of organizing and operating a rapidly expanding space program, it had concentrated too hard on technology and had not made the most of scientific potential.

NASA's budget requests for the fiscal year that began July 1 included $556 million for the Office of Space Sciences, $150 million more than the Fiscal 1962 appropriation and more than double the cost of the Fiscal 1961 science program. Most of the increase is for lunar and planetary probes that have reached or are nearing flight status and for the larger, more expensive observatory-type satellites.

The lunar and planetary program is to cost approximately $270 million this year and the scientific satellite programs $175 million. Since the reorganization was partly an attempt to pull together all space science elements into one office, Dr. Newell's group has responsibility for sounding rockets and the Scout, Delta and the Centaur launch vehicles. It does not have cognizance over the USAF-developed Thor Agena and Atlas Agena, although it uses these vehicles. The budget requests included $95 million for the NASA vehicles, the bulk of which is for Centaur.

Lunar, Planetary Work

NASA's lunar and planetary work is carried out chiefly by the Jet Propulsion Laboratory at Pasadena, Calif., and most of the scientific satellite work falls to the Goddard Space Flight Center at Greenbelt, Md. A number of sounding rocket shots and proving flights for scientific hardware that will later be flown in satellites are conducted at NASA's Wallops Station, Wallops Island, Va.

The space science office also oversees basic research performed for NASA by universities, industry and nonprofit firms and, since it is the focal point for the exploratory end of NASA's business, has by far the most contact with scientists from other countries who participate in the space agency's international program.

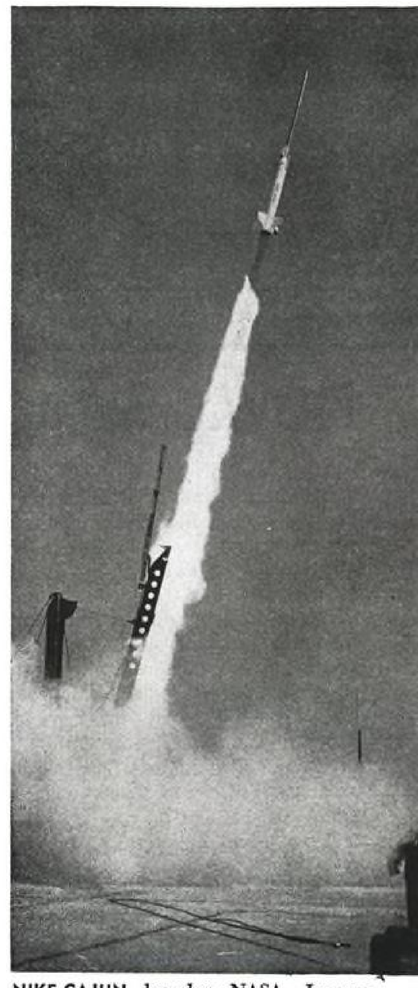
Bioscience programs dealing with life in space other than that of man has been placed in the space sciences office, while Aerospace Medicine is under the Office of Manned Space Flight and biotechnology is a part of the Office of Advanced Research and Technology. The sciences office also has cognizance over the recently renamed Pacific Launch Operations Office at the Pacific Missile Range, since most of the NASA launchings from there will be of scientific probes and satellites.

Scientific space exploration passed a milestone with the recent launching of the first Orbiting Solar Observatory. Although this was a medium-sized satellite compared with the huge Orbiting Astronomical Observatory now being built, its complexity places it in what Dr. Newell calls the advanced satellite category.

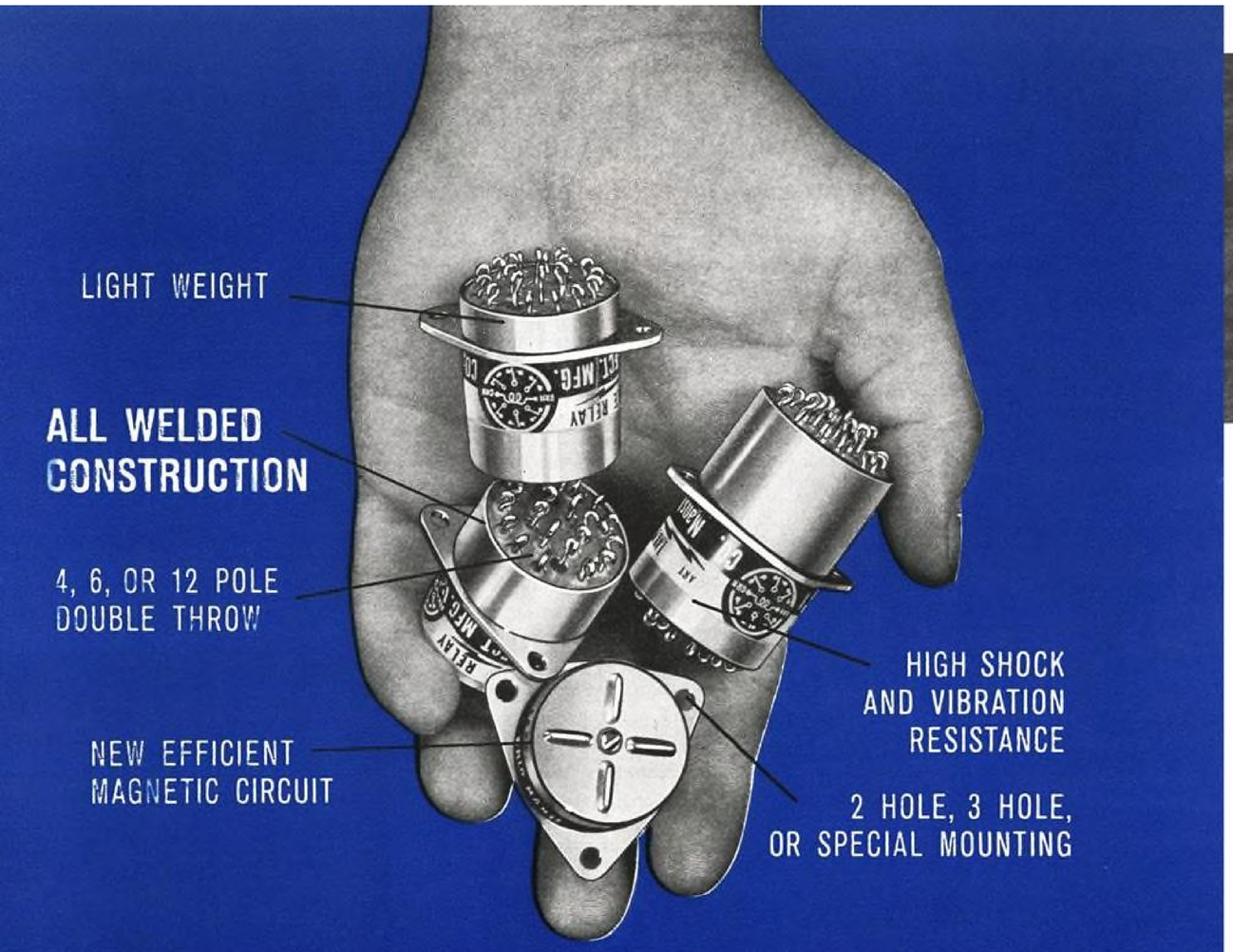
These observatories will serve as "streetcars" that can carry a large number and great variety of experiments at one time. But perhaps more important, they will permit important astronomical observations from above the earth's atmosphere, which Dr. Harry J. Goett, director of Goddard, has likened to "a translucent blindfold."

Dr. Newell recently told Congress that development of the necessary instrumentation and techniques for making observations in the ultraviolet portion of starlight, which is not visible from ground observatories, is "a major scientific objective of the present [astronomical] program."

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techniques involved are themselves on the forefront of science and technology, this program is one in which nearly any measurement is more likely to reveal the unexpected than the expected," Newell said.

Almost the same could be said about any primary area of space science exploration. NASA plans to launch 11 scientific satellites, 5 scientific probes and 84 sounding rockets in this calendar year, and Dr. Newell has said in effect that it takes about one year to organize returned satellite data and many years to make real sense of it.

Researchers still are digging back into rocket and satellite data gathered during the IGY in 1957-1958 as new data seem to affirm or contradict earlier findings. And Edgar M. Cortright, Newell's deputy, told Congress that six to eight large IBM 7090 computers are at work reducing information returned from satellites—a step that precedes and is much shorter than analysis of the data.

NASA's goal in the space science area is to achieve a one-year useful lifetime for satellites, compared with weeks or months now, and eventually to keep several basic types of observatories in orbit at one time. The problems this will pose for the great number of experimenters—in NASA, the universities and industry—who must interpret and try to understand the vast amount of information that will be gathered is illustrated well by Dr. Newell's summary of what satellites revealed in 1961.

The important scientific discoveries that the 1961 findings reverse or modify were only as old as 1958 and some were as new as 1960—an extreme telescoping of the process of collecting, studying and understanding, even for the world of science.

". . . The more recent observations showed the intensity of the electrons in the outer [radiation] belt appeared to be a thousand-fold lower than earlier measurements indicated," Dr. Newell said. These observations also indicated that "about as many medium energy protons as the [magnetic] field can hold were found in the outer belt, but the ultimate source of many of the protons appears to be solar protons coming in through the auroral regions . . . The earth's magnetic field appears compressed on the side toward the sun and blown out on the other side.

"If the field is distorted in such fashion, the presumption is that a steady solar wind is the cause. On the other hand, there have been no firm observations of such a solar wind . . . Finally, although the existence of a ring current around the earth appears established, the various measurements disagree as to where this current is actually located.

"The various observations and analyses of the past year have combined to indicate that the radiation hazard in the Van Allen belts may be appreciably less than had been thought earlier, while the hazard due to energetic solar proton streams may be considerably greater.

"Considerable progress has been made in this area during 1961 but in large measure that progress has been a continuing revelation of the complexity of the problem and of the need for much more detailed observation such as can be obtained with a monitoring-type satellite."

Although fundamental knowledge and basic understanding are the primary goals of the space science program, practicalities have necessitated a reorientation of some programs—particularly in the lunar area. Assignment of the Apollo manned lunar landing program has left the Ranger lunar spacecraft program relatively unaffected but has moved Surveyor experiments farther along the spectrum toward applied research—reconnaissance of the lunar terrain in preparation for man's landing there instead of a general mapping mission, for example.

The lunar and planetary programs also have suffered from unexpected delays in the development of the pioneering, hydrogen-fueled Centaur vehicle.

Despite these problems, the space science program remains the spearhead of NASA's efforts. Its complexity is illustrated by Newell's analogy of the difficulty of achieving a guiding accuracy of 0.1 sec. or arc for the Orbiting Astronomical Observatory—"about equivalent to the accuracy required to use a telescope located in Baltimore to pick out either the right or left eye of an individual in Washington (40 mi. away) for detailed study as to its color and brightness." But its importance and its promise are in some ways even greater than that of the manned flight program, because it is the exploratory work that must precede man to the moon and to the planets.

AEROBEE nose cone with one Geophysics Corp. and three Goddard experiments is retrieved by Sikorsky S-62 helicopter after launch from Wallops Island to test the Aerojet recovery system.



JPL Selects Discipline-Type Organization

NASA's contract laboratory structured along systems lines; procurement policies differ from government.

Pasadena, Calif.—Principal missions of the Jet Propulsion Laboratory—management and execution of unmanned U. S. lunar and planetary exploration programs—are carried out with an organization grouped into technical disciplines.

JPL has selected a discipline type of organization, rather than a project-oriented one because it believes it can maximize its long-term contributions to the space effort by developing a wide range of technologies.

These qualify it to conduct and direct space work from a total systems viewpoint, possibly with fewer people and spreading further than they otherwise might.

JPL has eight technical divisions corresponding to relevant space disciplines such as propulsion, guidance and control and telecommunications—each responsible for maintaining and advancing the laboratory's competence in their respective areas. Every division conducts its own supporting research, advanced development, field activity and contractual work. Seven are engineering divisions; the eighth, the Physical Sciences Division, is devoted exclusively to research as insurance that all important fields are covered.

Lunar, Planetary Programs

Organizationally, the lunar and planetary program offices are set apart from the division but draw heavily on their talents. Division chiefs and program managers alike report directly to the laboratory director, Dr. W. H. Pickering.

The discipline type of organization raises some managerial problems for program offices in that they do not have direct control over divisional activities. Program and project managers must exercise more diplomacy in encouraging cooperation of divisional people over whom they have no managerial responsibility. But this independence has resulted in good cooperation with division chiefs and better talent in the divisions and has permitted a balance to be maintained among disciplines.

JPL has a somewhat different relation to the National Aeronautics and Space Administration than NASA's own centers because it is a contractor. The laboratories, facilities and 146 acres on which they stand are owned by the government. California Institute of Technology, JPL's parent organization, is under contract to NASA to conduct assigned scientific and technical missions and to operate and maintain the facilities.

A JPL board of directors, consisting of CalTech faculty members and its board of trustees, governs the laboratory.

The contract, originally written in 1958 when NASA was formed and JPL was transferred from Army jurisdiction, has annual increments of funds. Each year the laboratory prepares a budget estimate of funds needed to conduct its efforts, submits it to NASA headquarters which scrutinizes and adjusts it, and incorporates it into the over-all budget for submission to the Congress.

Procurement Practices

The laboratory's contractual status is reflected partially in its procurement practices, which are not identical with government procedures but follow them in spirit and intent, according to V. C. Larsen, Jr., assistant director for business administration.

JPL does not advertise its impending procurement, for example, as do government agencies. It does, however, encourage competition for procurement, attempting to maintain equal capabilities among bidders and showing no reluctance to give contracts to anyone invited to bid, Larsen says. Bidders' lists are a composite of names submitted by procurement people and cognizant engineers.

The procurement office will receive contractors unfamiliar with the laboratory and arrange for them to make technical presentations to the cognizant laboratories, if necessary. It also accepts unsolicited proposals and directs these to the appropriate laboratory or section. Each division is now capable of creating any type of contract with industry.

In the past year approximately 75% of JPL's total budget money was placed with industry, covering the spectrum from exotic studies to pencils. This will rise to 80% in Fiscal 1963.

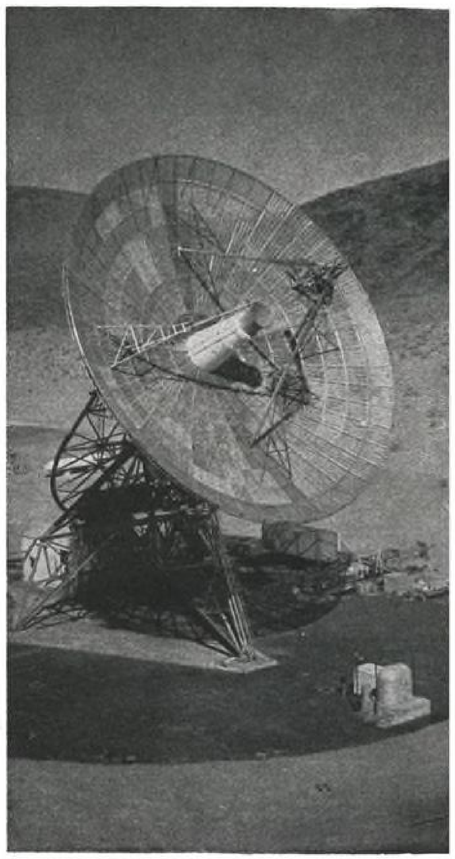
Industry Relationship

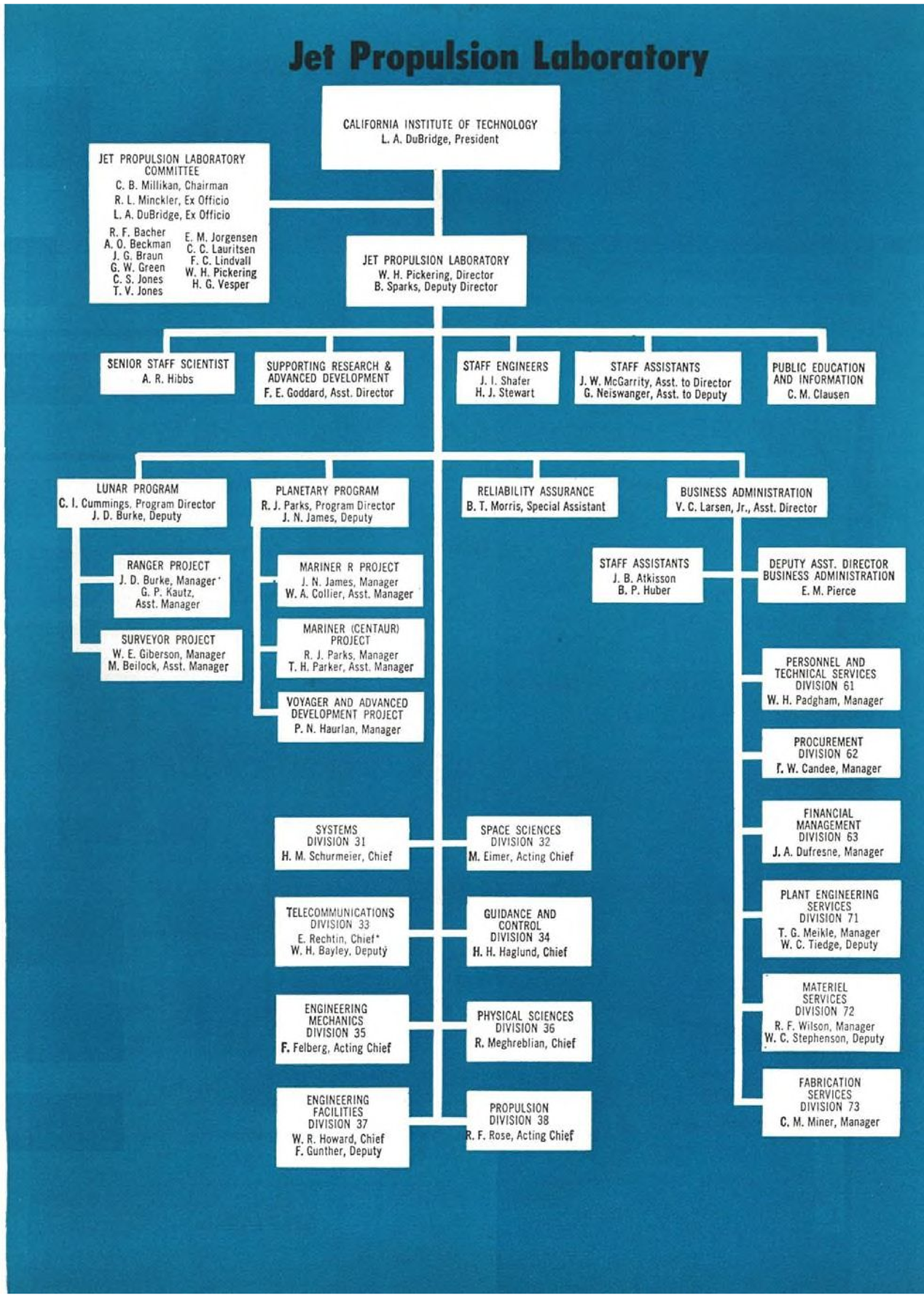
Decision whether a spacecraft project or major part of it, such as its mission package, will be contracted with industry is strongly influenced by the likely number of spacecraft to be used, which is in turn a reflection of the launch opportunities. Lunar launch opportunities occur more frequently—each month—than planetary opportunities and make possible more shots in a given project over a period of time. It is these high-density programs such as the Surveyor lunar spacecraft for which the laboratory will award a complete systems management contract with industry.

A less dense planetary project, such as Mariner, with launch opportunities spaced at 19-month intervals for Venus and about 25 months for Mars, are kept in-house. Mariner is kept in-house for another reason—to permit the laboratory to develop its skills in more difficult projects and remain in the forefront of space technology.

Ranger lunar spacecraft is an exception to the high-density rule of thumb. Like Mariner, it was kept in-house—although mission packages, or payloads, for 7 of 9 shots are handled by industry—to gain experience and develop technologies such as long-term attitude stabilization, long-distance communications, mid-course maneuvers, command, etc.

JPL's first 85-ft. dish at Pioneer site.





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JPL Requests

Pasadena, Calif.—Jet Propulsion Laboratory has requested a $49.7 million operating budget for Fiscal 1963, and an increase of 441 employes to bring the total to 3,766. The laboratory is situated on three sites: 148 acres here near the California Institute of Technology; 600 acres at Edwards, Calif., and a 50-sq. mi. site at Goldstone tracking facility.

Current plant value of JPL is $43.4 million. The laboratory has requested $10.4 million for FY 1963 expansion.

Spacecraft projects are handled within a lunar or planetary program office. The program managers for the two, respectively, are Clifford I. Cummings and Robert J. Parks. Each has small supporting staffs making up schedules and program analyses, handling fiscal and administrative matters, program planning, advanced development ideas and, in the lunar office, manned flight liaison.

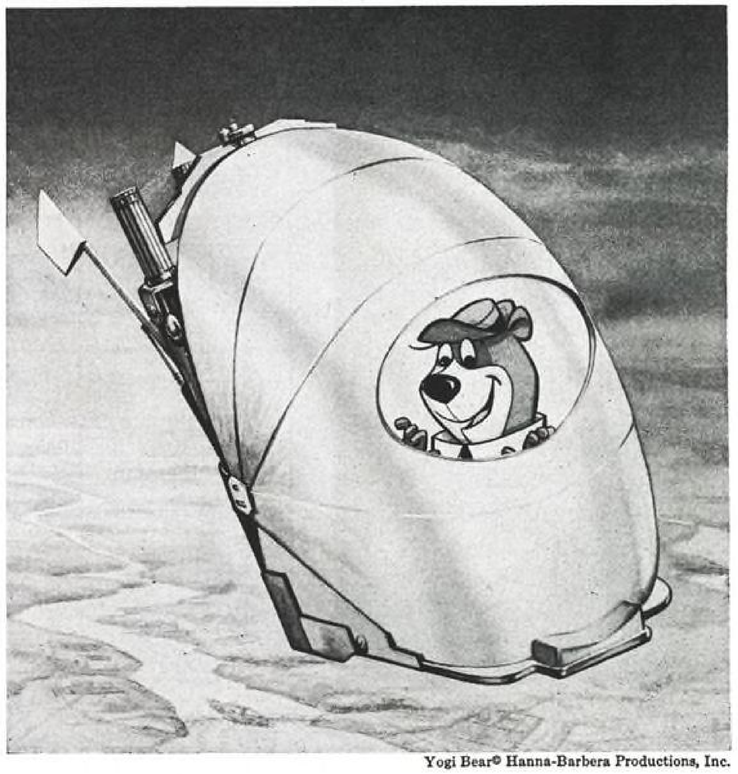
Program offices have at least two projects—Ranger and Surveyor in the lunar office and Mariner (Atlas-Agena), Mariner (Centaur) and Voyager in the planetary office.

Authority of the laboratory director, including allocation of and accountability for funds, has been delegated to the program managers and, in the lunar program, to project managers—W. E. Giberson for Surveyor and James D. Burke for Ranger.

For Surveyor, the project office sets guidelines, objectives and spacecraft requirements and has technical direction and contractual management of the systems engineering contract with Hughes Aircraft Co. Highly-qualified journeyman engineers are assigned to the Surveyor project office from the divisions, which receive technical assignments from the project office but report to their respective division chiefs. These engineers provide liaison among the divisions, project office and contractor, take special assignments and enable divisions to benefit from the Hughes Surveyor experience.

As with all JPL spacecraft programs, the Marshall Space Flight Center has responsibility for the launch vehicle, coordinated with the project office. Also reporting to the project manager are responsible engineers within the divisions for JPL's Space Flight Operations Center, Deep Space Instrumentation Facility and Spacecraft Systems Office. Surveyor contract is let from the project office. In the case of Ranger, for which system responsibility as well as total project responsibility remains in-house, the mission package contractors—Aeronutronic and Radio Corp. of America—report to a JPL spacecraft systems manager on the Ranger project staff.

Hydro-Space News



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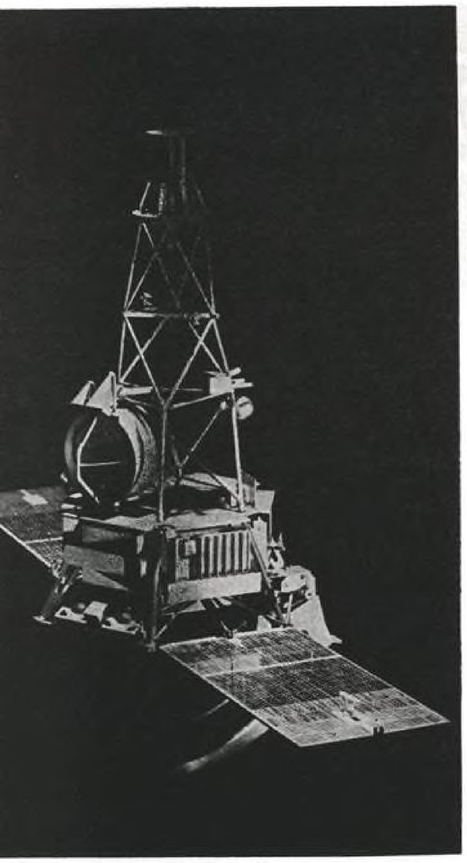
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UNMANNED LUNAR & PLANETARY PROGRAM

SPACECRAFT:	LAUNCH VEHICLE:	LAUNCH DATE	INJECTED WEIGHT (LB.)	INJECTED WEIGHT BREAKDOWN (LB.)	MISSION:	COMMENT
RANGER 1	Atlas-Agena B	Aug. 23 '61	675	Experiments: 121, Bus :554	Test of spacecraft to be employed in lunar landing missions and to obtain interplanetary data	Demonstrated spacecraft operation; failed to go into intended elliptical orbits
RANGER 2	"	Nov. 18 '61	675	" "		
RANGER 3	"	Jan. 26 '62	727	Capsule subsystem including retro, seismometer, transmitter: 329, other scientific experiments: Bus : 366	Rough landing of instrumented capsule on moon, TV pictures of surface before impact, gamma radiation measurements near moon, seismic data	Aeronutronic Division of Ford Motor Co. is mission package (instrumented capsule and retro system), or passenger, contractor. TV system optical resolution is 3 to 4 meters. Estimated capsule instrument life is 30 days maximum. Ranger 3 missed moon by 22,862, mi. due to excessive boost velocity; Ranger 4 impacted on moon; telemetry lost because of malfunction in spacecraft.
RANGER 4	"	Apr. 23 '62	730	Capsule subsystem including retro, seismometer, transmitter: 332; other scientific experiments : 30.9, Bus : 367		
RANGER 5	"	Oct. '62 (est.)	730 (est.)	Similar to above		
RANGER 6	"	1963	750 (est.)		Obtain high-resolution TV pictures of lunar impact area before rough landing.	Astro-Electronics Division of RCA is mission package (six synchronized videcon cameras), or passenger, contractor. Resolution will be between 1/2 meter and 10 cm.
RANGER 7	"	1963	750 (est.)			
RANGER 8	"	1963	750 (est.)			
RANGER 9	"	1963	750 (est.)			
MARINER 1	"	July '62 (est.)	450 (est.)	Instrumentation: 40	Venus flyby; obtain data on magnetic fields, atmospheric properties, surface temperature distribution	Spacecraft employs basic hexagonal Ranger bus. Two additional spacecraft of this type under consideration for planetary opportunities in 1964. Spacecraft formerly called Mariner R
MARINER 2	"	Aug. '62 (est.)	450 (est.)	Instrumentation: 40		
MARINER B SERIES	"	(see comment)	1,200-1,700 (est.)	Instrumentation on order of 200-300	Venus and Mars fly-by; possible capsule ejection on Mars, additional planetary property measurements	Test of escape mission in '63 or '64; two Venus shots in 1964, two Mars shots in '64 , four shots in '65. At least seven shots to start in late '63 or early '64 depending on development and payload capability of Centaur. Estimated lunar life: 30 days (min.). Hughes Aircraft Co. is systems contractor.
SURVEYOR A SERIES	Atlas-Centaur	Begin late '63	2,300-2,500 (est.)	About 2/3 of injected weight will be spacecraft propulsion ; remaining weight including about 200 lb. of instruments to be soft landed	Demonstrate soft-landing; determine lunar physical properties	
SURVEYOR B SERIES	Atlas-Centaur	Begin in '64	Roughly same as above	About 1/3 of injected weight will be propulsion	Lunar orbital flights; TV reconnaissance and landing site selection for Apollo, radiation and other physical measurements . Planetary exploration ; possible orbiting of Venus and Mars; ejection of planetary capsules.	Photographic resolution: 1 to 100 meters. Estimated life: 6 mo. to 1 yr. (ultimately). Five or more shots.
VOYAGER	Atlas-Centaur		5,000-10,000			Under study. Originally intended for Saturn C-2. Boost vehicle undecided.
PROSPECTOR						Mission, boost vehicle unsettled.

Unmanned Lunar Program to Aid Apollo

Pasadena, Calif.—Unmanned lunar exploration program is being reoriented in both tangible and subtle ways to provide support for the nation's accelerated effort to place a man on the moon later in this decade.

Simultaneously, as the pressure for specific knowledge about the moon, its environment and physical characteristics increases with progress in the Apollo program, the Jet Propulsion Laboratory, which manages the unmanned lunar program for National Aeronautics and Space Administration, faces a vexing problem not of its own making—the frustrating delay in the development of one of its primary boost vehicles, the Centaur.

Together, the need to compress the timetable for gathering lunar data and the erosion in the schedule of Centaur availability and capabilities are reshaping the course, but not the ultimate objectives, of the unmanned lunar program.

Fortunately, the spacecraft design philosophy followed here permits some reorientation of programs and even juggling of launch vehicles. Each spacecraft project—Ranger, intended to rough-land an instrumented capsule on the moon's surface; Surveyor, planned as a soft- or controlled-landing stationary lunar vehicle, and the Mariner series, intended for planetary flybys and having in later models the capability for ejecting a planetary entry capsule—consists of two separate identifiable parts.

Roughly, these are a "bus" or basic spacecraft structure and associated control and communications equipment, and a "passenger," or mission package. The demarcation varies from project to project, becoming physically less separable in a complex, tightly integrated spacecraft such as Surveyor (AW Feb. 20, 1961, p. 70).

The bus-passenger approach permits a passenger to be substituted with less lead time than would be required to replace the whole spacecraft. This gives both lunar and planetary programs a flexibility which to date has absorbed much of the effect of the accelerated need for lunar data and disappointing delays with launch vehicles. Both Surveyor and Mariner are scheduled to use the Centaur.

Influence on Programs

Specific examples of how these two factors combine to influence the lunar program are:

• **Lunar orbiter**—Lunar orbiter series, using the basic Surveyor bus and called Surveyor B, is receiving more detailed attention. When the paramount objective of the unmanned lunar program was science for science's sake, the orbiter was envisaged as a polar satellite which would map the front and back sides of the moon, concentrating more on the hidden side. Now the concept is recasting the primary function to one of observing the lunar terrain in regions of possible interest to the Apollo lunar landing program.

This puts the emphasis on the region of ±10 deg. lunar latitude and at particular longitudes on the facing side of the moon. The orbiter no longer is necessarily a polar orbiter and its mapping function drops to secondary importance.

The passenger for the bus will consist principally of an optical-camera subsystem, called Visual Instrumentation Subsystem (VISS). JPL was to ask for industry proposals recently for a study leading into development of VISS. The VISS contractor probably will have a similar relation to the Surveyor project that Aeronutronic Division of Ford or Radio Corp. of America has to the Ranger project. Funds for five Surveyor B spacecraft were included in the Fiscal 1963 budget request.

For the orbiter, the Surveyor bus will be the spaceframe without landing gear, with half of the spacecraft propulsion required for the soft lander and the same attitude control and communications systems. With a common spacecraft, the interface with the launch vehicle will be the same, making possible flexibility in selecting a B or an A (soft-lander) shot, once both series have begun and launch vehicles are up to full anticipated capability.

Since the spacecraft propulsion for an orbiter will be approximately half that needed for a soft-lander, JPL may want to trim the weight of VISS sufficiently to offset the reduced thrust capability and overweight condition expected in early Centaur vehicles.

• **Additional Rangers**—Four additional Ranger vehicles were added to the project (AW Sept. 4, p. 28) to obtain higher resolution television pictures of lunar impact areas than is possible with Rangers 3 through 5—maximum optical resolution on the order of ½ meter, compared with 3 to 4 meters. In the later Rangers, mission packages will contain four vidicon TV cameras, synchronized to take overlapping frames, making possible stereo reconstruction of particular areas of interest leading up to impact.

A fifth, wide-angle camera keeps the pictures of the other four narrow-angle cameras in its view and a sixth camera looks off at 30 deg. angles, giving reference to the landing point. This mission package—cameras, their electronics, power supply and regulator, telemetry, sequencer, etc., made by RCA's Astro Electronics Division—replaces the mission package of Rangers 3 through 5, which is an instrumented capsule and retrorocket system. The later pictures may give a clearer view of impacted areas of the moon next year, possibly contributing significantly to knowledge of physical nature or surface texture.

• **Prospector**—Probable requirement for a large vehicle, carrying a small lunar rover or sample return system as alternate passengers, and originally intended for boost by a Saturn C-1 with an additional upper stage, must now be coordinated with the manned Apollo program. The kind and size of roving vehicle, whether one is needed for the manned program as a logistics vehicle and whether the needs of the two programs can be mated are under study.

Surveyor A Slippage

Meanwhile, the Centaur situation has caused a slip in the first Surveyor A launching from the summer of next year to later in the fall, and more slippage may be on horizon, according to Clifford Cummings, lunar program director. Launch capability of initial Centaur boosters, on which Surveyor spacecraft may have to ride, are not expected to be up to expectation, making the slight weight margin between the injected spacecraft weight and the calculated Centaur injection weight capability for the soft landing shot appear dubious.

The slippage gives JPL and the Sur-

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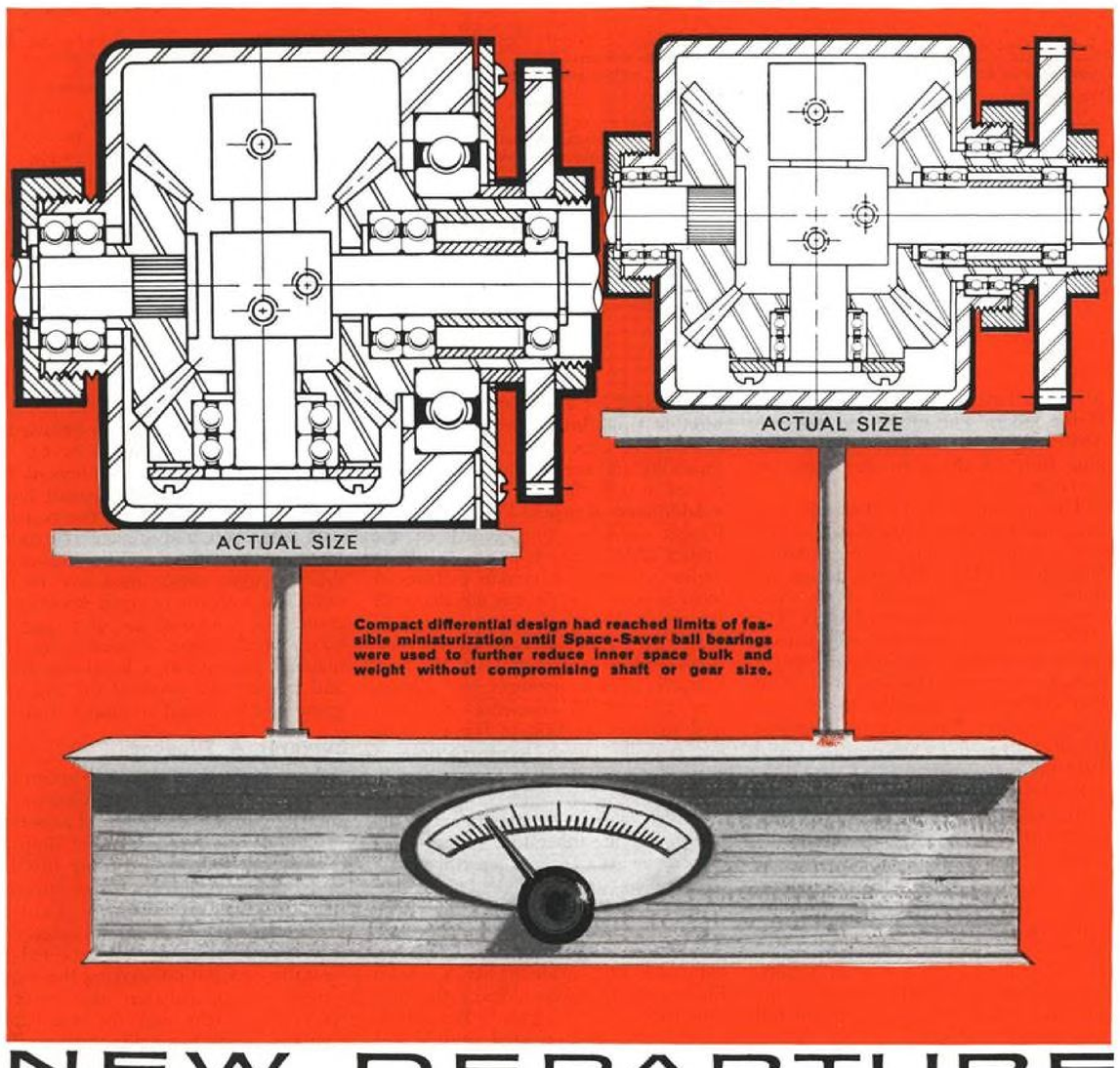
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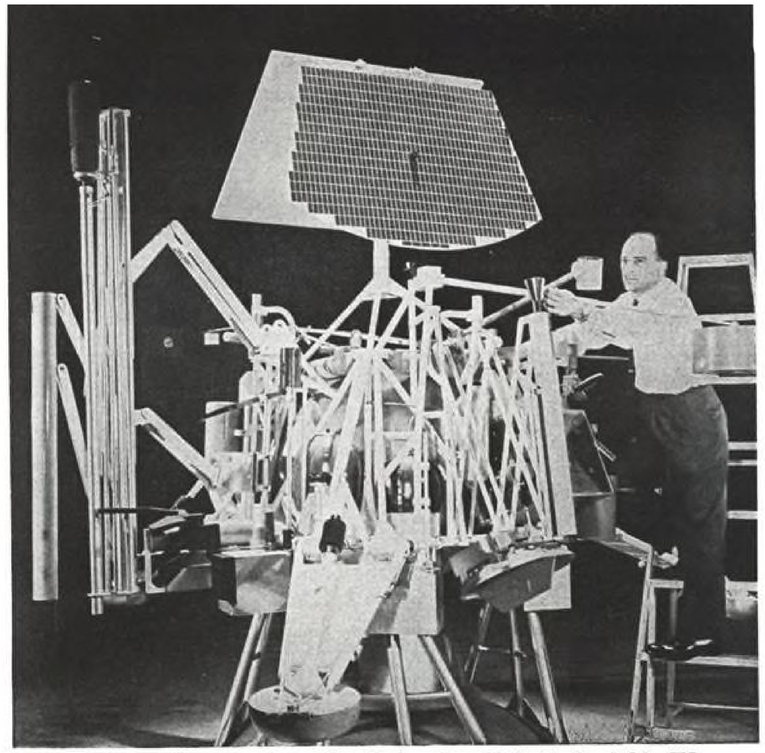
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FULL-SCALE Surveyor spacecraft model at Hughes plant. Project is directed by JPL.

veyor systems contractor, Hughes Aircraft, time for more extensive testing of prototypes of the spacecraft, which continues close to schedule.

JPL examined carefully the possibility of achieving a soft lunar landing with alternate launch vehicles, concluding that soft lunar landing with an Atlas-Agena B was technologically feasible but impractical. Injected weight of the lunar spacecraft would be only 750 lb., most of this weight consumed by spacecraft propulsion.

Additional Rangers

More Rangers may be added to maximize the lunar data that can be gathered during any enforced hiatus between the current Ranger series and full-scale Surveyor launches. Both Aeronutronic and other firms have suggested additional experiments, employing the embryonic-like Ranger hard-landed capsule and retrosystem or substituting new passengers on the Ranger bus.

Original objectives of the unmanned lunar program in order of importance were to:

- **Better understand** the origin of the moon and the solar system.
- **Obtain scientific data** and technological information for further lunar exploration.
- **Provide a maximum** of information to the manned space flight program.

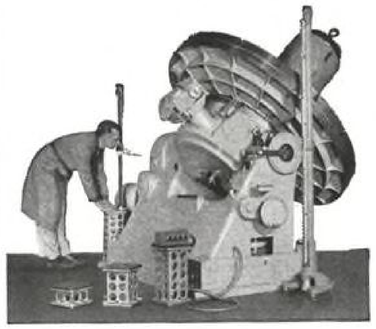
When these objectives were formulated, manned lunar exploration appeared 10 years off. As the Apollo program emerged to quicken the pace, however, the order of importance of the unmanned program's objectives became reversed.

This has caused a reorientation in the way projects—particularly Surveyor—are viewed, but not changes in the soft-landed vehicle itself. The new emphasis probably will reshape the sequence in which the many instruments being developed for the program (AW July 3, 1961, p. 62) will be flown, giving priority to those whose measurements may basically influence Apollo design. This means greater stress on measurements of physical properties and pictures of the terrain, less on chemical and mineralogical analyses.

Particularly, JPL hopes to learn about lunar surface characteristics—surface bearing strength, lunar radiation environment and answers to questions such as whether there are boulders, cracks or crevices, what happens to lunar dust and whether our ideas of lunar temperature and surface features are correct.

Four television cameras on the Surveyor should give a good idea of surface features and texture in the vicinity of the landing spot.

A set of experiments, being developed by Texaco Experiment, stacked on a 21-in. probe and inserted into a hole dug by the Surveyor's drill, with a partly duplicating set on the surface, may be of particular value. These experiments are to measure density, hardness, temperature, thermal diffusivity, penetrability, magnetic susceptibility, relative susceptibility, electrical resistivity and speed of propagation. If the drill fails to penetrate the lunar crust, the par-



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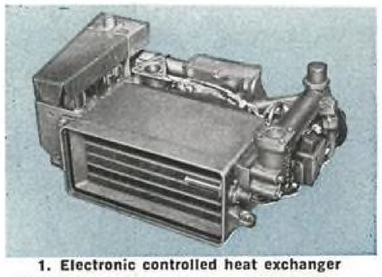
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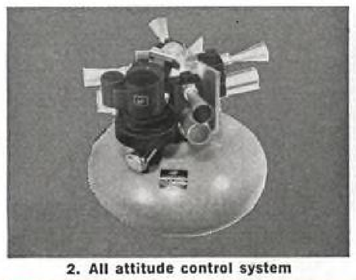
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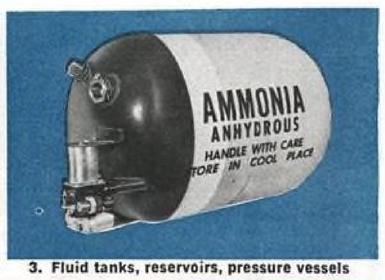
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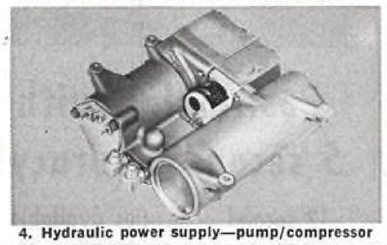
1. Electronic controlled heat exchanger



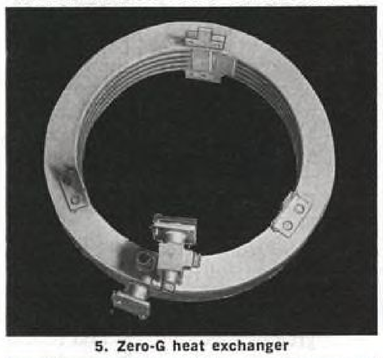
2. All attitude control system



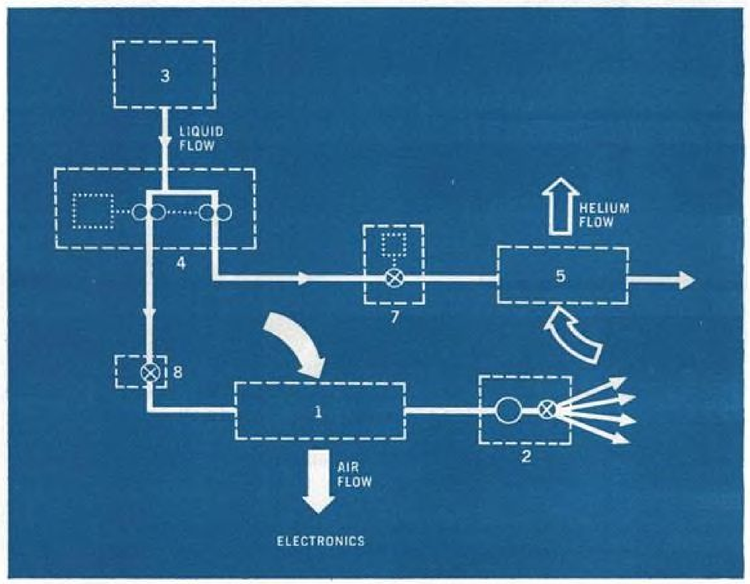
3. Fluid tanks, reservoirs, pressure vessels

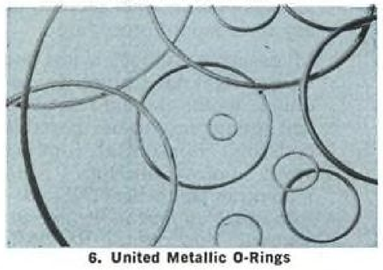


4. Hydraulic power supply—pump/compressor

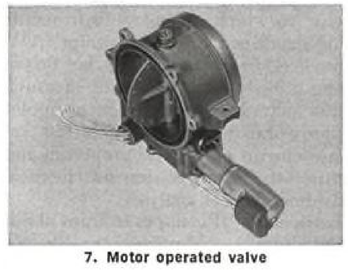


5. Zero-G heat exchanger

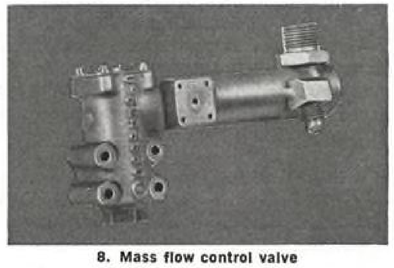




6. United Metallic O-Rings



7. Motor operated valve



8. Mass flow control valve

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Lunar Spacecraft Costs

NASA estimates that its Ranger rough-landed lunar spacecraft will cost about $7.5 million each. Soft-landed Surveyor vehicles may cost between $10 and $15 million each. Including launch vehicle and related costs raises these figures appreciably—in the Surveyor case to beyond $25 million per launch.

Seven projected Surveyor A soft-landed vehicle experiments are expected to cost between $180 and $200 million, according to an estimate made by Edgar Cortright, deputy director of NASA's Office of Space Sciences, before Congress.

Five Surveyor B shots—lunar orbiters using a modified Surveyor spacecraft—will cost about $132 million, including the costs of spacecraft development, launch vehicles, salaries and institutional support, Cortright estimated.

tially duplicate set of instruments offers a fallback set of readings. Should both sets operate and return data successfully, a comparison of surface and subsurface measurements will be possible.

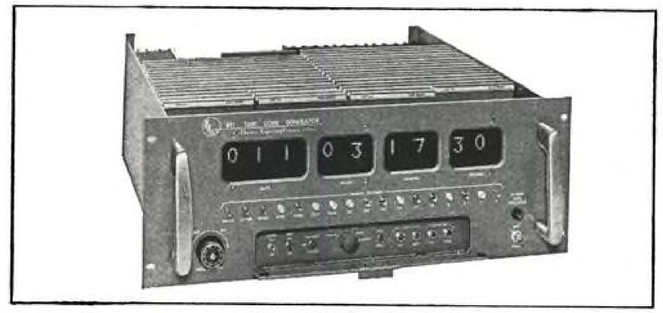
The shift of interest to support the manned lunar effort is nowhere more apparent than in the area of field and particle measurements in both the Surveyor and Mariner projects. The interplanetary medium presents hazards to man, and proton energies between 30 million electron volts (mev) and 300 mev are the ones of particular potential hazard and of particular concern in support of the Apollo efforts. The energy regions above and below this range, however, are of more interest to science. Low energy measurements provide information about solar phenomena, solar flares and possible existence and properties of a solar wind, while the higher energy levels might yield a better understanding of cosmic rays. Accumulated radiation intensities also assume more importance now.

JPL also is looking more closely at extending the portions of the moon that its spacecraft will view toward regions more likely to be of interest in Apollo. The western half of the moon generally is the target area for non-return shots because of lower energy requirements. For return missions, the requirements are less leaving from the eastern portion of the moon. Interest of the unmanned program is shifting eastward, with Rangers 6 through 9 intended to impact more easterly, toward the center of the disk.

Lunar orbiters may eventually serve a number of functions beyond the gathering of photographic data—with resolution perhaps from 100 to 1 meter—to aid in landing site selection. These would include conducting radiation and other physical experiments, determining lunar gravity and mass distribution.

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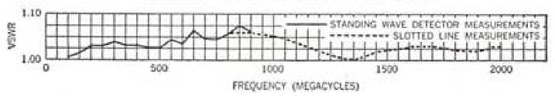


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Venus First Target in Planetary Series

JPL pushes Mariner 1 for basic scientific exploration; second-generation payloads to eject landing capsules.

Pasadena, Calif.—Jet Propulsion Laboratory's planetary and interplanetary program has generally escaped the reorientation required in its lunar program by a change in national goals, but the failure of the Centaur launch vehicle to be ready on time has cast its shadow over the timetable for exploring the planets.

Two attempts to launch spacecraft into Venus fly-by trajectories, scheduled for this summer, were scaled down and shifted to the lower thrust Atlas Agena B vehicle because of Centaur development delays (AW Oct. 2, p. 26), and two more lightweight Mariner spacecraft may have to be substituted into the program at one of the next planetary opportunities two years from now.

The flexibility of JPL's bus-and-passenger approach to spacecraft construction (see p. 156) permitted the use of a basic Ranger bus for construction, with about one year's lead time, of the special planetary payloads Mariner 1 and 2 (previously called Mariner R) as substitutes for the heavier Mariner A Venus fly-by spacecraft.

Since a Venus opportunity—the brief period when the earth and Venus will be approaching their closest proximity so a spacecraft launched from earth could encounter the planet by traveling a minimum distance—occurs only at 19-month intervals, NASA and JPL were reluctant to miss the opportunity this summer.

Using the basic hexagonal-shaped Ranger bus with extensive modifications to increase spacecraft propulsion, alter communications and add scientific instruments, JPL engineered a hybrid craft using many of the ideas and equipment from the discarded Mariner A. The change more than halved the 1,100-lb. anticipated injected weight of Mariner A (AW Feb. 5, p. 57).

Lightweight Instrument Pack

The lightweight Mariners are to be equipped with 40 to 50 lb. of instruments, including microwave and infrared radiometers, to obtain temperature measurements through the planet's atmosphere, thereby obtaining a temperature distribution; a magnetometer for measuring the strength of interplanetary and Venusian magnetic fields; plasma probes for gaging interplanetary plasma levels; an ionization chamber and Geiger counter package for measuring protons and electrons; and cosmic dust detectors.

The planet's rotation rate and inclination of its spin axis, critically important parameters in planning for possible Venusian entry capsules to be ejected from follow-on Mariner B and Voyager spacecraft, may be derived from the microwave measurements. Hints about the planet's atmospheric constituents may be inferred from radiometric readings of carbon dioxide and water vapor lines.

Mars and Venus are of immediate interest in the Mariner project because of their relative proximity to earth. The changing, perhaps seasonal nature of the Martian surface and infrared emissions, apparent in these wavelengths, are characteristic of sublife forms such as lichen on earth, and raise the possibility that life may exist there.

Conflicting Theories

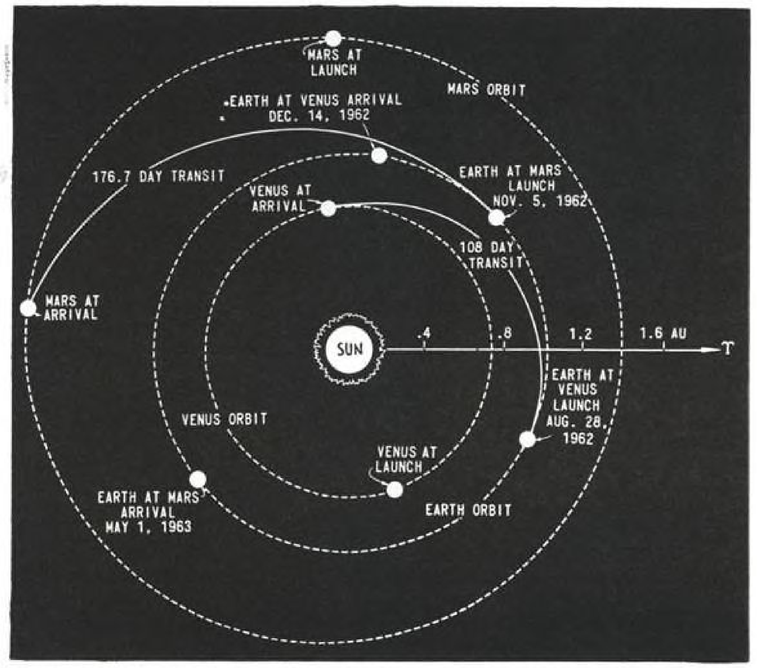
Venus, shrouded by a heavy cloud cover, is a greater mystery which has provoked many conflicting theories and conjectures. Why, for example, is the Venusian temperature as high as many independent radiometric, spectroscopic and other measurements now agree that it is?

One theory suggests that the clouds are creating a "greenhouse" effect. Another says the high temperature is due to frictional heating caused by strong Aeolian winds presumed to be sweeping the planet's surface. Still another contention, contradicted by radar data, is that the absence of a strong magnetic field permits sufficient electron density so that the high temperatures are actually ionospheric, not surface temperatures. Why the surface is so hot, if it is, may be deduced from measurements of the planet's temperature distribution, which the first Mariner shots may start to provide.

The planetary program faces a number of problems including the fewer lower propulsion energy shots at the planets that are available, compared with the moon. Rather heavy demands are placed on communications and guidance accuracy must be about 10 times greater than a long-range ballistic missile.

Yet eventual unmanned landings on the planets are essential to further planetary exploration, according to R. J. Parks, planetary program director.

The next round of planetary probes, using Mariner B spacecraft, will have this planetary landing capability. The spacecraft itself will be intended to fly past Mars and Venus but will be able

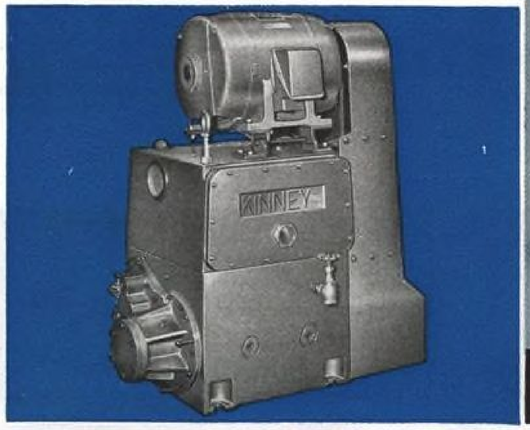


RELATIVE positions of earth, Venus and Mars are shown for 1962 transfer ellipses.

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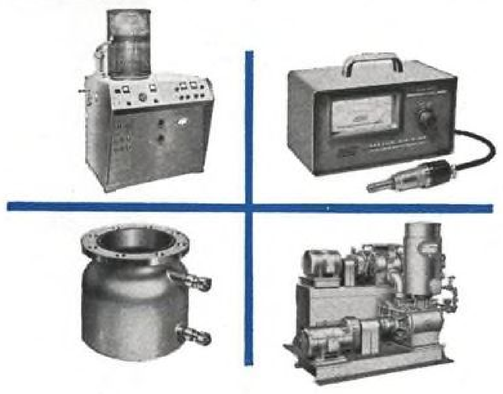




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to eject a small capsule into the planetary atmospheres.

The basic Mariner B bus will be hexagonal in shape, with a single structure folding out from each of its six sides. The foldouts are four solar panels, a high-gain antenna and a planetary horizon platform – PHP – containing planetary-oriented instruments such as a horizon scanner, infrared spectrometer and TV camera. A single capsule will fly as a passenger.

One interesting aspect of Mariner B is that it is designed with dual planet capability–Mars and Venus–even though there are factors which might make an optimized Mars vehicle different from an optimized Venus vehicle. For example, the solar constant at Venus is about five times that at Mars. Grossly, this means that an equivalent area solar panel will convert twice the energy at Venus that it would at earth; only about 40% at Mars. Communication distances from Mars to earth are greater than from Venus to earth at closest proximity, requiring more spacecraft communications power, tightening of bandwidth or greater sensitivity at the receiving site, or a combination of these. The hexagonal design minimizes the effect of the difference in solar constant.

The Mariner B bus consists of the basic hexagonal structure, guidance and control system, communications, telemetry, power system solar panels and batteries, high gain and omni-directional antennas and the PHP.

Two capsule types are under study. One would be released early on planetary fly-by without an additional velocity increment, while the other would contain a small rocket motor to impart additional velocity to the capsule.

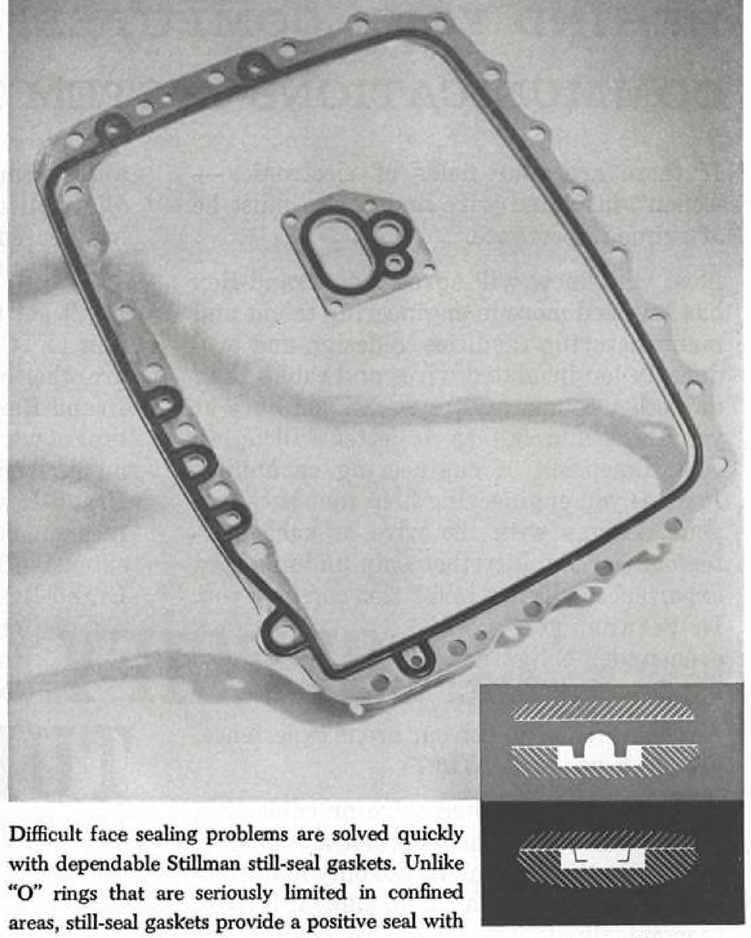
Capsule Landing Problems

Many problems are associated with successfully landing a capsule on either Mars or Venus. Some are caused by the lack of knowledge about the planets and their atmospheres. Mars entry is expected to be easier because its atmospheric structure is simpler, permitting the entry vehicle to be decelerated less abruptly. The Venus atmosphere is thick and estimates of its character, particularly the carbon dioxide content, are undergoing changes. High approach velocities and questions about blunt body heat transfer in gases of the possible compositions at Venus make entry into this planet appear particularly complex.

Investigations of entry capsules containing no active elements for stabilization and weighing 300 lb. and less were conducted for JPL by the Ames Research Center. JPL also has had two studies conducted by General Electric Co.

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neering Mechanics Division, centered on the feasibility of using a Discoverer type body, the Nerv (Nuclear Emulsion Recovery Vehicle) capsule (AW Sept. 26, 1960, p. 26) as a Mars entry vehicle. The Martian entry situation probably can be simulated, using a Discoverer capsule on earth entry. This would be based on an expected Mars atmospheric structure and would use self-biasing of the capsule and a slightly altered angle of entry.

General Electric's second study, an over-all look at Venus entry, is being done by the Systems Division.

Other problems, such as whether the capsule needs in-flight propulsion, how to communicate with observers and what experiments should be conducted are also under study. Data obtained by an instrumented capsule might be relayed to earth via the Mariner B spacecraft as it flew past the planet after ejecting its capsule. If the capsule were expected to survive impact and make measurements on the planet's surface, it is expected that it could still relay data via the mother craft for up to 24 hr. Relay might make the communications task of the battery-powered capsule easier.

Several groups of instruments are in varying stages of study and development for Martian entry because of the long lead time required. Instrumentation for Venusian entry also is receiving serious attention.

Instruments for making measurements both during descent through the planetary atmosphere and on the planet's surface are under investigation. Once it is reasonable to expect survival of the capsule after impact, instruments for making surface measurements could be added; others might be used both during descent and on the surface.

Descent type instruments include simple 1-to-3-lb. devices, each capable of measuring a single gas such as nitrogen, oxygen, ozone or carbon dioxide or water vapor. These are being developed by the Space Sciences Division. Two companies, Beckman Instruments and Melpar, have contracts to conduct studies of a gas chromatograph for determining atmospheric constituents during a Martian descent of up to 20-min. duration. A mass spectrometer also is under study.

Another series of possible experiments—essentially biological devices to search for life forms on Mars' surface, and intended for Mariner B capsule landing—are either under study or in development, some with industry under contracts from JPL and NASA.

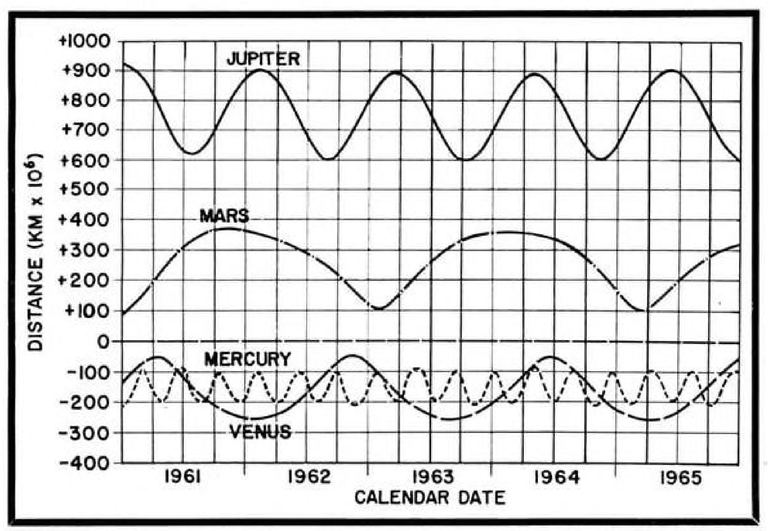
Contracts for instruments in feasibility or breadboard stage generally are let either from headquarters or the center, according to Manfred Eimer, acting chief of the Space Sciences Division. Once they advance to prototype stage and beyond to flight hardware, contracts are handled directly by the center responsible for the mission.

Planetary surface instruments attempt to determine whether life is present, and in some cases more detail about it, by four broad categories of experiments:

- **Growth experiments** to see whether a sample grows or multiplies.
- **Biochemistry experiments** to find enzymes and determine whether a life form has certain chemical constituents.
- **Microscopic investigations** to see whether the life form moves, changes form, etc.—an attempt to determine whether life is there by its appearance.
- **Study of the environment** to try to infer whether conditions, such as the presence of water, would permit life to survive.

Specific devices in development are:

- **Multivator**—Automatic biochemical



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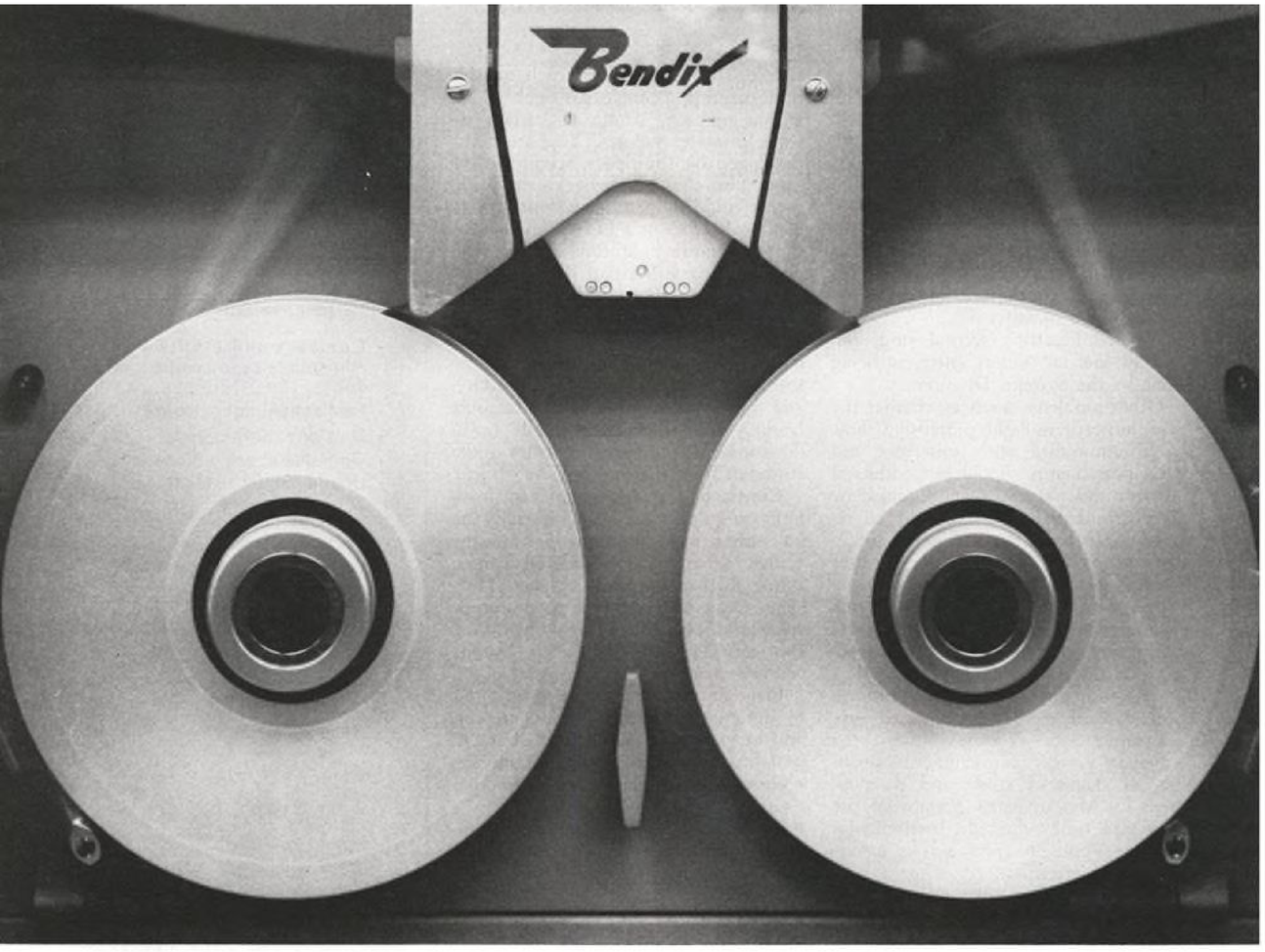
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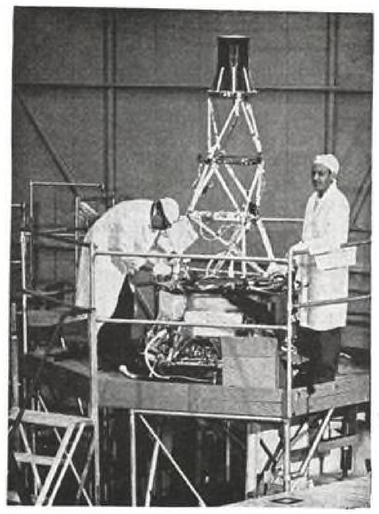
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MARINER 1 being assembled at JPL.

laboratory, devised by Dr. Joshua Lederberg of Stanford University, is capable of picking up and analyzing soil samples. A small centrifuge separates the sample into 18 or 20 cells for separate, and in some instances, duplicate experiments. The laboratory might perform a growth experiment by adding a surface sample to a nutrient to see whether this changed its appearance. A pH factor experiment also is considered. Results of the laboratory analyses would be detected optically and telemetered back to the Mariner B or directly to earth.

• **Microscope**—Unconventional microscope in which samples are separated, placed on a small conveyor, then viewed under a small-depth-of-focus, high-magnification microscope. The microscope views would be picked up by TV camera, processed and returned by telemetry.

• **Wolf trap**—In this possible experiment, named for designer Wolf Vishniac of the University of Rochester, the device sucks in air samples and places them in a prepared nutrient. Growth in the organisms is detected by cloudiness or turbidity in the original medium. This experiment, unlike the two foregoing, is funded through NASA headquarters.

• **Growth experiment**—Samples would be brought into this device by drawing a string across the Martian surface and placing it in a nutrient touched with radioactive carbon 14. If the microorganisms grow and multiply, radioactive carbon dioxide, which can be detected, might be produced by reaction. While there is a chance that this experiment might not work if the nutrient kills rather than supports the microorganisms and if carbon dioxide is not a product, it is regarded as a promising experiment. Samples would be brought into the device by a tethered projectile which carries a sticky string about 100 ft. The device, about the size of a pint jar and weighing less than 2 lb., was devised by Gil Levin of Resources Research, Inc. (AW May 21, p. 38).

A variety of exotic pick up devices, including a spectrum of "sticky tongues"—strings with sticky substances for grasping soil samples—as well as electrostatic pick ups and vacuum pick ups are under study. Selective monitoring schemes, which might pare the data that has to be returned and ease the communications burden, are also under study. Unlike the planets, the search for life on the moon is indirect, restricted to a gas chromatograph experiment which seeks pre-biotic, not living, materials.

Venus Experiments

The Space Sciences Division is beginning to tackle instrumentation problems that would be encountered on Venus, whose surface temperature is estimated to be over 550F. The laboratory will study the design of video circuits which could survive and operate in a blast furnace environment, an approximation of Venusian conditions.

The division has a contract with Electro-Optical Systems for making microcircuits capable of operating in planetary environments. The company is constructing hybrid microcircuits using silicon as a substrate and host for active elements and a deposited overlay of tantalum and tantalum oxide films for passive elements.

Operation at temperatures up to 550F is possible with these devices because of an unconventional fabrication method. If the estimated temperature for Venus is correct, the planet's temperature is roughly twice the maximum rated temperature of conventional high-quality semiconductor devices.

Other areas of study and advanced development in anticipation of planetary exploration include new types of sensors and a study of new video data processing concepts to aid reconstitution and display of returned data. In general many instruments developed for lunar exploration, with the exception of an X-ray spectrograph that needs a vacuum as available at the moon, are applicable to planetary exploration. Some techniques such as wet chemical analysis, which have been rejected for lunar exploration, may be valid on the planets, according to Eimer.

Ultimately, when the future of the Voyager project—particularly the launching vehicle—is settled, many of these techniques and developments will be advanced to flight hardware. Voyager is expected to be capable not only of flying by the inner planets but of going into tight orbits about them, ejecting large capsules, and possibly follow-

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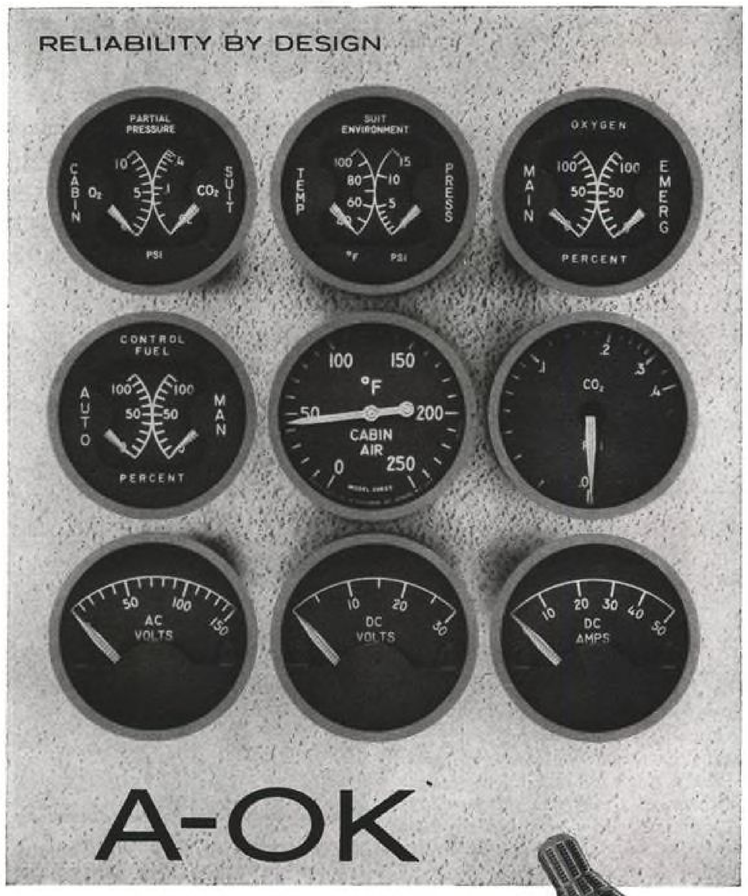
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ing an exploration sequence similar to that of the lunar program.

Backing up the unmanned lunar and planetary efforts and the Deep Space Instrumentation Facility network, also operated by JPL for NASA, is a vast, laboratory-wide supporting research and advanced development effort absorbing 40% of the in-house budget and a like amount of the activities of in-house personnel, according to Frank E. Goddard, who heads these supporting efforts.

Practically all basic research efforts are kept in-house. Much of the advanced development work is subcontracted to industry. These activities cut across divisional lines, with each engineering division conducting different types of research related to its disciplines. Apart from these is a Physical Sciences Division which conducts research under an annual budget insensitive to mid-year budgetary cuts in specific programs or other temporal problems such as booster availability. This division is responsible for 30% of the laboratory's personnel engaged in research—50 to 55 professionals out of more than 150—and about 25% of the research funds.

There are 35 separate research areas, including physics, planetology, turbulence and stability, plasma and ion propulsion, polymer research, field theory and relativity, reactor physics, molecular structure, magneto-fluid dynamics, digital communications, filtering and detection theory and space-borne computers.

Research is of two types: fundamental, aimed at understanding phenomena such as the plasma state and predicting its interaction with magnetic fields; and directed research, aimed at advancing technology. An example of the latter would be an ion propulsion effort directed toward hardware. Some directed research is subcontracted to industry, as was done recently when Physical Sciences Division and Guidance and Control Division jointly let a contract to develop super-conducting alloys.

About 80% of research in the engineering divisions is intended to improve technology and 20% is motivated by basic curiosity. In the Physical Sciences Division the percentages are reversed, according to R. Meghreblian, division chief.

In addition to its own research and development, JPL has other responsibilities in this area. The Propulsion Division, for example, acts as technical manager for about 40 "Advanced Technology Contracts," small, short duration contracts of less than $1 million and less than one year, placed with industry by NASA headquarters. The division helps headquarters select suitable areas for investigation and helps prepare work statements, evaluate resulting proposals and guide the contractors' efforts.

Deep Space Tracking Network Expanding

Pasadena, Calif.—Radio tracking, command, telemetry and data acquisition for unmanned lunar and planetary probes are requiring almost continual expansion and modernization of the Deep Space Instrumentation Facility (DSIF) managed and operated by Jet Propulsion Laboratory's Telecommunications Division.

By 1965 there will be about 10 or 12 lunar and planetary shots in a year, compared with two planetary and three lunar shots in Calendar 1962. The number of shots tells only part of the story. Command, telemetry and data handling requirements will increase sharply for more complicated lunar craft such as Surveyor—with many of its experiments requiring real-time commands—and Mariner B, which will require a high level of communication system performance.

In the near future, DSIF will have six stations—three located at Goldstone, near Barstow, Calif., in the Mojave Desert. By June of next year, when DSIF has been converted to a higher frequency—2290 to 2300 mc., the portion of S-band reserved for space research and communications and less subject to cosmic noise than the one now used—its capabilities will increase further.

The original Goldstone site, from which DSIF had its beginning, now is greatly improved from the original station which began operation by tracking Pioneer 3 in late 1958. The Pioneer site had a system temperature of approximately 1500K, where system temperature, a measure of the performance of the system, is defined as 290 times the difference between noise figure and one. New low-noise traveling wave maser, being developed for JPL by Microwave Electronics Corp., is expected to give that site a system temperature of 30 deg., or improvement by a factor of 50, achieved in several steps in less than four years.

By this fall, when its so-called Venus station goes into operation on a research and development basis, DSIF will consist of:

• **Woomera, Australia**—Maintained and operated for the U. S. government by Australians. Consists of a receiving station using an 85-ft. polar mounted parabolic antenna (±30 deg. to the equator).

• **Johannesburg, S. A.**—Located 40 mi. north of Johannesburg in a valley protected from man-made RF noises. Transmits and receives and employs the familiar 85-ft. polar mounted dish of all three major sites. Staffed and operated by the Council of Industrial Research with only one American, a JPL-NASA representative.

• **Transportable station**—Small, transportable transmitter and 10-ft. dish used in the early portion of low altitude injection, up to the point of about 10,000 mi. where the spacecraft is in continuous view of one or another of the main fixed stations (Woomera, Johannesburg and Goldstone).

• **Goldstone**—Goldstone equipment will include the original 85-ft. polar mounted antenna with highly sensitive receiving system. A second site, 7 mi. to the south and east, set up to participate in the Echo satellite relay experiment with Bell Telephone Laboratories in Holmdel, N. J., presently has a 10-kw. transmitter and a receiver installed after the Echo experiments early in 1960. It will have an 85-ft. polar mount antenna and its original 85-ft. azimuth-elevation mounted antenna is being moved to the third site. The latter, called the Venus site, will be a high-power—at least 100 kw.—transmitting station, intended to be in full operation for a 1964 Mariner B Venus shot. It will supply commands, overcoming loss of command if a high-gain antenna on Mariner B fails to point properly. The modified Echo site will help relieve the tendency toward saturation of DSIF when frequency of shots increases.

Funds were included in the Fiscal 1963 budget request for another antenna, a 210-ft. dish, which would initiate work on a fourth Goldstone site. This antenna, compared with an 85-ft. dish like others in use in DSIF and combined with a sensitive receiver comparable to the one at the Pioneer site, will provide a 6 to 10 db. improvement in signal to noise ratio. System temperature goal is about 20K.

In an unusual experiment last year, the Echo transmitter directed signals to the planet Venus, signals which were reflected from the planet and picked up by the Pioneer site receiver. Results included what is believed to be a highly accurate determination of the Astronomical Unit, a better apparent calculation of the radar cross section of the planet and deductions about rotation rate of the planet.

Data from DSIF stations are transmitted by commercial teletype into the Space Flight Operations Center (SFOC) at JPL in Pasadena, to which command reverts after launch.

The center will undergo considerable expansion in the next year, resulting in a Space Flight Operation Facility (SFOF) that may be ready before the end of 1963. Western Union will install a wide band microwave link to transmit tracking, telemetry and television pictures from Goldstone.

The facility will reduce and evaluate telemetry, compute maneuvers, collect and reduce scientific data. It will be designed to carry out one real-time mission—direct and control one mission in real-time mode—and support checkout on another spacecraft at JPL or Atlantic Missile Range.

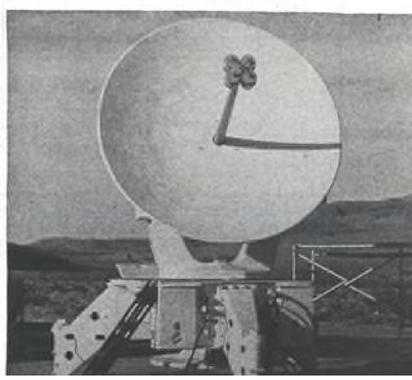
Initially, the facility—for which a building is to be constructed with funds appropriated for it this year—will use essentially the same equipment available to SFOC, including IBM 7090 computer, backed up by additional peripheral gear. It will be built on a modular basis to permit expansion.

JPL is awarding a systems study contract with industry to take a look at the total system, including DSIF sites. General Electric recently was selected to conduct a several month study of status displays. Hughes Aircraft at Fullerton has the task of looking at SFOF communications—how to get data back from overseas DSIF stations, how to improve communications, what type of teletype should be used, how communications are best conducted within the facility, whether there should be message routes, TV displays, etc.

SFOF will be manned by people who have fundamental gear on specific flights, aided by the Space Flight Operations Section of the Systems Division.

For Surveyor, planning and executing space flight operations will be the responsibility of the systems contractor, Hughes Aircraft. Hughes will calculate its own spacecraft commands and will supply a spacecraft data analysis team. JPL will handle orbit determination and supply a tracking data analysis group and JPL and Hughes will form a scientific data group.

DISH ANTENNA for transportable tracking station near Johannesburg, S. A.



VIBRATION NEWS

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MB Hydraulic Shakers cut vibration-testing costs for large payloads

Vibration or shock testing of very large payloads—such as missile sections, or complete missiles—usually requires extremely high forces at moderate velocities and frequencies. It is not unusual for force levels to be in the order of 100,000 lbs.

In this force range, MB's electro-hydraulic shakers may cost as low as 1/5th the price of comparable electro-dynamic units. What's more the electro-hydraulic shaker is much smaller and more compact. For example, a hydraulic actuator with a 100,000 lb. force rating is only 18" square by 13" high!

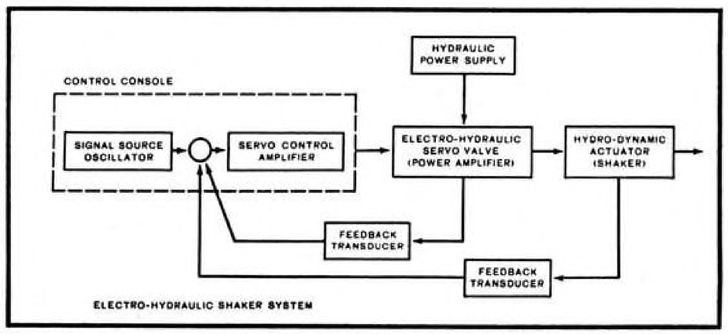
MB's hydraulic shakers complement our line of electro-dynamic exciters and extend the limits of vibration, shock and fatigue testing. The electro-dynamic exciter fills the need for testing at high frequencies and relatively low forces and amplitudes, whereas hydraulic shakers are most advantageous for tests requiring extremely high vibratory forces and long strokes in the low to intermediate frequency range.



View of typical MB hydraulic actuator with a force rating of 100,000 lbs. Measures only 18" x 18" x 13".

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- vibrating heavy mass loads directly-supported on the shaker
- simulating transportation specifications
- applying static and dynamic loads simultaneously
- pulse testing and combined tests in environmental chambers
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Principle of operation—input signals are fed to electronic servo amplifier, where they are combined with feedback signals from hydraulic shaker. After amplification, this signal is supplied to the electro-hydraulic servo valve which converts electrical variations into fluid flow variations which in turn are reproduced by the hydraulic power stage of the valve. Actuator velocity is proportional to oil flow and varies according to electric input signal.

An MB hydraulic shaker system can add extensively to your testing capabilities; available in 27 standard models with forces of 1,000 to 100,000 lbs. and strokes to 18". These shaker systems can also be custom designed to meet your specific requirements.

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Goddard Role Focused on Space Sciences

Center has satellite, sounding rocket responsibility, operates tracking network for most space flights.

Greenbelt, Md.—Goddard Space Flight Center works in the rich seam of space science that lies between the earth and its nearest neighbor.

It shares the bulk of NASA's space sciences program with the Jet Propulsion Laboratory. But by the limitations of its mission statement, Goddard works on earth-orbiting spacecraft and sounding rockets while JPL has the job of lunar and planetary exploration.

Scientists at this center, directed by Dr. Harry J. Goett, currently are managing or developing 61 major satellite projects. Scientific satellites such as the Explorer series account for 34 projects; remaining 27 are applications satellites in communications or meteorology.

Goddard also has responsibility for the aerodynamic design, payload integration and flight test of all NASA sounding rockets.

Finally, the center scientists operate two world-wide tracking networks—Mercury and Minitrack—for tracking and data acquisition of most manned and unmanned space flights. Reduction of much of the data from these networks is also done at Goddard.

Feedback Loop

Management of this center likes to look at the across-the-board capabilities of its staff as a feedback loop from science to engineering to data and back to science again.

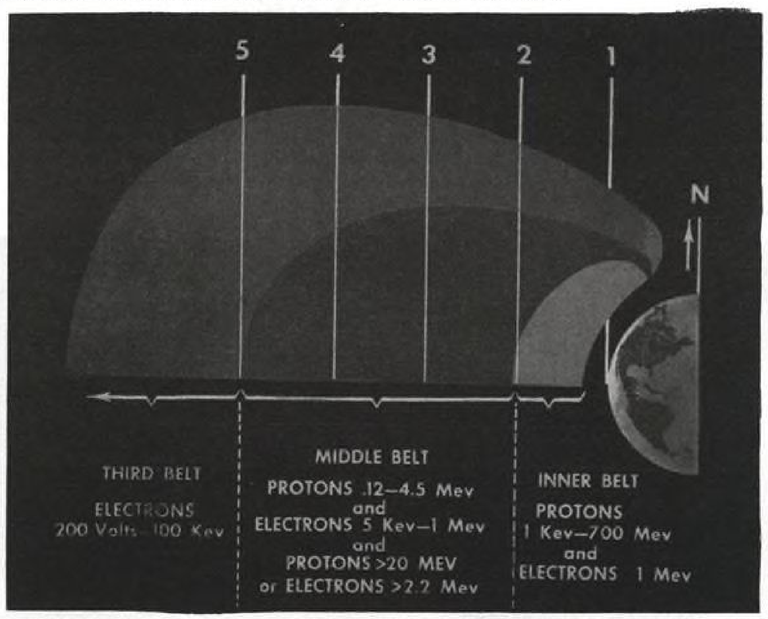
Scientific capability is found in both theoretical work and in laboratory or analytical approaches. It can begin with studies of the nature of the universe as a whole, in the work being done in Dr. Robert Jastrow's Institute for Space Studies in New York City. This experimental group is an attempt to stimulate college and university interest in the space sciences, to help bridge the gap between these institutions and Goddard.

Or the science can be experimental work done in the Space Sciences Division, aimed at better understanding of ionospheres or of astrophysics.

Engineering capability also has a paired approach. The center uses engineers to manage contractual developments in satellites and spacecraft, and other engineers—or sometimes the same ones—to design, develop and test scientific satellites completely within the Goddard organization.

Finally, the wealth of data obtained from tests in the laboratory or in flight can furnish basic information that helps the space scientist understand his hypotheses, or prove his assumption.

This portion of the Goddard story deals with the engineering phases of the center's work; other phases are described elsewhere.



COMPOSITION OF VAN ALLEN RADIATION BELTS

Goddard's management of a satellite project is typified in the Orbiting Astronomical Observatory program. This second-generation, "streetcar" satellite is an extremely complex structure that will be orbited to perform a variety of astronomical experiments. The major requirements, once the spacecraft is in orbit, are for stability of the platform and accuracy of pointing.

Project Staff

"In this job, we're not doers, but onlookers and analyzers," said Daniel Mazur, head of Goddard's Spacecraft Systems and Project Division. "Our project staff is like a review board, looking at manpower, costs, technical tasks. If we see a place where we can get some improvement, either by a backup approach or by redundancy, we speak up."

Five basic systems on the OAO spacecraft help define the organization of Mazur's management team: structures, control and guidance, power, thermal and communications. Scientists from each of these specialty areas within Goddard are on the team. There also is an experiment coordinator who helps the project scientist, a tracking scientist from the Tracking and Data Acquisition Division, and a test and evaluation engineer from that division. These men are led by a project manager, his assistant and a project coordinator.

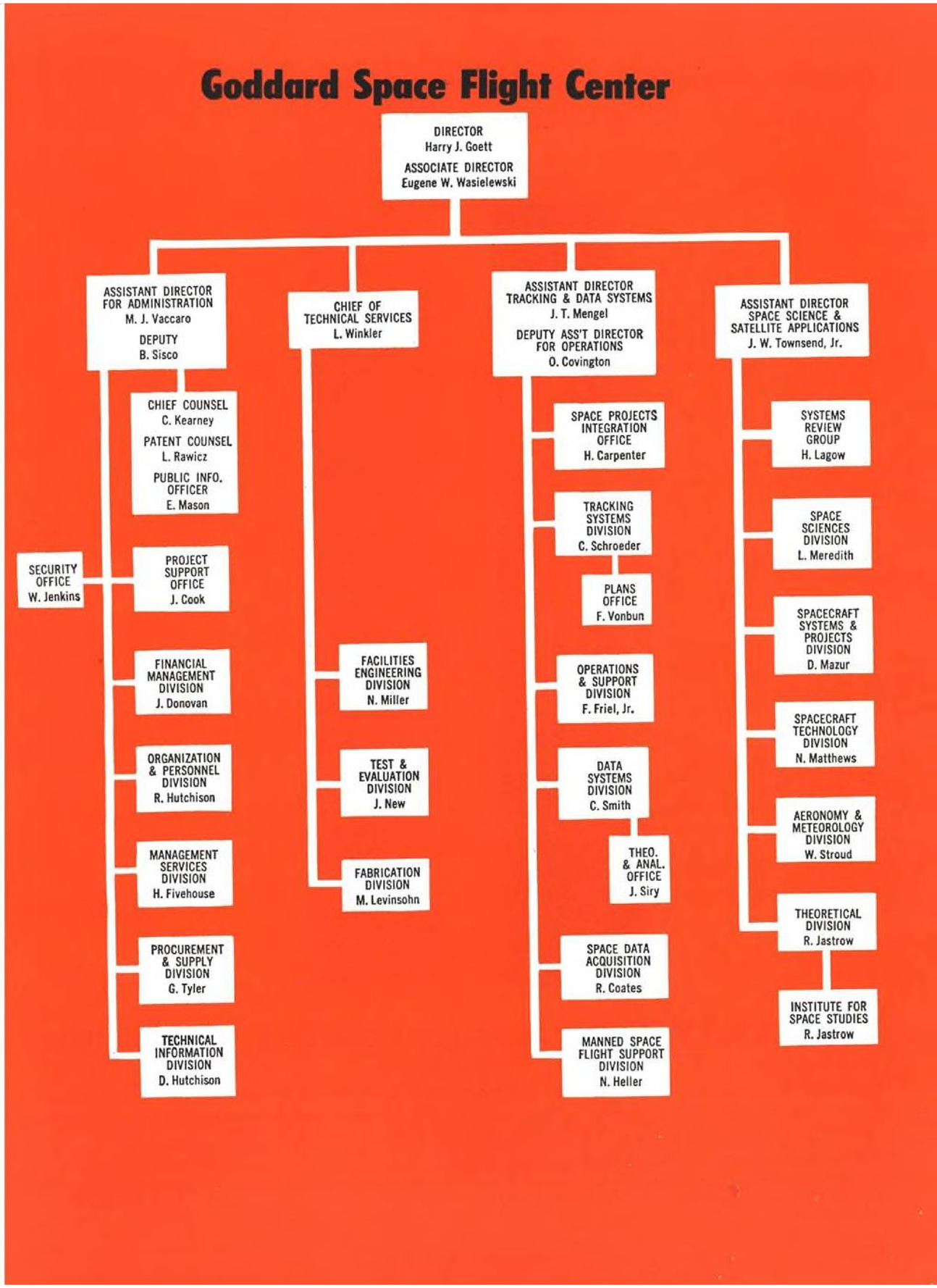
Working engineers from the project team maintain contact with Grumman Aircraft Engineering Corp., prime contractors for the spacecraft, and with subcontractors at IBM Corp., General Electric Co. and Radiation, Inc. The project scientist is in daily contact with the project leaders at Grumman; twice or three times a month the working engineers visit Grumman.

In structures, to use one example, the Goddard team reviews the Grumman work. In thermal control evaluation, they felt that there were so many uncertainties that it would be logical to have a backup contract.

Similar backup contracts exist with Eclipse-Pioneer, for the star trackers on which Kollsman Instrument is prime, and with other companies.

The Goddard group sets environmental specifications for the OAO, using data from Vanguard and Atlas Agena vehicle vibration measurements. The contractor sets up his test plan based on that specification and performs the first tests. The prototype spacecraft final tests, plus its only tests as a complete observatory—that is, with the experimental package installed—will be done at Goddard.

In contrast to Mazur's management group, the Spacecraft Technical Divi-





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Goddard Request

Greenbelt, Md.—Goddard Space Flight Center, located about 15 mi. northeast of Washington, has requested a $54 million operating budget for Fiscal 1963, and an increase of 350 employes to bring its total to 2,749.

The center, which has a $23.8 million construction request for the current fiscal year, is situated on a 578-acre tract. Plant value is $50.7 million.

sion, headed by Whitney Matthews, represents Goddard's in-house development and fabrication group. His basic group was part of the old Vanguard organization at the Naval Research Laboratory, and many of the staff have been together working on these kinds of problems for 15 years.

Matthews' responsibilities include the provision of small scientific satellites. By definition, that means less than 500 lb. His group has built a total of 25 spacecraft, of which seven are now in orbit.

Ariel Satellite

One of these was the UK-1 "Ariel", the first international satellite, developed by a group of British scientists and Matthews' people. This and other international satellites follow a set plan. The British scientists—or those from whatever other country may participate—chose the experiments and planned them, built the instrumentation and decided what they wanted in the line of results. Matthews' group did the basic design of the satellite itself and worked out all the rest of the spacecraft; in short, they provided the means of getting the British experiments into space, of helping them work, and of getting the data back in a useful form.

That is the plan for a first international satellite. But the second—UK-2—is now being built by a joint team of British and Westinghouse scientists in accordance with the Goddard philosophy—first, not getting into "production" on any satellite, and second, doing as much as possible to educate and help others into the business. Project plans for UK-3 call for the entire job to be done by the British, at the Roval Aircraft Establishment, Farnborough, England.

Testing Division

One of the unique facilities at Goddard has been jokingly referred to as the John C. New Space Flight Center, after the division head in charge of test and evaluation. Now under construction at Goddard is an enormous test and evaluation laboratory which, when it is completed, is expected to set the standard for spacecraft checkout. Its primary value, says New, is expected to be in improving reliability.

For this reason, and because New didn't want to be in the position of heading a group of critics of design, his organization reports through a different channel to the Goddard director (see chart on p. 179).

Testing is rapidly becoming a different field from what it used to be, New says. There was a time when the test engineer was low man on the totem pole, and when test departments were composed either of the rawest new engineers or the oldest and deadest employes.

Test Equipment

But testing now demands test equipment that can measure at least one order of magnitude better than the toughest prototype requirement. New carries that philosophy over into his personnel, and tries to get people who are "also an order of magnitude better." Two-thirds of New's people have graduate degrees, with about half of them Ph.Ds.

This is high for any kind of engineering organization, and almost unheard-of in test work.

"Our real problem is to do the job right the first time," New points out. "We want to get into the project early, to establish the test requirements, and to set up the program."

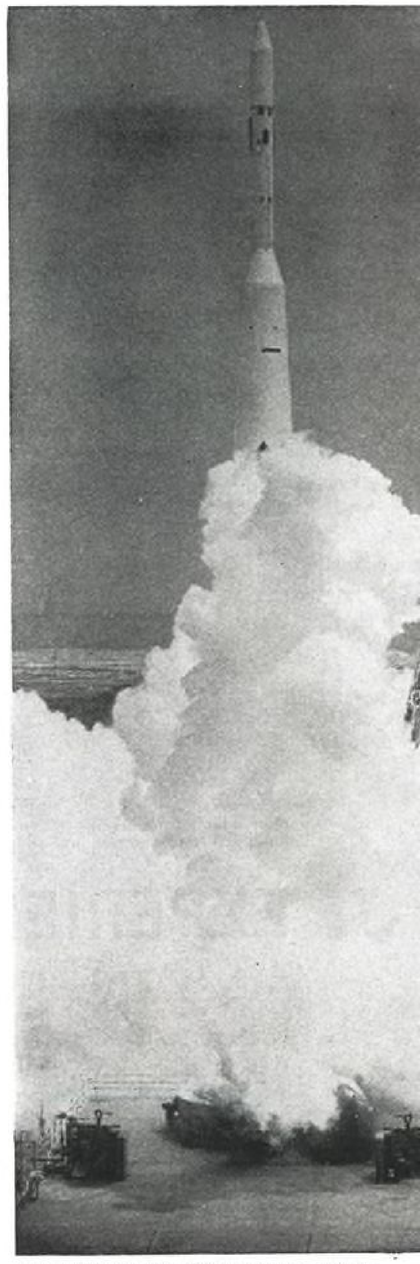
The program generally uses three test articles: the engineering model, which is not much more than a detailed mockup; the structural model, which is complete and accurate in structure; and the prototype, which is essentially indistinguishable from the flight model.

The engineering model gets some testing, but the real work starts with the structural model. It gets dynamic tests to find amplification factors and the strength of the over-all system. These results largely define the specifications for the subsystems, according to center engineers.

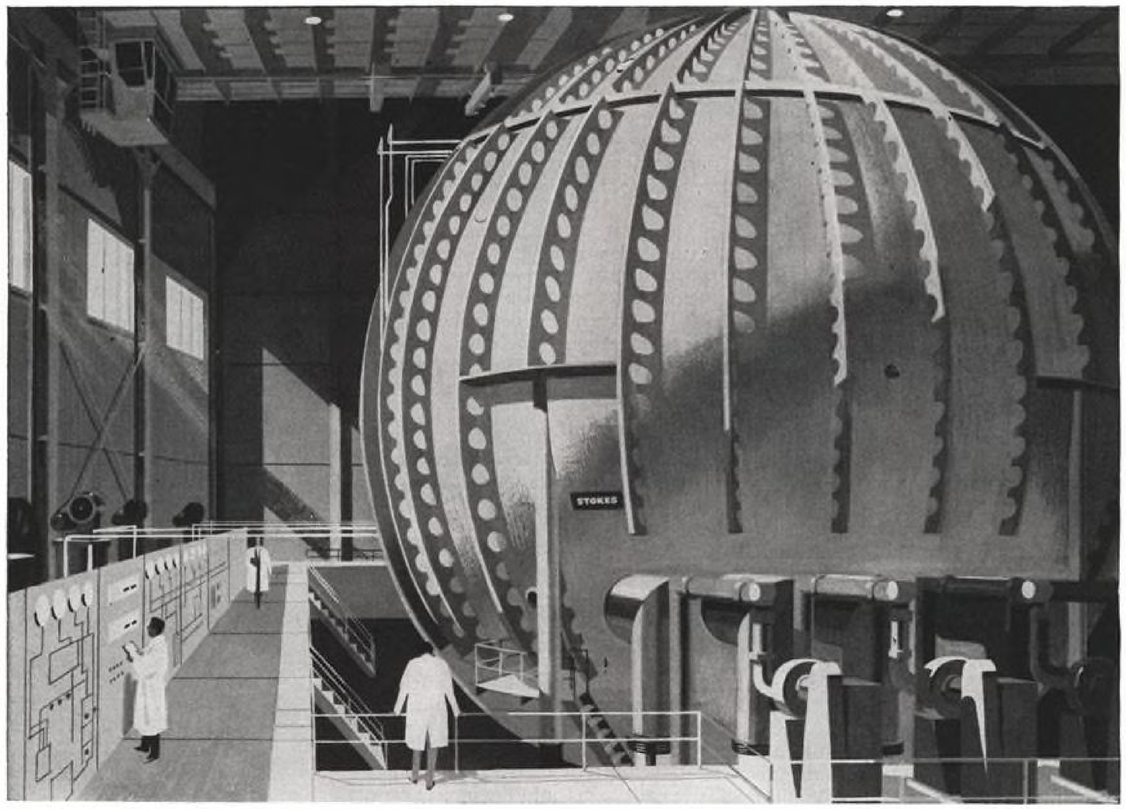
Prototype Tests

Prototype model testing is as rigorous as it is possible to make it, with the basic aim of reproducing the entire range of environments. Zero-gravity and radiation are out, but everything else is done: humidity; cold storage; high temperature; shock; accelerations and vibrations 1.5 times those expected at launch; spin and balancing tests; hot and cold temperature at ambient pressure; thermal vacuum exposure.

"Our big interest is the failure mode," New emphasizes, "because that's how we can improve quality assurance. Sometimes we have to fight off the project team that just wants a quick fix."



ARIEL SATELLITE, UK-1, developed jointly by U. S. and British scientists, is shown at lift-off Apr. 26, 1962, from Cape Canaveral's Complex 17. Launching of the first international satellite was successful, with Thor Delta used as launch vehicle. Ariel was outgrowth of standard procedure under which NASA's Goddard center will help develop other international satellites. Goddard personnel design satellite and launch it. Participating nation selects the experiments to be carried aboard satellite, plans them, and builds instrumentation. UK-2 will be built by British and Westinghouse scientists, UK-3 by British entirely at Farnborough.



For General Electric's Valley Forge Space Technology Center, Stokes designed and is currently installing three space environmental test chambers like the one shown above in an artist's sketch. The chambers, 38'6" in diameter, will be cryogenically pumped to ultra-high vacuum, and reproduce a variety of conditions encountered by satellites making lengthy missions into space.

EXPERIENCE IS WHAT COUNTS IN SPACE SIMULATION

While space simulation is a new and rapidly changing art, experience in designing and building equipment for its full-scale accomplishment is of the utmost importance. That is because no inaccuracies, no approximations are possible; reliability proving depends on ascertaining absolute values.

F. J. Stokes offers an impressive backlog of experience in supplying major space test facilities. The installation described above and others for General Electric, the vacuum and cryogenic systems for facilities at NASA's Goddard Space Flight Center, the test chamber for Bell Telephone Laboratories' Telstar project, reliability testing facilities for space-borne electronic components, and pumping systems for various aeronautical research centers stand as benchmarks in Stokes' progress in this specialized area.

Behind this specific activity stands half a century's experience as one of the world's leading manufacturers of high-vacuum industrial systems. Since vacuum is the common denominator of all space test equipment, it follows that Stokes' high-vacuum experience, unique engineering capabilities in this field, and extensive, heavy-duty fabrication facilities can be successfully applied to problems of space simulation.

If you are engaged in any phase of space test work, we will gladly explore the possibilities of putting Stokes space simulation and high-vacuum experience to work for you, on a project management, single-source, turnkey, or any other basis. **Space Systems Department, F. J. Stokes Corporation, Philadelphia 20, Pa.**

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Goddard Satellites Probe Space Sciences

Space phenomena observations opening new areas of knowledge about earth, moon and solar system.

Greenbelt, Md.—In quality and quantity, scientific satellites developed or managed by scientists of the Goddard Space Flight Center are adding immeasurably to man's knowledge of the universe he inhabits.

For the first time in scientific history, instruments can make their measurements free of the distortions of the earth's atmosphere and thus improve the quality of the measurements.

A single orbit of a typical satellite has produced more data on a single phenomenon than all man's observations from the dawn of time until its flight.

There is no hard and fast definition of a scientific satellite. All satellites produce scientific information of one kind or another; whether or not they have on-board instrumentation is immaterial. Much can be learned in a geophysical sense from tracking a known vehicle.

But in NASA, there is a rather rigid definition of a scientific satellite, and it is tied to the legislation that created the administration.

Satellite Tasks

NASA considers that scientific satellites are those that advance the space sciences program. Consequently, they measure the basic physical phenomena that characterize the earth, the moon, the sun, the solar system or the universe and the interplanetary matter surrounding them.

Since the first exploratory forays into space, satellites have grown in size and capability. Today's sophisticated vehicles are being used to study and define a variety of things that had to wait for this unique tool to discover them.

Approximately a dozen scientific satellites launched during the past four years are still in orbit, although many of them have stopped transmitting. Typical of these have been the Explorer series, a number of compact specialized spacecraft aimed at a variety of targets in the vast unknown that surrounds the earth. These have been the milestones:

• **Explorer 6 results:** First complete televised cloud-cover picture was obtained; large ring of electrical current circling the earth was detected; complete map of the Van Allen radiation belt was obtained.

• **Explorer 7 results:** Significant geophysical information on radiation and magnetic storms was obtained; internal temperature control method was demonstrated; first micrometeoroid penetration of a sensor in flight was detected; large-scale weather patterns were observed.

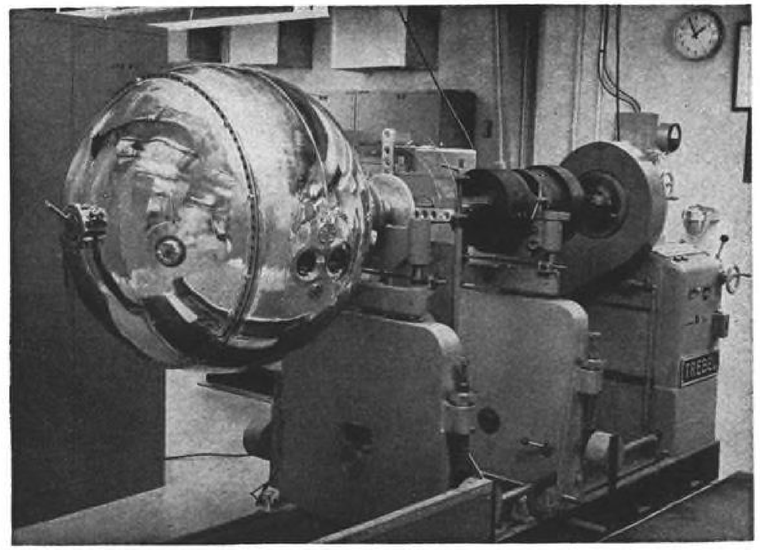
• **Explorer 8 results:** Discovery of a layer of helium surrounding the earth between the altitudes of 600 mi. and 1,500 mi.

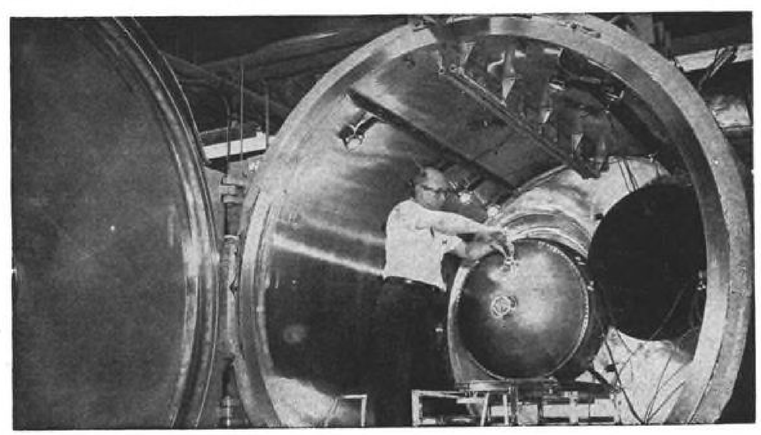
• **Explorer 9 results:** Atmospheric density was about one-tenth that measured during the previous year at the same time, attributed to decreased solar activity during this portion of the 11-year solar cycle.

• **Explorer 10 results:** Ring of electric current around the earth was detected at about two or three earth radii, suggesting a correlation with the results of Explorer 6; interplanetary magnetic fields were found to be far more intense than previously believed; terrestrial magnetic field merges with the interplanetary magnetic field about 40,000 mi. from earth.

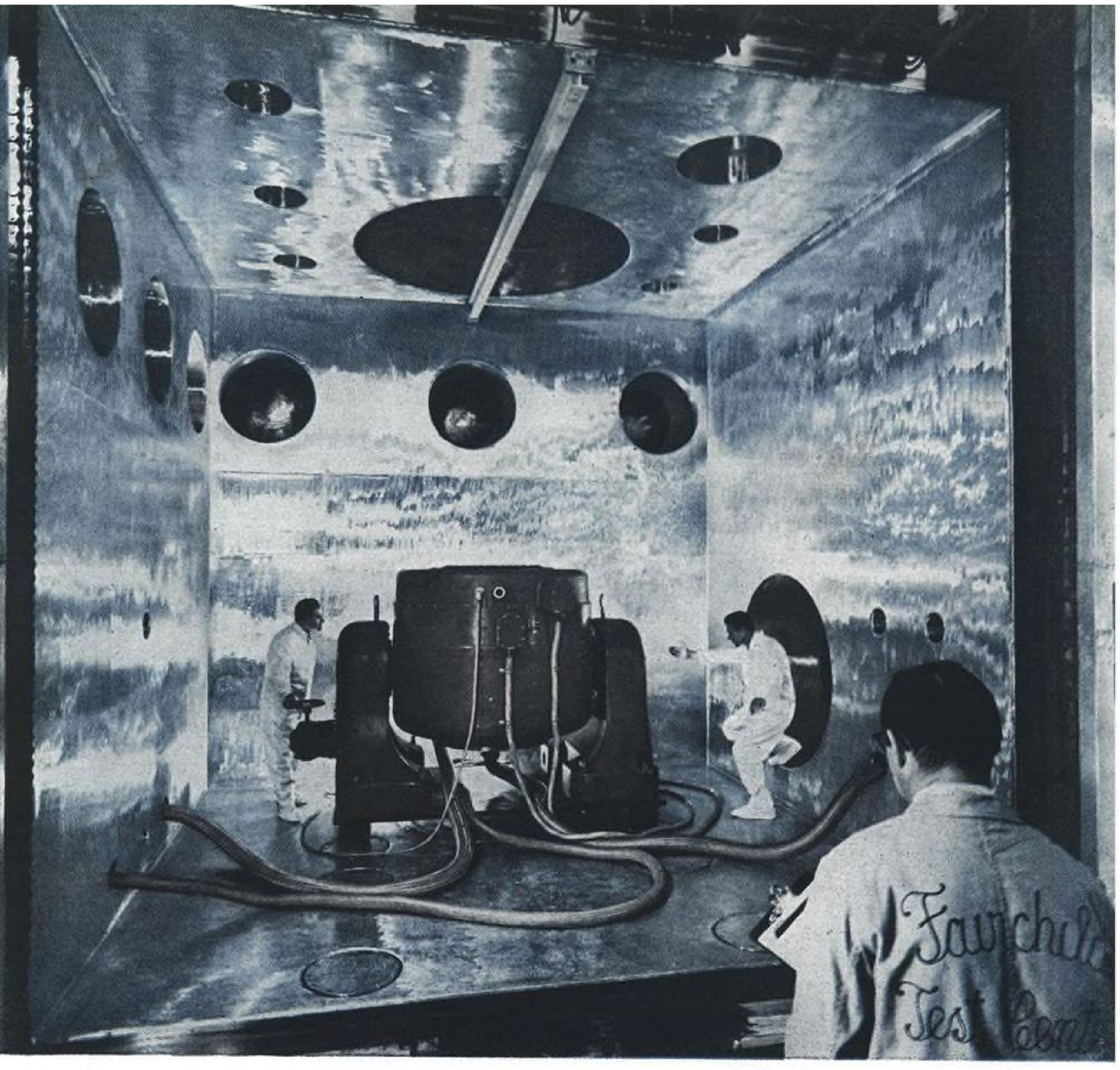
• **Explorer 11 results:** Disproved one theory of the origin of the universe. The theory contended that matter and anti-matter were created continuously and equally.

• **Explorer 12 results:** Van Allen belt was discovered to be a single radiation zone instead of two as believed formerly; outer zone of the belt was found to contain large flux of medium-energy protons not before found in the





S-6 ATMOSPHERIC structures satellites on spin and balance test (above) and being prepared for checkout in the thermal vacuum tank.



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belt; outer-zone electron density was measured to be one thousand times less than previous counts had indicated, attributed either to faulty early measurements or the decline in a solar sunspot cycle.

The part that Goddard plays in the scientific satellite program is a dual role. First, it conceives, designs, develops, builds and tests scientific satellites within its own organization. This includes, as desirable by-products, advances in the technology in telemetry and encoders, for example, both areas in which specific and major contributions have been made by the center's personnel during their work on the projects.

Such in-house work also pays off in the second Goddard role, where it acts as a managing agency for contracted programs. The technical work done on its own satellites gives Goddard the badge of authority for management of outside projects, and a degree of expertise that would not be achievable without the home-built spacecraft.

Goddard's organization, although young in the framework of NASA, is experienced in just this kind of scientific work. The core of the group came from the Naval Research Laboratory, where they had specialized in an outstanding and internationally recognized program of upper-atmosphere research.

First of their projects in-house was Vanguard 3, a logical follow-on to the Navy's former Vanguard program, taken over by NASA. Much of Explorer 8 was also Goddard in-house work. Explorers 10 and 12 were all-Goddard satellites. Ariel, the first international satellite, was a Goddard spacecraft with British- designed and -developed experiments aboard.

Early last month, typical work in the Goddard laboratories and shops included the first two flight units of the atmospheric structures satellites (S-6) and the S-3A (follow-on to the energetic particles satellite Explorer 12). First S-6 was in final checkout; second flight unit was having its components and sub-assemblies installed. The S-3A was in the engineering mockup stage, with its components being carefully fitted into the spherical plastic housing that serves to define the dimensional limits for the spacecraft.

At the same time, unique tape recorders were being built and tested. These fit into a 7-in.-dia. disk, will record for 100 min. and play back the recorded data in two minutes. Fidelity of the playback on output is less than one per cent peak-to-peak wow and flutter. Power requirement for recording is 0.1 watt, and for playback is 0.7 watt. Tape is a continuous-loop type. All this is achieved at a weight of about three pounds.

The NASA budget for scientific sat-



GIANNINI CONTROLS CORPORATION

LOOKING FORWARD

by Julian Hartt

PASADENA, CALIFORNIA: To the searching mind, President Kennedy's reference to space as the "new ocean" sparked some interesting similarities in the problems that face our astronauts and the problems that stretched the ingenuity of world explorers 450 years ago.

Compare, for example, the technical complexities of measuring speed. Columbus' Santa Maria and John Glenn's Freedom 7 were both subject to their own shock waves.

Columbus, however, had merely to toss his simple chiplog and knotted line beyond the Santa Maria's bow-wave to calculate his speed and the Venturi principle could remain undiscovered for all it concerned him.

Today, the challenges of measuring the speed of space vehicles are the barbells on which men like young James R. Rochester flex their scientific muscles. Rochester is concerned with hypervelocity here at the GCC Research Laboratories of Giannini Controls Corporation, pursuing a project sponsored by the Flight Control Laboratory, A.S.D., Air Force Systems Command.

Modestly but enthusiastically, Rochester explains that he and his group of experts are applying the same principles toward determining the rate of travel of space vehicles, especially in the dangerous "waters" of re-entry, as did Columbus, Vasco da Gama, and Drake.

They literally are putting "markers" into the flow past a simulated re-entry vehicle to measure its velocity. In the same environment Columbus' chiplog would, of course, fry in the heat of friction.

Then what of Rochester's "markers" in this hot corridor of re-entry?

"If you can't lick 'em, join 'em," grins Rochester. "Get instrumentation that not only is compatible with the environment, but also employs the environment."

That's precisely what they are doing, making use of the conducting properties of the ionized gas, the plasma with its "conglomerate mixture of ions and electrons" sheathing the re-entry vehicle.

"One method," Rochester explains, "is essentially introducing a 'marker' into the ionized gas, and watching the transit of this marker as it moves around the vehicle."

This space-age chip log is not a mechanical thing, of course.

"We're doing this by a magnetic interaction," Rochester continues, "with the plasma itself.

"It is a pulse magnetic interaction, using an electromagnet to give us a particular magnetic configuration in the shock layer.

"As we pulse the plasma, we change its character at that point. This sets up a wave in the plasma that propagates at a particular velocity."

The velocity of this "blob" as it moves around the vehicle has a relationship to the velocity of the vehicle itself, and this in turn can lead ultimately to determination of angle of attack.

Of course, the velocity of the "blob" cannot be assumed to be the same as that of the vehicle but, says Rochester in anticipating the future results of the work, "we are looking for the relationship between one velocity and the other."

Most dramatic application of such a system could well be the return of the first men safely from a lunar voyage. Rochester, a native Californian and UCLA graduate, notes:

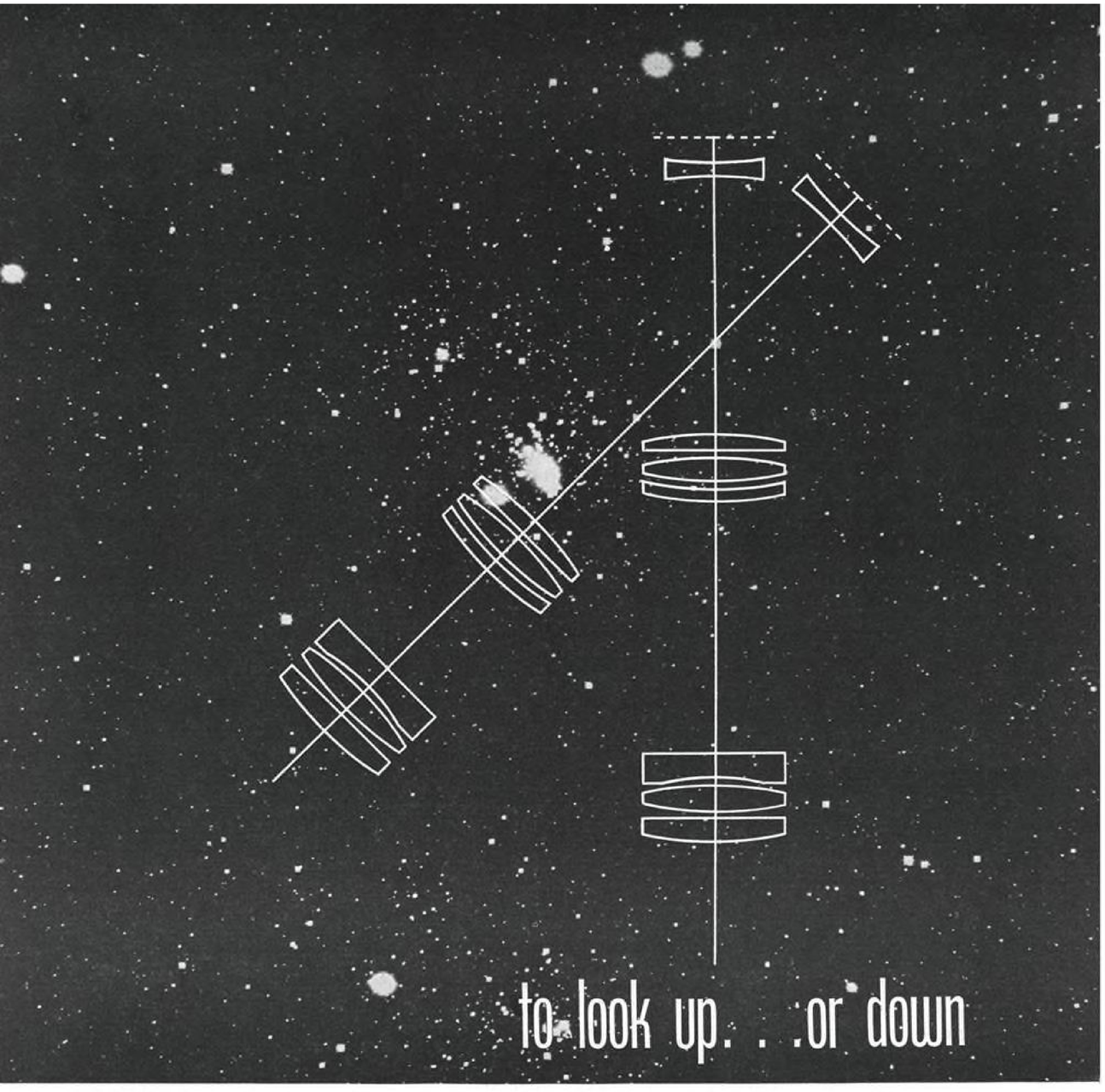
"When they are coming back, their vehicle will be in an ionized sheath for a large amount of the re-entry phase, and it won't be for only a matter of minutes like Glenn and Carpenter. It will be a matter of circling the earth possibly once or several times.

"They will have to know their exact velocity and angle of attack to be sure that their vehicle structures will be able to take it."

Thus in a quiet Pasadena laboratory, still another team is ..... Looking Forward.

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ellites during Fiscal 1961 was $54.4 million. The following year it doubled, to $117.6 million. The requested budget figure for Fiscal 1963 was $175.2 million.

What this buys and has bought is listed by NASA by calendar years. During 1961, seven Explorer satellites were launched. This calendar year, the schedule calls for nine Explorers and two Orbiting Solar Observatories (OSO), making a total of 11 scientific satellites.

In Calendar Year 1963, NASA has scheduled three Explorers, two Orbiting Geophysical Observatories (OGO) —although only one may make it—and two OSO launches, for a total of seven.

For 1964, plans call for five Explorers, four OGOs, three OSOs and the first two Orbiting Astronomical Observatory (OAO) launches, totaling 14 scientific satellites.

In 1965, the NASA schedule shows nine Explorers, four OGOs, four OSOs and two OAOs, a total of 19 scientific satellites. The 1964-1965 period includes the Year of the Quiet Sun, during which there will be a major effort all over the world to observe the sun and to correlate and coordinate results, somewhat in the manner of the International Geophysical Year.

Experiment Selection

The problem of selecting experiments for scientific satellites could become overwhelming; every scientist in the business has at least one idea for an experiment he'd like to do in space.

NASA has established the Space Sciences Steering Committee, with Dr. Homer E. Newell as chairman, to make the final selection of what flies in every scientific payload.

There are half-a-dozen subcommittees of the steering committee that make recommendations for experiments to be flown.

They are reviewed by Dr. John Clark, associate director and chief scientist of the Office of Space Sciences.

Typical of the detailed procedure involved was the choice of experiments for the EGO (Eccentric-Orbiting Geophysical Observatory) launch. Four subcommittees, including about 50 scientists from universities, reviewed all the experiments that had been proposed for EGO. Some of the experiments could be ruled out as unacceptable, others because they were becoming obsolescent due to the continually-generated new knowledge in space sciences.

There were new experiments that were ahead of themselves as far as the state of technology was concerned; they would be interesting to do if they could be done. The subcommittees recommended that the ideas be developed further for possible future launches.

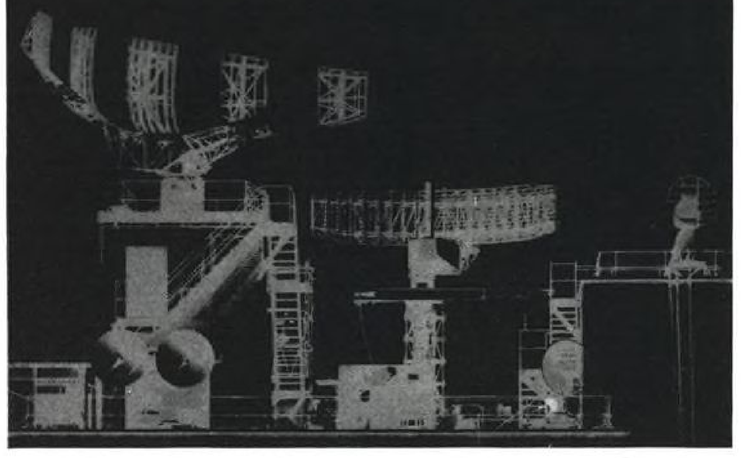
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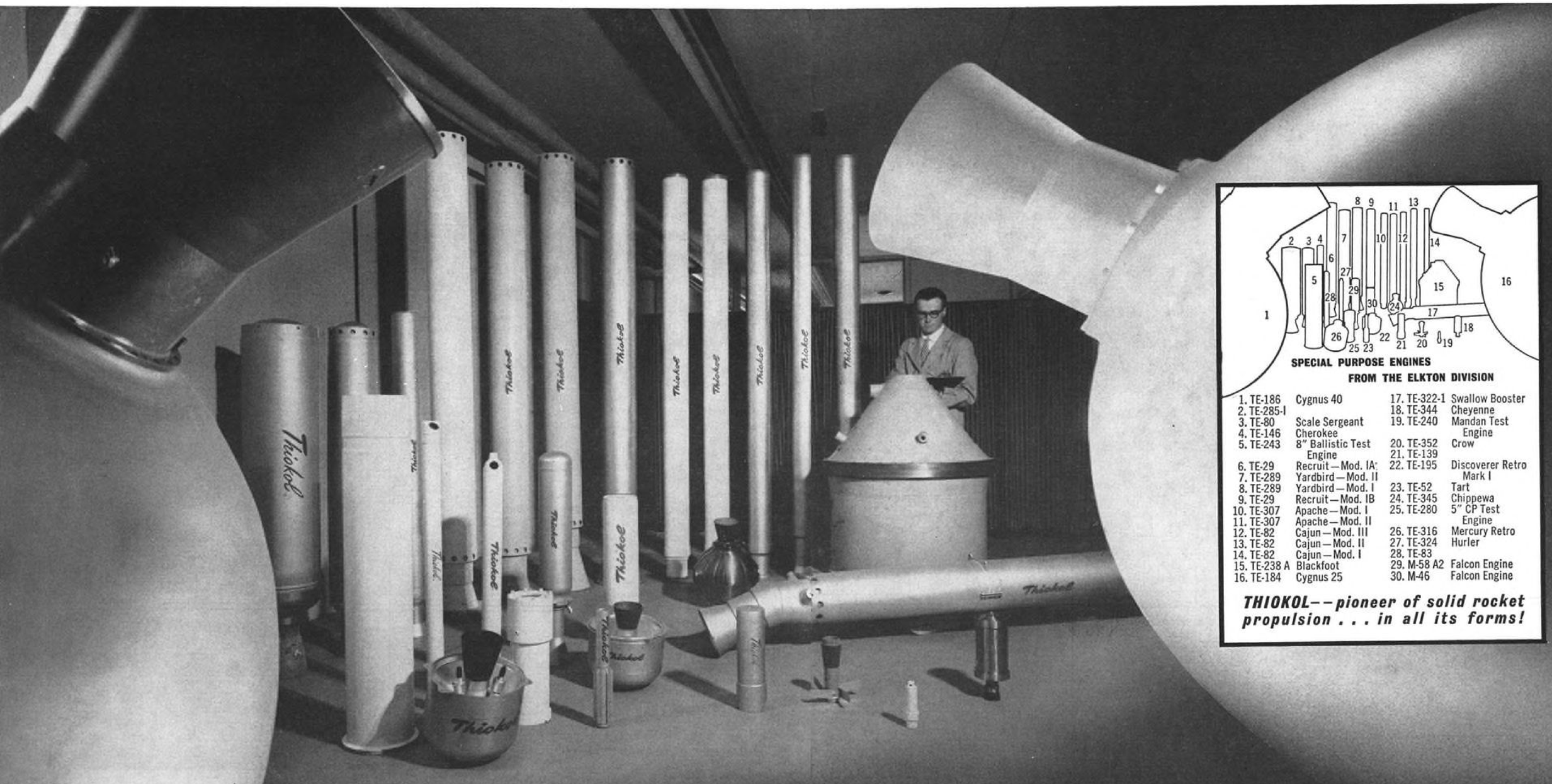
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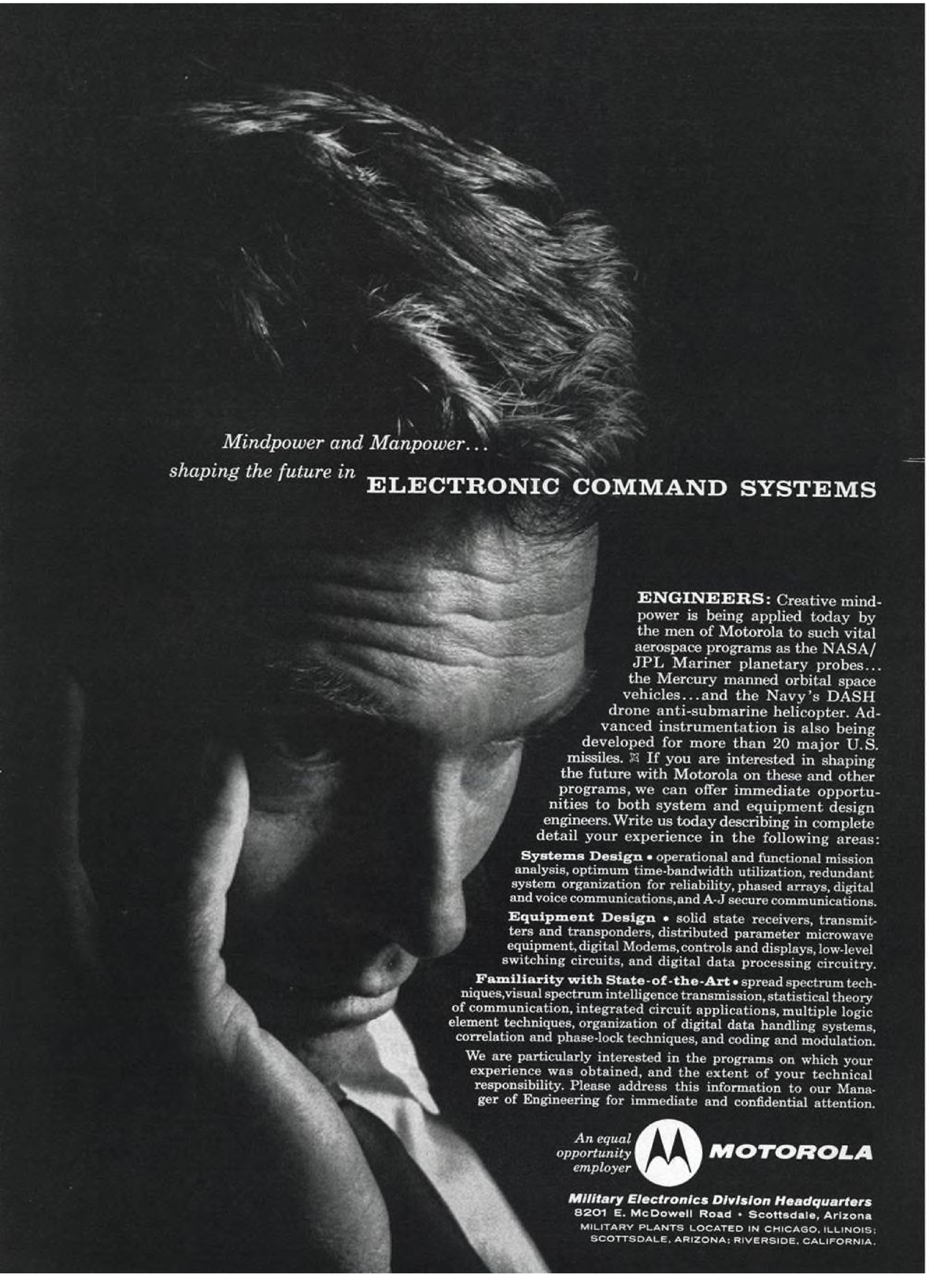
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13. TE-82	Cajun—Mod. II	27. TE-324	Hurler
14. TE-82	Cajun—Mod. I	28. TE-83	
15. TE-238 A	Blackfoot	29. M-58 A2	Falcon Engine
16. TE-184	Cygnus 25	30. M-46	Falcon Engine

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experiments which looked good scientifically and feasible technologically. About 25 of these were selected and funded so that individual scientists could spend time and effort developing detailed plans.

After this had been done, NASA called a two-day meeting at which the scientists were given about a half-hour each to describe the experiment and to answer questions from NASA staff and consultants.

"It amounted to a graduate school thesis defense in which each of these men who believed in their work was required to defend it," said Dr. Clark.

After the meeting, the four subcommittees met and made final recommendations for experiments in their fields of proficiency. They developed a list which they approved unanimously and which was endorsed by the Space Sciences Steering Committee.

To use Clark's words again: "We feel this is the most advanced and significant payload in our entire geophysics program."

But the effective performance of these related experiments depends on all of them getting to orbit. A few years ago such planning would have been impossible. Now, the large observatory class of spacecraft opens new vistas.

Observatory Class

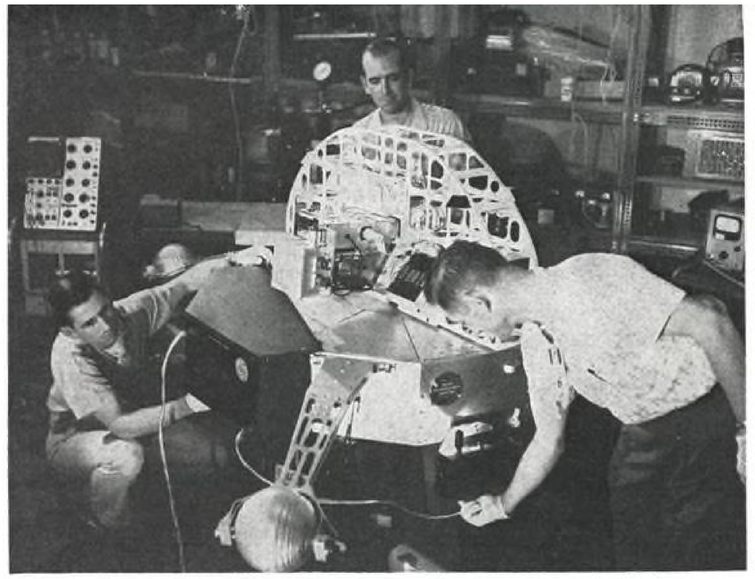
Development of the observatory class of spacecraft was a logical outgrowth in the space exploration program, after larger and more powerful launch vehicles were programed for the future.

The restricting weight and volume of early satellites, which was forced upon them by the limited capability of launch vehicles, led designers to plan payloads and experiments that were closely integrated. Often it required complete disassembly of the satellite to change a single component.

Later experiments attempted to beat these restrictions by designing a number of sub-assemblies that could be integrated into a single frame. Each of these smaller units could be built, tested, installed and, if necessary, removed or replaced as an individual unit without the necessity of tearing down the entire structure of the spacecraft.

The idea of an orbiting observatory evolved from this experience. The basic idea was to provide a big vehicle with a large amount of volume and weight for experiments. These would be mounted on shelves or brackets within the structure, and would be completely separate from the structure. Size and shape of the experimental package would not be determined too rigidly by the confines of the frame.

Auxiliary systems for power, thermal control, and attitude control would be installed as common systems serving all



FIRST Orbiting Solar Observatory (OSO) undergoes pre-flight tests at Goddard.

the experiments. Data handling system for reading, storing and transmitting the data would be included as a spacecraft system. A ground station command system would be part of the control loop so that remote observers on earth could point the observatory toward areas of interest.

Goddard Space Flight Center is managing the development of three classes of these spacecraft: Orbiting Solar Observatory, Orbiting Geophysical Observatory and Orbiting Astronomical Observatory. The first OSO was launched Mar. 7 this year; first OGO is scheduled for launch late next year, and the first OAO for 1964.

Orbiting Solar Observatory was, until it stopped useful transmission on May 22, the near-perfect satellite. NASA's largest and heaviest satellite launched so far, the OSO was designed to make measurements of X-ray and solar radiation from the sun. There were 13 experiments on board.

OSO, which carries the NASA designation of S-16 and the astronomical notation of 1962 zeta, was launched from Cape Canaveral, using a three-stage Delta 8 vehicle. The complete spacecraft weighed 458 lb., was 44 in. in diameter and 37 in. high.

Its orbit was very close to the circular path intended; it had a 343.5-mi. perigee and a 369.8-mi. apogee. Orbital plane was inclined at 32.8 deg. to the equator. Orbital period was 96.15 min.

Basically, the OSO spacecraft is a spinning wheel with a fixed platform mounted on top. The fixed platform was oriented toward the sun at all times so that it could be used for sun-pointing experiments. The wheel was packed with experiments that saw the sun only once per revolution.

Goddard shared the experimental payload with three universities and the Ames Research Center. The Goddard experiments were an X-ray spectrometer, monitors for gamma rays and X-rays, and measurements of dust particles, solar radiation, solar ultraviolet and gamma-ray energies. University of California had a proton and electron flux analyzer and a neutron flux measurement device on board. University of Minnesota had an experiment to measure the intensity and angular distribution of gamma rays. The University of Rochester developed an experiment to measure high-energy gamma rays. Ames Research Center had a device to make studies of surface erosion.

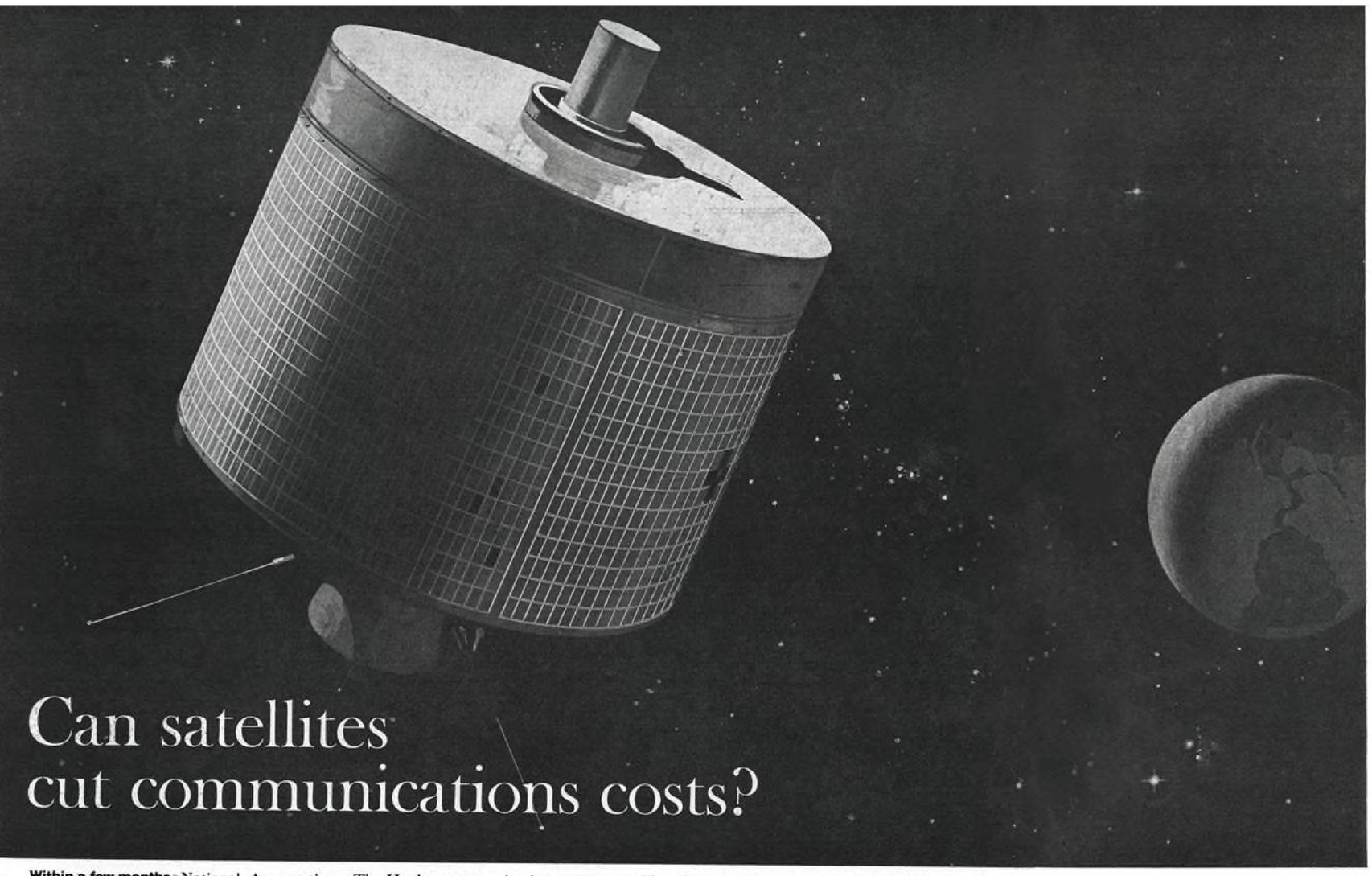
On the way up to orbit, the OSO was spun up to a high rate and three arms—which mounted tip jets and gas storage spheres—were deployed by centrifugal force. Once the arms were fully extended, the tip jets were used to de-spin the OSO down to one-half revolution per second.

Concept and general layout of the OSO was done entirely by Ball Bros. Research Laboratories, whose previous experience in the field has been building pointing control systems for sounding rockets.

During the 11-week operating life of OSO, it had completed more than 1,100 orbits and had transmitted scientific data for more than 1,000 hr. In complete contrast, the total amount of time spent in unimpeded observation of the sun's surface and corona before the OSO was just 300 sec., obtained during sounding rocket experiments.

Total development cost for the OSO program, through four vehicles of a size to be launched with a Delta vehicle, is estimated by NASA sources to be $60 million, plus another $10 million for the four launchers. This figure includes personnel salaries, support, and the spacecraft.

Next class of observatory spacecraft



Can satellites cut communications costs?

Within a few months, National Aeronautics and Space Administration plans to launch the first Hughes Syncom communications satellite into orbit. Hughes engineers foresee that this Syncom can be the prototype for an advanced *synchronous* satellite system which could significantly reduce intercontinental communications costs.

A synchronous satellite is one which orbits the earth at an altitude of 22,300 miles. At this altitude it can be made stationary over an assigned latitude—traveling one revolution with the earth each day.

From this position the satellite would "see" 40% of the earth's surface. And it could serve as a "switchboard in space"—relaying signals between ground stations as far as 10,000 miles apart.

The Hughes communications system would require just three such satellites spaced around the earth (see fig. 3 below). They could bring intercontinental telephone, TV, telegraph and radiophoto service to *every* inhabited place on our globe.

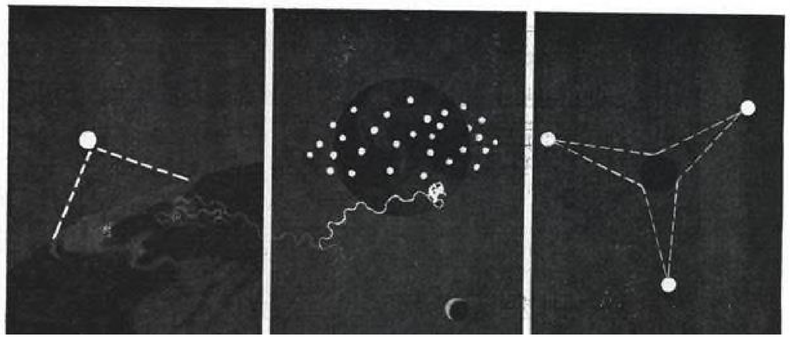
Equally important, the Hughes concept would accomplish this with greater simplicity and economy. For example, with just three satellites to put into orbit, fewer boost rockets would be expended—and valuable launch pad time would be saved.

Compared to other proposals, the Hughes system would require much less expensive ground stations. And because each satellite in the Hughes system would remain stationary over a point on earth, each could continuously communicate with many stations. This permits a feature called "multiple access," where as many as 100 countries can be interconnected in whatever combinations the telephone demand requires at any time. In fact, one operational synchronous satellite over the Atlantic Ocean could handle the intercontinental service between 90% of the world's phones—1,200 conversations simultaneously!

Initially designed as a Hughes-sponsored project and built under contract to NASA's Goddard Space Flight Center, the Syncom satellite system may inaugurate the most practical use of space so far visualized. It could reduce communications costs while permitting people throughout the world, even in less developed countries, to share in a communications system built by free men in the cause of greater world understanding.

Three concepts of satellite communications

***(1) Passive reflector satellite**—NASA'S Echo balloon helped prove signals could be "bounced" from one point on earth to another. **(2) Low altitude active satellites** would move in random orbits. Estimates indicate approximately 50 such satellites, together with complex ground stations, would be required to adequately cover the globe. **(3) A stationary high-altitude synchronous system** will require just three satellites to serve all of the populated areas of the globe with low cost telephone, TV and other forms of communications.*



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to orbit will be the Orbiting Geophysical Observatory (OGO), a series of satellites intended to perform many experiments in a wide variety of orbits, and to orient these experiments simultaneously to both earth and sun. First of this class will be the EGO. It gets its name from the highly eccentric orbit which is planned; if successfully established, it will have a 160-mi. perigee and a 70,000-mi. apogee. Orbital inclination will be at 31 deg. to the equator, and orbital period is expected to be about 43 hr.

Weight of any of the OGO series will be about 1,000 lb. per observatory, regardless of type and number of experiments. EGO will be launched from Cape Canaveral using an Atlas Agena B.

Second of the OGO class is known as POGO, for Polar Orbiting Geophysical Observatory, and is intended to be launched late in 1964 into a polar orbit. For this reason, it will be fired from the Pacific Missile Range; the launch vehicle will be the Thor Agena B. Planned orbit will have an inclination of 90 deg. to the equator, a 160-mi. perigee, a 575-mi. apogee, and a period of about 90 min.

These orbits—one highly eccentric, one polar—represent two extremes; later OGO shots will be launched into planned orbits with inclinations, apogee heights and periods between these values.

NASA sources say that OGO development will cost $138 million, including salaries, support, spacecraft and launchers for five development-phase flights. Repeat cost would be approximately $15 million per launch including the experimental packages.

Space Technology Laboratories is developing the OGO series for NASA.

Astronomer Satellites

Biggest and heaviest of the currently planned observatory class, the Orbiting Astronomical Observatory (OAO) is a spacecraft designed to be capable of carrying a number of astronomical experiments and of pointing them with extreme accuracy. For the first time in history, astronomers will be able to make observations of the heavens without having to look through the filters and distortions of the earth's atmosphere.

Early planned experiments center on ultraviolet astronomy, with visible light observations coming along on later OAO spacecraft. Some indication of the kind of experiments possible is given by the dimensions of the experimental package, which is 40 in. in diameter and 116 in. long. One of the planned experiments will use an optical telescope with a 36-in. mirror.

Weight of the observatory will be about 3,300 lb., including the experimental packages, and it will be launched by an Atlas Agena B vehicle from Cape Canaveral. Plans call for a circular orbit at 500-mi. altitude.

Development cost for the OAO program for three flights is estimated at $184 million, including salaries, support, procurement of spacecraft and launch vehicles.

Prime contractor for the spacecraft is Grumman Aircraft Engineering Corp. Principal subcontractors are General Electric Co.'s Missile and Space Vehicle Dept., for the stabilization and control system, and IBM Space Guidance Center, for the control center.

Future Satellites

Meanwhile, the special-purpose satellites also have a future. The philosophy seems to be two-pronged; first, develop a "streetcar" satellite that can carry a lot of experiments. Rough out the areas of special interest with these and then, as the second prong, develop special-purpose satellites which will investigate only a few phenomena.

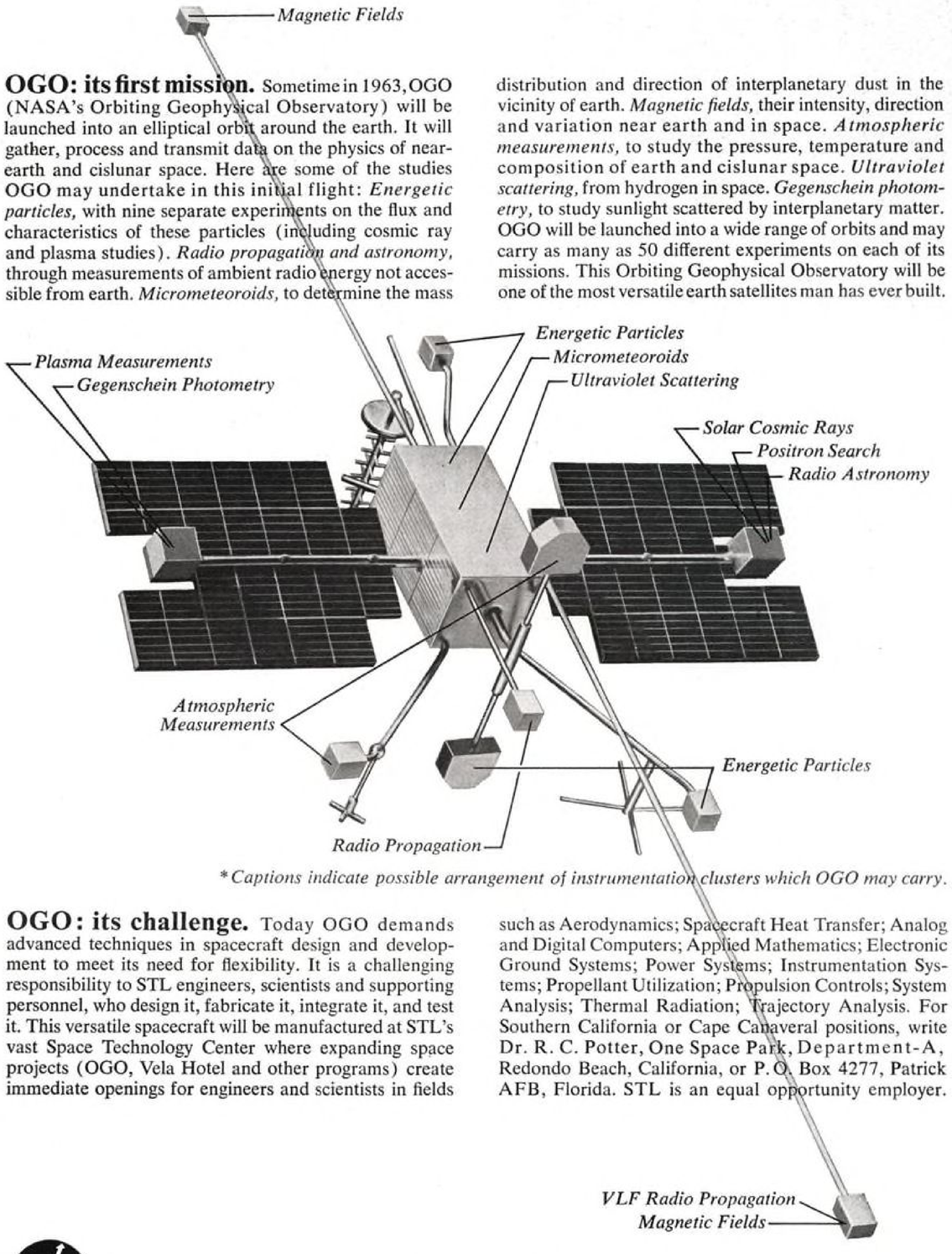
One example of the special-purpose satellite is Goddard's IMP (Interplanetary Monitoring Probe). This spacecraft is like a combination of Explorers 10 and 12, and is being designed to monitor radiation through a complete solar cycle of 11 years.

There will also be future satellites which will repeat experiments already conducted, or will extend their range.

Ultimately, there will develop a third-generation spacecraft which will be characterized chiefly by provision of some on-board logic. Goddard scientists say they consider the first generation of satellites those types that in effect look at everything. They continuously monitor and record data and transmit miles of tape. Only a portion of this may be of value, and the work involved is in winnowing the wheat from the chaff.

Second-generation satellites, according to the scientists, include those spacecraft that can be told to look at something special by command from the ground or by built-in program. The selectivity of these spacecraft will be greatly improved, and the mountains of data, while not reduced to molehills, will be considerably smaller.

Finally, the current ideal of the space scientist is the discriminating satellite, the spacecraft that scans the heavens and recognizes something of interest on which to concentrate. It then swings into action and records data, rejecting everything that appears normal except for a few baseline parameters. As soon as some abnormality appears, the entire battery of sensing and recording instrumentation starts and remains on until the phenomenon has stopped and normal conditions have been re-established.



OGO: its first mission. Sometime in 1963, OGO (NASA's Orbiting Geophysical Observatory) will be launched into an elliptical orbit around the earth. It will gather, process and transmit data on the physics of near-earth and cislunar space. Here are some of the studies OGO may undertake in this initial flight: *Energetic particles,* with nine separate experiments on the flux and characteristics of these particles (including cosmic ray and plasma studies). *Radio propagation and astronomy,* through measurements of ambient radio energy not accessible from earth. *Micrometeoroids,* to determine the mass distribution and direction of interplanetary dust in the vicinity of earth. *Magnetic fields,* their intensity, direction and variation near earth and in space. *Atmospheric measurements,* to study the pressure, temperature and composition of earth and cislunar space. *Ultraviolet scattering,* from hydrogen in space. *Gegenschein photometry,* to study sunlight scattered by interplanetary matter. OGO will be launched into a wide range of orbits and may carry as many as 50 different experiments on each of its missions. This Orbiting Geophysical Observatory will be one of the most versatile earth satellites man has ever built.

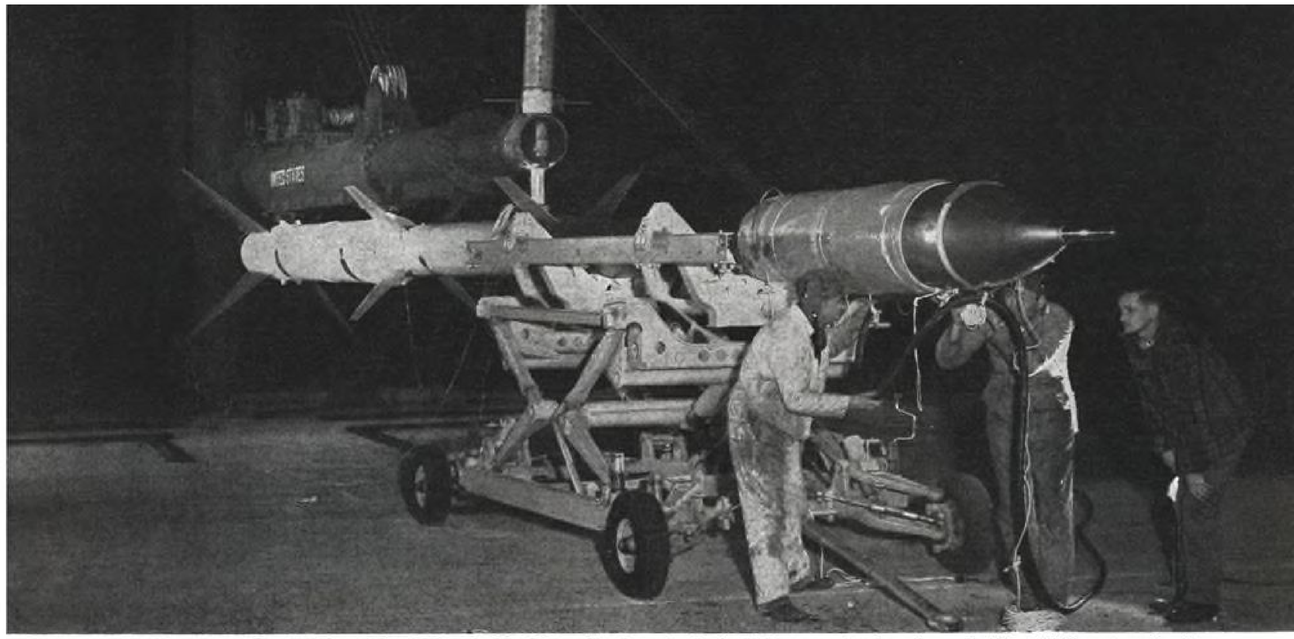
**Captions indicate possible arrangement of instrumentation clusters which OGO may carry.*

OGO: its challenge. Today OGO demands advanced techniques in spacecraft design and development to meet its need for flexibility. It is a challenging responsibility to STL engineers, scientists and supporting personnel, who design it, fabricate it, integrate it, and test it. This versatile spacecraft will be manufactured at STL's vast Space Technology Center where expanding space projects (OGO, Vela Hotel and other programs) create immediate openings for engineers and scientists in fields such as Aerodynamics; Spacecraft Heat Transfer; Analog and Digital Computers; Applied Mathematics; Electronic Ground Systems; Power Systems; Instrumentation Systems; Propellant Utilization; Propulsion Controls; System Analysis; Thermal Radiation; Trajectory Analysis. For Southern California or Cape Canaveral positions, write Dr. R. C. Potter, One Space Park, Department-A, Redondo Beach, California, or P. O. Box 4277, Patrick AFB, Florida. STL is an equal opportunity employer.

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JAVELIN is prepared at Wallops Island, Va. Goddard-Canadian launch obtained data on galactic noise and ABL X-248 motor vibrations.

Sounding Rockets Play Prime Science Role

Greenbelt, Md.—Sounding rockets, one of the specific responsibilities of the Goddard Space Flight Center, are the workhorses of the space sciences program.

Primary purpose of sounding rockets is to obtain useful atmospheric and astronomical data from altitudes unreachable by other means. These uncomplicated vehicles have a record of better than 50% successful operation.

Working in the region between 20 mi.—upper limit for balloon-borne experiments—and about 100 mi.—lower limit for satellites—the rockets have been the basis for determination of all upper-air composition and pressure information. They have photographed cloud cover, determined types and energies of solar beams, obtained the first ultraviolet stellar spectra, and carried nuclear emulsions into the radiation region.

The entire program funnels through Goddard, which is charged with the responsibility for aerodynamic design, payload integration and flight-test firings.

Primary justification for sounding rockets is their ability to measure in the altitude range between 20 and 100 mi. This region, of particular interest to scientists, contains the D-layer and the lower E-layer of the atmosphere. The properties of air, controlled near the surface of the earth by mixing processes, are influenced here more by diffusive processes.

Many of the available sounding rockets have altitude capabilities much greater than 100 mi., which give them the unique ability to give a vertical sampling of the atmosphere. The E and F regions of the ionosphere, out to a few hundred miles, are best probed by rockets to get a sample which is useful in itself, and which also can be integrated to get total properties.

Altitude capability of some sounding rockets also makes them useful for pre-satellite experimentation. Special instrumentation needed for satellite measurements can often be built and tested at the proper altitude in a much shorter time than it would take to get it flown on a satellite. A sounding rocket payload can be built and flown in a time span of six to nine months. A satellite payload, takes time more on the order of two years.

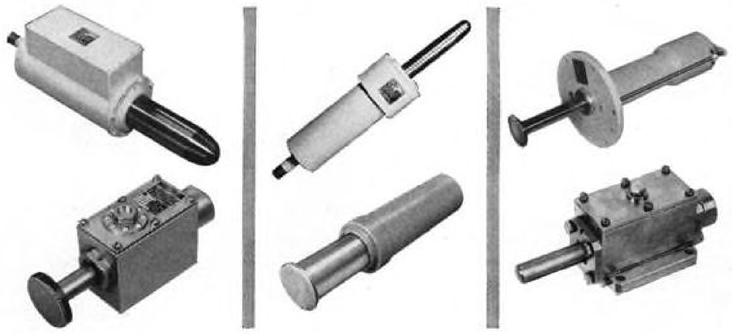
The problems of the preparation of the payload, the launch, acquisition and reduction of the data are similar to those of a satellite. That similarity, the relative inexpensiveness of the sounding rocket, its simpler operation and shorter lead times for every phase, make the sounding rocket program a relatively easy initiation to space programs in general.

Quick reaction capability, a term usually associated with military weapons, also applies to sounding rockets. All of the types used (see box), with the exception of the Aerobees, have solid-propellant rocket motors. They can be set up and fired with a minimum of make-ready time, so that measurements can be made shortly after a keying event—such as a solar flare—has been observed.

NASA Sounding Rockets

Rocket	Payload wt. (lb.)	Design alt. (mi.)	Firings 1959	1960	1961	1962
Aerobee 100	70	80	0	4	8	..
Aerobee 150, 150A	150	150	4	11	8	4
Aerobee 300	50	300	0	3	2	..
Argo E-5 Jason	50	600	..	..	..	..
Argo D-4 Javelin	50	800	1	5	8	1
Argo D-8 Journeyman	130	1,300	0	1	2	..
Arcon	40	55	6	..	..	..
Iris	100	180	0	2	1	1
Nike-Asp	50	150	5	10	8	..
Nike-Cajun	50	150	0	24	23	12
Skylark	150	150	..	..	4	..
Nike-Apache	...	.....	0	0	5	..

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There might not always be a satellite of the right type in the right place when needed.

Finally, the current sounding rockets have enough payload weight and volume, and operate for a short enough time, that large amounts of on-board power can be carried. The experimenter can use standardized components instead of developing specialized payloads for each flight, and he doesn't have to worry too much about the amount of battery power needed.

Philosophy of Use

Basic philosophy governing the choice of a rocket or a satellite to perform an experiment is simple. If you can accomplish the experiment with a sounding rocket, don't waste a satellite. And, as a sort of corollary philosophy: use the sounding rocket for experiments that can't be done much better with a satellite.

These are typical of the experiments done by sounding rockets in the NASA program:

- **Composition of the atmosphere** was determined by mass- and ion-spectrometers carried 154-mi. high by an Aerobee.
- **Wind shears and turbulence** in the region from 50 to 120 mi. were determined from sodium-vapor trails released from the payloads of several Nike-Asp rockets. Experiments of this type will be performed at Cape Canaveral this year to determine the wind pattern over the Cape.
- **Atmospheric temperatures** were determined by correlating the flash of explosive grenades carried aloft by Nike-Cajun rockets with the time that the explosions were heard.
- **Cloud cover photography** was done during a pair of Aerobee firings.
- **Ionospheric investigations** were made by six Aerobees, two of them carrying ejectable payloads to obtain measurements free of the influence of the vehicles. Others measured the D-layer conductivity and the E-layer electron densities.
- **Solar beam experiments.** Fourteen successful flights out of 14 launchings characterized this program, which was done to obtain information on the types and energies of particles in solar beams produced by solar eruptions.
- **Upper-atmosphere neutron intensity.** This was measured on an Aerobee flight of 120 mi. altitude.
- **Ultraviolet stellar spectra.** Four Aerobees were fired for astronomical studies of ultraviolet radiation from stars and nebulae. In one case, out of 10 stars observed, only one of the cooler ones—at about 12,000F—appeared in the ultraviolet as was expected, based on knowledge of the sun. The hotter the star, the more the readings of the other nine disagreed with theory. Some Goddard scientists have postulated that the different behavior might be due to quasi-molecules of helium hydride, which do not, under earth conditions, form compounds.
- **Radiation intensity.** First Nerv (Nuclear Emulsion Recovery Vehicle) experiment was flown from the Pacific Missile Range on board an Argo D-8. Three bread-mold spore cultures were flown to be studied for correlation of mutations with the radiation intensity measured on the emulsions.
- **Earth magnetic field.** The first alkali-vapor magnetometer was flown to measure the earth magnetic field to an accuracy of better than one part in one hundred thousand.

Fired Anywhere

The relative simplicity of the sounding rockets and their supporting equipment makes it easy to set them up at various sites for firing as was done during the International Geophysical Year and as is still being done. Rounds are fired from NASA's Wallops Station, the Pacific Missile Range, White Sands Missile Range, Australia's Woomera Rocket Range, and Canada's Ft. Churchill.

Re-entry is not much of a problem. Payloads are most often not recovered, with the exception of special shots such as the Nerv firing.

Not only firing sites form the international side of the sounding rocket program. For many of the reasons cited earlier, many foreign countries have been able to gain entree into space much sooner and much more economically than if they had had to wait for a satellite experiment.

Cooperative Efforts

Italy has been doing cooperative sodium flare experiments on the range in Sardinia, tying the timing to a Wallops firing for similar sampling. Japanese instrumentation for their sounding rocket program has been flown on a NASA-fired Nike-Cajun for comparison of techniques.

Sweden has fired Nike-Cajun rounds. A Norwegian engineer is stationed at Goddard gaining experience to take home. India and the Argentine are talking about a similar approach. France checked ground installation for the Colomb-Bechar range at Goddard.

Universities have joined the program, also, along with scientific and research institutes.

As a result of this increased interest, plus the continued requirement for a steady, high level of sounding rocket activity, next year's firings call for a scheduled increase of about 50%. This calendar year, about 70 sounding rockets will be fired.

For the calendar year 1963, 100 are scheduled.

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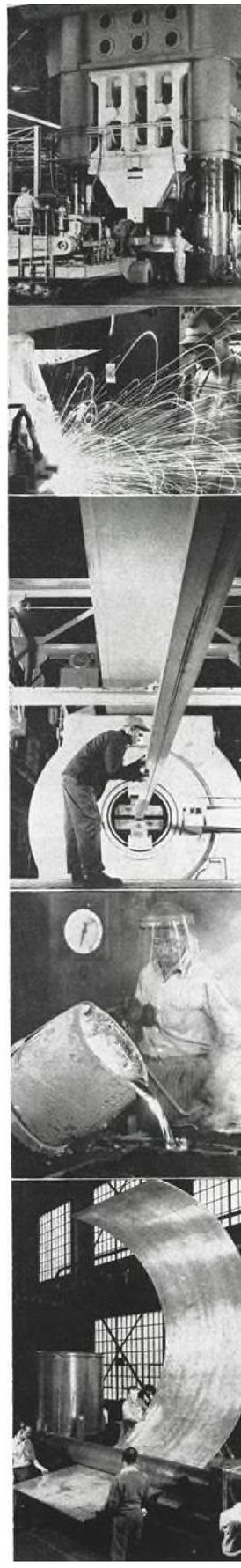
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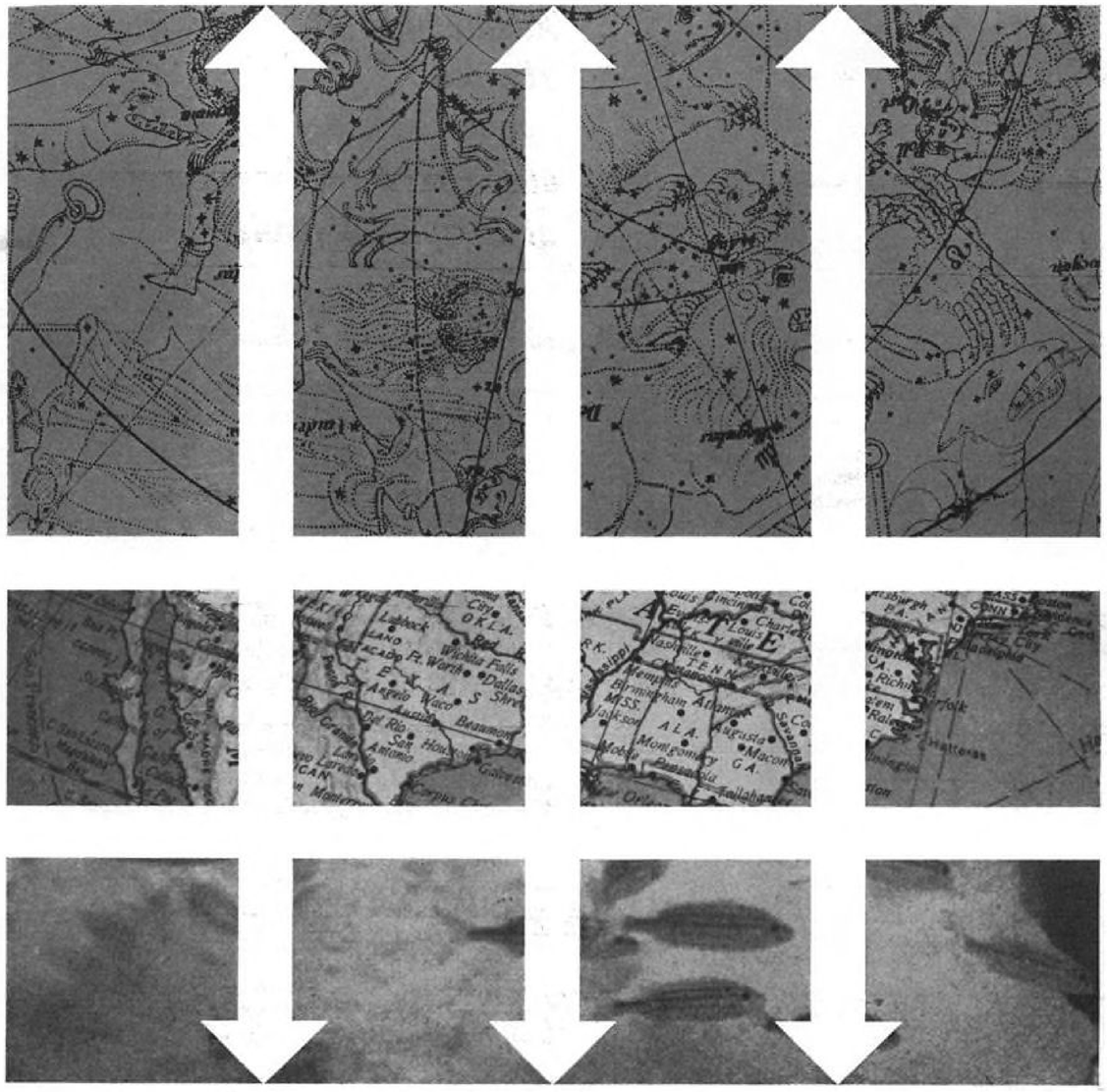
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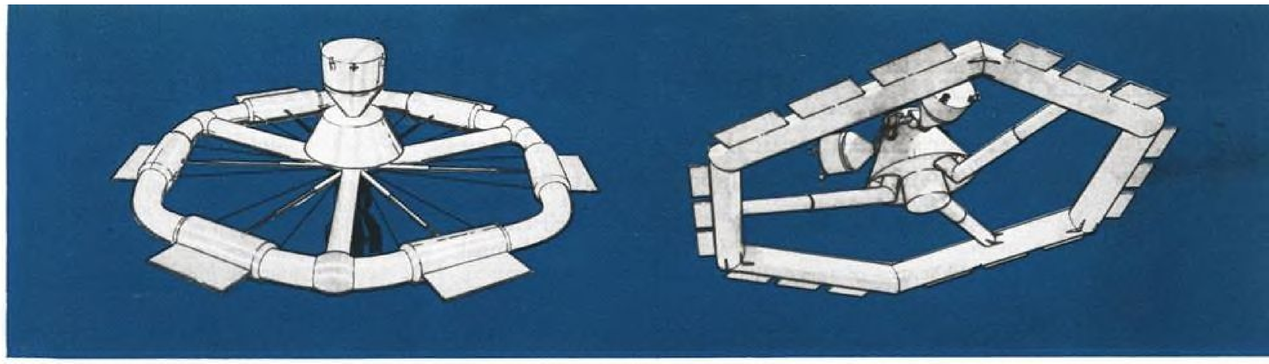
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ERECTABLE SPACE STATION concepts, with docking points for several manned re-entry vehicles, are studied by NASA centers.

Research Provides Data for Space Missions

Studies in aeronautical, nuclear and space technology aimed at developing new concepts and techniques.

Advanced research and technology, one of the National Aeronautics and Space Administration's five basic program areas, builds the foundation for future engineering of aeronautical and space vehicles.

Part of this over-all program is tied to specific missions such as Apollo or one of the scientific satellites. But the major portion of the work aims at the future, at the undefined, nebulous jobs that will have to be done someday by systems not yet developed and by techniques not yet understood.

This kind of information also provides a basis for defining and selecting future space missions.

Three fundamental areas of activity comprise the subject matter of advanced research and technology:

- **Aeronautical research and technology,** which deals with the problems of the entire aircraft speed range, from the zero-velocity conditions of the helicopter or VTOL designs to the hypersonic aircraft proposed for future development. Major efforts in this area include V/STOL aircraft, the supersonic transport and multi-mission aircraft.
- **Nuclear systems technology,** which includes nuclear propulsion systems such as the rocket program jointly conducted by NASA and the Atomic Energy Commission, electric power generation from nuclear power sources, and electric propulsion systems.
- **Space vehicle research and technology,** which covers launch vehicles, spacecraft and re-entry vehicles with their associated problems of propulsion, power generation, avionics, guidance and control, structures, materials, gas dynamics and space environment.

On top of this foundation there is a superstructure of general research, with no specific problem area in mind. This portion of NASA's work is regarded as vital; from it may come completely new techniques or new concepts that will lead future development into areas that might have been closed off, had this type of research not been programed.

Mutual interest in most of these areas is shared by NASA and other agencies in the government, particularly the Department of Defense. There is coordination of these programs, through the Aeronautics and Astronautics Coordinating Board so that unwarranted duplication is avoided.

Most of the workload of the Ames, Langley, Lewis and Flight Research Centers is chargeable to programs outlined by the Office of Advanced Research and Technology. That office performs a managerial and coordinating function, with the usual objectives of such offices—reduction of duplication, provision of resources in anticipation of the need, support of planning or scheduling, etc.

NASA's work in fundamental research, not tied to any specific mission, falls into four general areas: fluid physics, electrophysics, materials and applied mathematics. Space science, which might be considered as a fifth area for fundamental work, has been established as one of the five major NASA program areas, and is therefore not duplicated in the Office of Advanced Research and Technology.

A typical example of fundamental research is the investigation of atomic recombination, a basic physical process whose control could result in tremendous reductions in re-entry heating, and equally large increases in the thrust of hypersonic air-breathing engines.

The only trouble is that in one case, for re-entry, the scientist doesn't want recombination to happen; for the case of thrust of the airbreathing engine, it is vital that the recombination take place.

The phenomenon of recombination has to start with uncombined particles in the first place. In a re-entry situation, the air passing through the shock wave is heated so much that molecules break down into atoms and in the process, absorb some heat. If they then strike a so-called catalytic-body surface—and most normal vehicles seem to fall in that category—the atoms recombine to form a molecule and give up their heat. This extra increment of heat is what causes the trouble during re-entry.

In a rocket nozzle flow, the desired situation is just the opposite. Every bit of recombination adds heat energy and therefore thrust to the system. In fact, in the case of the hypersonic air-breathing engine, thrust with recombination is twice that without recombination. There are some NASA scientists who believe that these types of engines will be practical only if some way can be found to guarantee recombination of the dissociated atoms; without recombination engine performance deteriorates badly.

The advanced research office has asked for a major increase in funds for this fiscal year—$618.5 million compared with a total of $349.3 million last year—which reflects budgeted increases right across the board. The largest increments are requested for launch operations development, nuclear systems technology, electric propulsion and liquid propulsion (see box). But the numbers don't tell the whole story.

In liquid propulsion, to use one example, the cost increases reflect the status change of programs from study to development. The $163.1 million requested for this item includes a major increase in funding for the 1-million-lb. thrust M-1 hydrogen-oxygen engine for the Nova launch vehicle.

Langley Gives Space Effort Predominance

Traditional center of aeronautical research knowledge now channels greatest effort to space flight studies.

Hampton, Va.—Engineers and scientists of the Langley Research Center, historically leaders in aeronautical research, have turned their traditional disciplines to meet the challenges of space flight.

Approach toward these objectives is a new one, but the trail is being blazed by the old standard disciplines of aerodynamics, structures, flight mechanics and fluid mechanics.

Four years ago, the major jobs at the center—then the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics—were aimed at making airplanes fly better. Today, more than two-thirds of Langley's effort is channeled toward space flight and the remainder toward aeronautics.

Biggest single portion of the workload is chargeable against lunar and interplanetary vehicles—about 30%. Supersonic aircraft research, about evenly divided between the Mach 3 transport and the multi-mission military aircraft, accounts for 15%. Launch vehicles for space experimentation account for approximately 14% of the work.

Langley Mission

Formally, Langley is charged with this mission:

- **"To engage in basic and objective** research that will provide the technical background necessary for the accomplishment of such missions as: (1) the manned and unmanned exploration and use of space and (2) improvement in the performance, safety and utility of airborne flight.
- **"On the basis of research findings,** to generate new and advanced concepts for future national missions.
- **"To advise and provide research** assistance to other branches of the government, including assistance to the Department of Defense in the development of new weapons systems."

Within this framework, Langley's tasks bridge the gap between hovering flight at sea level and hyperbolic velocities in space. Detailed investigations branch off this main line, touching the structures of space stations and supersonic transports; the attenuation of radio measurements during re-entry; the fabrication of inflatable earth-orbiting laboratories and paragliders; the noise of turbofan engines and sonic booms; the creation of man-made meteorites; the study of the hardnesses of the moon's surface and of spray-deposited beryllium.

Langley scientists still delve into the areas of the turbulent boundary layer and the problems of flutter, but now with a heightened urgency which has been spurred by the pace of project development.

But neither research nor project work can go on without some help from experimentation, and that demands test facilities. The third leg of the Langley tripod is a collection of test facilities which have been modified and rebuilt almost continually to meet the changing challenges of the times. The full-scale tunnel now tests free-flight models; the 19-ft. pressure tunnel has been converted to a 16- x 16-ft. transonic dynamics test facility; the towing tank now checks landing characteristics of spacecraft.

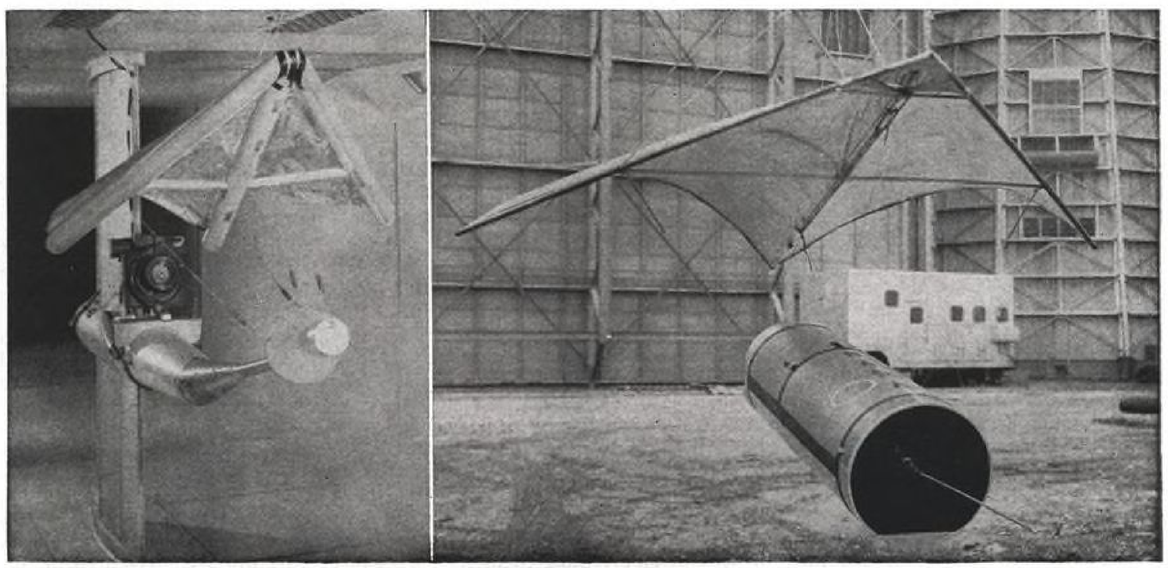
Organization Changes

Langley, in the past, has been organized on the basis of scientific disciplines which were related in their approach or application to the varying tasks of the center.

But much of the workload now falls in project categories that cut across a number of the disciplines. Work on the supersonic transport involves aerodynamicists, structures specialists, mathematicians who can develop the complex equations of flight mechanics, wind tunnel technicians and a host of other specialists. So does work on the earth-orbiting manned laboratory, or the Saturn launch vehicle.

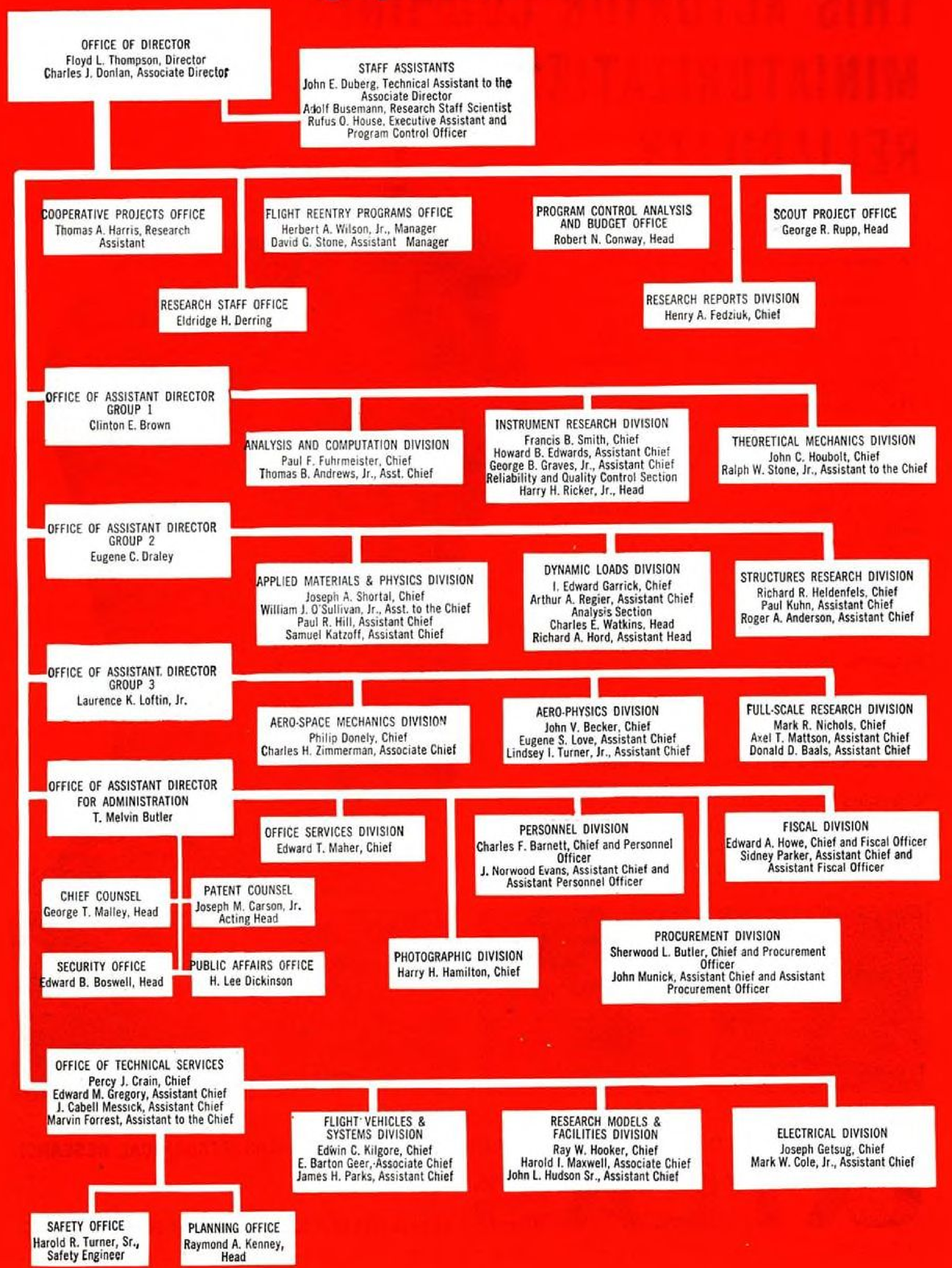
To operate this intertwined organization, Director Floyd L. Thompson and Associate Director Charles J. Donlan manage the center as a matrix of interleaved disciplines and projects.

They point out that an air loads specialist understands the problems of air loads whether they occur on a helicopter rotor blade, a supersonic fighter elevator, or a rocket nose cone. Logically and administratively, therefore, he belongs to a discipline group; functionally, he acts as a consultant on loan to a



GEMINI MODEL, left, is prepared for wind tunnel test with Rogallo paraglider; dummy Saturn booster, right, is tested with flex-wing.

Langley Research Center



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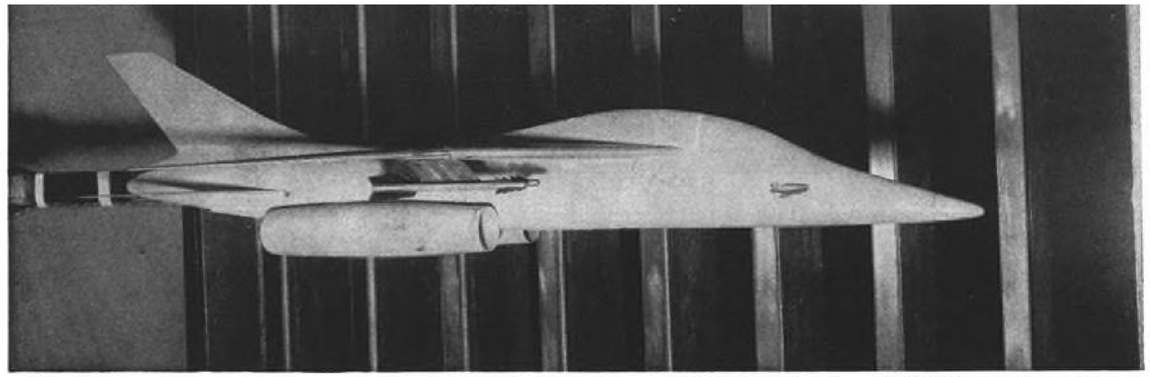

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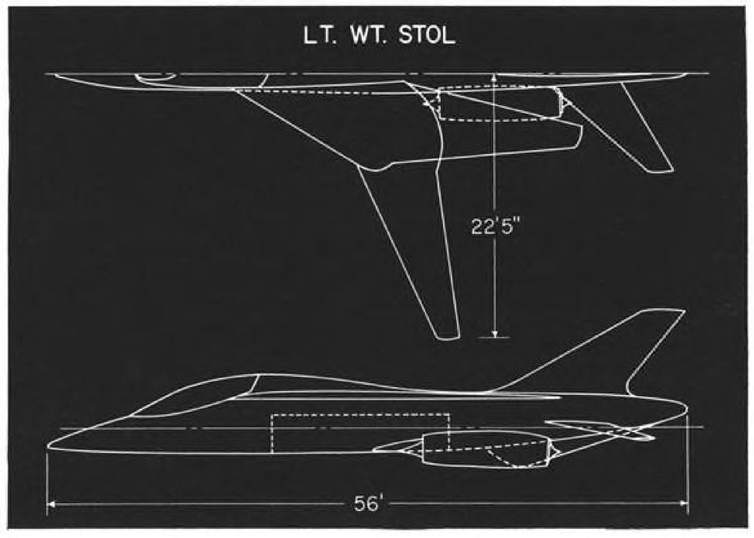
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PROPOSED 'LITTLE BOY' supersonic military aircraft model is being wind tunnel-tested, above, at Langley Research Center. Sidewinder missile models are attached to wings. Below, drawing shows design of variable sweep wings.



particular project for the duration of the job.

To handle this workload, Thompson directs a staff of 3,628 employes, the second-largest number in NASA; about 1,200 of these are professional grades. Almost one-third of the professional staff specializes in aerodynamics; 20% are structural specialists; 15% work on the mechanics of flight and 13.5% on fluid mechanics.

Predominant Work

These types of projects dominate the research and development tasks of Langley Research Center:

• **Support of the lunar mission.** Studies here are concentrating on the problems of guidance and control, of simulation of lunar approach, descent, landing and takeoff, and of rendezvous and docking. One fascinating aspect of the work is a series of simple, low-cost simulators using unsophisticated techniques to narrow the problem areas. These simulators include a "cinerama" approach to a landing in a moon crater, and a three-body rendezvous problem in which the pilot tries to align two orbiting tanks and then to dock his spacecraft to the paired tanks.

• **Manned earth-orbiting laboratory.** In this project area, studies cover conceptual design, structural techniques, operational problems and guidance and control. One example: dynamic stability studies of a typical toroidal shape are being made to determine some of the parameters of response to unsymmetrical mass distribution, meteorite impact with consequent rupture of the shell, and spin-up rockets for increasing or maintaining a level of gravity.

• **Unmanned earth satellites.** Inflatable structure for the Echo series of passive communication satellites has been developed here. The work continues, primarily in the area of structures.

• **Re-entry physics.** Project Fire, the studies of re-entry at hyperbolic velocities, is a major effort at Langley both physically and financially. Other aspects of this work include the Trailblazer series of launches, Scout re-entry vehicles, and the development of ground test facilities for checking flight data against experiment and theory.

• **Aeronautics.** Biggest single effort is aimed at technical development of a supersonic transport, one of the national missions outlined in the Langley charter. Related technology is developing for the multi-mission fighter, featuring variable-geometry wings. Aeronautical work also includes helicopters, V/STOL aircraft and ground-effect machines.

• **Launch vehicles.** Primary emphasis is on the dynamic loads of launch during the time period of the ". . . drama of the first hundred seconds." Scout and Saturn are the two vehicles under consideration for the most part. Basic investigations into such phenomena as wind shear occupy a large portion of this specialized workload. One of the most useful test facilities is a one-fifth scale model of the Saturn which is dynamically similar to the full-scale vehicle.

Not Alone

Back in the days when Langley was the hard core of aerodynamic knowledge in this country—a position which the center claims it still holds—it was in-house invention, experimentation and theory that developed the cowling for radial air-cooled engines, the low-drag airfoil, the transonic wind tunnel and many other contributions to aeronautics. But now, as the mission has changed and the tasks have become

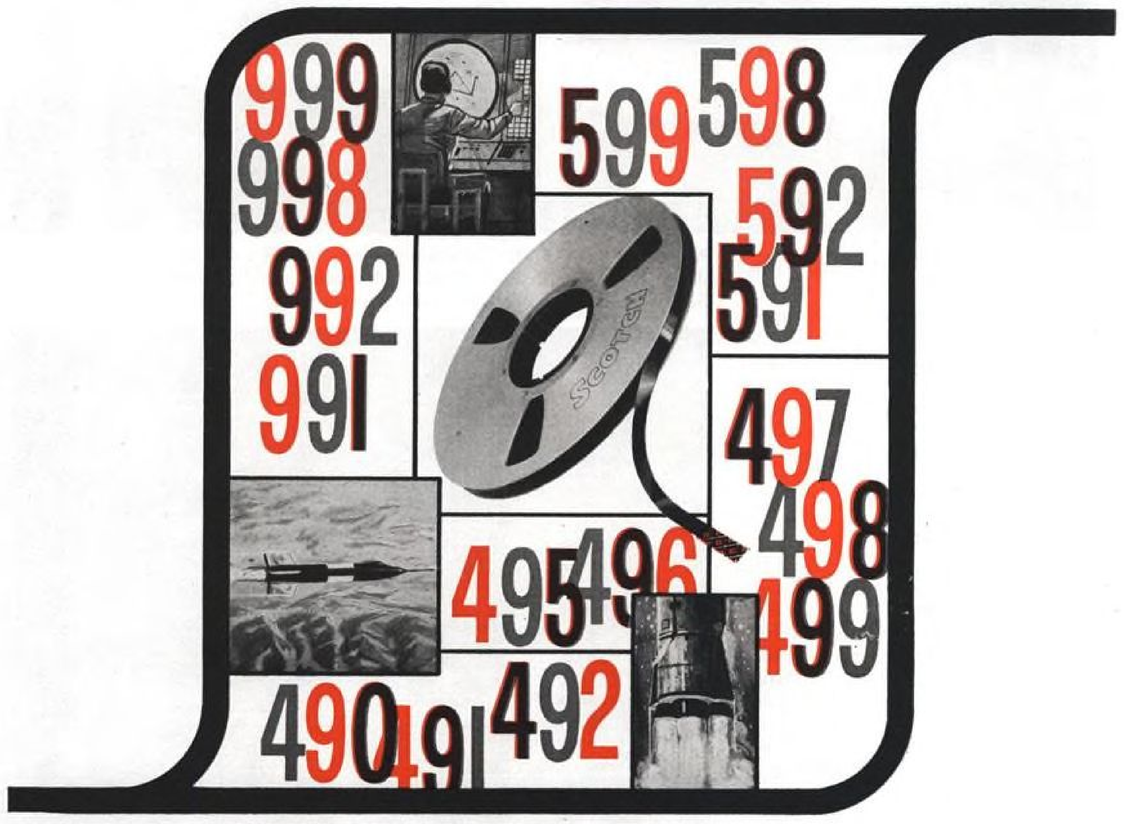
Langley Research Center

NASA's Langley Research Center is located at Langley Station, Hampton, Va., and is divided into two areas by Langley AFB, headquarters of USAF's Tactical Air Command. NASA property totals 772 acres occupied, of which 430 are owned by NASA and 342 are occupied under permit from the Air Force. Runways and some utilities are used jointly by NASA and USAF.

Current plant value of the installation is $231,151,000. Operating cost for Fiscal 1962, which ended June 30, was $41,643,000; for this fiscal year, NASA asked for an increase to $50,705,000. Construction during last fiscal year amounted to $6,530,000; this year's is budgeted at $8,092,000.

Langley Research Center also asked for an increase in its authorized staff from the Fiscal 1962 level of 3,628 to 4,000.

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more complex, NASA has logically had to rely on groups or individuals who can do specific jobs in specific disciplines more efficiently and economically than would be possible at Langley alone.

In addition to these outside expenditures, large portions of the center's budget are directed toward the purchase of large equipment or its construction. Project Fire, which started off at a $5-million level in its exploratory phase, is expected to grow to a multi-million dollar contract.

This kind of money will go to the outside contractor—in this case Republic Aviation Corp.—working on the development.

Personnel Training

There is a final important task, implied in the mission statement, that center management takes very seriously: training people for advanced capability. The center encourages graduate degree training and one in four of the professional staff is currently enrolled in the center's Graduate Education Program. Apprentice training is a major part of the education program. More than 80% of the 524 craftsmen and designers who have completed apprentice courses here in the past 20 years are still employed by NASA.

Hypersonic Aircraft

Hampton, Va.—Studies of winged reentry vehicles and air-breathing boosters continue to point toward the ultimate value and possible use of both of these concepts.

Scientists here have made preliminary design and configuration studies of several concepts of these two extensions of aeronautical technology.

Major advantage of the winged reentry vehicle over its ballistic counterpart is that it gives occupants the ability to return at will from orbital positions. Conventional landing also has obvious advantages.

The real problem here centers on the leading edge materials; the only way to improve lift-drag ratios for winged reentry aircraft is through greatly improved materials.

The engine cycle seems to be the toughest problem for the air-breathing boost. There is some belief now that a turbo-ramjet is a good starting point, to be phase-followed by an oxygen collection and liquefaction cycle, and then by burning the oxygen with liquid hydrogen.

One NASA engineer said that current studies show a one-stage-to-orbit aircraft is probably out of the running.

Another engineer said that about half of Langley's future aeronautical research will be on the air-breathing booster design.



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Langley Explores Manned Space Station

Hampton, Va.—Self-erecting manned space laboratory which could be operational before 1970 has been developed in conceptual form at the Langley Research Center.

Design features six rigid cylindrical sections joined by inflatable sections to form a toroidal shape. Three radial, inflatable elements join the rim to a central, non-rotating section. The station folds into a payload designed to be topped by an Apollo re-entry vehicle for the first crew. It is to be boosted into orbit by a single Saturn C-5 launcher.

After orbit has been established and the laboratory has deployed, the Apollo crew can enter the station and begin setting up and checking out equipment.

There will be a "shirt-sleeve" environment for a crew varying from four to 30 persons, taken to the station by additional Apollo vehicles refitted as five- or six-man taxis. Seven of the Apollo capsules could be docked at one time in the station.

Diameter of the station is 150 ft. It would rotate slowly to produce a low level of artificial gravity varying from 1/6g (the level of moon gravity compared with earth's) to 0.4g at the outer edge of the rim. A small zero-gravity laboratory could be provided at the hub.

Total weight to be boosted into orbit approximates 150,000 lb.

Progress in Time

Manned space laboratory serves two basic purposes: It furnishes a very special environment for experimental studies, and it acts as a stepping-stone into space. Langley's studies began with zero-gravity stations several years back, but they quickly changed to include artificial gravity for experimental reasons. This required rotation of the station.

At this point, human factors studies dominated the concept. Rotation rates are closely tied to human comfort: Rotate too slowly, and normal body functions are impaired; too rapidly, and nausea or circulation impairment sets in.

The result of these considerations was the idea for a large station with slow rotational speeds. Weighing the pros and cons of space assembly against those of boosting a complete station into orbit ruled out—from Langley's viewpoint—the multi-mission assembly.

This led to consideration of an inflatable or expandable station. But these have two drawbacks: First, equipment cannot be installed in the station until it is deployed in orbit; second, inflatable structure can't take meteorite penetration for a long-duration mission.

But a rigid station overcomes those disadvantages. Hence the solution was to combine the best features of the rigid station and the inflatable or expandable station. This is the current Langley approach.

Key to the successful working of such a station is its deployment in space. With rigid sections joined by inflatable transition sections, the job is not too difficult. But even a partially inflatable station has disadvantages that might be overcome by going to an all-rigid construction. In that case, folding becomes difficult.

Consequently, both approaches are being studied. North American Aviation is working on a contract to study the feasibility of a rigid station whose elements are hinged with a number of skew-axis hinges so that they fold to form parallel cylinders as a payload, but expand to the familiar toroidal shape after deployment.

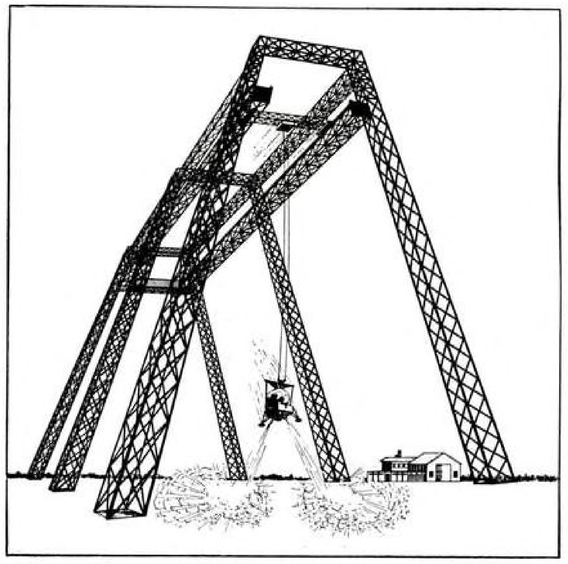
Justification

NASA lists major uses for such a manned, earth-orbiting laboratory, most of which are tied directly to either current or possible future national missions in space and include: Orbital launch operational research, rendezvous study, controlled space systems experiments including biological and botanical tests, astronomical research.

These projected uses help to define requirements for the space station. First, they demand a large diameter, a large usable volume—the concept shows about 60,000 cu. ft., equal to three large houses—and rotation. Operational considerations require automatic erection in space. The perturbations of docking, of meteorite impact, or of people walking around inside require that the station have a natural stability for which the moment of inertia about the vertical axis must be very much greater than the moments about any horizontal axis. There must be damping of these disturbances.

Materials and structures must be compatible with the space environment. There must be control of the internal environment of the station. Power will be required. Protection against radiation and meteorites must be provided. Safety must be a predominant factor in case of fire, use of toxic materials, structural failure or the need to escape. Finally, a laboratory is no good if it runs out of equipment or personnel; there must be re-supply capability.





RESEARCH PILOT, left, operates lunar landing simulator pilot model; right, artist's concept shows eventual simulator configuration.

There is much to do before the space laboratory concept becomes a reality. More configuration studies will have to be made. The dynamics of the station will be checked in model form. Stability and orientation will also be checked the same way. In addition to North American's work, thermal balance is currently being studied under contract to Grumman Aircraft Engineering Corp. Materials and structures will take shape and be broken here. Life support systems and power systems will be investigated for the laboratory.

In addition to manned space laboratory work, Langley also is studying spaceflight piloting techniques for orbital rendezvous and for lunar and planetary approach, descent and landing in a series of unusual simulators being developed in preliminary form.

Purpose of the simulators is to derive first impressions of the complexity and difficulty of the task, and to get preliminary pilot reaction to instrumentation layout, control systems and navigation techniques.

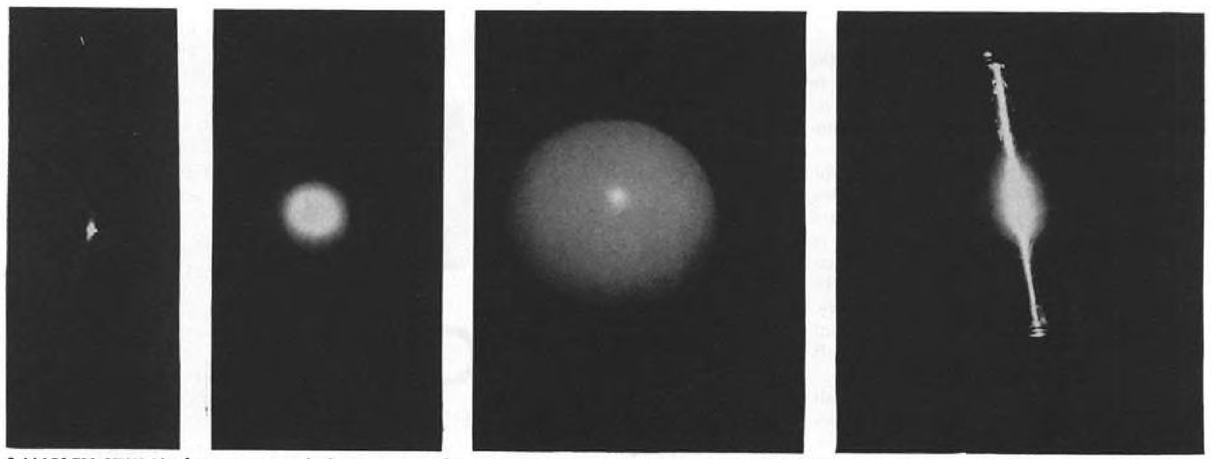
Preliminary results of studies of the problem show that the lunar orbiting technique calls for nothing beyond current developments of guidance systems and the standard human pilot. It seems as if the best way is to make the man the primary system with automatic systems as an aid, rather than trying to do the job automatically with man along for maintenance.

Results of these studies, and the current NASA approach to simulation of spaceflight pilot tasks, seems to underscore the arguments of some engineers who, during all the mathematical treatments showing the near-impossibility of automatic rendezvous, kept arguing the task was no more difficult than bringing a ship into a dock during a high wind with a heavy sea running.

Simulator experiments and studies are being made with inventive, low-cost approaches. Surplus inflatable structures are used for the simulation of the heavens. Plastic radomes make a perfect "cinerama" theater for projection of lunar approaches. A home-made planetarium, costing about $300 and featuring a couple of Christmas-tree ornaments as part of the optical system, serves as a star projector for one navigational simulator. In a rendezvous simulator, a toy planetarium costing about $15 projects a realistic sky background.

In one study, a simulated approach to the Alphonsus crater on the moon is created by projection of a filmed approach to a plaster model, projected on the inside of a plastic radome.

Another simulator study, now being developed for guidance and control techniques, uses an inflatable radome as the night sky, with the star pat-

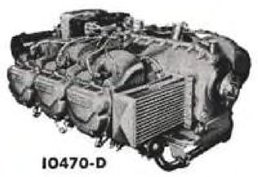


LANGLEY STUDY of appearance of objects in simulated space environment shows point light effects on, l. to r., polished sphere, dull sphere, flat-white painted sphere, polished cylinder, dull cylinder, flat-white painted cylinder and rough-coated cylinder.

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Moon-Gravity Simulation

Unique simulator of the dynamics of lunar impact is nearing the test stage in Langley's Dynamic Loads Division.

It consists of an evacuated chamber, suspended by a cable running over a pulley, counterbalanced by a static weight equal to one-sixth of the chamber weight. Inside the chamber is a table to simulate the moon's surface and provisions for suspending and dropping a model of a lunar vehicle.

The chamber is loaded with the model and the simulated lunar surface, and then evacuated. To make the test, the model is released inside the chamber. It starts to drop at 6g. Just before it impacts the surface, the chamber is released so that it starts to drop at 5/6g. Resultant deceleration at impact felt by the model is therefore 1/6g, or the lunar equivalent gravity.

Following the impact, the time scale of the rebound is exactly that of the real case, so that the bounce trajectory can be plotted accurately.

First tests of the simulator are scheduled for Aug. 1.

terns projected by the $300 planetarium. A cockpit will be installed at the center of the spherical housing to study the problems inherent in deep-space navigation.

One of the more ambitious simulator projects here is a lunar landing and take-off research facility, which will be used to develop technology which will determine the characteristics for an astronaut mission training simulator for lunar letdown and takeoff. To be in operation in about 15 months, this facility will be an outdoor gantry-type structure housing a pilot's compartment on a propulsion module.

Propulsion module will contain live retrorocket motors and a system of small maneuvering jets. A traveling crane will support five-sixths of the vehicle weight at all times to simulate the lunar gravity.

Gemini rendezvous and docking simulator is being studied with a cabin mockup added to a surplus gunnery trainer obtained from the military. It will handle the last 1,000 ft. of approach of the Gemini to the Agena stage, which will be done visually in the real rendezvous.

Still another simulator study is in the area of the three-body rendezvous problem. It simulates the rendezvous of two fuel tanks and a capsule; object is to get the tanks together without exceeding closing rates of a few tenths of a foot per second.

This center recently awarded a contract for still another type of simulator —for visual control of lunar landings— to Bell Aerosystem Co.



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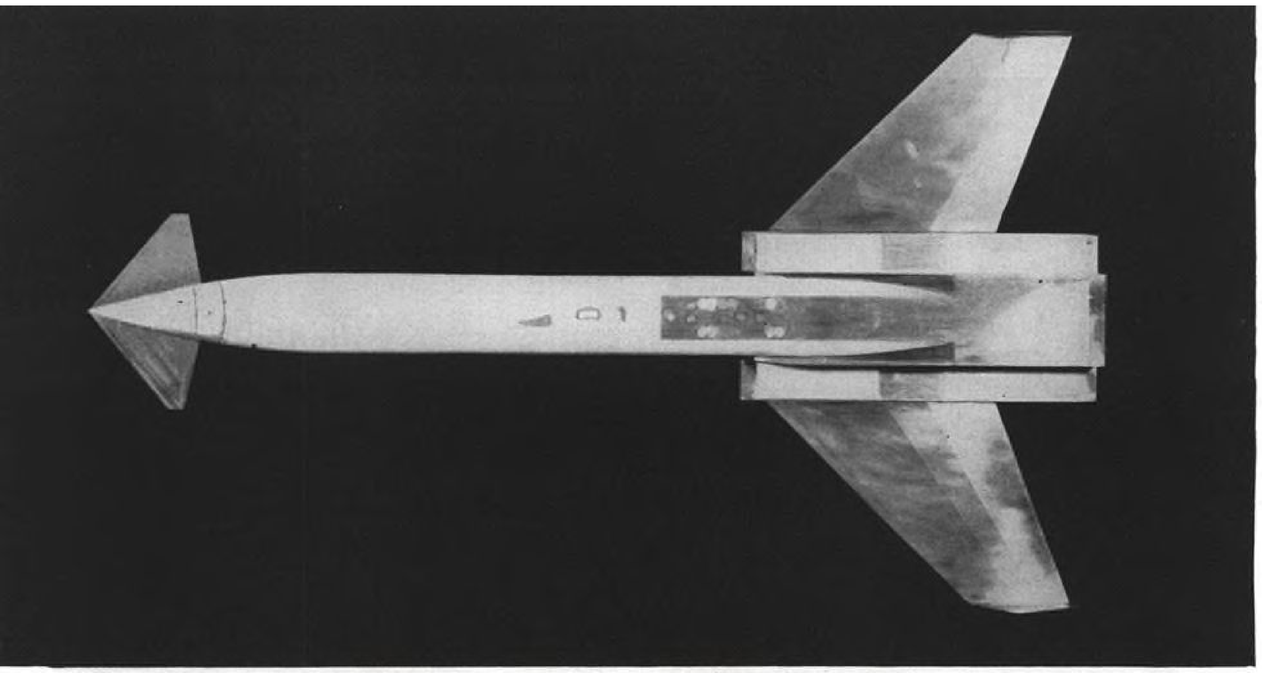
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SCAT 3 model is designed to reduce friction drag by means of very thin surfaces and minimum surface area. Model was tested in the Langley unitary tunnel to determine performance and stability characteristics into the Mach 3 speed range.

NASA Evolves Two Basic SST Designs

Hampton, Va.—Two advanced configurations for supersonic transports have been evolved at the Langley Research Center as part of NASA's over-all mission of basic research and technical support to the SST program.

One is SCAT-15—SCAT is the local acronym for Supersonic Commercial Air Transport—a variable-sweep design credited to John Stack, formerly NASA's director of aeronautical research. It features a highly swept wing which can be spread forward to increase the span and aspect ratio and to decrease the sweep angle. These factors improve low-speed performance and handling characteristics.

The other is SCAT-4 developed by Richard T. Whitcomb, who originated the area-rule concept. This design is based on a fixed, highly swept wing with careful contouring of fuselage, powerplants and wing to account for the nonlinearities of flow over such a shape.

Both these designs represent a major aerodynamic improvement over the USAF/North American B-70 configuration, but this is to be expected of designs which came along later and continued to develop. Both are aimed at obtaining cruising lift-drag ratios much greater than those of the B-70, combined with the ability to operate efficiently at off-design conditions, such as subsonic flight in a holding pattern.

Parallel to these two approaches, Ames Research Laboratory is pushing the aerodynamic development of the fixed canard-delta geometry.

SCAT-15, with its wings pulled all the way back, looks like a slim delta shape with 75 deg. leading-edge sweepback. Spread, the wing leading-edge sweep angle reduces to 25 deg. If it were a full-sized aircraft, it would be 172 ft. long, with a 160-ft. spread wingspan. Fully swept, the wingspan is 45.4 ft.

Data from the SCAT-15 wind tunnel test program, now nearly completed, shows the configuration to be getting the needed lift-drag ratios. Low-speed handling characteristics are expected to be like those of current subsonic jet transports, and the configuration shows promise of being able to operate at subsonic speeds over fairly short-range routes with efficiency and economy.

SCAT-4 starts with an arrow wing, as does the SCAT-15, in which the leading edge is swept behind the Mach angle to get a wing whose aerodynamics theoretically become like the subsonic case. But tests do not verify the high lift-drag ratios predicted by theory; the reason is that there is a substantial cross-flow—outboard on the lower surface, inboard on the upper surface—which changes the wing characteristics. Whitcomb's approach has been partially "cut-and try," using many model tests.

The configuration reduces to a highly swept wing with underslung inlets for the engines, and engine afterbodies which are like the anti-shock bodies developed by Whitcomb for the Convair 990. The fuselage has negative camber.

First test data of the configuration shows subsonic lift-drag ratios less than current jets, but greater than a B-70 configuration. Supersonic lift-drag ratios are much greater than the B-70 type of geometry. Expected sonic boom situation should be much better than a canard delta because of the lower supersonic wave drag of Whitcomb's configuration.

Parallel Studies

Langley's responsibilities do not end with the aerodynamics of a possible SST configuration. The center also is concerned with the sonic boom program, propulsion, materials, structures, operating problems and handling characteristics.

Further, the configuration studies are continuing. SCAT-4 and SCAT-15 are not considered as ultimate layouts.

Behind these detailed investigations, linked closely to the actual design and operation of a supersonic transport, lie some fundamental areas requiring clarification. Assistant Director Laurence K. Loftin, Jr., elaborated on some of these points.

• **Laminar flow over the wing.** With about 25 years' experience in the study of laminar flow phenomena, Langley feels it still has to locate the correct answer. Fluid injection looks like one way, he said; the numbers from the tests look right. But secondary air or fluid has to come from somewhere; engine air is best, being readily available. But what is the price paid for that air? It it acceptable?

• **Effects on highly swept wings** under load. Langley ran these tests on a Boeing B-47 some years ago, measuring the dynamic response of the structure in rough air and trying to check those results with some static load work. There are many unknowns here, Loftin said.

• **Jet exit problem.** Engine exhaust and intake areas don't match over the flight performance range; their areas have to be matched by combinations of variable geometry and bleed. Langley is performing some of this kind of work in the 16-ft. tunnel now, but primarily the engine inlet problem belongs to Ames Research Center.

• **Turbulent friction drag.** It has never been measured at Mach 3 and the problem is to get accurate simulation of the surface and its environment. Langley is starting wind tunnel tests aimed at better definition of the magnitude of turbulent friction drag, using cylindrical shapes with variations in surface contour to obtain roughness effects. These will be run at Reynolds' numbers above 100 million in order to be applicable to the problems of the Mach transport.

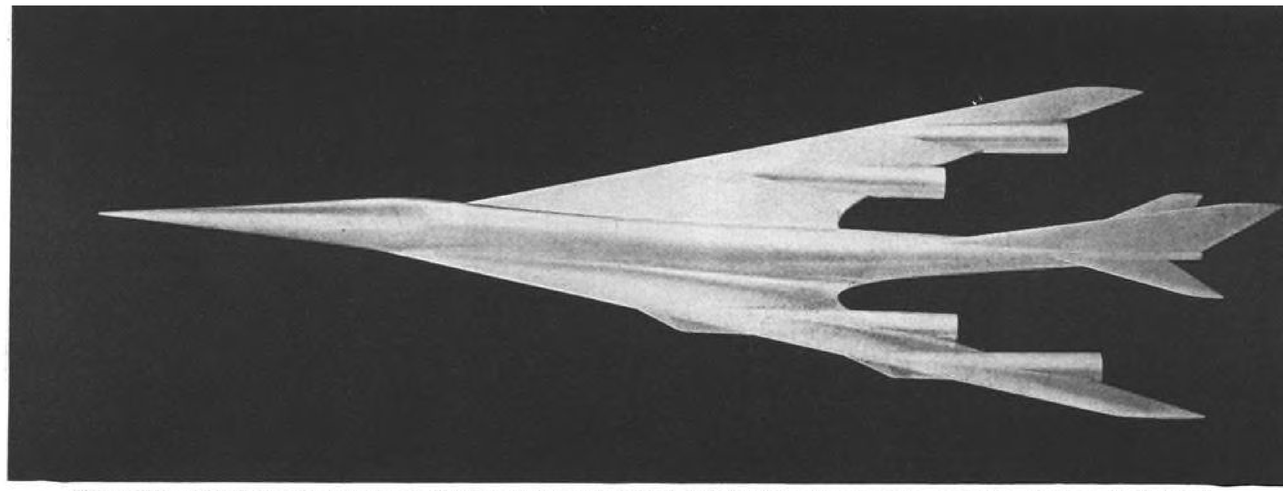
So research problems and development projects run parallel tracks through Langley's effort on the supersonic transport. In Aero-Space Mechanics Division, they work on the operating problems. One question: What happens when a supersonic transport, flying at Mach 3 and 72,000 ft., enters the New York City air traffic complex at 5:00 p.m. on a Friday?

NASA hopes to work with Federal Aviation Agency's Air Traffic Control Facility—part of the National Aircraft Facilities Experimental Center (NAFEC) at Atlantic City, N. J.—to study the problem through the use of a fixed-base simulator combined with the Langley data-computation equipment and tied to NAFEC by a leased telephone line. The four-man crew in the simulator will be put into realistic air traffic situations to help develop instrumentation requirements, crew duties, communications needs and the like.

One of the very important by-products of this simulator should be more accurate determination of fuel reserves needed to fly in realistic transport situations. Calculated data is little better than useless here; the simulated routine approach, using the characteristics of any reasonable SST fed through the data-computation equipment and the simulator itself, should provide values that will be much closer to the actual fuel burned.

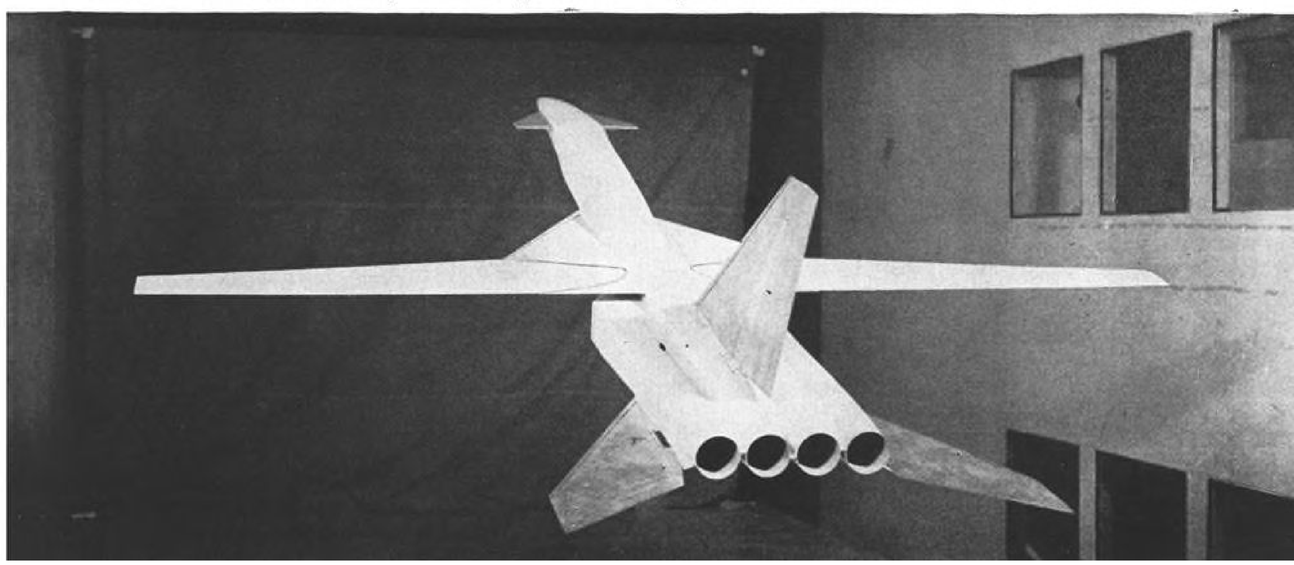
First complaints that runway roughness is affecting aircraft performance at rotation are beginning to be heard from pilots now and the supersonic transport probably will be worse in its response to runway roughness, according to Langley engineers.

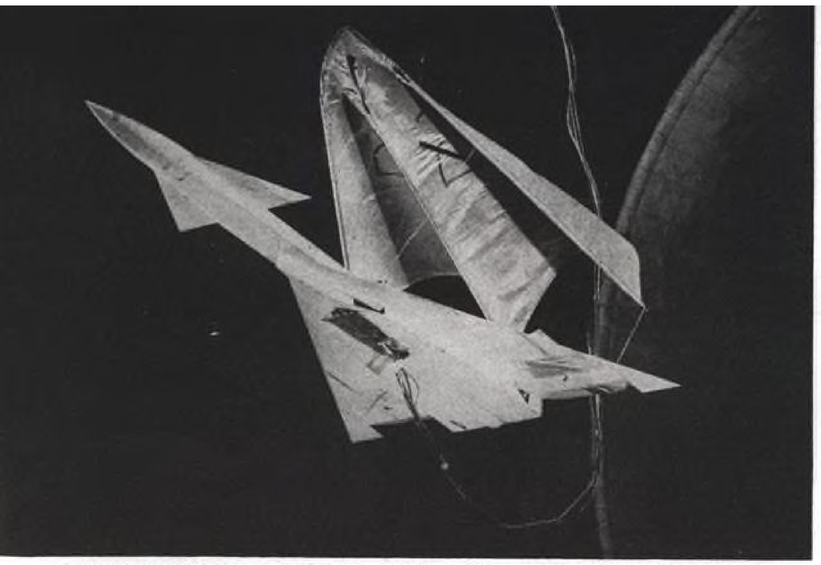
Analytical studies are progressing,



SST MODEL, (SCAT 4), prior to testing in Langley wind tunnel. Model is designed to reduce drag to a minimum between Mach 2 and 3. Note specially cambered, highly swept wing, engine nacelles mounted at the top and to the rear of wing, cambered fuselage.

SIMPLIFIED MODEL is used for study of basic concept of variable sweep for SSTs and is shown installed in the 7 x 10 ft. wind tunnel.





REMOTE-CONTROLLED, jet-driven research model of supersonic bomber and a flexible, lightweight auxiliary wing are tested in free-flight in the Full Scale Tunnel at Langley.

calculating response of the SST at its center of gravity, cockpit and other locations, and using known runway profiles as input data. These studies are aimed at determining optimum locations for nose gear and main gear, so that their geometry doesn't reinforce the oscillations set up by roughness.

Work on the sonic boom problem involves the construction of the most delicate and smallest wind tunnel models this observer has yet seen. Imagine a complete Convair B-58 with a wing span approximating one-quarter of an inch. This model, and others like it, scaled down from conceptual layouts, are mounted in supersonic wind tunnel test sections and "flown" at speeds corresponding to those of a typical SST flight profile. A tiny probe is used to measure the pressure jump across the shock wave and the results are interpreted in terms of the strength of the sonic boom or the pressure rise at a point on the ground below.

This testing technique shows fair correlation with full-scale flights, and is pointing the way to some possible ways to alleviate the sonic boom. General investigations of the sonic boom problem have also pointed out new aspects. One of these is that the shock wave strength on the ground is amplified when the airplane is accelerating in climb or in level flight, and also when the airplane is turning at supersonic speeds. This amplification may well be the worst aspect of the boom.

Supersonic transport problems are concentrated in areas of materials and fatigue on the project charts of the Structures Research Division headed by Richard R. Heldenfels.

Materials, one of the big grey areas in the vehicle design, are being screened here by the usual process of testing after exposure to elevated temperatures for periods of time. Heldenfels' division is working with some steel and titanium alloy candidate materials, aiming at a final test exposure of 20,000 hr. at elevated temperature. During this time, samples are taken from ovens at periodic intervals and tested for determination of stress-strain characteristics and notch sensitivity. But Heldenfels points out the difficulty: There is no way to compress time. If the airplane life is going to be set at 30,000 to 50,000 hr., there's no way to test materials for a shorter period and be absolutely sure of their properties after the longer interval has passed.

One saving grace is that many materials can be rejected after only 1,000 hr. of exposure, during which time they lose so much of their strength or resistance to notch-sensitivity that they obviously won't maintain any kind of strength over a long-time exposure.

Most of the fatigue work hinges on the supersonic transport. Fatigue tests are run on materials which have been exposed to high temperatures; the tests themselves are performed at room temperature. The engineers are looking for a link between what they know of fatigue and what they surmise the load experience will be. Now, they expect most fatigue effects to occur on the supersonic transport while it is on the ground, or in climb and letdown. The cruise phase is expected to be a minor contributor.

In addition to Langley's supersonic transport program, the facility is engaged in sustaining older aeronautical programs and in performing research in some new areas like paragliders.

These are typical projects:

• **Multi-mission aircraft.** Commonly identified and frequently confused with Department of Defense's TFX (tactical fighter) requirement, the Langley work on multi-mission aircraft has centered on the development of an acceptable variable-sweep wing. Wind tunnel and analytical work has gone into the evolution of the currently favored shape which takes the form of a diamond for supersonic flight at low altitudes and spreads out to a straight-wing form for subsonic mission phases. With this kind of geometry, NASA claims, a tactical fighter would be able to cross the Atlantic unrefueled; fly at supersonic speeds close to the ground; handle the air superiority or intercept mission at altitude for the Air Force; and fill the Navy's requirement for air superiority and combat air patrol.

• **V/STOL aircraft.** Langley engineers have been using the free-flight model technique, flying dynamically similar models in the full-scale wind tunnel, to get a first qualitative evaluation of any particular design. This test work has been supplemented by flying full-scale test vehicles such as the Vertol VZ-2. But they envy the British position in this field. Said one NASA expert: "The British Short SC.1 has gotten much more data than is possible with model work here. All our exploratory dynamics work with models has already been done full-scale by the British." For the lower-speed range, NASA engineers think they have found the best solution in a combination of the tilt-wing and deflected-slipstream types. That's what current test work seems to indicate. Many questions remain; one of these is how to get higher speeds than are possible with propellers.

• **Subsonic transport.** It seems possible to produce another generation of subsonic transports with increased productivity through expansion of present aerodynamic and propulsive state-of-the-art. By using cambered and twisted wings, the lift-drag ratio might be pushed to values around 20 at Mach numbers approximating 0.9. A future turbofan engine could solve the propulsive problem, and the combination could provide one more generation of subsonic, highly efficient transports.

• **Rigid-rotor helicopter.** NASA soon expects to have a testbed rigid-rotor helicopter—or as they prefer to call it, a hingeless-rotor helicopter—flying. The machine is basically a Bell helicopter with some new and borrowed parts, intended to perform a flight research project to determine control linkage loads and the relations of blade stresses to hub moments. In another investigation, NASA will participate in a program on the Lockheed rigid-rotor helicopter by testing a dynamic model in the 16- x 16-ft. transonic dynamics tunnel. The model will act as if it were flying, and it will be possible to make sizable changes in stiffness parameters and their ratios.

• **Paragliders.** This development of the Rogallo wing is progressing. Testing is planned in the 16-ft. transonic dynamics tunnel of an elastically similar Apollo wing, an inflatable paraglider type being built for Langley by Goodyear. Another current project is the fitting of irreversible boost controls to the Ryan flying testbed aircraft to improve its handling qualities. One major problem with these flexible wings is to keep the trailing edge stiff; obviously, one of the best ways to change pitching moments violently on a wing is to wiggle the trailing edge.

• **Vgh program.** This program, which involves flying recorders in selected commercial airliners, has furnished much useful data since its inception almost 30 years ago. The recorders furnish a time history of velocity (V), vertical acceleration (g), and altitude (h), so that the loads can be related to their causes: gusts, maneuvers, or ground roughness. One disquieting result from the 20 or so Vgh recorders now flying in jet transports: Unusual flight events occur much more frequently now than they used to. The

Hawker P.1127

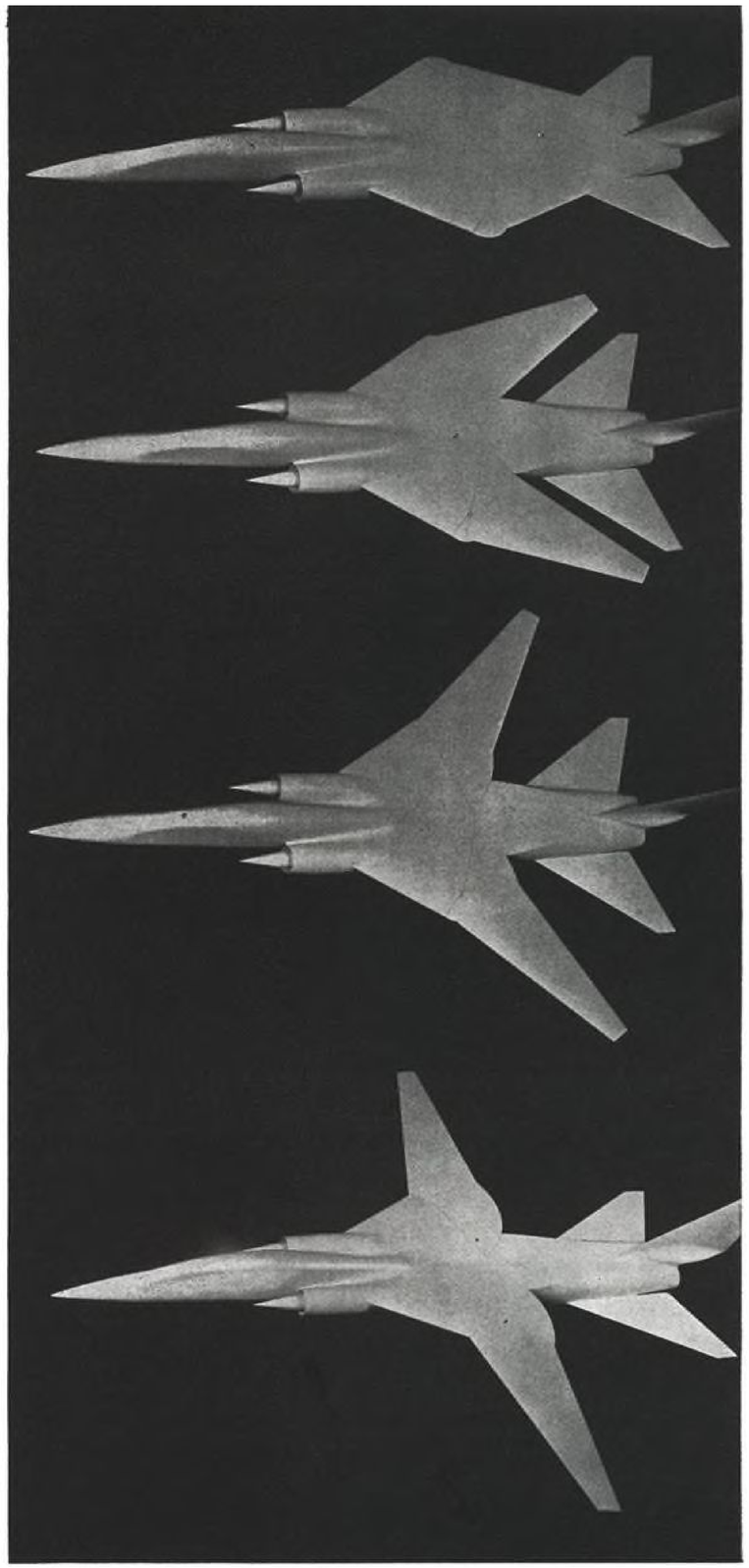
Development of the Hawker P.1127, British prototype of a subsonic VTOL fighter, was supported technically by Langley Research Center in two critical areas.

Free-flight dynamically similar model of the aircraft was flown on towline and in the full-scale tunnel to check transition from hovering to forward flight.

Tests of the propulsion system were made with the dynamically similar model in the 16- x 16-ft. transonic dynamics tunnel, with full simulation of both engine intake and jet-pipe exhaust flows.

Flow simulation was done with a hydrogen-peroxide system which generated steam and oxygen at high pressure and volume. The primary stream, which simulated the exhaust, was used also to drive an ejector pump which drew in air through the intakes, simulating the inlet flow. The peroxide was pumped in through a one-quarter inch line, which provided enough restraint so that no other model support was needed for the tests.

Other parameters measured were: effects of the ground proximity; suckdown of the aircraft due to decreased pressure on the fuselage bottom caused by outflow patterns of the engine exhaust; and reingestion of the engine air. Much work also was done in the field of dynamic stability, particularly in response to forced oscillations.



POSSIBLE CONFIGURATION of multi-mission fighter showing operation of wing sweep as angle changes from that required by supersonic flight at low altitudes (top) to takeoff and landing configuration (bottom).



measure

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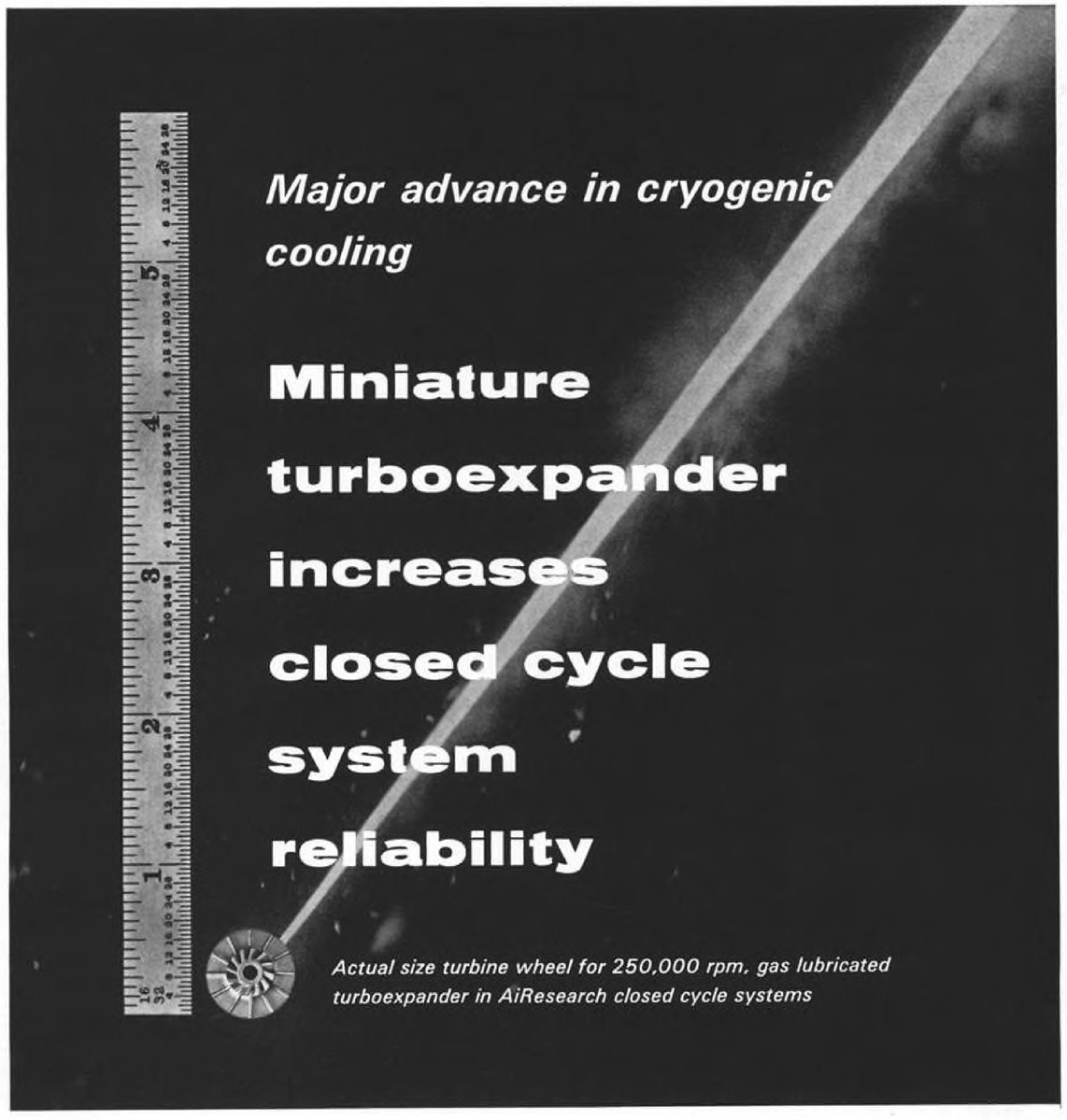
MODEL of supersonic transport examined.

transports are being operated closer to, and sometimes in excess of, their airspeed limit. There are several times as many maneuvers per flight hour for the jet transports as there were for piston-engine aircraft; this may be associated with increased training time.

• **Runway slush.** A NASA report is the basis for FAA's current "half-inch" rule, which forbids takeoffs if there is a half-inch or more of slush on the runway. Langley performed tests on the landing track to measure the drag of runway slush. When FAA made some full-scale tests, that agency got twice the drag reported by NASA. The difference was the added drag of flap, fuselage and interference between front and rear wheels on the landing-gear bogie. Now NASA is revising its test apparatus to simulate flaps and bogie gear, and expects to get more-accurate measures of the drag due to slush.

• **16- x 16-ft. transonic dynamics tunnel.** This unusual research tool used to be the 19-ft. diameter, circular-throat, low-speed, pressure wind tunnel, but during the early 1950s it became apparent that a large-scale transonic aeroelastic tunnel would be very useful. The 19-ft. tunnel was converted to a 16- x 16-ft. slotted-throat test section which can be run with air or Freon at speeds between zero and Mach 1.2, using only 20,000 hp. Elastically similar models are run in this tunnel; in Freon, a one-fifth scale model satisfies the similarity parameters ideally. One problem now drawing attention is mounting models. Langley engineers devised a mount using a pair of wires in mutually perpendicular planes; wires run over pulleys inside model.

• **Noise program.** Besides the specific application to the supersonic transport in the sonic boom program, Langley is involved in more general aspects of noise. The increasing volume of complaints traceable to the landing, not the takeoff, of turbofan-powered airplanes stimulated the interest. First results of investigations show that fan noise appears as spikes in a narrow-frequency band superimposed on a broad-band noise spectrum. The noise is very highly directional forward of the engine, just off the axis.



Garrett-AiResearch is completing development work on closed cycle nitrogen, helium and neon systems using a tiny turboexpander in place of a piston expander.

This promises to dramatically increase system reliability and service life because all wearing surfaces, valves and troublesome reciprocating loads have been eliminated.

These compact, lightweight systems for masers, parametric amplifiers, IR cell cooling and computer components are ideally suited to commercial applications as well as military ground and aerospace uses.

AiResearch was first in production with an open cycle IR cooling system, and has already produced a closed cycle nitrogen system. The company is now working on military programs for 30°K and 4.2°K closed cycle systems.

Utilizing its experience as a world leader in lightweight turbomachinery and cryogenic cooling, AiResearch is also developing an all-turbomachinery closed cycle system incorporating a turbocompressor as well as turboexpander.

Your inquiries are invited.

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Be fussy

Two things determine whether or not a particular printed circuit connector is "right" for your application:

1. How the printed circuit board mates with the connector, and

2. How the connector connects to the rest of the system.

Take mating, for example. Besides having the correct number of contacts, a printed circuit connector must hold the board securely whether the board happens to fall at the high or low end of thickness tolerances.

IT TAKES THREE

These considerations convinced Amphenol engineers that no single contact design could satisfy the requirements of a wide range of applications. So they designed three contacts that will.

One, used in Prin-Cir* connectors, looks a lot like a tuning fork with lips. The circle lip design makes contact overstressing or "setting" impossible —even after repeated insertions. The contact's long spring base also enables it to accommodate boards that range in thickness from .055″ to .073″, while doing an excellent "wiping" job.

EASY DOES IT

But not every application requires the Prin-Cir "bite." For this reason, Amphenol engineers designed connectors with ribbon contacts that mate with a gradual wedge-like force. In blind mating applications, gradual mating makes the feeling of *correct* mating unmistakable. (Just the thing when your equipment may eventually be maintained by less-skilled and less-concerned personnel.) Ribbon contact wedge action also makes it possible for connectors using these contacts to accept the same wide range (.055″ to .073″) of board thicknesses as do Prin-Cir connectors.

Finally, advances in micro-miniaturization (like Amphenol-Borg's Intercon® pre-fabricated circuitry) meant that tinier-than-ever-before connectors were needed. Amphenol's answer was the Micro-Min® receptacle and printed circuit board adapter. Micro-Min contacts are actually tiny springs of beryllium copper wire, formed in a precisely designed arc to assure firm circuit board retention. This unique design makes it possible to space contacts on .050″ centers and crowd 19 connections into a little more than an inch of space.

TERMINATIONS COUNT, TOO

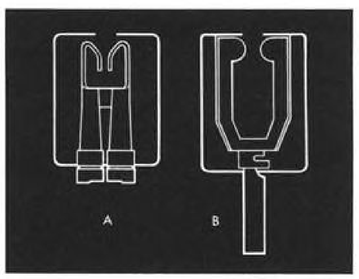
"How to connect connectors to the rest of the system" also merits a good deal of consideration. In some cases, hand soldered terminations will do just fine. In others, higher volume requirements call for high production rate methods like dip soldering and wire-wrapping. Some engineers prefer taper pin terminations.

Our printed circuit connectors are available with contact tails designed for each of these termination methods. In addition, adapters are available for use in connecting printed circuit boards at right angles to each other or in modular arrangements. We make printed circuit connectors with hermetically sealed contacts — still others with coaxial contacts.

Take your choice.

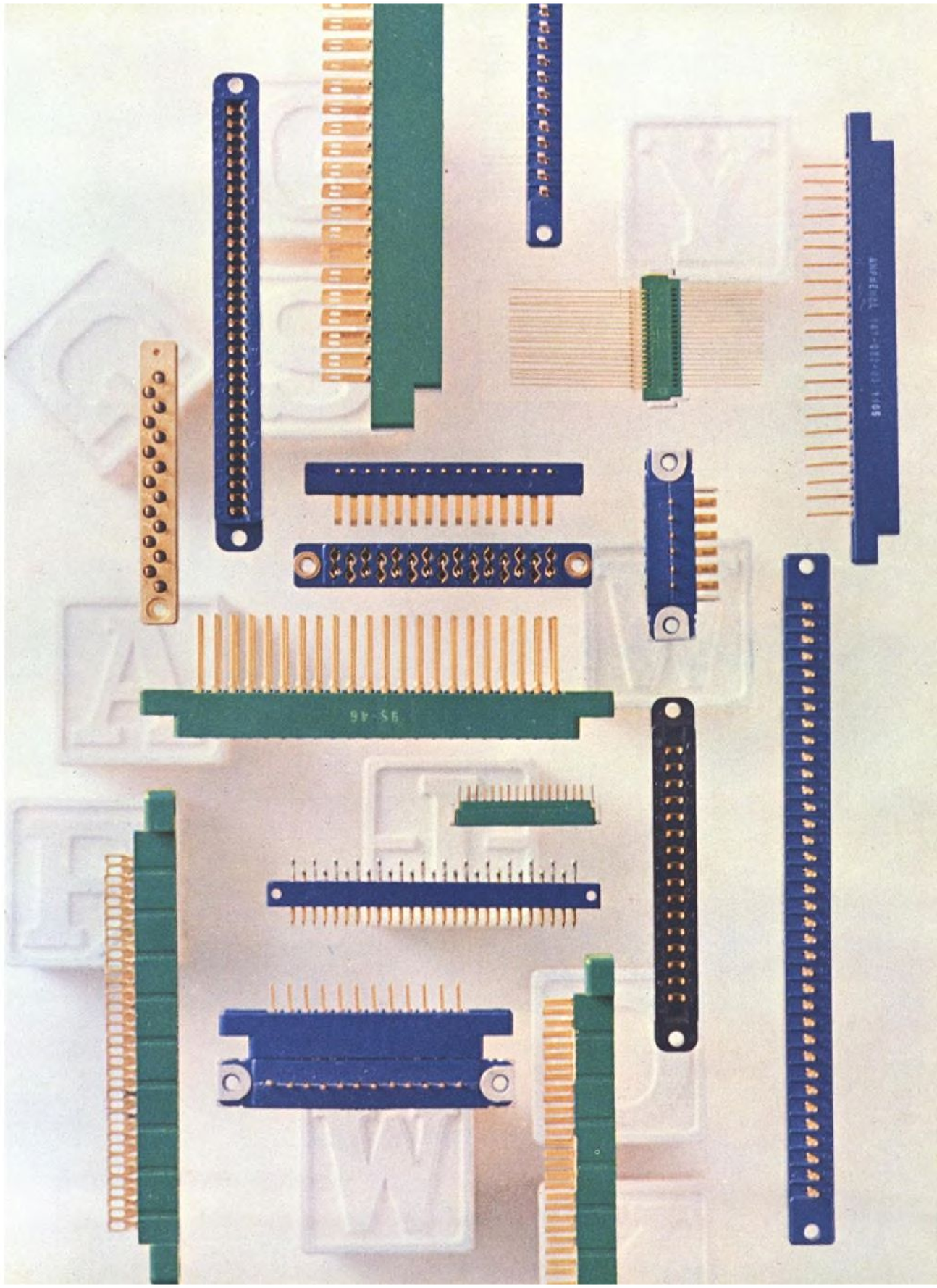
Any Amphenol Sales Engineer or authorized Amphenol Industrial Distributor will be happy to discuss printed circuit connectors (ours) with you. Or, if you prefer, write directly to Dick Hall, Vice President, Marketing, Amphenol Connector Division, 1830 S. 54th Avenue, Chicago 50, Illinois.

*T.M. Amphenol-Borg Electronics Corp.



Wedging action of Amphenol ribbon-type (A) and long spring base of Amphenol Prin-Cir connectors (B) assure firm printed circuit board retention, whether board happens to fall at low (.055″) or high (.073″) end of thickness tolerance.

AMPHENOL ***Connector Division*** / Amphenol-Borg Electronics Corporation



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Circle Number 222 on Reader-Service Card



THREE FRAMES OF FILM from Project Ram flight test show formation of ionized ring in region of interference between rocket exhaust and vehicle flow field. First frame was taken shortly after second-stage ignition; second frame shows formation of ring, and third frame in the series of photos shows ionized ring near burnout of the motor.

Re-entry Heating Is Under Intense Study

Hampton, Va.—Heating inputs up to 10 times as great as those experienced during ballistic missile re-entry are being studied at Langley Research Center as part of a comprehensive program in re-entry physics.

Speed range covered starts at satellite speeds around 26,000 fps. and extends to the hyperbolic velocities—greater than 36,000 fps.—that are associated with return from planetary voyages. Test velocities up to 47,000 fps. have been achieved in flight tests using multi-stage rockets firing on both the upward and downward legs of the trajectory.

In addition to measurement of heating, other studies are attempting to define the radar signatures of different materials at re-entry velocities; to explore the insulating value and behavior of protective materials; and to investigate the ways to combat communications loss during re-entry.

Flight tests and analytical techniques heavy with chemistry and physics are part of four re-entry programs here: Trailblazer, Five-Stage Scout, Ram, and Fire. In addition, tests are being run in a hypersonic, Mach 12 wind tunnel with a 31-in. square throat to aid correlation of experiment and theory.

Radiative Heating

Problem of re-entry heating of manned vehicles returning from lunar or planetary voyages is different from that of missile re-entry. The heat load increases out of all proportion to the speed increase. At ICBM or satellite re-entry speeds up to 26,000 fps., convective heating is the problem. Heat is transferred by convection from the hot ionized gas cap to the vehicle.

As speeds increase, so does the heating input. At about 34,000 fps., radiative heating begins to appear. The vehicle now gets heat energy from both convective heating and the radiated heat of the hot gas cap. This means that an Apollo vehicle, re-entering the earth's atmosphere at about 38,000 fps., will be subjected to more than twice the heat load on Mercury, or in other re-entry from satellite speeds.

Further increase in heat load goes with added increases in speed; but the relation is exponential, with the heat input proportional to a value somewhere between the 13th and 20th power of the velocity. If the speed doubles, the heat load may increase one million times.

Pre-radiative heating occurs at these higher velocities, stemming from the radiation from the hot gas cap. That source radiates some energy at short wavelengths and preheats the upstream gas before it comes near enough to pick up the longer wavelength radiative heating and eventually the convective heating.

What can be done about this? Right now, ballistic missile nose cones can be protected; so can the slightly faster Mercury capsule. Apollo looks feasible. Beyond that, Langley engineers frankly admit they don't know the answers.

One of the most important answers hopefully will define the shape of the radiative and pre-radiative heating rate curves by tieing down the proper exponent of velocity to use. Is it 13, or 20, or where does it lie between? Langley researchers hope to find out.

Trailblazer

Firings made with the six- and seven-stage Trailblazer rocket vehicles are planned to produce ballistic-missile re-entry speeds so that radar signatures, and other radar and optical measurements may be made. The program is a cooperative one, with NASA getting funds from Defense Department's Advanced Research Projects Agency by way of Lincoln Laboratory at the Massachusetts Institute of Technology.

Flight path of the Trailblazer shots is called a "boomerang" trajectory; the vehicle climbs out from the Wallops Station launching site under the thrust of the first two or three stages. It coasts over the top of the trajectory and then is turned to head toward, but not at, Wallops. The remaining stages fire on the downward leg to produce the required velocity, and the re-entry event occurs about 150 mi. slant range from the launch site.

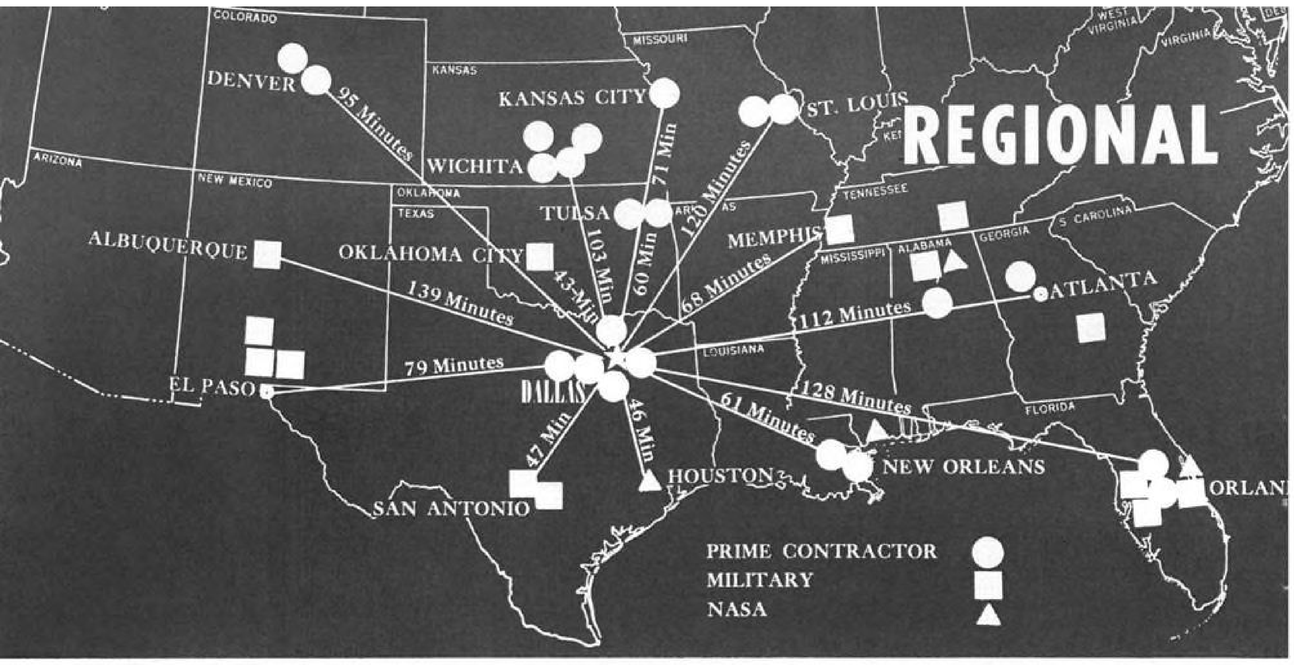
Trailblazer-1 is a six-stage, solid-propellant rocket vehicle about 56 ft. long, weighing 7,700 lb. The first three-stages—Honest John, Nike and TX-77 Lance boosters—carry the final stages to peak altitude of about 200 mi. Re-entry speeds are produced by a T-40, T-55 and a 5-in. spherical rocket motor fired on the downward leg. One experimental Trailblazer-1 shot added a shaped-charge accelerator as a seventh stage to get a first look at meteor velocities near 34,000 fps. Eleven out of 13 Trailblazer-1 shots fired have produced useful data.

Standardized Vehicle

Trailblazer-2 has been standardized as a four-stage vehicle using an XM-33 Castor first stage with two Recruit rocket motors and a second-stage TX-77 Lance to boost the other two stages to 200 mi. altitude. Standard third stage is the X-248 Altair motor, and the fourth stage is a NASA-developed 15-in. diameter spherical motor. For the first shot, a fifth-stage, five-inch spherical motor and a sixth-stage shaped-charge accelerator were added, to produce a re-entry velocity of 47,000 fps., highest yet achieved artificially. Two more Trailblazer-2 shots are currently scheduled.

Purpose of the firings with the five-stage Scout is to study the performance of protective materials. The re-entry package is instrumented and protected with a Teflon ablative layer which is transparent to radio frequencies. Velocity range being studied lies between 26,000 and 30,000 fps. During the re-entry, the ionization sheath prohibits telemetry transmission from the package. To remedy this, NASA uses an on-board, continuous-loop tape recorder which picks up data and plays it back after 60 sec. Since the blackout doesn't usually last that long, return of data taken during the blackout is assured.

Five-Stage Scout uses the standard



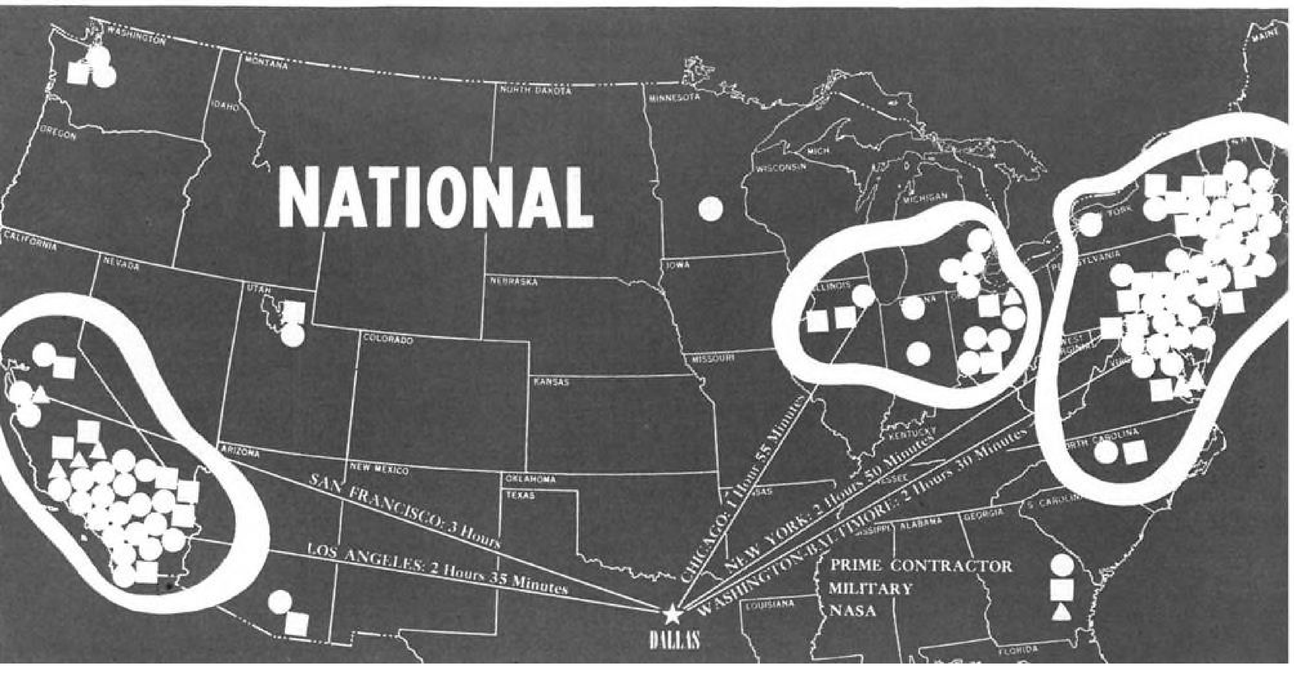
Three-color reprints of this map, in 8½" x 11" size, with facilities identified, are available on request to Industrial Dallas, Inc.

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Scout vehicle with the addition of a 17-in. spherical rocket motor originally developed by Naval Ordnance Test Station at China Lake, Calif. The re-entry package and its instrumentation are built around the rocket motor. The first two stages are fired on the way up, and the last three produce re-entry speeds by thrusting on the downward leg.

Peak altitudes are on the order of 700,000 ft. (132 mi.).

Purpose of Project Ram—Radio Attenuation Measurements—is to find ways of combating the communications loss that occurs during re-entry. Wind tunnel studies and flight tests with two different rocket vehicles are being used as experimental techniques. Primary objective of the program is to determine how the ionized flow fields interfere with communications, data transmission and radar tracking.

One recent flight used a recoverable camera pod mounted on the second stage to get photographic coverage of the mixing region of the booster exhaust and the vehicle flow field. Pictures were taken during the flight from launch to burnout of the second stage. Ejection of the camera pod and its recovery at sea followed.

The film showed the time history of exhaust growth with altitude. This was known and understood; but the pictures revealed a formerly unknown phenomenon. A bright ring appeared at the edge of the exhaust image at the same time the loss in telemetry signal occurred. Analysis of the pictures showed the ring to have been caused by interaction of the rocket exhaust and the vehicle flow field, forming a localized region of increased ionization. This caused the interference with telemetry.

Ram-A vehicle is a four-stage solid-rocket unit, made up of a castor plus two Recruits for a first stage, two Scats as second and third stages, and a single Recruit for the fourth stage.

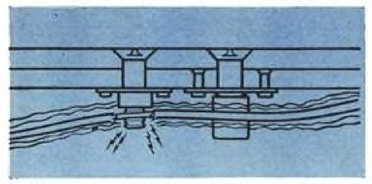
Ram-B uses a 41-ft. long, three-stage modified Scout with an Aerojet Junior first stage, Antares second stage and Aerojet third-stage booster.

Project Fire, subject to a negotiated contract between NASA and Republic Aviation Corp., is intended for the exploration of heating at hyperbolic velocities greater than 36,000 fps. It is a sizable project, both in scope and in cost; an initial $5 million has been earmarked to buy payloads.

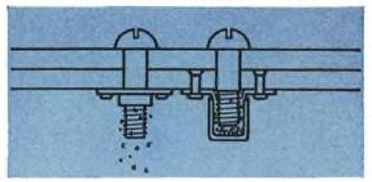
Fire vehicle will be the re-entry spacecraft powered by an advanced Antares solid-propellant rocket engine. Spacecraft and velocity package will be launched from Cape Canaveral by a standard Atlas D booster. Terminal impact area will be in the vicinity of Ascension Island; the spacecraft will not be recovered.

BOOTS CAPPED LOCKNUTS

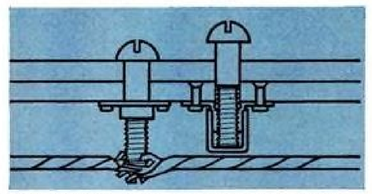
Protect Vital Assemblies, Assure Safe, Trouble-Free Operation



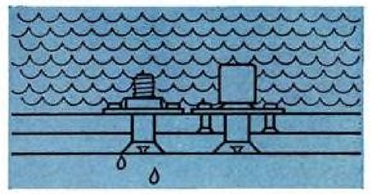
Under conditions of vibration, capped locknuts increase assembly reliability by preventing the abrasive removal of insulation from wires near protruding bolt threads.



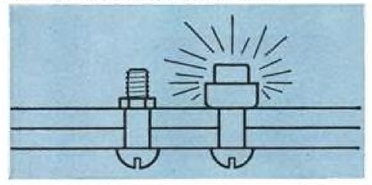
Increased reliability and protection for delicate exposed circuits—cap effectively traps metallic flakes or other fallout resulting from assembly of screw and nut.



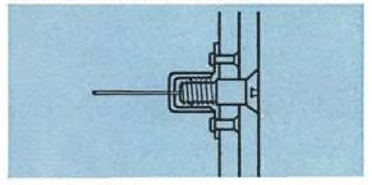
Automatic quality control—capped locknut prevents damage to internal and hidden assembly from screw that is too long. Important wire bundle circuits are safe.



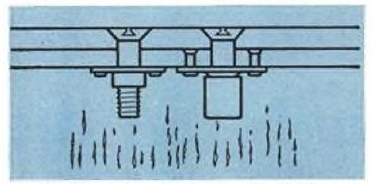
Used in conjunction with liquid sealing "gunk," capped locknuts provide one of the lightest weight integral seals possible for fastening integral tanks or other liquid reservoirs.



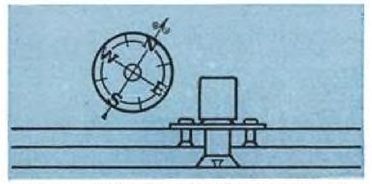
Neat, workmanlike appearance is always a product plus—capped locknuts show extra care in design and manufacturing—experienced buyers look for these extras.



For maximum reliability, caps can be provided with a probe hole so inspectors can check penetration of screw in nut locking element.

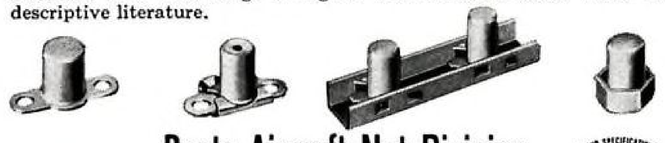


Protection from galling of screw threads in high temperature and corrosive atmospheres. Capped nut protects threads and permits easy subsequent removal of screw—fast replacement of sub-assemblies.



Available in A-286 stainless steel which has extremely low magnetic permeability—ideal for navigation instrument applications, ASW devices, as well as certain corrosive atmospheres.

Boots all-metal, one piece self-locking nuts are simple in design, compact, lightweight and exceed government specifications for tensile strength. Torque and loading is uniform. Re-usability factor is high. Available in a wide range of regular and miniature sizes. Write for descriptive literature.



Boots Aircraft Nut Division

Norwalk, Conn.

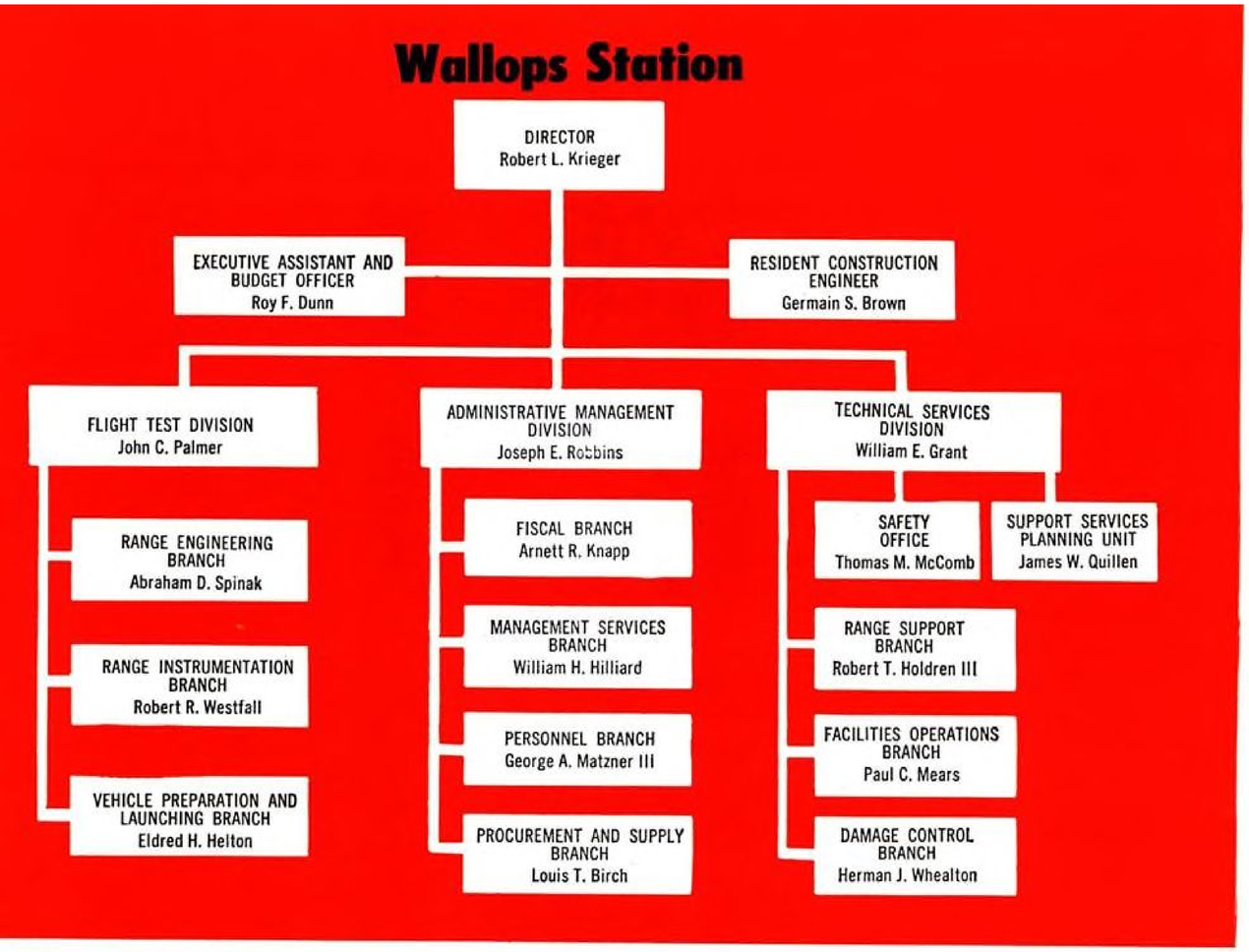
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Wallops Key in NASA Research Circuit

Flexible facilities at launch site used for 250 shots yearly; competence built in tracking, acquisition.

Wallops Island, Va.—Wallops Station, an operating base for scientific experimentation with rocket-propelled vehicles, performs an essential feedback function in National Aeronautics and Space Administration's research circuit.

Primarily, the job of the station is to conduct tests, and to support test activities with instrumentation development, launch facilities, tracking and data acquisition and recovery of the payloads.

Working under assignment from NASA headquarters, the station performs a wide variety of experiments for NASA centers and for other groups both in the American and foreign scientific community.

In this testing function, it helps to close the loop that runs through research and development of satellites, of scientific payloads, and of experiments in the new sciences of space.

Behind the formal language of the mission statement for Wallops Station is a long list of jobs done over nearly 20 years in the business of boosting experiments into a speed or altitude region not reachable by other means. A long time ago, it was the Pilotless Aircraft Research Division of Langley Memorial Aeronautical Laboratory and its head was Robert R. Gilruth, now director of the Manned Spacecraft Center. Then its workload consisted of firing basic shapes and airplane models to measure transonic drag and flight characteristics in the low supersonic range.

Now its work includes experiments which recently created the fastest-moving made-made object; shots using a seven-stage rocket; checkout shots for the Echo satellite; and hundreds of tests related to Project Mercury. From Wallops, two satellites have been orbited, using the Scout solid-propellant rocket. To Wallops, foreign countries have sent teams to stay, to study and to do experiments under the watchful eyes of experienced NASA launch crews.

In director Robert Krieger's office hangs a citation addressed to him and the personnel of the station for one unscheduled mission: aid and comfort to the victims of this year's late-winter storms that tore and flooded the Atlantic Coast. Wallops personnel cared for several hundred people who had been evacuated from danger areas and flown into the mainland base where they were housed in the hospital and other permanent buildings until the Red Cross was able to take over in aiding the storm victims.

Since its inception, this all-civilian range—the only one in the world—has launched close to 5,000 experiments. Current rate runs about one shot per day good weather, or 250 annually.

Among the typical experiments done by Wallops crews was the series of six checkout shots related to the Echo passive communications satellite. The launches were intended to prove out the system of ejection of the deflated and folded sphere, and to follow that with a demonstration of the actual inflation. Several sizes of spheres were used for the purpose, both for convenience and to provide some scale effects as fall-out data.

Saturn Test

When the second Saturn blasted tons of water into space to build an ice-crystal cloud that could be seen for miles, its success hinged partly on a similar test done at Wallops about three months before in order to check the technique and the hypothesis.

The re-entry physics shots under Langley's Project Ram, Trailblazer and five-stage Scout are all done here. The Explorer 9 and Explorer 13 satellites were orbited from Wallops by Scout rockets.

Apart from the capability of launching vehicles, Wallops has also developed a strong competence in tracking and data acquisition. The prototype Mercury tracking station, located here, is used to test proposed changes or new developments in the system. The station also is the principal East Coast tracker for the Tiros weather satellites.

A major role of the station is in education and training of other groups who come to Wallops for initial guidance. Earlier, the groups were from American universities and research institutes that became associated with upper atmospheric studies or similar projects. Wallops technicians worked with them, aided them in assembling vehicles for their firings, and helped them through the countdown and launch.

Now the groups that come to Wallops are from other countries, 36 of them at the last count. Twelve foreign groups came because they planned to establish their own national ranges. Four countries sent teams to stay at Wallops, in residence, working on a day-by-day basis with the resident technicians until some of the expertise had been transferred.

Five countries have come to Wallops for the purpose of joint experiments or for conducting their own experiments for correlation. Most recently, there was a series of joint shots with Japanese technicians.

Pakistan sent a team which stayed six months learning the business. Then advisers from Wallops went to Pakistan to serve as consultants while the Pakistani set up their own range and launched some initial sounding rocket shots with sodium-vapor cloud experiments. The same routine was followed with a group of Italian technicians from their range in Sardinia. A Swedish team has just left Wallops, after being in residence there for some time. Presumably, a similar routine will follow for starting the Swedish range.

But in spite of the increased pace of activity here, the programed growth of the station is not rapid. The major reason is the flexibility of the existing facilities. Wallops now has five launch sites but they serve multiple uses and utilize multiple launchers—one has an even dozen of them. One pad handles Scout exclusively, and another is planned as the tempo of that program increases. Another is exclusively for Trailblazer shots now.

Pads, tracking stations and the rest of the buildings associated with the operations are located on Wallops Island; the remainder of the administration and supporting facilities are on the mainland, at the old Chincoteague Naval Air Station. NASA fell heir to the installation in a move aimed primarily at keeping the local economy at a constant level.

Now Wallops officials are beginning to see the Chincoteague takeover as a godsend instead of as a white elephant. Shortly after acquiring the site, a team went over every square foot of building and ground space, evaluating it against foreseeable plans for NASA. They condemned and later disposed of more than 200 buildings, mostly wooden "temporary" structures that are built to last for five years but used for twenty. What is left largely consists of more-permanent brick buildings, and NASA is gradually working into them, rehabilitating them and moving in as the staff and facilities expand.

Wallops Station

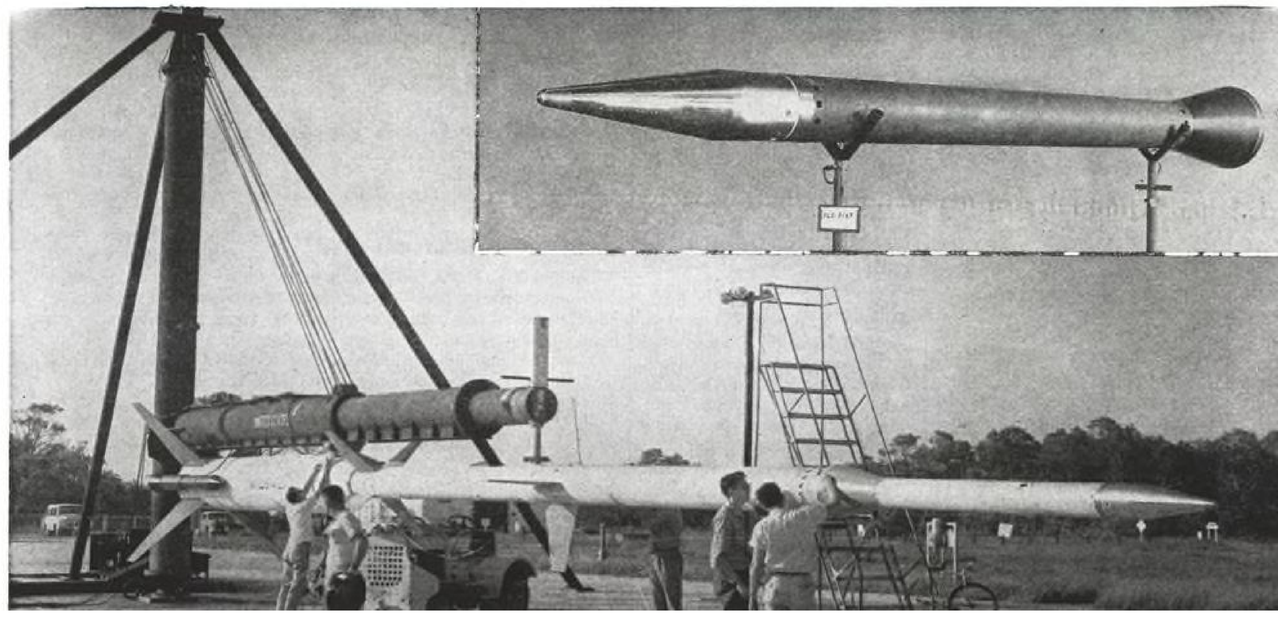
NASA's Wallops Station is located on a small island off the Virginia coast near Chincoteague, and on the nearby mainland. The launching site for small boosters and sounding rockets is on the island; the mainland site includes offices, shops and tracking facilities.

Total area occupied by NASA is 4,335 acres. Value of the plant is $24,173,000.

Operating cost for Fiscal 1962 was $7,546,000; for this Fiscal year, NASA asked for an increase to $10,126,000. Construction program last year cost $7,965,000; this fiscal year's construction is budgeted at $4,300,000.

Wallops Station staff, which totaled 399 for Fiscal 1962, was budgeted at 440 in NASA's request for Fiscal 1963 authorizations.

RADIO ATTENUATION MEASUREMENT (RAM) experiment is readied for launch at Wallops. Inset shows experimental nose cone.



COST & LEAD TIME REDUCED

Development And Production Costs Cut 50%

FARMINGDALE, L. I., N. Y.—The record-size rocket motor cases of HYSTRAN reinforced plastic made by Lamtex Industries, Inc. substantially reduce costs and delivery time as compared to conventional cases made of steel.

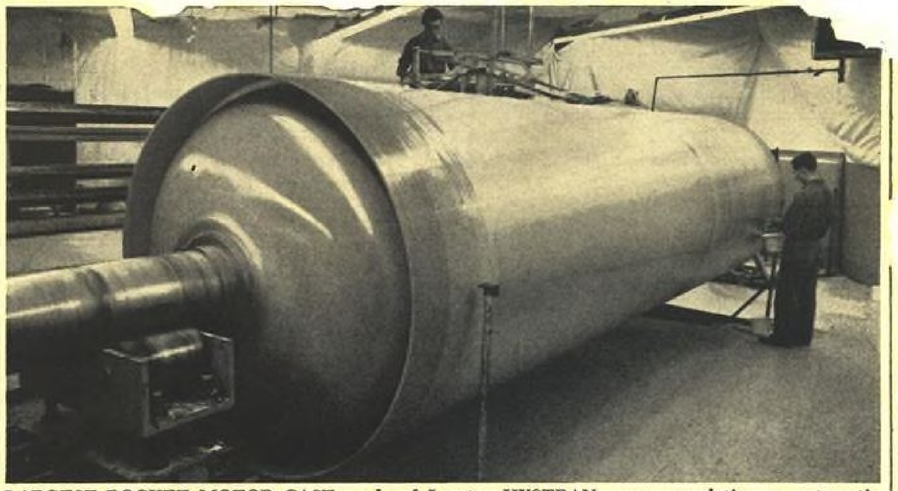
Development costs for a typical HYSTRAN case are one-quarter those for a similar steel case. Production costs for the plastic cases (after all development, tooling, and design modifications have been completed) are expected to be one-half those for comparable steel cases. Tooling costs for the HYSTRAN cases are approximately one-quarter those for steel cases.

Plastic: 5 Months
Steel: 24 Months

The large reinforced plastic cases produced at Lamtex were delivered five months after the start of the program, including all development, tool design, and fabrication. By contrast, the delivery lead time required for comparable steel cases is in the area of 24 months. While the delivery time for production-model steel cases (after all tooling and final designs have been completed) is about nine months after ordering, Lamtex can deliver production-run HYSTRAN cases in two to three months.



Wound in one piece, Lamtex's HYSTRAN rocket motor case includes precisely located, wound-in aft ports fitted with nozzle blast tube hardware.



LARGEST ROCKET MOTOR CASE made of Lamtex HYSTRAN nears completion as automatic filament winding machine applies final layers of fiberglass and epoxy resin to attach handling and supporting skirts at both ends of case.

Lamtex Produces Largest Fiberglass Reinforced Plastic Rocket Cases

FARMINGDALE, L. I., N. Y.—Solid propellant rocket motor cases of reinforced plastic larger than any previously produced have been developed and manufactured here by Lamtex Industries, Inc. The 22-foot long, 5½-foot diameter cases are made of HYSTRAN, Lamtex's exclusive filament wound reinforced plastic.

These lightweight structures were produced for Thiokol Chemical Corp. as part of a Process Development Program to investigate reinforced plastics for use in large rocket motor cases. The program is sponsored by the Air Force Systems Command, Manufacturing Technology Laboratory, Chemical Engineering Branch.

Greater Strength Per Pound

An outstanding advantage of the HYSTRAN reinforced plastic cases over conventional cases made of metal is their much higher strength-to-weight ratio. In a conservative, prototype design, Lamtex reinforced plastic cases carry a weight only 87% that of comparable steel cases. A more sophisticated, flight-weight design is expected to reduce weight further to just 60% of steel cases.

Design And Performance

Additional advantages resulting from the use of HYSTRAN for rocket motor cases include:

Thermal insulation, inherent in reinforced plastic, as contrasted to the conductivity of metals. During flight, HYSTRAN also resists scorching friction heat—usually without any special external insulating materials.

Superior corrosion resistance. The same resins used in HYSTRAN are frequently applied to metallic structures to improve corrosion resistance.

Safety lacking in metals, because this reinforced plastic is non-magnetic and non-sparking.

Impact and shatter resistance. A basic characteristic of HYSTRAN is its relative flexibility, providing high impact resistance to shocks and blows.

Built-in insulating liners are an integral part of HYSTRAN filament wound cases. Additional special inside liners are not required prior to casting of the propellant.

No notch sensitivity exists in HYSTRAN structures, alleviating a problem which plagues all high strength-to-density metallic structures.

Make Own Equipment

Lamtex Industries, producer of these record-size rocket motor cases, designed and built its own filament winding machines, since no standard machinery or proven procedures existed. As an industry recognized leader in this new field, Lamtex has pioneered the design of filament winding equipment, including new servo-controlled machines.

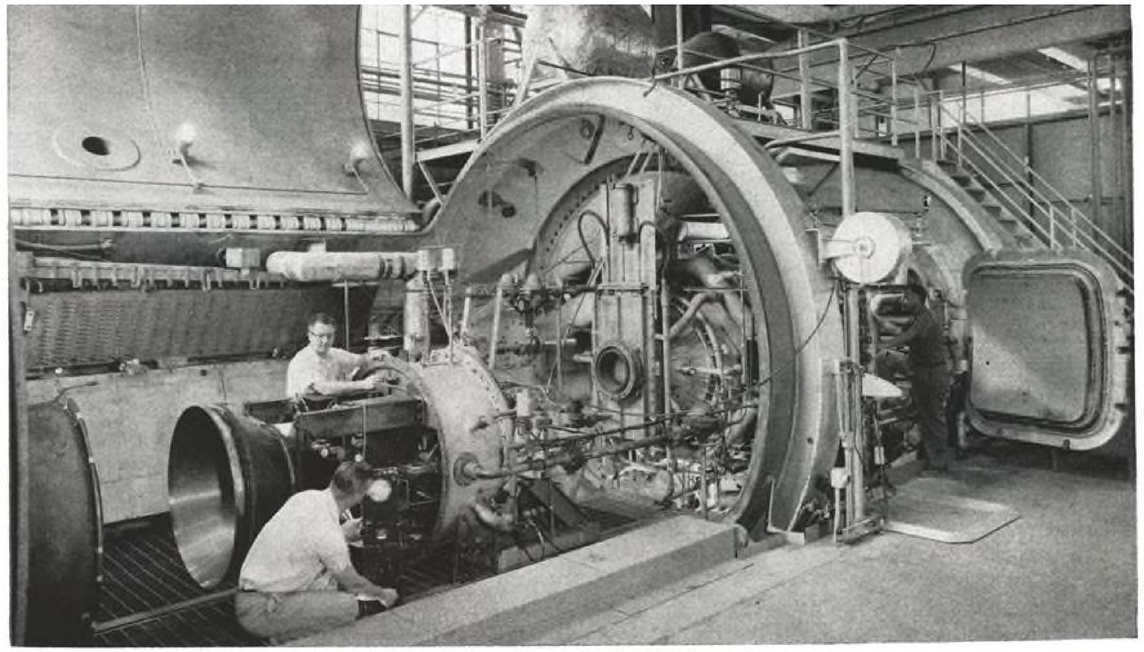
Quality And Reliability Are Important

With new materials and techniques being developed almost daily, continuous testing and quality control are necessary to insure the high degree of reliability required. A typical example of this involved the actual filament winding of a sub-scale model to test a new, super-high-strength fiberglass for use on the large case.

Other Plastic Products

Lamtex is currently producing high quality reinforced plastic products for a wide range of industrial, commercial and military applications. Included are such products as filament wound pipe and tubing, torpedo battery cases, radomes, nose cones, high voltage insulators, pressure vessels, high strength undersea structures, antenna towers, compression and vacuum molded parts, rocket launcher tubes. A host of vital space-age programs utilize Lamtex products — included are POLARIS, PERSHING, MERCURY, VORTAC, BOMARC, MINUTEMAN, RANGER, SCOUT, NIKE-ZEUS, LAW and a variety of NASA projects.

LAMTEX
Motor Avenue, Farmingdale, L.I., N.Y.



HIGH-ENERGY fuel rocket engine, using liquid hydrogen and fluorine, is readied for test firing in near-space environment.

Lewis Aims at Future Propulsion, Power

Center explores chemical, nuclear and electric engines, technologies to support future spacecraft.

Cleveland—Propulsion and power systems for future space probes and spacecraft are twin goals of the major effort at the Lewis Research Center.

In these broad areas, the job is to create things that will lead to programs 10 years from now. "We're aiming toward the future," says Dr. Abe Silverstein, director of Lewis, "toward Saturn C-5 types of spacecraft in orbit for civilian or military purposes. For these, you need a power source and you need propulsion. They have to have long life and high reliability. Our job is to find out how you get them."

For today and the immediate future, Lewis researchers are deep in a variety of support tasks tied to such national programs as the Apollo manned lunar expedition, the supersonic transport, and the Nerva nuclear rocket.

These latter jobs forced a shift in the traditional approach of Lewis toward its work. Once almost entirely devoted to propulsion research, Lewis now adds to that job the management of development projects, such as the planned Apollo lunar-landing module, a specific responsibility assigned to it by National Aeronautics and Space Administration headquarters. Lewis got the job because the propulsion system dominates the module. The task of the center would include management of the contract work that will be done, in-house technical support, systems and engineering evaluation, quality assurance, and a number of other jobs that are a far cry from research on air-breathing engines.

These new technologies of management are in an area where many research scientists are strangers. Consequently, the center has the job of "retreading" many of its specialists in an educational program that teaches the specific problems connected with management activities.

Management Structure

This spectrum of work demands a broader organizational structure than tradition has developed at many NASA centers. Last February, Silverstein announced a new management structure for the Center which split the house into research-oriented and development-oriented divisions.

Silverstein's deputy director and long-time associate, Eugene J. Manganiello, holds a second position as associate director for research. Bruce T. Lundin is the associate director for development. In their two sets of divisions is the bulk of the work at Lewis.

The balance of personnel still favors research—about 900 professional people, compared with about 350 in development divisions.

Naturally there is some overlap. There is in-house research on the development side, chargeable to the need to maintain scientific and technical competence, and development work on the research side, in support of work on specific projects.

Interwoven through this work is exhaustive testing, today on a more-complex level than ever. Parts of the test programs still are done at the center site; but other parts involve toxic products, dangerous chemicals or nuclear radiation, and can only be done at remote areas. For this purpose, Lewis operates the Plum Brook Research Station near Sandusky, Ohio, about 50 mi. from the center.

These operating divisions of the Lewis Research Center receive their support from the standard administrative and service organizations.

There is one organization not shown on the chart that is attached to Lewis for housekeeping purposes. It is the Cleveland Extension of the Space Nuclear Propulsion Office, a joint operation of NASA and the Atomic Energy Commission. Its functions include direction of contractor work on the Rover nuclear rocket program, as assigned by the SNPO, and maintaining technical liaison with nuclear propulsion research at Lewis.

With air-breathing propulsion systems out of the house now—"we got gas turbines up to Mach 4 long ago," says Silverstein—Lewis propulsion research centers on three types of systems:

• **Chemical propulsion**, which starts with fundamental analytical work in

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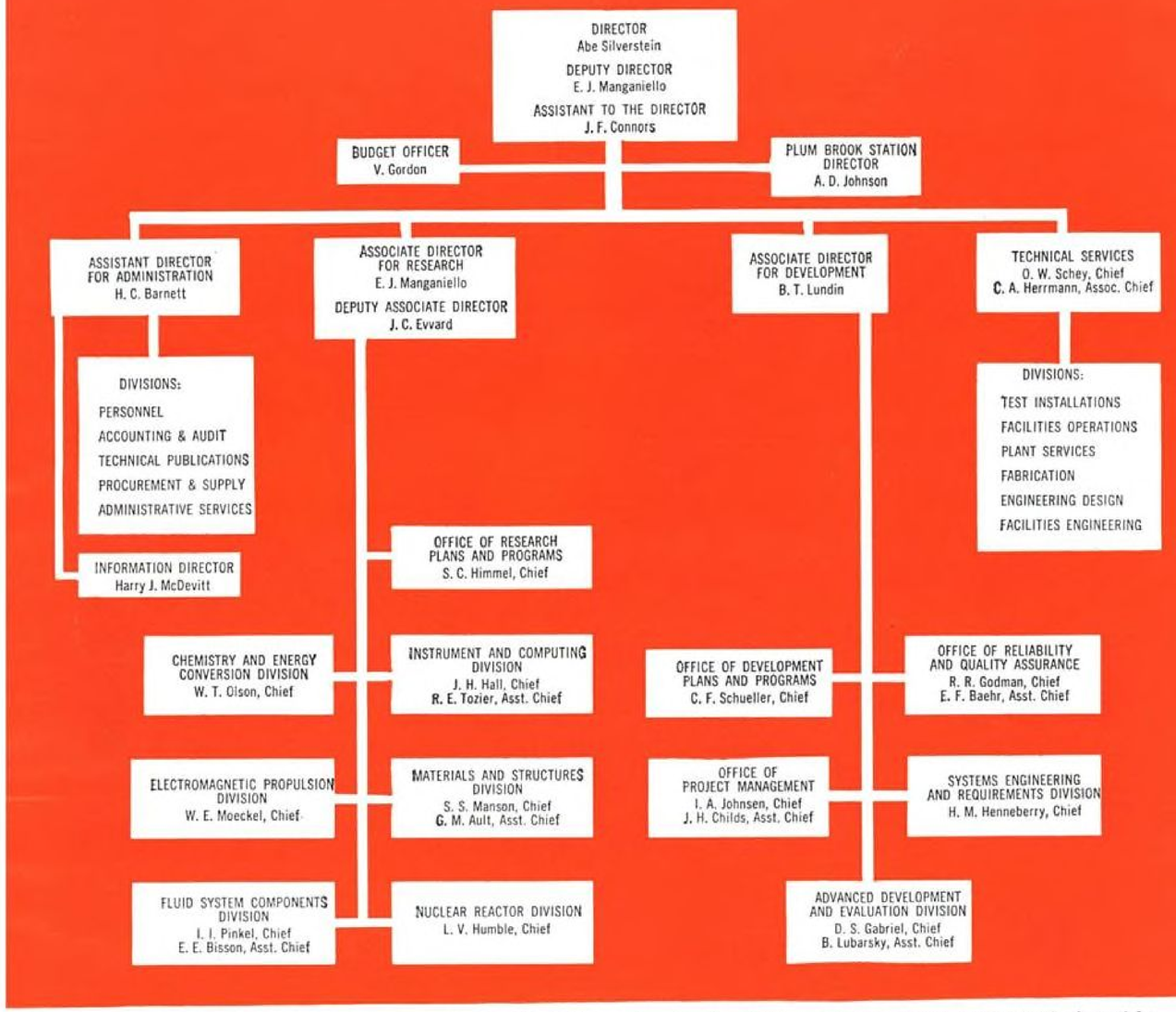
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Lewis Research Center



chemical kinetics and goes through system concepts to detailed consideration of components such as pumps and turbines, tanks and insulation. Supporting materials work spans the temperature range from the elevated values in a rocket nozzle to the cryogenic figures in a fuel storage tank. Special problems include combustion instability, supersonic combustion, solid-propellant rocket cutoff and restart.

• **Electric propulsion,** which studies three types of engines: electrothermal (arc jet, resistance heater jet), electromagnetic (plasma accelerators) and electrostatic (ion accelerators). One promising approach in this field is the electron-bombardment ion engine developed at the center and scheduled to fly on the first SERT (Space Electric Rocket Test) flight of a Scout rocket. Further work is being done on heavy-molecule engines, colloidal-particle engines and other advanced designs.

• **Nuclear propulsion,** which includes basic reactor design, nuclear-electric conversion systems, reactor dynamics and similar projects. Lewis' mission does not include management responsibility for the Rover nuclear propulsion program, which is assigned to the SNPO. Lewis supports the program in evaluation of technical studies and other consultative work. Applied research projects in the Center also support Rover extensively. Examples are nozzle studies, single- and two-phase heat transfer studies, and film- and nucleate-boiling studies. Additional theoretical work is being done by groups at Lewis in the field of particle physics and heat transfer. The nature of this work is general, but it might lead to specific applications.

Related Areas

Once the systems concept is applied to a propulsion scheme, it traces its lineage back through the engine, through pumps and valves and lines to the tanks. In space systems, radiators add another portion.

One major area in which Lewis has prime responsibility for development and a project to manage is in the generation of power in space. Currently, the center manages the Snap-8, a 30-kilowatt power-generating system for deep space missions.

"But we're also looking to powers



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very much greater than 30 kw.," said Silverstein. "When you send a space probe as far off as Jupiter, you need power levels in the megawatt range to send data back."

In space, most of the heat made is wasted and has to be rejected. The only way to do this is by radiation cooling. "So radiator weight becomes almost the key factor," Silverstein said. "And we're talking about acres of radiating surface now. You want thin-walled radiators; but what about the meteoroid problem? How about liquid metal corrosion in the radiator tubes? These are the kinds of problems we keep trying to solve."

Long space voyages mean operations for 20,000 to 30,000 hr. at temperatures never used before with materials never tried under those temperatures. The space vehicle operates over a temperature range from the cryogenic to several thousand degrees in the nozzle. It runs on molten metals for working fluids. It may be hit by meteoroids, or subjected to severe doses of radiation. Its surface finish may be changed as much by sputtering—losing atoms and molecules through collisions with particles—as it would be by meteoroid holing.

This environment generates new sets of requirements for every type of work done at Lewis. Metallurgists, once used to the simpler problems of high-temperature materials for gas turbines, have to turn to extremes at both ends of the temperature scale besides subjecting their test specimens to nuclear radiations. Test installations have to run at hard vacuum levels not reached before, and artificial sunlight and heat sinks have to be created.

On a more mundane level, Lewis metallurgists have been contributing a major share of the country's effort in materials choice and development for the supersonic transport. Here the work centers on screening alloys of steel and titanium and on testing some of the high-temperature alloys such as Rene-41 under conditions that begin to approximate those which the supersonic transport will impose.

Other support work at Lewis for the supersonic transport program includes some analytical studies of propulsion, but there is no current program for propulsion system tests or development.

The development divisions under Bruce Lundin are built around a core of five project management offices for these projects:

• **Apollo lunar-landing module.** This office was to have the management job if this module remains in the Apollo program, and handle all contractual work as well as plan in-house support jobs. The module has an entirely new degree of sophistication; the engine has to start, stop, throttle, control attitude and orientation for periods up to 15 min. of running time. Thrust of the rocket will be on the order of 50,000 lb. The rocket has to live in a different environment from any previous propulsion system. There is a three-day cold soak on the way to the moon, and the lunar environment imposes a different set of conditions on top of the restrictions imposed by the operational requirements.

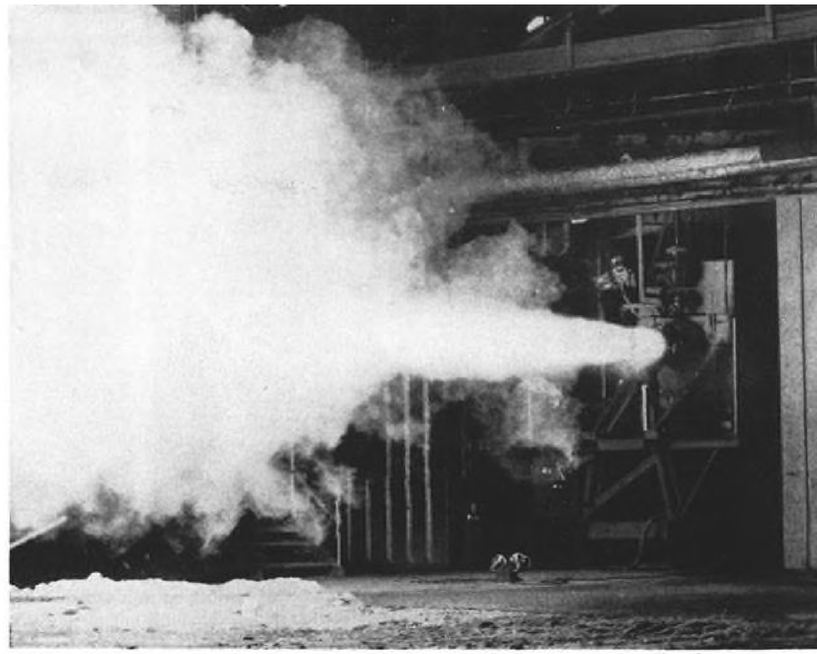
• **Chemical rocket propulsion.** Most of the work handled in this division is contractual, and is aimed at advancing the technology.

• **Electric propulsion.** About 50 contracts to be monitored comprise the major effort here. This work was transferred from Marshall Space Flight Center because of Lewis' in-house competence in electric propulsion on the research side. The group there is probably the largest working on electric propulsion in the country.

• **Nuclear electric power generation.** This is the office charged with management of the Snap-8 program. It also is monitoring contracts and Lewis Research on liquid metal properties, compatible materials, heat transfer, etc.

• **Solar and chemical power.** This group assigns programs in the areas of thermionics, solar dynamics, fuel cells and batteries, and lets contracts for industrial work on various related subject areas.

One of Lundin's most important divisions is concerned with reliability and quality assurance. Functions of this group include establishment of specifications for environment, test acceptance, quality and similar subjects.



THICK COPPER engine and nozzle are used for heat-transfer studies at Plum Brook.

Lewis Research Center

Lewis Research Center is located on 350 acres of NASA-owned land adjacent to the Cleveland-Hopkins Airport in Cleveland, Ohio. Value of the plant is $149,687,000.

Operating cost for Fiscal 1962 was $38,885,000, a figure which was budgeted to increase to $49,480,000 for this year's operations. Construction program last year cost $1,040,000; this year's construction request is $4,650,000.

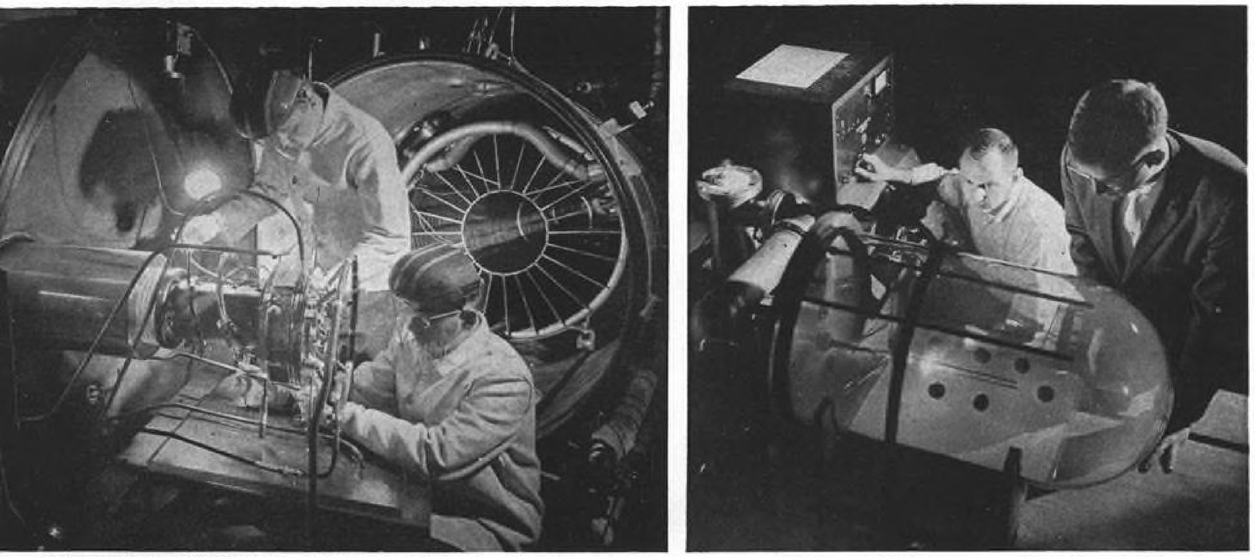
Lewis staff growth continues, with an increase budgeted for this fiscal year. Last year, authorized staff was 3,208; this year's figure is 3,983.

Management Training

Seven seminar courses covering subjects from orientation through technical management are part of the system established at the Lewis Research Center for retraining engineers and scientists to be managers of programs and procurement.

Training of new employes starts with an orientation seminar, running through two weeks of morning sessions, and covering the facilities, services, projects in the research and development divisions, where they are done and who is doing them.

For more-experienced employes, there are four technical seminars on chemical propulsion, electric power production in space, electrical propulsion, and PERT. Purpose is to bring the present staff up-to-date on current states of technologies outside their own specialist fields.



LEWIS RESEARCH CENTER scientists install a cesium-fueled ion engine in a vacuum chamber, left, to study operating characteristics of electrical propulsion systems in space. At right, a plasma rail accelerator is operated in a bell jar rig.

Advanced Space Engines Evolve At Lewis

Cleveland—Roar of large turbojets and the howl of ramjets have been replaced at the Lewis Research Center by the noiseless thrust production of electric rockets in high-vacuum tanks.

The research team that was responsible for pioneering work in turbojet afterburners, thrust reversers and noise suppressors, in transonic compressor design and the development of supersonic compressors and efficient inlets for engines, still directs its effort to the myriad problems of propulsion today.

But the problems and the powerplants now are different. Even the names of the buildings have changed, although in one case the initials have stayed. What used to be the Engine Propeller Research Building in 1942 is the Electrical Propulsion Research Building in 1962.

The old altitude wind tunnel has been turned into a large space chamber, 30 ft. by 100 ft., which has been pumped down to 10^{-5} mm. of mercury pressure. Engineers are looking at the larger section upstream of the old throat, where they say they can put a 40 ft. by 110 ft. chamber with a double wall and a stainless-steel liner, and go to even harder vacuums.

The immediate past has seen Lewis participation in a number of projects still classified as propulsion research, but with applications far above the highest altitudes that the researchers dreamed of a decade ago.

The stabilization and control system for Mercury capsules was a Lewis responsibility as a subsystem manager. High-energy fuel technology—specifically for upper stages of such vehicles as Centaur and Saturn—has filled the work schedules at this Center. Electric propulsion methods and developments have joined the chemical rocket work here, and have acquired major status at the Center in a very short time.

As in other Centers, Lewis' problems have been those of transition to new fields of work with people whose experience lay in the more traditional areas of propulsion.

The work of this Center touches three areas of propulsion: chemical, nuclear and electric. By the broad definition of terms, propulsion systems include tanks, lines, pumps, valves, turbines, turbopumps, thrust chambers, insulation, materials, propellants, igniters and anything else conceivable that plays some part in producing thrust.

Electric Propulsion

Theoretical mission analyses have shown that there are long-range, long-duration missions that can only be performed efficiently by electrical propulsion systems. There is considerable promise in these systems for less demanding missions also, from earth-orbit path adjustment to deep-space instrumented probes.

Thrust for these systems is produced by what is generally termed an electric rocket engine. Experimental and theoretical work on these engines has developed a group of three types which are related:

- **Electrothermal rocket,** which uses an electrical heating system, such as an arc or a resistance heater, to heat a gaseous propellant. The rest of the cycle is conventional—the heated gas is accelerated by means of a conventional nozzle to get the thrust. Specific impulse of this class of engines goes up to about 1,200 sec. Examples of this type are the Avco arc-jet or plasma-jet engines.
- **Electromagnetic rocket,** which uses an electromagnetic field to accelerate a plasma—an ionized gas mixture of electrons and ions—to produce useful thrust. Specific impulse values extend upward from the 1,200 sec. of the electrothermal rockets.
- **Electrostatic rocket,** which uses an electrostatic field to accelerate ions to produce thrust. In this type, electrons must also be injected into the exhaust to neutralize the charge and produce useful thrust. Specific impulse is on the order of several thousand seconds. Status of these engines in development is well ahead of the electromagnetic type, and because of their high specific impulse values, they demand more attention in the deep-space mission area than the arc-jet electrothermal type.

Consequently, the major portion of the work of Lewis' electrical propulsion group, the largest in the country, is centered on the various sub-types of the electrostatic engine even though it maintains an interest in the other types.

First of the electrostatic engines to fly in the SERT (Space Electric Rocket Test) experiments will be the electron-bombardment ion engine conceived by Lewis' Harold R. Kaufman. This engine grew out of a research project aimed at finding an efficient source of ions for electric rockets. Lowest power consumption for ionizing atoms comes either from electron-bombardment or contact-ionization method. In the latter—being used also by Hughes and Electro-Optical in their electric rocket designs—the propellant atoms are ionized by contact with heating elements. In the electron-bombardment method, the atoms of propellant are forced to collide with electrons, generally produced by electric arcs and held by strong magnetic fields in a spiral path to increase the possibility of collision.

Kaufman found that he could produce ions efficiently without electric arcs and with a low magnetic-field strength. He used mercury-vapor propellant, led into an ionizer chamber where an electron emitter filament furnished the electrons for collisions. A magnetic field was maintained around the chamber; the electrons drift to attach to a part of the chamber which is held at a slightly higher electrical potential than the charge needed to accelerate. The ions formed start to move toward a grid and are further accelerated by a difference in potential between the grid and the accelerating electrodes at the end of the ionizer chamber.

Total energy used is the sum of the power required to emit and accelerate the ionizing electrons and to maintain the magnetic field. NASA says that 83% of the mercury atoms are ionized at a specific impulse of 5,500 sec.

Second sub-type of electrostatic engine is essentially a Kaufman electric rocket which is being designed to use heavy molecules—hopefully some day with molecular weights in the thousands—in place of the mercury-vapor propellant. Such an engine is being built for preliminary testing now.

Colloidal particles made up of many molecules have been proposed as alternates to the large atoms of cesium and mercury that have characterized electric rocket propellants up to now. Production of these particles within narrow size limits is one of the major problems with this type of engine. But Lewis' Carl T. Norgren devised a scheme for generating colloidal particles from mercuric chloride or cobalt chloride vapors by running them through a subsonic and then a supersonic nozzle to condense out the particles. Analysis has shown that the particle size is held within very narrow limits and that there is a high degree of conversion of the vapor to particles.

This colloidal-particle engine is considered as the third sub-type of the electrostatic rocket and is believed to have great potential.

Kaufman's engine has been tested at Lewis to establish compatibility with the power supply, to check the long-duration performance, and in general to get it ready for the SERT shot. Purpose of the rocket test is to find out about electrostatic rocket engine operation in space, particularly whether or not the ion exhaust can be neutralized by the injection of electrons.

Beyond this flight test, two full-scale engines are being developed for tests in the Lewis vacuum facility. These non-flyable engines will include most of the system to make the tests as realistic as possible.

One engine is an array of 10 contact-ionization engines developed at Lewis, and will draw about five kilowatts of power. The other is an array of 12 Kaufman engines drawing 30 kw.—the power rating of the Snap-8 system.

Theoretical Work

Beyond the experimental development and test of these powerplants is a large amount of work on theoretical and experimental work aimed at improved systems for electrical propulsion. One combines a heavy-molecule electric rocket with a radioisotope generator. By using a balloon-type structure for a space vehicle incorporating this system, NASA scientists believe the installed weight of the powerplant could be brought down as low as half a pound per kilowatt, and make 30-day trips to Mars possible.

Major worry in the design of powerplants for upper-stage propulsion systems has been what happens to the fuel under conditions of zero gravity. Theoretically, surface tension is the only influencing force left in the environment of zero-gravity, and the fuel should form itself into a neat sphere. What happens in practice may be exactly the same or completely different, depending on the circumstances.

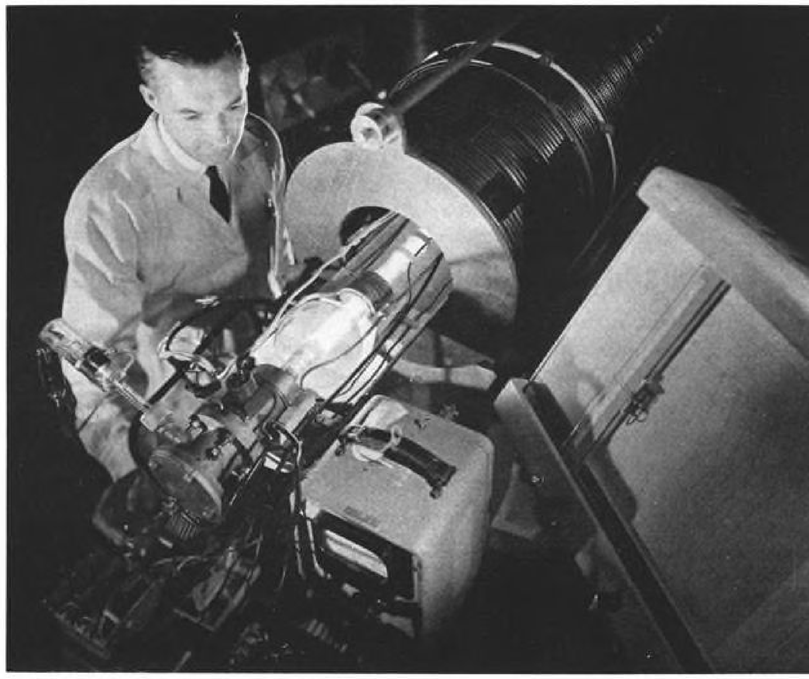
For some time, Lewis researchers have been studying fluid behavior in a zero-gravity environment using the tools available: an aircraft, a drop tower and rocket flights.

The aircraft is an ex-Navy North American A2J, whose bomb bay has been converted into an environmental laboratory for zero-g studies. The bay is big enough to take a man plus a package of experiments. The experiments are encased in a large Styrofoam block so the package can bang around without smashing either the experiment or the airplane.

The drop tower is a 100-ft.-high facility which allows an experimental package to be dropped into a sandbox. Energy-absorbing spikes take the brunt of the impact and make the payloads recoverable. Plans are under way to extend the drop capability by building a 400-ft. tower completely underground some time after Fiscal 1963.

Five Aerobee rockets have been fired for zero-gravity tests of liquid hydrogen, and four more are funded for completion of the program. Three will be fired during Fiscal 1963; the fourth was to have been fired before the end of June this year.

Late this summer an additional zero-



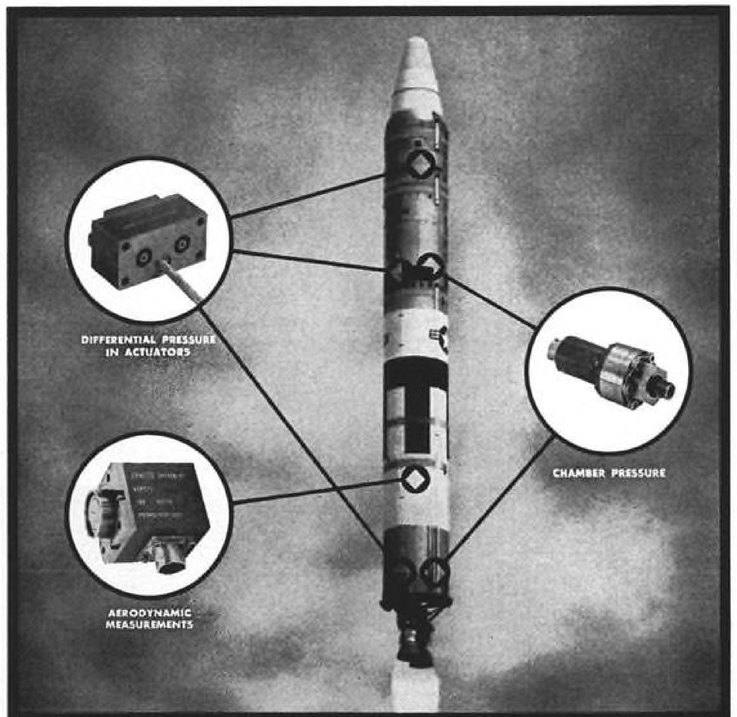
ION CYCLOTRON resonance apparatus used at Lewis to heat plasmas to high temperatures.

gravity flight is scheduled in which a Lewis experiment will fly as a piggyback package on an Atlas.

The value of these rocket tests has stimulated the in-house development of a two-stage, solid-propellant rocket for extended zero-gravity tests. The vehicle will be able to handle a payload between 500 and 1,000 lb., about 30 in. in diameter, and will subject it to 5 to 10 min. of zero-gravity operation.

On Lt. Cdr. Scott Carpenter's orbital Mercury flight, one experiment was a zero-gravity type devised by Lewis. It consisted of a spherical container about five inches in diameter with a one-inch diameter standpipe inside extending about one radius into the center of the sphere. A green-tinted fluid filled about one-quarter of the container. Purpose of the experiment was to see if the fuel stayed in the standpipe during all the time of the zero-gravity period. The application of this experiment is obvious; it was planned to get long-time data to check on possible way of maintaining a constant fuel supply at a pump inlet.

All these experimental results show about the same thing: The fluid tries to take on the shape for minimum wetted area. In the presence of a standpipe, the equal-tension sphere is, of course, distorted by the geometry of the pipe. But the important thing is that the fluid continues to keep the standpipe wet so that in some future full-scale system, there will always be fuel at the pump inlet when it is needed.



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Materials Studies

One of the great areas for exploration lies in the metallurgy of the cryogenic temperatures and in the behavior of materials at these low values near absolute zero.

The application of this metallurgy will be largely to the tanks and lines of space vehicles using hydrogen propellant, either for chemical rockets such as Centaur, or for nuclear rockets such as Nerva. It starts with the problem of hydrogen embrittlement and fans out from there.

Hydrogen, being the smallest of the atoms, will diffuse through cracks that are sub-microscopic. That was one of the problem areas on the Centaur. Liquid hydrogen diffused through the steel sandwich face of a bulkhead separating the liquid hydrogen from the relatively "hot" liquid oxygen, and the insulating value of the sandwich dropped to nothing in the region of diffusion.

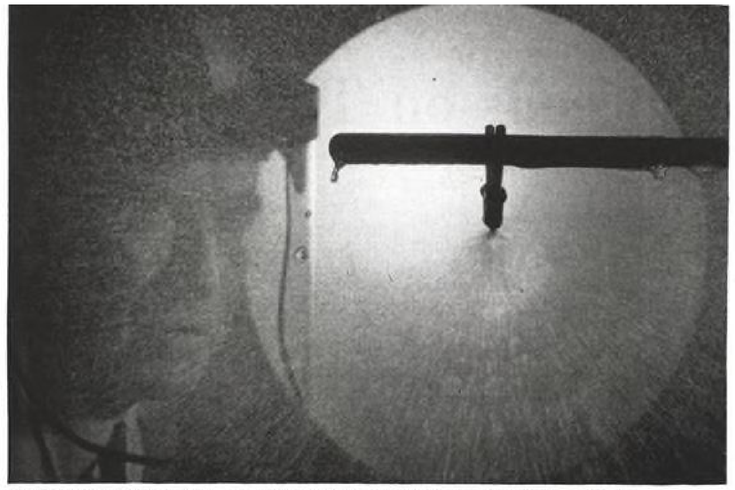
But the inclusion of hydrogen does worse things than reducing insulation properties. It causes a phenomenon known as hydrogen embrittlement, in which the material gets more brittle because of the occlusion. One problem of Lewis metallurgists is to understand the embrittlement process and to see if anything can be done about it.

Cryogenic temperatures change many of the customary and understood characteristics of materials to unknowns. The case of hypervelocity impact is an example. Micrometeoroids hitting a thin shield of steel or aluminum should go right through, leaving a pinhole, according to laboratory simulations. Small particles shear out a hole and—if the leakage can be handled—no more trouble develops.

But cryogenic temperatures make most structural materials very sensitive to stress-raisers. Material tests at Lewis and elsewhere showed that the low temperatures increased the notch sensitivity of metals. So a simple test was devised at Lewis to check what happens when a tank full of cryogenic propellants is struck by a micrometeoroid.

There was no elaborate hypervelocity impact range. The gun fired a standard .22-cal. bullet with an oversized case, producing the relatively low—for meteoroids—velocity of about 7,000 fps. The tank was a small unit with some liquefied gas inside.

The result was a tremendous explosion and a shattered tank whose pieces were like shrapnel. "Now," said one researcher, "what are we going to do?"



LEWIS ENGINEER studies spray characteristics for basic injector design criteria.

Research programs are one answer, and there is an extensive one under way here in the testing of all kinds of materials at all kinds of temperature ranges for all kinds of powerplants. There is technology in tungsten, sintered metals, dispersed metals, cermets refractories, plastics.

At cryogenic temperatures, most conventional structural materials gain strength compared to their room temperature values. But they suffer a loss in brittleness and in notch sensitivity. Tests so far have indicated that stainless steel is very good for cryogenic work, that titanium and glass fiber are outstandingly good.

So many of the Lewis scientific staff have come to their new areas of interest from others that they proudly wear the label of "re-tread." For example, the people who worked on compressors and turbines for turbojet engines 10 years back, have become converted to the different, yet similar, job of pump research, where the same problem remains—how can the operating limits be increased without running into stall or cavitation?

One of the big areas of effort in the Fluid System Components Division centers on the design of cryogenic pumps. Two major philosophies govern the approach. First, researchers are trying for high work per stage, both on axial-flow and centrifugal-flow pumps. Second, they are trying to exploit the unique characteristics of the cryogenic fluids to operate in the cavitating regime.

It works this way: Liquids accelerated through a pump experience local areas of reduced pressure, such as over the back side of a pump impeller blade. If the pressure falls below the pressure at which the liquid boils, it will flash to vapor. For water, the flashed vapor takes up 1,600 times the volume of the fluid; but for liquid hydrogen, the vapor is only 52 times that of the fluid liquid. Properly designed, a pump can handle boiling hydrogen, Lewis research has found. It looks as if the same holds for liquid fluorine, also.

The trick is to add an inducer upstream of the first-stage impeller to get a small pressure rise without doing much work on the liquid. This pressure rise can be enough to recondense any vapor caused by cavitation.

One unusual phenomenon is being investigated to help lick the problem of cavitation. By careful demineralization and outgassing of a liquid, it can be placed under tension, just like a solid material, and it resists the tendency to break apart. Liquids, of course, are commonly supposed to have no tensile strength; the experiments at Lewis have shown that specially prepared fluids do have some measurable strength in tension, and there is a possibility that it may prove to be of some help in cavitation problems.

Lubrication is an area where space environment adds a complicating factor. Most lubricants depend on an oxide film between the bearing surfaces; this is easy to get in air, because everything oxidizes immediately upon exposure. But in space, there is none of this; in fact, liquid hydrogen is one of the best reducing (opposite of oxidizing) agents in that environment. Lewis research is leaning toward pre-coating of materials to provide lubricating films.

The propagation of pressure and velocity waves in the lines between components of a liquid-propulsion system is a hard subject to understand, unless you happen to use classical electrical transmission line data. This satisfying discovery was made by Lewis scientists who were trying to find analytical solutions to the problems generated by disturbances in the flow such as might be caused by a right-angled bend. Somebody thought of electrical transmission lines as an analogy; the theory was checked and it worked.

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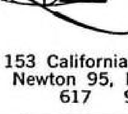
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Nuclear Work Proceeds on Three Lines

Nuclear systems technology in NASA is advancing along three salients aimed at propulsion and auxiliary power for advanced spacecraft of the 1970s.

Each approach—the nuclear rocket, the conversion of nuclear energy to electric power, and the application of that electric power to propulsion—starts with the energy in the nucleus of the atom.

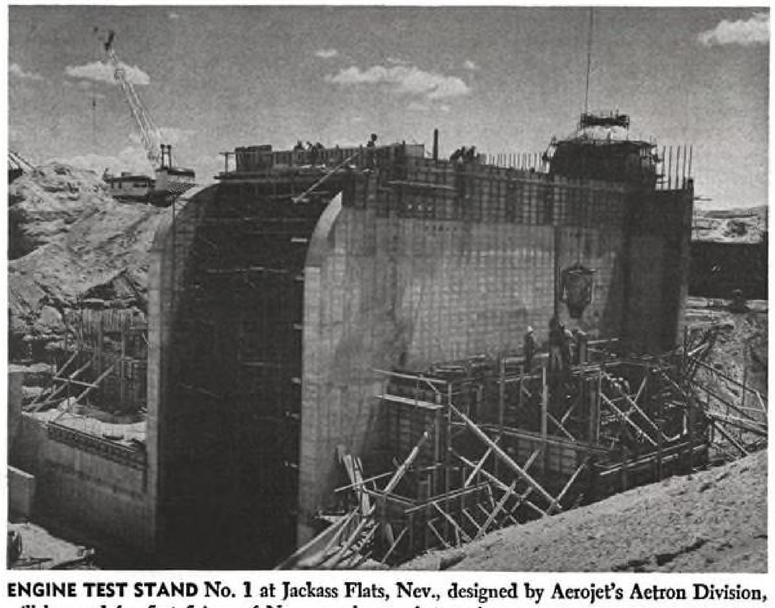
Spacecraft now being planned around these system concepts are expected to perform long-range, high-payload missions far beyond the capabilities of tomorrow's chemical rockets. Applications of these systems to the upper stages of advanced chemical rockets now under development should give a substantial payload increase for near-Earth missions.

NASA's work in nuclear systems takes three routes:

- **Project Rover,** the U.S. nuclear rocket propulsion development program. This consists of three major projects: Kiwi reactors, whose development is expected to lead to the design of a flyable unit; Nerva engine, first of the nuclear rocket propulsion powerplants; and Rift, a flight-test operation of a Nerva-powered, upper-stage vehicle.
- **Nuclear-electric power conversion** now primarily in the form of the Snap-8 30-kilowatt powerplant development, with additional feasibility studies of much higher power levels. Goal of the Snap-8 program is a paired unit delivering 60 kw. for about 50 lb. weight per kw. Ultimate goal of the power conversion program is to achieve figures of 10 lb. per kilowatt.
- **Electric propulsion,** now being studied in both system and component form. There are three general types of these engines: electrothermal, sometimes called the arc jet engine; electrostatic, generally called the ion engine, and electromagnetic, generally designated the plasma engine. Each type seems to have specific areas where its performance is an optimum. One expected result of NASA studies will be analytical, ground and flight tests of these three different categories of engines to verify the performance claims made by their developers.

Joint Effort

Because these programs depend on the development of nuclear reactors for the basic energy source, much of this work currently is conducted as a joint effort by NASA and the Atomic Energy Commission. Electric propulsion is the exception now; its development is being done with conventional electric power sources which have several advantages for development programs, primarily their present availability. But application of these systems to space propulsion means that nuclear reactors will be the necessary energy source, and therefore at some future point these propulsion systems will be developed jointly by NASA and AEC just as the nuclear rocket is being managed today.



ENGINE TEST STAND No. 1 at Jackass Flats, Nev., designed by Aerojet's Aetron Division, will be used for first firings of Nerva nuclear rocket engine.

NASA and AEC operate within broad legislation which defines the general scope of each agency's responsibility. AEC is responsible for ". . . conducting, assisting and fostering research and development in the field of atomic energy, including the utilization of special nuclear material to generate usable energy." NASA's responsibilities involve ". . . conducting the aeronautical and space activities of the U.S. for peaceful purposes."

These broad definitions apply in the areas of NASA's nuclear systems development. AEC does research and development on the nuclear reactors and NASA has the job of research and development on non-nuclear components and sub-systems, and the responsibility for integration of the reactor into space-oriented propulsion and power-generation systems.

Both agencies signed a memorandum of understanding Aug. 26, 1960, which organized a single project office for Rover management. By the terms of the memorandum and later agreements, this joint office was named the Space Nuclear Propulsion Office (SNPO) and Harold B. Finger was named as its manager.

Finger holds two jobs. In addition to being SNPO Manager, he is also Director of Nuclear Systems in NASA's Office of Advanced Research and Technology. His Deputy is an AEC man. Finger reports to the Director of Launch Vehicle Programs, NASA, and the Director of the Division of Reactor Development, AEC.

Two extensions of the SNPO were also established to simplify some of the management functions and technical liaison jobs. One of these is the Albuquerque (N. M.) Extension of SNPO (SNPOA), located near the AEC's Los Alamos Scientific Laboratory. The other is the Cleveland (O.) Extension of SNPO (SNPOC), attached to the Lewis Research Center for housekeeping purposes.

Both extension offices have the job of maintaining technical liaison with the nearby branch of either AEC or NASA.

Each office also directs contractor work as assigned by SNPO.

The Los Alamos laboratory reports technically directly to the SNPO on its responsibilities in the Rover program. It is responsible for reactor and reactor component research and development and for furnishing nuclear reactors for Rover.

Test work for both reactors and engines will be done on the AEC's Nevada Test Site at Jackass Flats. This facility, recently designated as the Nuclear Rocket Development Station (NRDS), is managed by SNPO.

These four groups—at Albuquerque, Cleveland, Los Alamos and the development station—are directly responsible for all functions from planning to testing of the Rover program.

Lewis Research Center, which is responsible for research and development of all kinds of propulsion and power systems for space, plays a supporting role in nuclear propulsion and power systems. Lewis, which reports to the Office of Advanced Research Programs in NASA headquarters, works on projects agreed upon by that office and the SNPO. The Plum Brook Research Station, one of the Lewis staff operations, also supports the nuclear programs by test work programed for its reactor and by the operation of test stands whose primary results bear directly on the development problems of components and systems for nuclear rockets.

Site Expansion

New facilities for engine and stage work have been requested for both the development station and Plum Brook. Additions to existing structures also have been requested with the aim of building a completely integrated nuclear rocket area where work can start with reactor assembly and go through static firing of complete stages.

Existing or funded construction at the development station includes:

- **Reactor maintenance, assembly and disassembly** (MAD) building, provided by AEC.
- **Reactor test cell A,** used for all Kiwi reactor tests to date, but now being modified. Original funding was from AEC.
- **Reactor test cell C,** now under construction.
- **Engine test stand 1,** funded by AEC, and now under construction to designs by Aetron Division, Aerojet-General Corp.
- **Engine test stand 2,** funded by NASA in Fiscal 1962, now under design by Aetron.
- **Engine maintenance, assembly and disassembly** building, partially funded in NASA's Fiscal 1962 budget, now just starting to be built to designs by Vitro.

Most of the funds requested for expansion of the station in NASA's Fiscal 1963 budget are for construction of facilities which extend the capability for handling complete engines and stages of the nuclear rocket. They will become

Rover Status Report

Development progress of the Rover nuclear rocket propulsion system hinges on good reactor data, which must be obtained this year if the Rift flight schedule of 1966-1967 is to be met.

Several possible flight reactors have been designed, drawing on the development of the Kiwi-B series of non-flight reactors. First tests with Kiwi-B were completed with a curtailed power run last December. The Rover schedule called for reactor tests at the rate of one every two months during this year, and selection of a flight reactor this year. If reactor troubles develop during these scheduled tests, the flight schedules will be reviewed and probably delays will result.

Reactor test cell A, which is being converted to handle more Kiwi-B tests, was recently still in the process of checkout, with cold-flow tests scheduled for about a month ago.

There are large-scale problems with liquid hydrogen, in areas where the technology is either weak or unknown. Unless these problems can be solved, and unless their solutions agree with assumed data, the program is in for some tough going. Typical examples of these problems include:

- Radiation effects on liquid hydrogen. Still unknown are the effects of nuclear radiation on the fundamental properties of hydrogen, and the effects of heating due to radiative transfer from the reactor to hydrogen fuel in the stage vehicle stage tank.
- Heat-transfer coefficients of hydrogen. Nozzle walls have been designed using assumed values for the heat transfer coefficient of gaseous hydrogen at extremely high temperature and low pressure. Test data is very meagre, and the actual heat transfer could be 50 to 100% higher than the assumed values.
- Fundamental properties of liquid hydrogen. In spite of much thermonuclear weapons work, and extensive studies on hydrogen-burning air-breathing powerplants, there is a dearth of data on such fundamental properties as viscosity.
- Dissociation effects. At high temperatures, the hydrogen molecule breaks into two hydrogen atoms. There is no data yet to indicate at what temperature this occurs, and what happens to heat transfer when it does.
- Behavior in a reactor core. In the Nerva engine, the liquid hydrogen goes through a phase change to gaseous state before entering the reactor core. If a slug of liquid hydrogen should get in the core through miscalculation, it would affect moderation of the fission process and therefore the design of the control system. Analysis indicates this should not happen, but the fact remains that the process has never been tested and until it is, the uncertainty remains.

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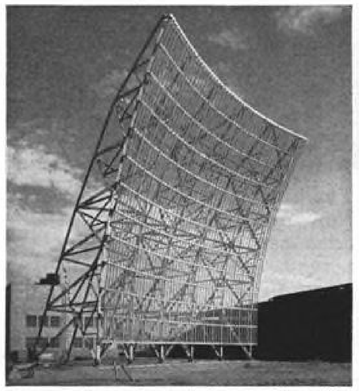
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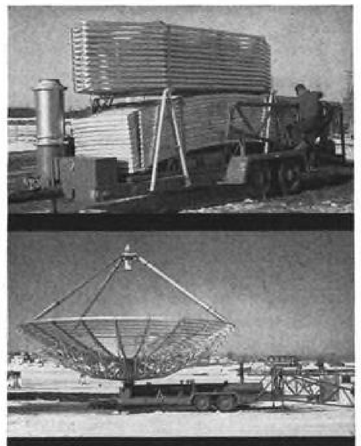
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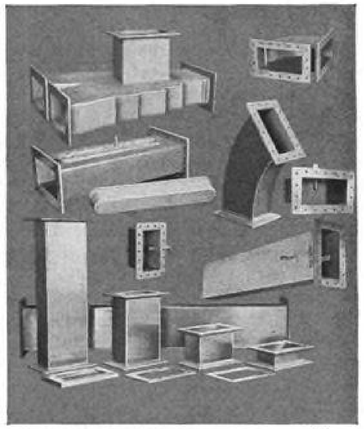
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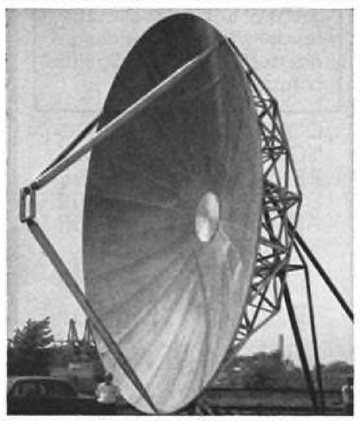
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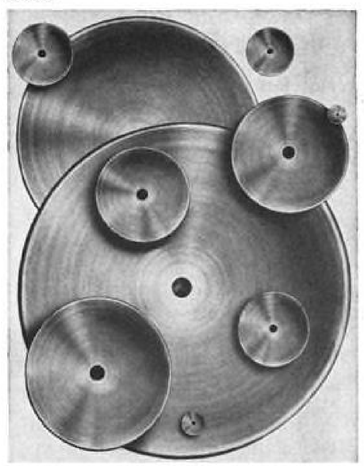
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part of an over-all area referred to as stage static test and maintenance facilities, and they include:

- **Engine maintenance, assembly and disassembly** building addition.
- **Stage assembly and maintenance** building, for work on the Rift portion of the Rover program. Designed with two operating areas, only one bay is requested initially.
- **Stage test position,** for firings of the complete Rift stage.
- **Stage demating, maintenance and disassembly** facility, where the stage would go after hot firings for teardown. Engine would be taken to engine MAD building addition for teardown.
- **Radiation effects facility,** for development of flow components and systems in operating configurations.
- **Components test facility,** for cold-flow, non-nuclear tests of components and systems.
- **Support facilities,** including a railroad and turntable system for moving assembled reactors, engines and stages around the site; extension of power lines and communications; road improvement; a decontamination facility; an office building and an electromechanical area for shop work.

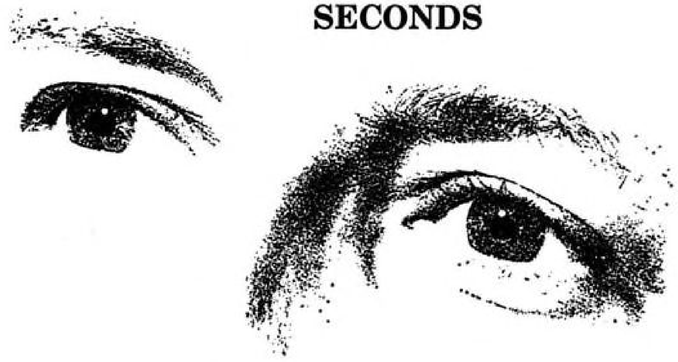
There are three related facilities requested in the Fiscal 1963 budget which are to be built at the Plum Brook station:

- **Space propulsion research** facility, for research on and testing of complete space electrical propulsion systems under simulated environmental conditions; $25,675,000.
- **Nuclear rocket dynamics** and control facility, which is the addition and extension of facility B-1 at Plum Brook. This will be used to study the initial portion of the starting cycle using simulated reactor heating. Requested amount was $3.5 million.
- **Hydrogen heat transfer** facility, to study the properties of liquid hydrogen under the restrictions of the nuclear rocket system. Nozzle work will receive concentrated attention. Budget request: $2.4 million.

Nuclear Rocket Development Station

Unlike other NASA centers and stations, this is a joint operation, with facilities shared by NASA and Atomic Energy Commission. NASA owns no land, and plant value has not been determined because much of it is under development. Actual location of site is at Jackass Flats, on AEC's Nevada Test Site. Last year's construction program was $15 million; this year, the figure is budgeted at $40 million. Expected operating cost this fiscal year is $2 million. A staff of 200 has been budgeted.

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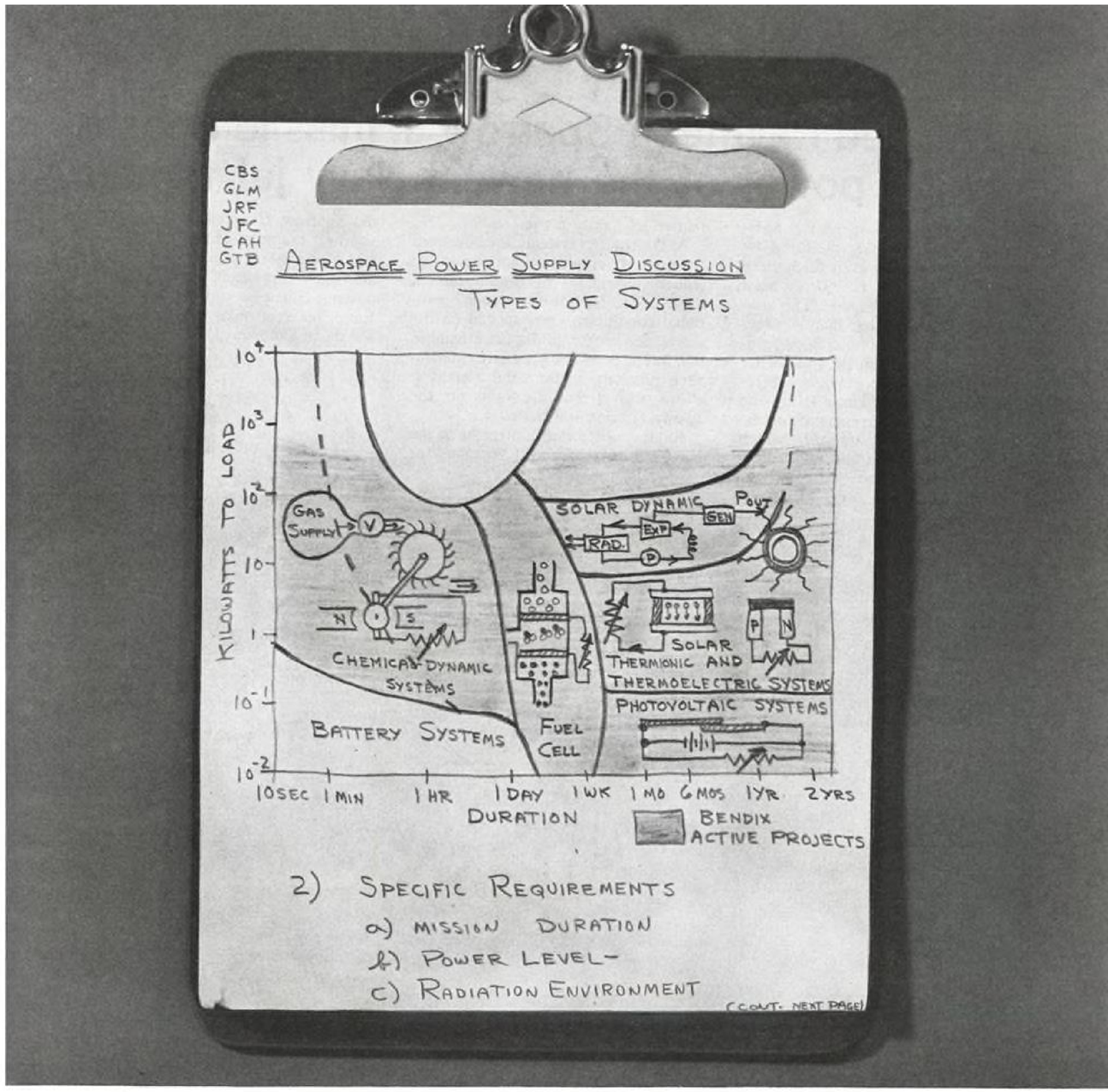
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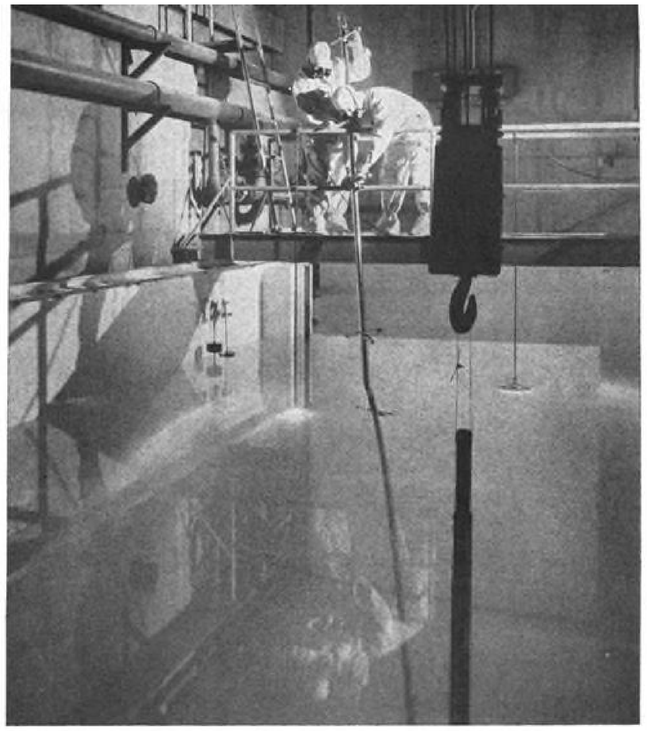
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PLUM BROOK RESEARCH STATION technicians work at apparatus for testing simulated nuclear rocket fuel elements, left. At right, technicians manipulate radioactive materials in canal leading from Plum Brook Research Reactor to hot laboratory.

Plum Brook Testing Advanced Propulsion

Sandusky, Ohio—Dual testing capability for advanced space propulsion systems and components is taking shape at the Plum Brook Research Station near here.

One side of this capability is a nuclear reactor designed primarily for materials testing. It has a maximum power of 60 megawatts and a flux density on the order of 10^{14} neutrons/sq. cm./sec.

The other side is a rocket systems test operation now building toward large-scale flow studies on complete upper stage chemical and nuclear rocket systems.

Both groups of facilities are just getting started. The station has been operating for about six months. The reactor is currently licensed to run at 100 kilowatts, pending approval by the Atomic Energy Commission for full-power runs. That permission is expected later this month.

Rocket test units have been operating since last November in some programs, but the anticipated workload has yet to come and is waiting for completion of some facilities.

Staff doubled during the last fiscal year, from 200 to 400, reflecting the rapid building of the station to an initial operational status. Further staff increase has been requested by NASA and $40 million of new facilities has been planned and requested.

Administratively, Plum Brook Research Station is a staff function of the Lewis Research Center. The station director, A. D. Johnson, reports to Lewis Director Abe Silverstein. Functionally, the station performs test operations, accepting research projects from Lewis, its contractors and subcontractors.

Nuclear Reactor

The Plum Brook reactor can be thought of as a cube with holes in it. Experiments are placed in these holes, exposed to the radiation flux of the reactor, and then removed for study or testing.

The reactor core containing the holes is about a 30-in. cube. Surrounding it are: a vessel containing primary cooling water; a secondary cooling-water transfer system; four quadrant-shaped rooms for experiment access; three million gallons of processed water and up to nine feet of special concrete, which weighs about 250 pounds per cubic foot. Topping it are three 20-ton steel shields to bear the brunt of the maximum credible accident—an explosion, equal to that of about 400 lb. of TNT. Housing all this is a 100-ft. dia. steel containment vessel, designed to take whatever overpressure is left after the three steel slabs have borne the brunt of the explosion.

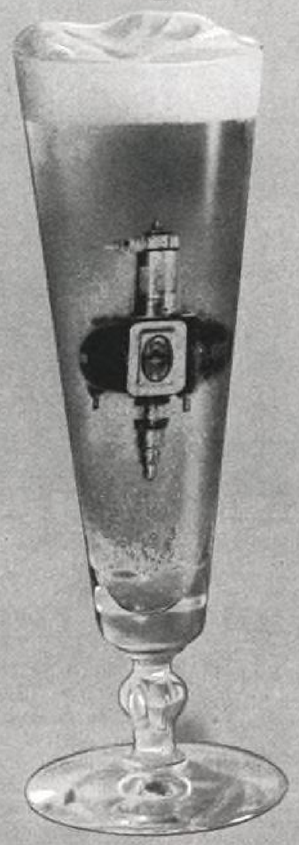
Around the quadrant there is a canal system; through it, experiments can be moved under water for maximum shielding.

A row of hot laboratories stretches off on a tangent, its thick-walled cells broken only by lead-glass windows, separated by oil films and nearly five feet thick. Behind these windows, protected from the radiation in the cell, stand the operators of remote hands and instruments.

Other building areas house the water and air processing plants. Neither can be released outside the plant unless they meet AEC minimum requirements for contamination. Thus, the cooling water goes to "hot" retention tanks, where much of the radioactivity settles out, then passes to the "cold" tanks for further processing before being dumped into Plum Brook.

Air from the reactor containment dome is monitored in a holdup tank until it is safe, and then is exhausted through a 100-ft. high stack. There is an extra safeguard—a 150-ft. weather tower continuously measures and records the temperatures at heights of 10,

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75 and 150 ft., to detect any possible temperature inversion that would not permit exhaust air to disperse normally.

There are six primary areas in the reactor where experiments can be made:

• **HB-1, for solid-film** lubricant test. The simple experiment will consist of a steel ball, rolling on a circular steel disk which has been lubricated with a film of molybdenum disulfide. The object is to check the characteristics of the lubricant under exposure and compare them with the known characteristics without radiation damage.

• **HB-2, for materials samples** at cryogenic temperatures. Stainless steel, aluminum and titanium alloy samples will be subjected to a thermal neutron density of about 4×10^{14} and a fast flux of 2×10^{14} while being cooled by gaseous helium to cryogenic temperatures. There is some belief that radiation damage may be greater at low than at high temperatures. These experiments are being devised to check that hypothesis which, hopefully, is wrong. This work is part of a contract study between NASA and Lockheed Aircraft Corp.

• **HB-3 and HB-4,** for studies in basic nuclear physics, especially in studies of materials.

• **HT-1, for high-temperature** materials. Experiments here will be subjected to the highest level of thermal neutrons—5.6×10^{14}—of which the reactor is capable. Purpose of the experiments will be to radiate samples of materials at high temperatures and check them for radiation damage.

• **HT-2, for Nerva actuator** experiment. This test will consist of checking a prototype actuator developed for the Nerva engine system under radiation comparable to its proposed environment. The unit will be cycled while under test as it would be in the real engine.

All these experiments will be subjected to the 10-day full-power cycle of reactor operation except for the Lockheed cryogenic tests, which will be irradiated for one hour.

Normal cycle of the reactor will follow the 10-day "on" period with a 5-day shutdown before resuming full-power operations again.

Primary job of the rocket systems division here is to make operational tests on high-energy, upper-stage propulsion systems. For that reason, their technology is weighed in the direction of hydrogen-oxygen and hydrogen-fluorine systems.

The range of test work covers the current running of system components, such as a liquid fluorine pump, to future runs of the Nerva stage through the first quarter of its starting cycle.

To do this large variety of missions, the station has activated or is working on these test facilities:

• **A: Pump tests at large flows.** Capability of this unit is about 100 lbs./sec. of liquid hydrogen, although it can test other liquid propellants. Some checkout runs have already been made with liquid nitrogen, and a couple of tests have been made with liquid hydrogen.

• **B-1: Nerva altitude test.** This test stand, now being modified for increased altitude capability for the Nerva engine, will check the starting transients of the rocket for about the first quarter—15 sec. or so—of the start. These tests, which have to be non-nuclear in nature, will be run with a simulated reactor.

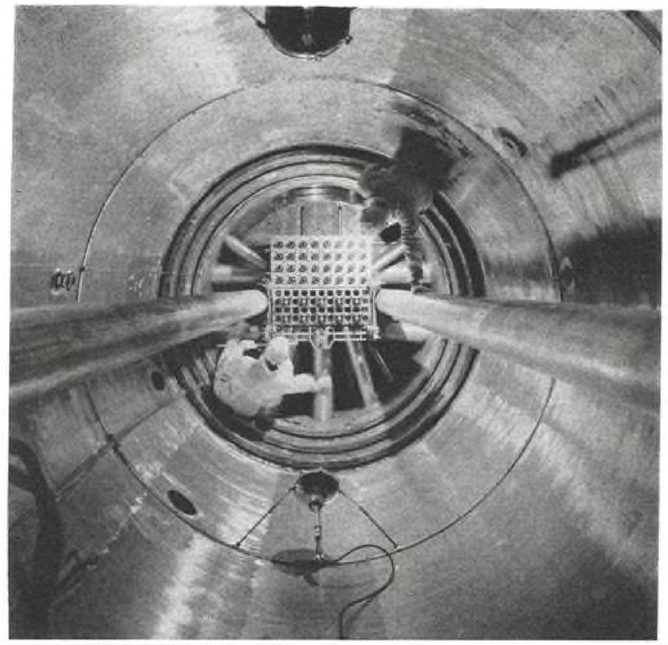
• **B-2: Apollo lunar landing** module test. This unit is being planned for simulated runs of the Apollo lunar-landing module.

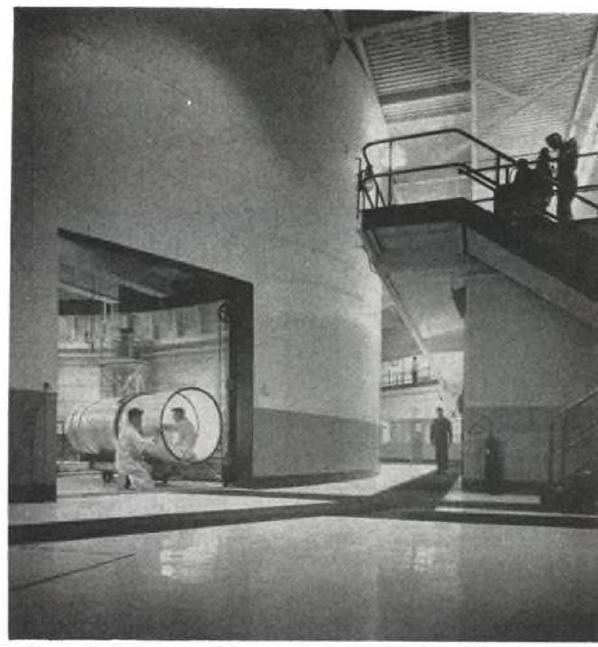
• **C: Turbopumps for liquid hydrogen** and liquid oxygen. This unit has a flow capability of about 100 lb./sec. It is presently running with two liquid-hydrogen pump rigs; one of these is a boiling-fluid type with low net positive suction; the other is a research pump for inlet studies.

• **D: Turbine research.** This stand is a double one which can handle two experiments simultaneously. Eddy-current dynamometers absorb the power from the turbines, and can handle up to 15,000 hp. There are three dynamometers, rated at 5,000 hp. each. Currently this stand is being calibrated and checked.

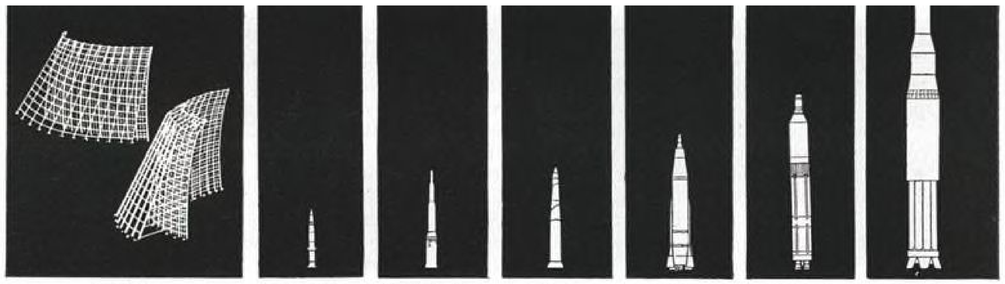
• **E: Dynamics tests.** This huge apparatus, originally planned to shake complete, loaded missiles somewhat bigger than the Atlas, stands 120 ft. high. Electromagnetic shakers are installed, and it is possible to simulate burning by dumping propellants at a programed rate. But the stand was never used for this purpose, and is now being studied to fit the Apollo support mission.

• **F: Hydraulic laboratory.** In this area, both cryogenic and non-cryogenic sys-





OVERHEAD VIEW of Plum Brook reactor core box in pressure tank, left. Box is 21 ft. below building's grade level. At right, 100-ft.-dia. reactor containment vessel. Technicians inspect large "thimble" for containing irradiation experiments.



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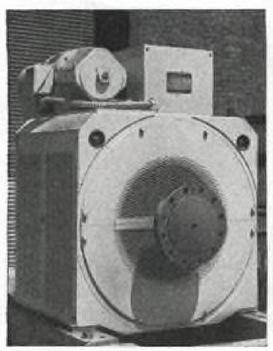
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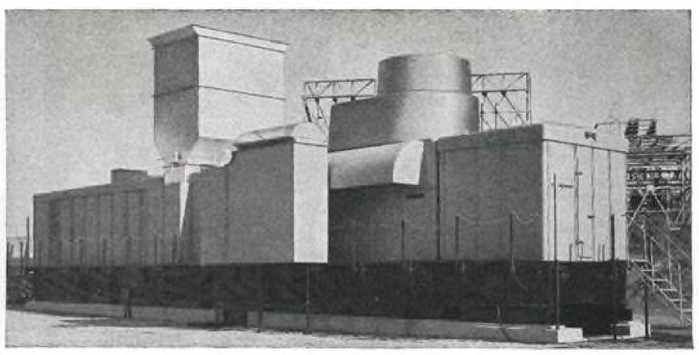
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tem components can be studied over a wide range of conditions up to high flow rates and high pressures.

• **G: Pilot facility.** In this earth-bunkered test site, the first to operate here in rocket systems test, small pumps and turbines are being run to get design data for other facilities.

• **H: Central control and instrumentation.** This building is the common component of all stands except B and J, which have their own control and instrumentation. All operational tests are controlled from panels in this building, and the data measured at the site is recorded here.

• **I: Fluorine pump stand.** This test apparatus was developed specifically for testing liquid fluorine pumps with flow rates about 50 lb./sec. It has run two such tests. First of these was a Lewis-designed pump; the second was a contractor design.

• **J-1: Heat transfer stand.** This apparatus burns hydrogen and oxygen to generate a high-temperature gas for Rover nozzle studies. Nozzle is made of thick copper to measure temperatures after one second of running at a very high heat flux.

• **J-2: Heat transfer stand.** This test stand was originally a low-pressure hydrogen fluoride unit, but the test stand currently is being modified for hydrogen-oxygen work.

• **J-3 and J-4: Advanced tank** tests. These stands will be used to study tank designs for liquid hydrogen fuel in terms of insulation problems and related heat-transfer work.

• **J-5: Fluorine hydraulics** laboratory. This stand originally did work on the hydraulic properties of liquid fluorine and is now inactive.

Plum Brook Research Station

Plum Brook Research Station, operated by Lewis Research Center, is located at the former Plum Brook Ordnance Works near Sandusky, Ohio.

Total area occupied is 5,968 acres, of which 3,168 are occupied under permit from the U. S. Army, and the remaining 2,800 acres are in process of being transferred from Army jurisdiction to NASA.

Value of the plant is listed at $28,114,000.

Operating cost for Fiscal 1962 was $5,560,000; for this fiscal year, the space agency asked for $8,283,000 for operations.

Construction program budgeted for this year is $39,183,000.

Staff was authorized at 400 for Fiscal 1962; NASA hopes to increase it to 525 this fiscal year.



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Adjustable relief ranges:
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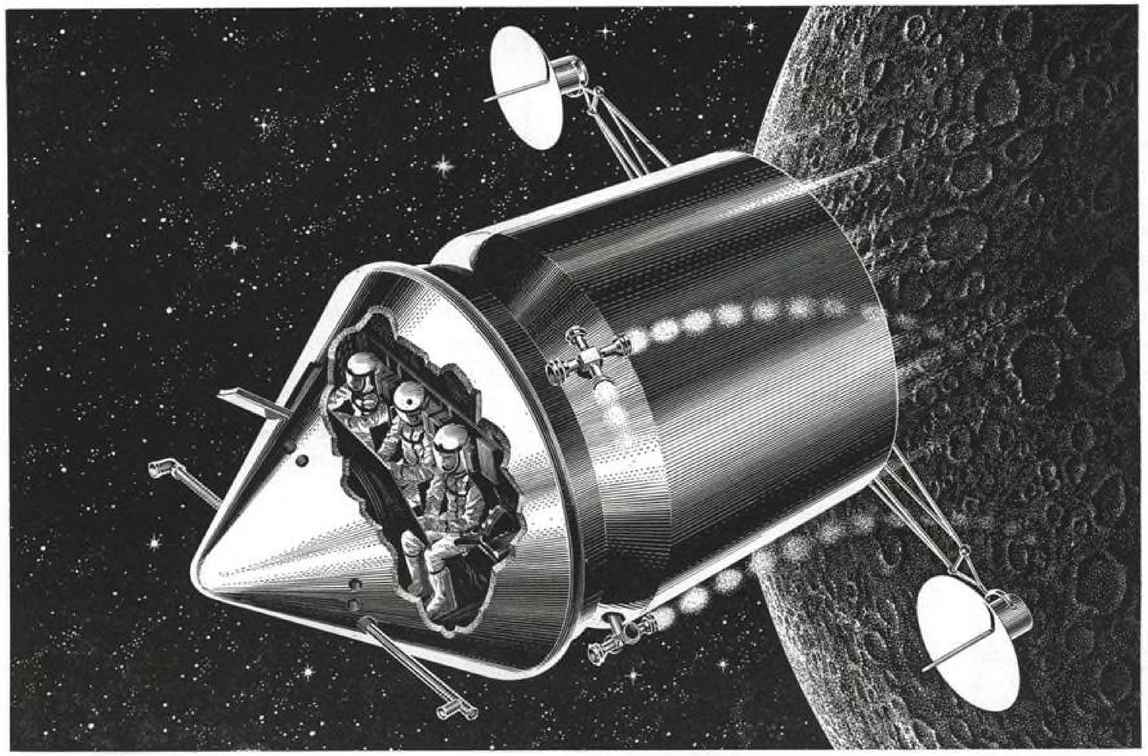
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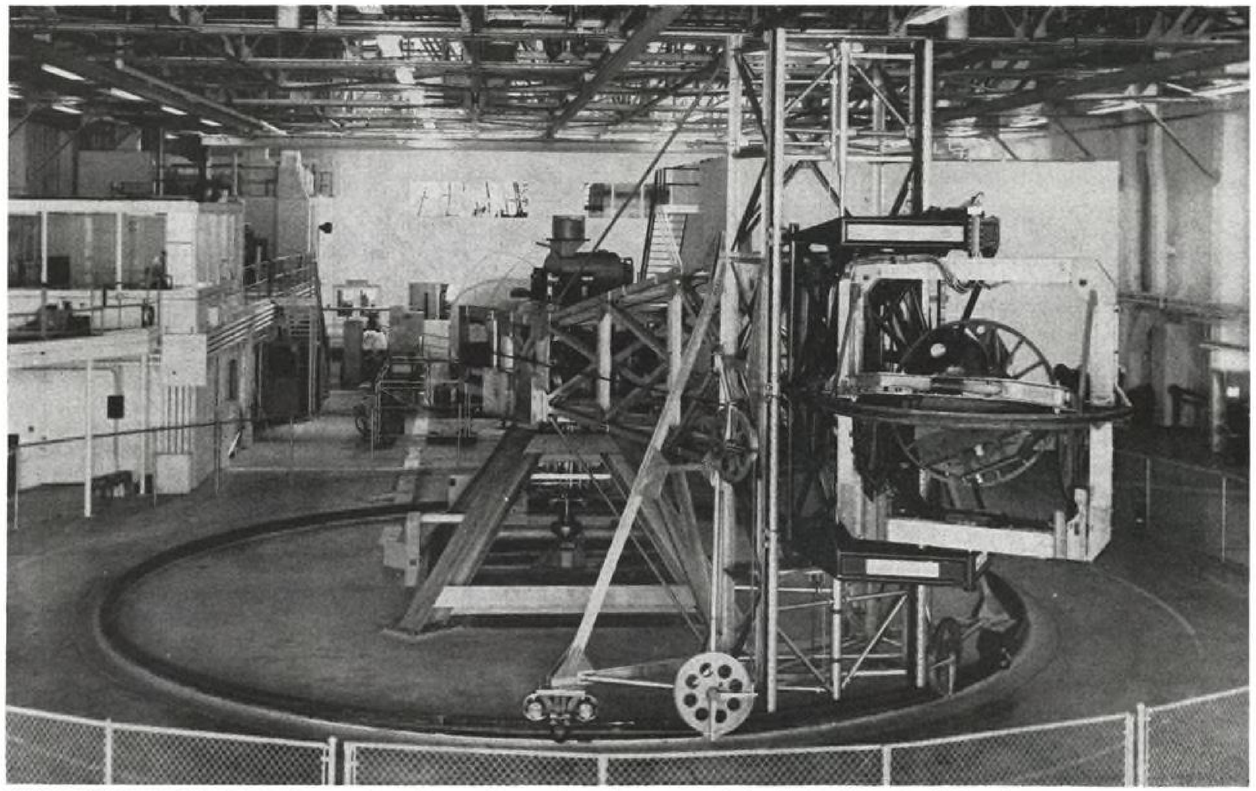
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Ames Generates Basic, Applied Knowledge

Research goals advance greatly in both physical and life sciences; entry physics is chief study effort.

Moffett Field, Calif.—Critical fund of basic and applied research knowledge needed for the mushrooming technologies of space and advanced aeronautics is being generated at Ames Research Center here for use by National Aeronautics and Space Administration, the military services, other government agencies, and industry.

In this job, Ames has sighted on research goals far beyond those it sought during its outstanding contribution as a key part of the predecessor National Advisory Committee for Aeronautics.

Ames' broad effort, oriented heavily toward basic research, falls into two general categories—the physical and the life sciences. Physical science research is an umbrella-like activity totaling about 92% of the center's effort and divided into four general areas—entry and environmental physics (45%), aeronautic's (25%), guidance, control and navigation (20%) and space sciences (2%). Bulk of the work in physical sciences is performed for NASA's Office of Advanced Research and Technology at headquarters.

Life sciences, a relatively new activity comprising about 8% of the Ames mission, has been assigned the responsibility for advanced research and technology in this vital field for NASA. Most of its work will be performed for the Advanced Research Office and the Office of Space Sciences at headquarters.

The physical sciences are organized under five main divisions— vehicle environment, aerothermodynamics, full-scale and systems research, unitary plan wind tunnel, and instrumentation. An indication of the capability of the Ames facilities is that the unitary plan wind tunnel division was assigned a substantial share of the aerodynamic studies that were being conducted at the USAF's Arnold Air Development Center at Tullahoma, Tenn., when the main wind tunnel there was rendered inoperable. The Instrumentation Division at Ames primarily is a supporting organization for the center.

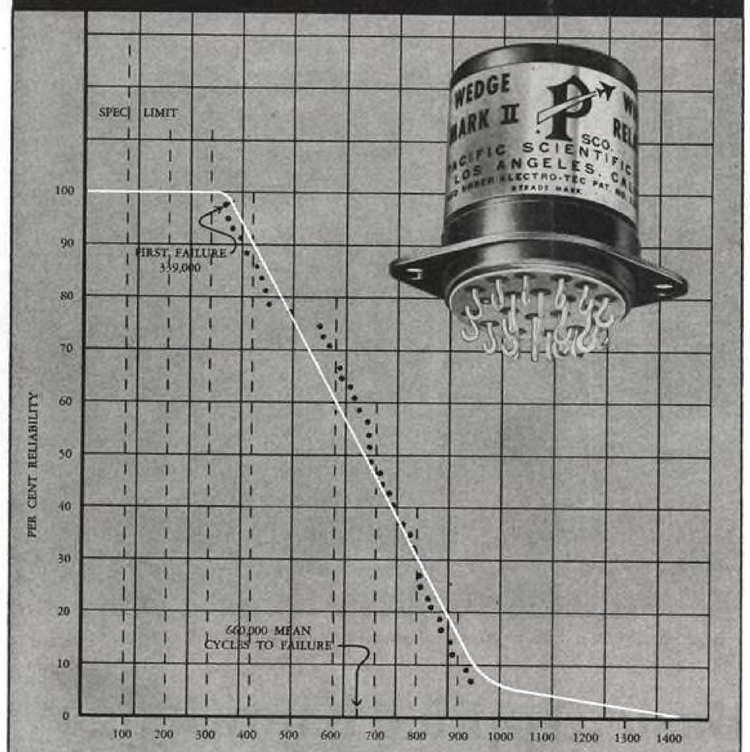
Life sciences work is divided among three divisions—exobiology, environmental biology and biotechnology.

Despite this organization by divisions, each having a number of branches as further subdivisions, Ames scientists are not committed rigidly to specific channels of research. Key to the effectiveness in maximizing the flow of information in the broad areas in which the center works is organizational flexibility.

This allows cutting across divisional and branch lines for coordination of research teams and for transferring researchers to related efforts when a promising line of study shows up as a "byproduct" of another study.

An example of this flexibility is the Mission Analysis Group operating under the Vehicle Environment Division, with a complement of scientists drawn from many branches. This group now

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Ground Winds Studies

Moffett Field, Calif.—Effects of ground winds on booster and payload combinations are being investigated at Ames Research Center for both National Aeronautics and Space Administration and the Air Force, encompassing launch site conditions at both the Pacific and Atlantic missile ranges. These experimental studies have been performed in the 12-ft. pressure tunnel with 1/10th to 1/12th scale models, with simulation of wind speeds in excess of 40 mph.

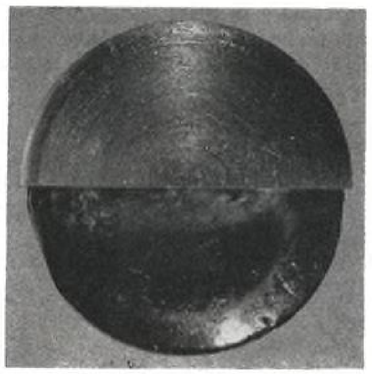
General conclusion of the studies so far is that the effects of ground winds do not lend themselves to any theoretical analysis. Certain combinations of payloads and umbilical towers can severely reduce the wind speeds that a vehicle can withstand.

But the impression is that minor modifications can minimize these effects. Work in this problem area is expected to be completed in a few months and result in a semi-empirical approach, which will demand more detailed knowledge of flow phenomena than has been accumulated thus far.

is evaluating the feasibility of methods for carrying out high-performance space missions that may be required perhaps 10 years in the future.

This type of activity is considered essential to Ames' own research efforts and to general support of NASA's programs, because Ames' management feels the center has the talent to evaluate what the state of the art will be able to support in the future. Investigations by this group include missions involving the Apollo spacecraft, incipient phases of lunar basing and follow-on missions to Mars.

Personnel strength at Ames at the end of FY1961 was 1,487, which increased to 1,611 by the end of March, 1962. By the end of last month this figure was scheduled to have increased



COMPOSITE before (top) and after photograph shows performance of plastics in reentry. Ames experiment produced heat load of 20,000F, velocity of 17,000 mph.

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ATL Horizon Scanner orbited in Agena-launched satellites





ATL Horizon Scanner employing an advanced scanning mechanism for extreme reliability to meet 1-year life requirement in OGO orbital assignments



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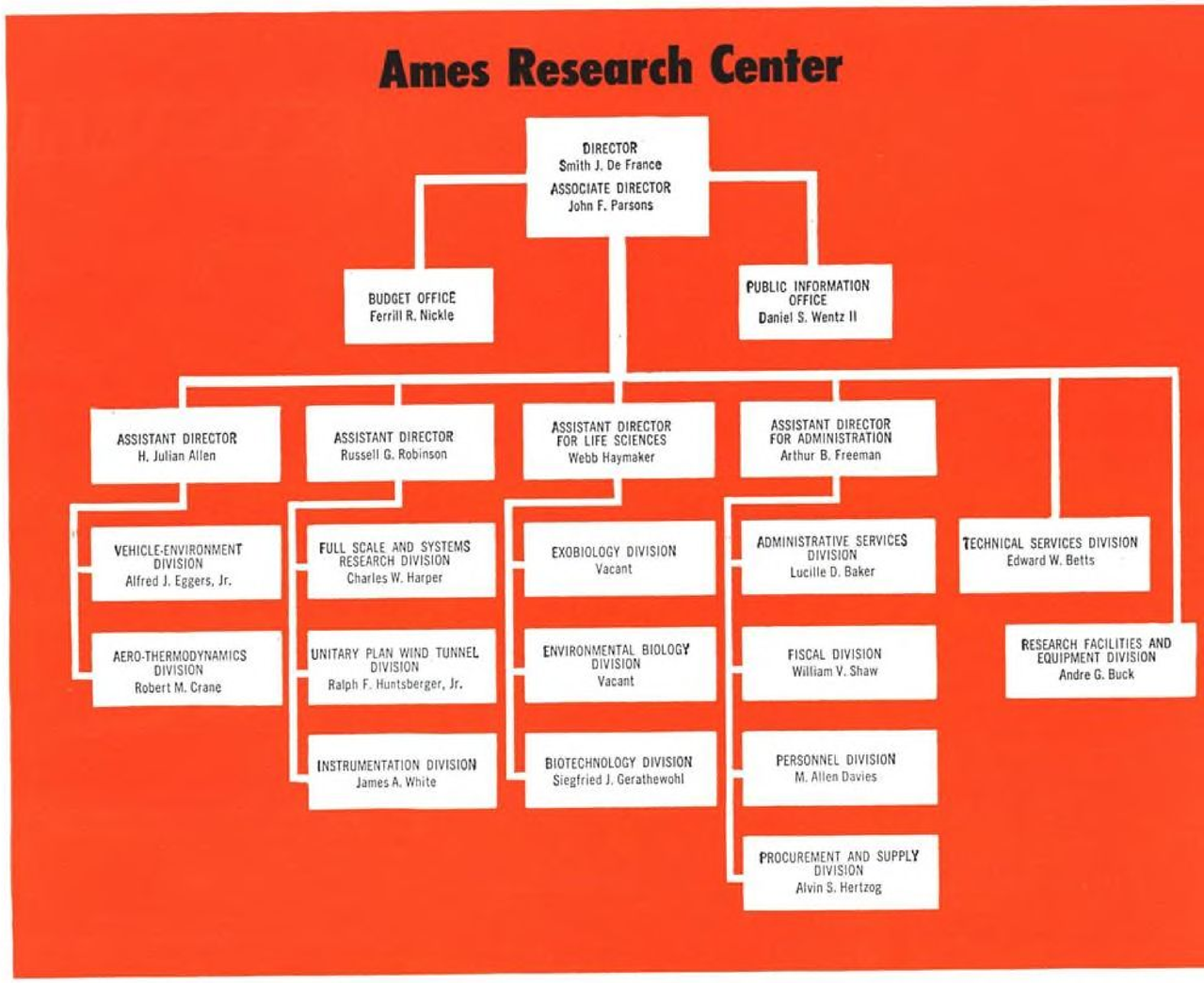
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to 1.675. At the end of Fiscal 1963, personnel strength is expected to reach approximately 2,050—an increase of 375 over Fiscal 1962.

The center occupies 115 acres of land. Plant value—including office buildings, shops, hangars, flight simulator facilities, laboratories, specialized wind tunnels, hypervelocity test ranges, and other installations—is estimated at approximately $125 million. Operating cost of the center was approximately $21.5 million for Fiscal 1962 and is expected to be approximately $28.5 million for Fiscal 1963.

Cost of construction program for Fiscal 1962 was estimated at $6.1 million. The proposed program for Fiscal 1963 totals approximately $14.4 million and includes:

• **Mach 50 helium tunnel,** which will afford detailed information, such as load distribution and hinge moments, not obtainable over the same Mach range in any other installation. The tunnel is expected to produce research results which will be applicable to the Apollo spacecraft during engineering design and construction phases.

Blowdown Type

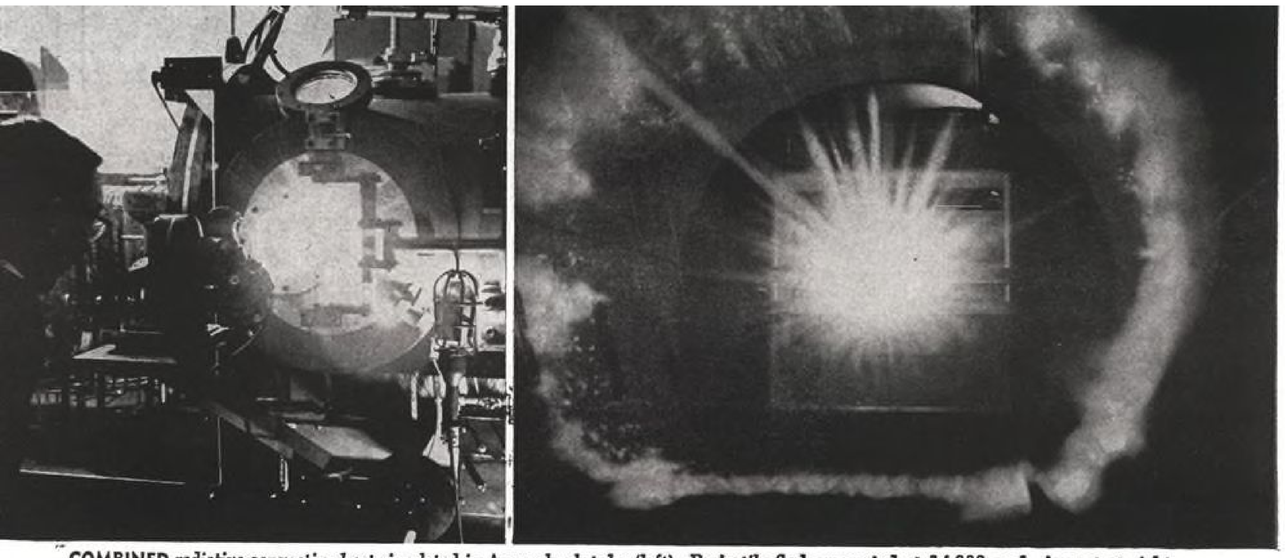
The tunnel will be a blowdown type with a 48-in.-dia. test section. Interchangeable nozzles will provide Mach numbers of 30 and 50 at Reynolds numbers in the span of 0.1 million to 1.4 million. Ten consecutive 60-sec. runs will be possible before refilling the reservoir, which will require three hours, and have a 5,000-psi. pressure capability. Facility's maximum temperature capability will be 1,500F.

• **Radiative heat system** for the mass transfer facility, which will permit runs with simultaneous inputs and radiative and convective heating. The system will allow use of 6-in.-dia. models, considered to be the smallest practical limit in this type of testing, and will allow evaluation of heat shield sections consisting of the ablative layer, insulating layer, and the backface structure.

Scientists agree that Apollo will be the last-generation re-entry vehicle that will not have to face significant combinations of radiative and convective heat loads. This new facility will furnish basic data in connection with future vehicles.

• **Space flight guidance** research facility, which will permit simulation during the takeoff, midcourse trajectory, entry and landing phases of the environment, acceleration, deceleration, motion, and specific tasks of astronauts in a realistic space capsule.

• **Bioscience laboratory** for systemic and subsystemic research and studies in immunology, genetics, radiobiology and exobiology. Advances in these fields will be explored both in-house and by contract.



COMBINED radiative-convective heat simulated in Ames shock tube (left). Projectile flash generated at 14,000 mph. impact at right.

Ames Examines Re-entry Heat Problems

Moffett Field, Calif.—Broad spectrum of convective and radiative heat problems associated with the re-entry from lunar and planetary flight is being analyzed both experimentally and theoretically at the Ames Research Center, paced by the necessity for data that will promote the safety of the Apollo manned lunar mission.

Varied effects of convective and radiative heating and the results of interplay between the two are complicated by many factors, including vehicle speed, face and afterbody configurations, materials, ablation phenomena, ionization in the gas cap, and other environmental factors.

In the process leading to convective heating, the gas in front of the entering body is compressed as it passes through the shock wave, and forms a hot gas cap. The portion of the cap adjacent to the body usually forms a boundary layer flowing around the vehicle. Part of the energy in the boundary layer is transferred to the body by the motion of the fluid itself, and this phenomenon is called convective heating.

The collision of high-energy gas particles in the hot gas cap raises their energy states. As these energy states fall to lower levels, the excess energy is emitted as electromagnetic waves. Much of the energy in the shock wave is therefore transmitted directly to the vehicle in the form of radiative heating.

Apollo Heating Problems

The large fraction of heating of the three-man Apollo spacecraft will result from convection, and the heat shield has been designed specifically to cope with this. But an appreciable heat contribution—enough to be considered serious but not disabling—will come from radiative heating, and an appreciable amount of the Apollo heat shield weight will be used to deal with it.

In the earth-entry regime, at the 36,000-fps. parabolic speed (speed with which the spacecraft approaches the earth without any additional impulse), the blunt shape tends to minimize convective heating, whereas the pointed shape minimizes the radiative heating pulse. Frequently, therefore, the shape of the entry vehicle will be the result of compromise.

For higher-than-parabolic speeds that are desirable for shortening trip time—40,000 fps., for example—radiative heating becomes the primary cause of aerodynamic heating. At speeds sufficiently high, it is expected to dictate vehicle configurations.

For conditions where radiative heating is predominant, Ames researchers believe it will be necessary to employ sweepback—incline the vehicle's front surface so that it is not perpendicular to the wind direction—as opposed to the flat, almost unswept face of the Mercury spacecraft or a heat-sink missile re-entry body. The angle of attack used by the Apollo for re-entry affords the desired sweepback for its speed regime.

In planetary probes, where entry speeds of 40,000-50,000 fps. can be anticipated and where a simple ballistic trajectory would seem to be preferred to eliminate the need for elaborate control systems and attitude programing, the required sweepback of the vehicle face may be achieved by using pointed cones as entry bodies. Degree of sweepback would be defined by the included angle of the cone.

Current Studies

Such bodies, on the basis of theoretical studies now being made by Ames researchers H. Julian and Alvin Seiff, appear to be optimum from the standpoint of minimizing the total heating (convective plus radiative).

A six-fold reduction in the radiative component is achieved by going from a 45-deg. half-angle to 30-deg. half-angle, for example. By comparison, the angle associated with the Apollo flight attitude would be about 60 deg. At this angle, the radiative component would be about three times as great as for the 45-deg. half-angle cone.

Shapes appreciably more slender than the Apollo configuration are being examined in connection with a series of planetary missions. Experimental studies to determine configurations suitable for a Mars entry capsule for the Mariner B mission are being conducted as part of an over-all study of planetary entry problems.

Design logic, to be applied in greater-than-parabolic entry speeds, to balance the effects of convective and radiating heat may vary the geometry of the nose, possibly by starting with a pointed cone configuration comprised of different materials and allowing successive sections of the cone, from the nose back, to be ablated. This would produce an increasingly blunter face as ablation progressed, until entry speed began to be slowed mechanically.



NOSE and wake flow on re-entry model studied at Ames. Velocity in test was 31,800 fps.

Heat transfer resulting from air ionization is being studied closely to determine how this phenomenon affects convective heating, because considerable controversy exists on its importance. Air ionization tends to increase, researchers feel, when radiative heat transfer is present as an aggravating factor. Charge exchange cross-section studies also are being conducted because of their relevancy to ionization heating, and numerical measurements are made of the tendency of the charged particles to surrender their charge to the neutral gas medium.

Radiative Heating Identification

Another problem relating to radiative heating is the need to determine what part of the spectrum is emitting the energy. Although temperature of the hot gas cap rises as entry velocity increases, with most of the radiant energy probably being emitted in the ultraviolet range, the relationship of vehicle velocity to radiative heat transfer has yet to be defined with any degree of exactitude. Studies indicate the dependence of radiative transfer on velocity ranges from the 8th power to the 16th power of velocity and possibly even higher.

To determine intensity of radiation as a function of wave lengths up to speeds of 45,000 fps.—earth-entry at the return from a Martian mission—free flight models are being studied with photo and filter pickups.

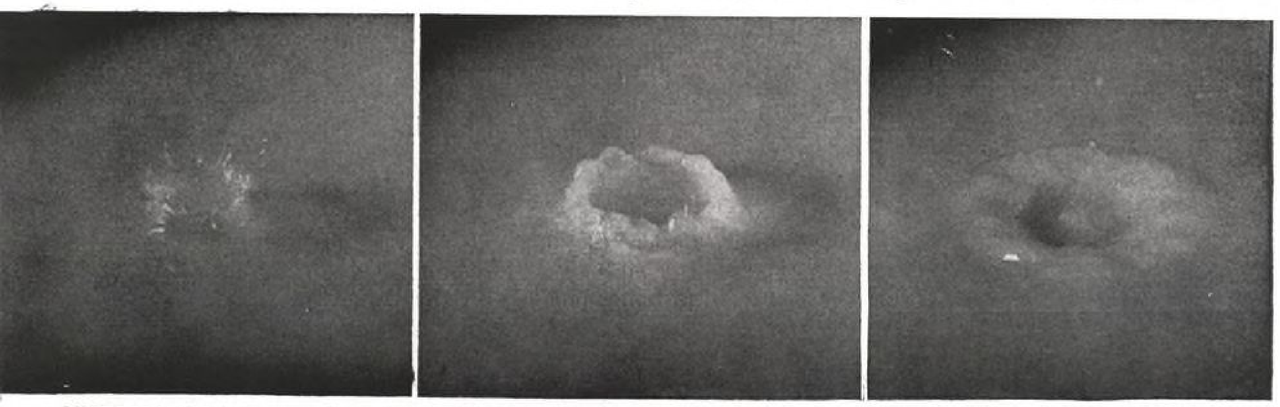
Many materials have been tested under combined heat loads comparable to those which Apollo will experience. This testing regime is concerned not only with ablative characteristics of the material but with the self-insulative properties as well—determination of backface temperatures for a given weight of material.

So far, this testing has been limited to an impulsive heating cycle, in which maximum heat flux is imposed and held constant for a time before termination. The time span is less than that to which Apollo would be subjected, but good combined radiative-convective heating rates are obtained and give some understanding of Apollo conditions. The tests are considered valid because the aim is to show which materials are promising. Materials studied have included phenolic nylon, low-temperature ablatives, and charring ablatives.

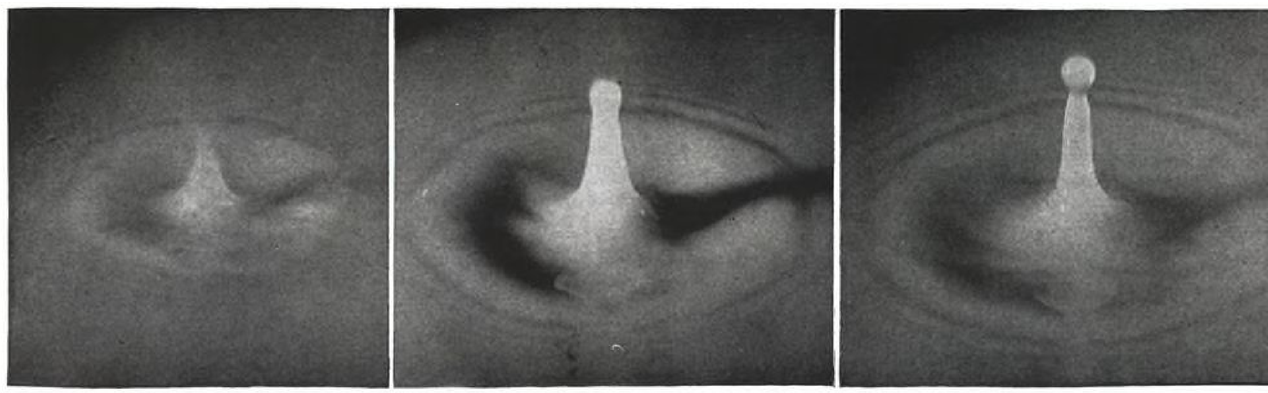
Theoretical studies are being conducted on the total mechanism of charring ablatives—the development of the char, the manner in which it recedes, and the controlling factor determining the rate of pyrolosis (breaking down of the base of the material into a charring layer).

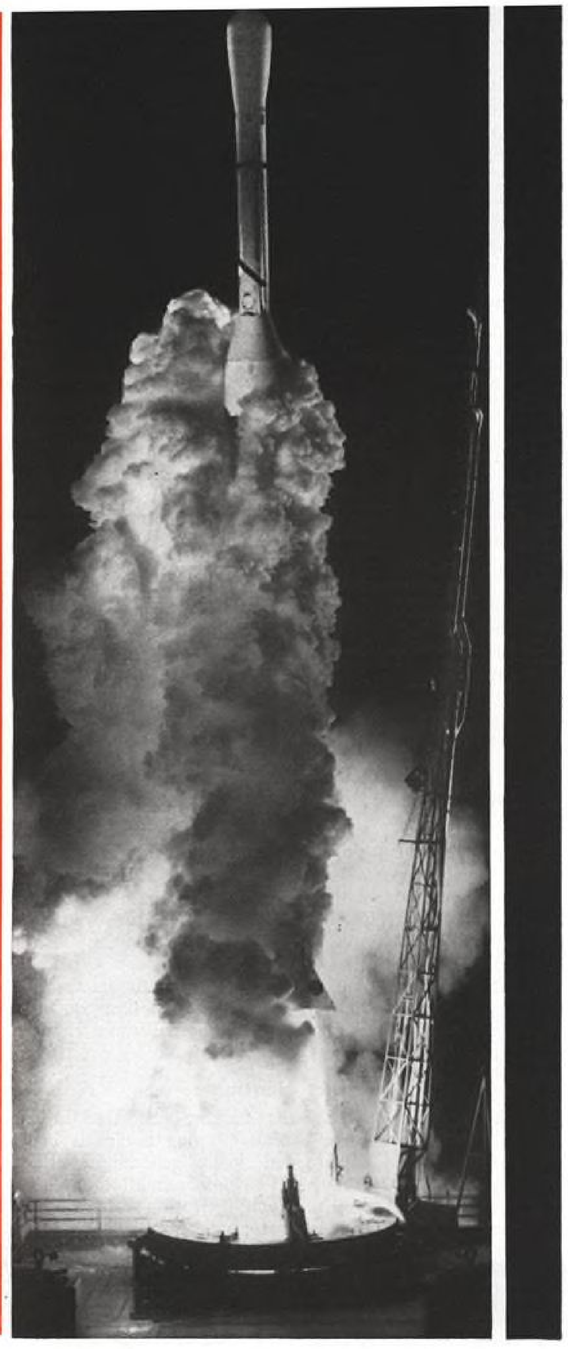
Wake Heating

Radiative heating generated in the wake behind entering bodies is being investigated in a generalized study. Apollo will have such an afterbody heating problem. Heating rate will be modest but application will be for a



PHOTOGRAPHIC SEQUENCE shows characteristics of drop of water impacting on a water surface in Ames Research Center study. This test is part of a fundamental program to obtain data on the effects of materials landing on simulated planetary surfaces.





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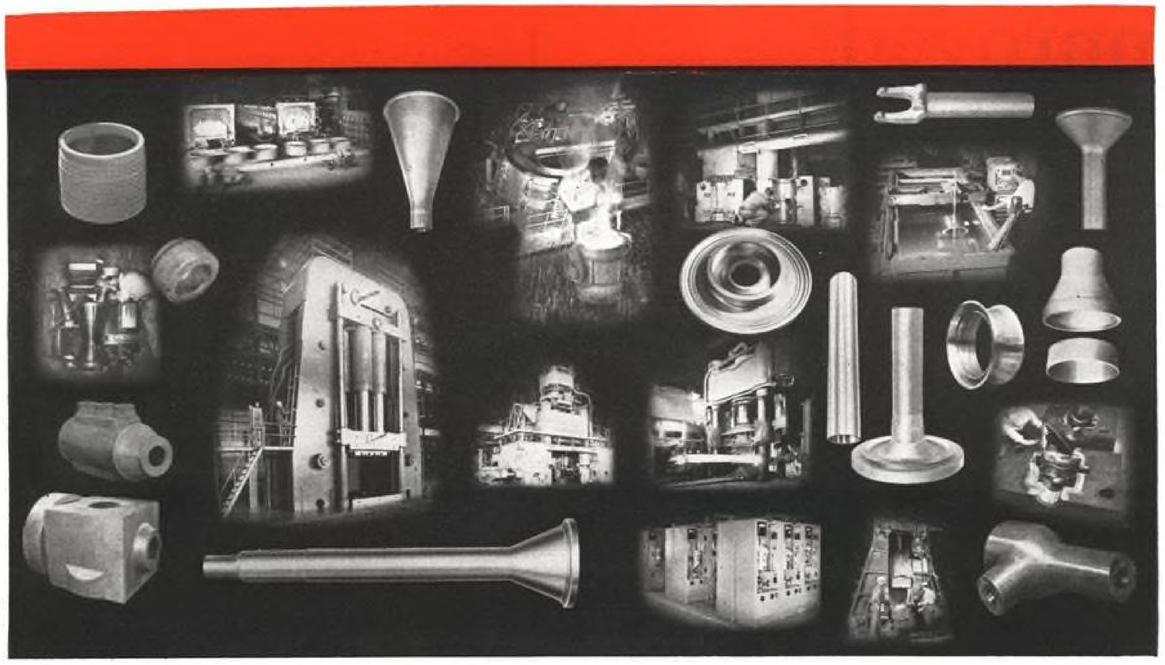
The basic concept of EHR is "building-in reliability in addition to testing for it." Pictured above is an EHR semiconductor line at Texas Instruments. Each EHR device is subjected to repeated 100% microscopic inspection under positive pressure, controlled atmosphere by TI's independent Quality and Reliability Assurance department.

EHR was developed by Texas Instruments, working with Douglas Missiles and Space Systems Division, prime contractor to NASA for the Delta space vehicle program. EHR helps assure the success of programs such as the TIROS II, shown here boosted by the NASA/Douglas Delta space vehicle.

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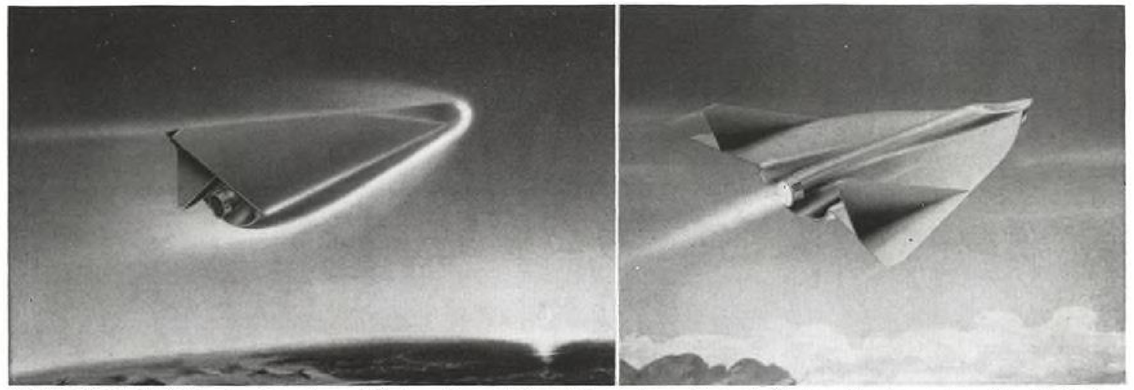
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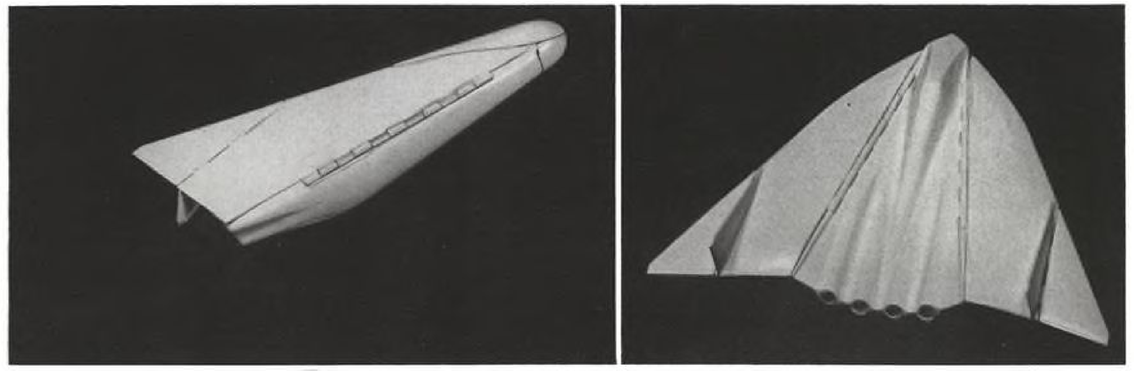
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VARIABLE GEOMETRY winged re-entry vehicle is under analytical study at Ames Research Center. Drawing and model at left show semi-ballistic configuration for re-entry. After reaching the atmosphere, the wings would be unfolded (right) for point landing control.



long time, creating a heat soak. Tests are conducted with rates of 10 to 100 Btu./sq. ft./sec. to simulate, roughly, the afterbody conditions expected for Apollo. The tests are run in an arc jet tunnel using a cylindrical model with the ablative material as an insert section.

Because radiative heating is sensitive to gas mixtures, Ames is studying the mixtures believed to be representative of planetary atmospheres. The problem is aggravated by the variance in estimates of atmospheric constituency. For example, carbon dioxide content for Venus has been estimated to be anywhere from 10 to 90%.

One of the key facilities at Ames which has resulted in major contributions to the general study of radiative heat transfer from the shock wave is the hypersonic free flight wind tunnel, which has been in operation about one year and is an outgrowth of the supersonic free flight facility that has been operating at Ames for about 15 years. It is devoted primarily to the study of heating problems which Apollo will encounter.

Information is obtained on the radiative power emitted per cubic centimeter of gas behind a shock wave traveling at speeds up to about 40,000 fps. These speeds are obtained from the facility's combination of a shock tunnel and light-gas gun. The facility's capability is expected to be raised to 50,000 fps.

Both the equilibrium and non-equilibrium aspects of radiative heating phenomena are being studied. It has been found that equilibrium radiation quantities can be accounted for conveniently on the basis of existing theory. Non-equilibrium radiative heating phenomena are not understood as well, and one problem is that of scaling. It is doubtful if Apollo has any serious non-equilibrium radiative heat problems.

Ames scientists are working on design specifications for two more larger-scale hypersonic free flight facilities. One will be devoted to the study of radiation and physics of high temperature air in the shock layer. It also will design a combination installation of shock tunnel and light-gas gun for a capability of 50,000 fps. It will permit the use of larger models—up to 1.5 in. in diameter, as contrasted to 0.5-in. dia. models used now—and broader ranges of atmospheric densities to allow detailed studies of non-equilibrium radiation phenomena. The facility will permit attainment of 30,000 psi. stagnation pressure to allow the Reynolds number of entry to be equaled or exceeded.

Hypersonic Behavior

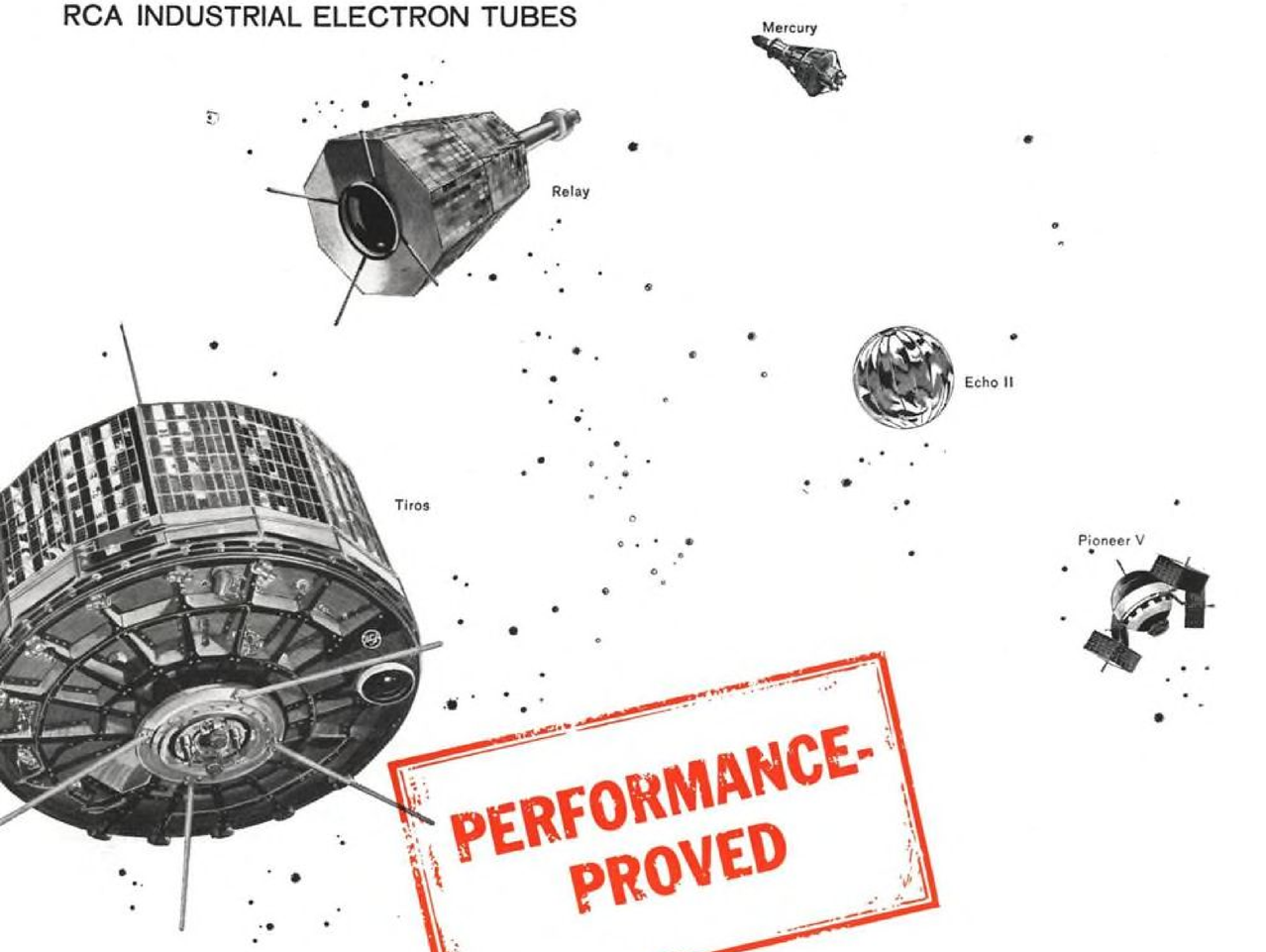
Moffett Field, Calif.—Stability and control problem areas in which hypersonic behavior differs greatly from Newtonian flow predictions have been revealed in the Ames Research Center's free flight tunnel at speeds above Mach 15. These phenomena have been observed:

- Failure of the bow shock wave to be wrapped closely on the after part of blunt-nose bodies.
- Generation of secondary flow fields inside the hypersonic shock layer by flaps or stabilizing flares.

These effects could cause the hypersonic stability and controllability of some entry vehicles—such as the missile warhead configurations—to differ appreciably, even drastically, from what was expected initially. Result could cause tumbling, with consequent failure of the mission due to inadequate heat shielding in the tumbling condition, or structural breakup.

In the case of secondary flow fields generated by flaps, a theory has been derived which indicates that the pressures on flaps and flares can range from one-tenth to three times that expected from Newtonian predictions, depending on the specific situation.

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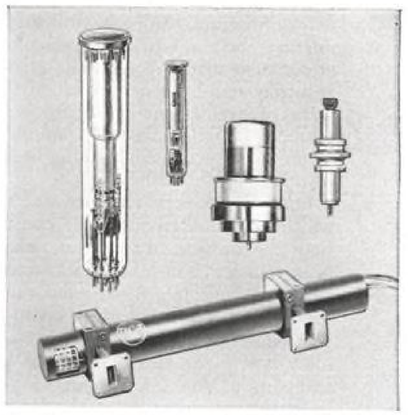
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Ames Aids Apollo Guidance Development

Moffett Field, Calif.—Development of the guidance system for the three-man Apollo spacecraft has channeled Ames Research Center's talents into a supporting function for the Massachusetts Institute of Technology, which has the responsibility for design and development of a prototype system.

Ames research is focused on the midcourse and earth-entry guidance phases of Apollo's flight to the moon and back. The midcourse navigation technique now is fairly firm and has been developed on the ground by simulation. The technique is based on Ames-developed principles stemming from work begun about two years ago, and growing out of experience in similar problems in aircraft flight.

Guidance procedure adopted is considered simple regarding on-board computer requirement. It will use an IBM 7090 digital unit and is known as the reference-trajectory technique, which anticipates the use of a total velocity correction of about 100 fps. This is relatively small, considering the spacecraft injection speed into its escape trajectory of approximately 36,000 fps.

Pre-computation on the ground gives the precise trajectory, based on four-body equations of motion that take into account the effects of gravitational fields of the earth, moon and sun on the vehicle's motion.

Celestial Observations

The midcourse navigation system takes over after the spacecraft is injected into the chosen trajectory for the particular launch time. The celestial observations on which the system is based consist of measuring the angle between a navigational star and the limb (tangent) of the earth, or between another navigational star and the limb of the moon.

In this procedure, the small on-board digital computer calculates what the angle should be between these reference points if the spacecraft were on the proper trajectory. Then, an observation of the same star and limb of the earth (or moon) is taken with a sextant (not hand-held) and the variance from the computed angle is obtained.

Degree of Deviation

On the basis of this difference, the computer calculates the degree of deviation from the reference trajectory. This procedure is repeated perhaps 10 or 12 times at half-hour intervals after the first hour of the trip. Based on these various differences, the computer performs a mathematical smoothing process which calculates the most probable position of the vehicle in space, a result which is more reliable than depending upon a single reading.

Another program in the computer takes this position information and predicts the pre-selected miss-distance from the aiming point at the moon, which may vary from 10 to 100 mi. moon altitude, depending on the specific lunar mission.

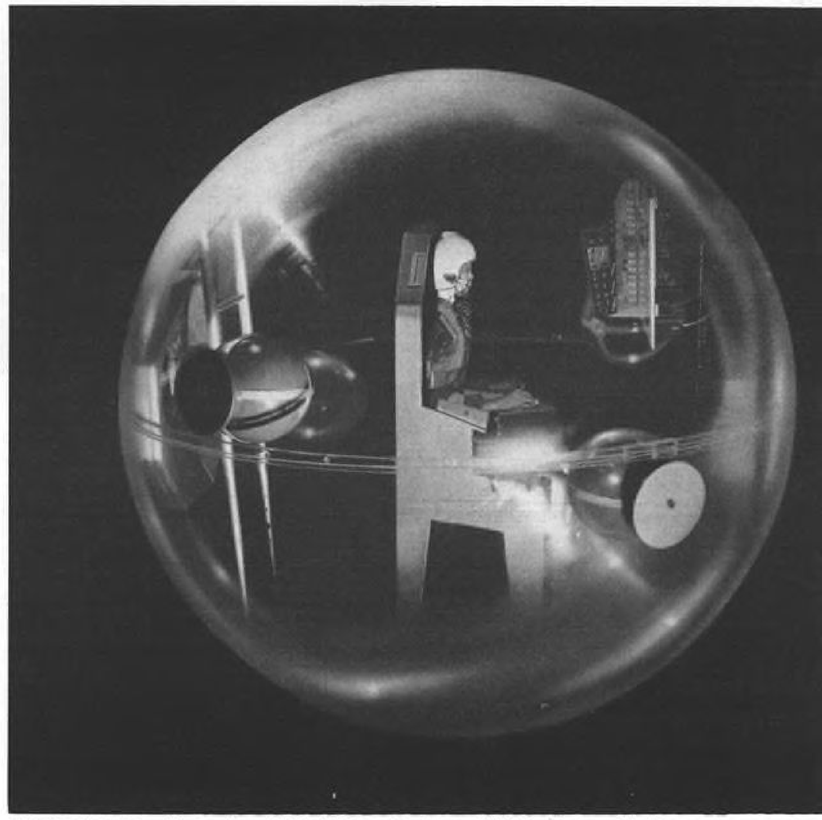
This total procedure is repeated probably once more during the trajectory and again just before the pre-selected aim-point or end-point is reached. After each end-point calculation, the computer determines the required velocity correction to establish a new trajectory to hit the end-point, based on a minimum expenditure of fuel for the correcting propulsion system. It also computes the time downstream when the corrective thrust should be applied and determines precisely how to re-orient the vehicle with attitude jets by specifying when to fire and for what duration.

In the entire application of this reference-trajectory technique, the midcourse guidance system never attempts to return the vehicle to the reference trajectory but attempts to make it meet the trajectory at end-point.

Return from the moon would use the same midcourse guidance technique, but for the earth-entry trajectory, Ames is examining an alternate scheme to the one being programed by MIT. The basic concept of the Ames approach is to enter the "Chapman entry corridor," which varies in depth for every entry vehicle, depending upon its maximum lift/drag capability and ratio of weight to drag coefficient. For the Apollo vehicle, this corridor depth is 38 mi., for a 10g maximum limit on the structure.

Space Window

In effect, the technique establishes a window in space that the midcourse trajectory must hit. If the vehicle enters below (undershoots) the lower boundary, the g-limit will be exceeded, although it is still possible to enter for earth return. If the vehicle comes in appreciably over (overshoots) the top boundary, it will continue on around



ONE-QUARTER scale mockup of the 105-in. dia. Ames Vehicle Motion Simulator.



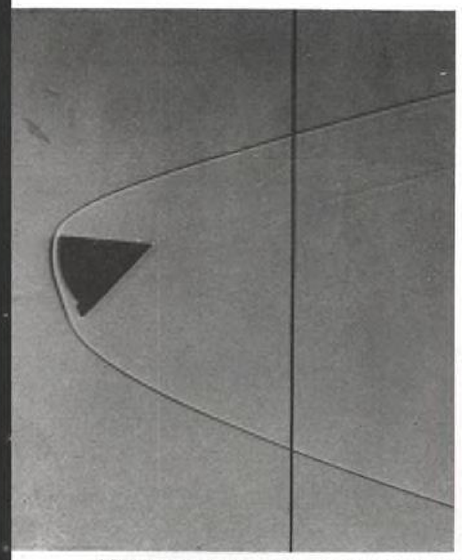
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SCHLIEREN photograph shows preliminary version of the Apollo capsule with a flap control at the corner of the front face. Ames Research Center tested this model before the Apollo configuration was set. Tests were made with the flap control shown at the lower front corner and with an off-center location of the center of gravity.

the earth along the same parabolic trajectory which is used for approach to the earth.

Final Path Control

For the flight to earth from the Chapman corridor, Ames is pursuing the following two schemes to control the path:

• **Repetitive prediction technique.** Considerable pilot simulation work has been done with this technique, and it indicates much promise. Based on present position, velocity, and acceleration of the vehicle, a high-speed digital com-

OSO Instruments

Moffett Field, Calif.—Experimental package on the Orbiting Solar Observatory satellite contains instrumentation developed by Ames Research Center to define the lifetime of temperature-control coatings for spacecraft. Six different samples—four paints and two thin films —are carried to determine the degradation characteristics of each.

Although telemetry from the satellite now is inoperative, information on efficiencies of the coatings had been obtained before its failure. One paint coating had degraded to introduce a temperature change of more than 5 deg. in a period of weeks. This is considered a significant degradation in view of the six-month lifetime which had been predicted for the satellite.





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puter—not likely to be available in the time span required for Apollo—would calculate the trajectory the vehicle would follow and the point on the earth where it would land. This computation would be performed repetitively all along the path, and as the astronaut flew the vehicle according to a display, he would correct in accordance with computer outputs to vary the lift/drag value and roll angle to achieve the desired letdown point. Each time the astronaut made a control correction, the computer would calculate his new trajectory and the display would change accordingly.

• **Reference trajectory technique.** This is similar to the midcourse guidance technique in many respects, depending upon precomputed reference trajectory data stored in the on-board computer, It would not require the speed and complexity of the computer envisioned for the repetitive correction technique and therefore would be available in the Apollo development time-span. This technique also is being simulated for laboratory checkout.

Each system, when fully developed, is expected to allow a landing-selection area on earth that is roughly elliptical, with a major axis of approximately 8,000 mi. and a minor axis of about 2,000 mi. Both schemes are expected to be applicable to follow-on vehicles beyond Apollo.

Lunar Surface Conditions

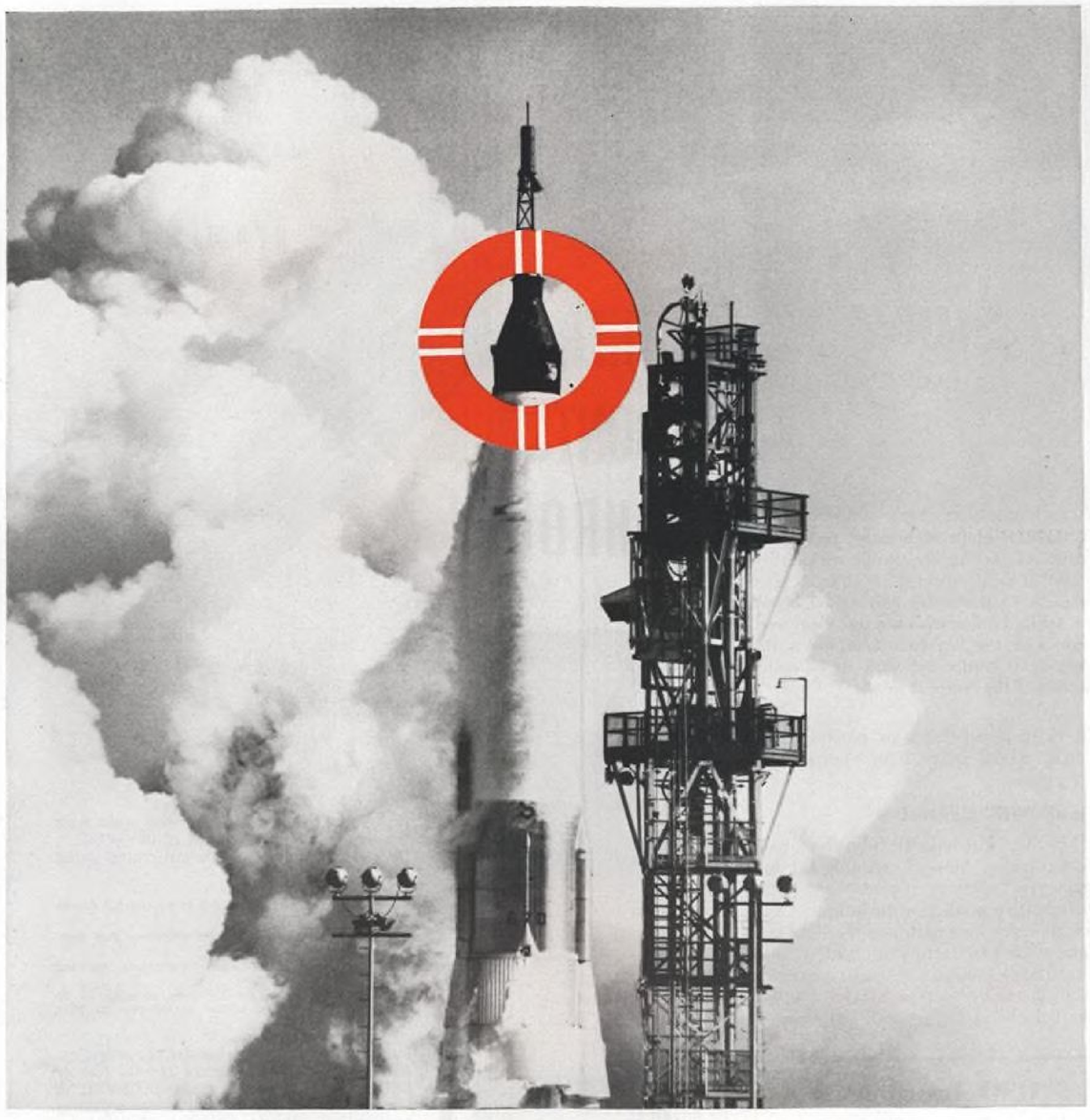
Moffett Field, Calif—Clues to lunar surface conditions that will facilitate the design of spacecraft landing systems and treads for lunar mobile vehicles are being generated in hypervelocity impact studies by the Ames Research Center, in cooperation with U. S. Geological Survey.

The studies are conducted to explore the mechanism of meteoroidal impact and the resulting physical phenomena. Two main materials have been chosen as representative of the lunar surface—basalt for the underlying constituent medium and sand for surface texture material. Conclusions drawn from test data accumulated so far indicate these general lunar conditions:

• Atmosphere of dust exists with a spatial density of 10^5 times greater than the interplanetary debris which caused the dust by impact. This indicates that there is a thin layer of loose, fine powdery material on the lunar surface.

• Lunar surface also is covered with a general rubble of fractured rock ranging in size from microns to large angular blocks.

• Spray from craters formed by impact at oblique angles will lie symmetrically around the crater, instead of in the general direction of the trajectory of impact.



Scott put the LIFEGUARD on the Mercury Spacecraft

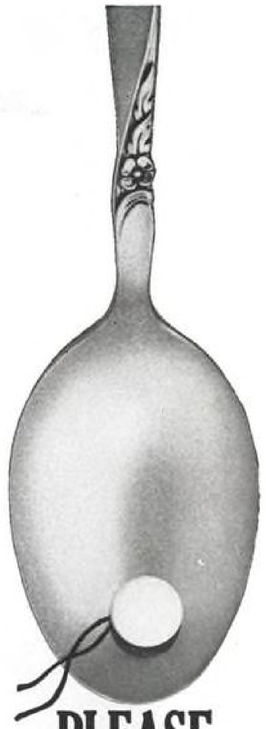
The two-stage Scott regulator used to support the reaction controls system of the Mercury spacecraft played an important role in helping Astronaut John Glenn successfully complete his historic mission and return safely to earth.

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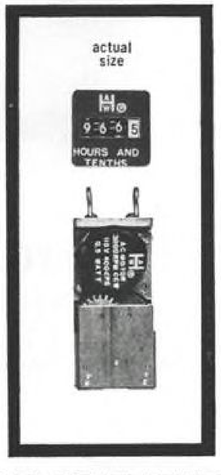
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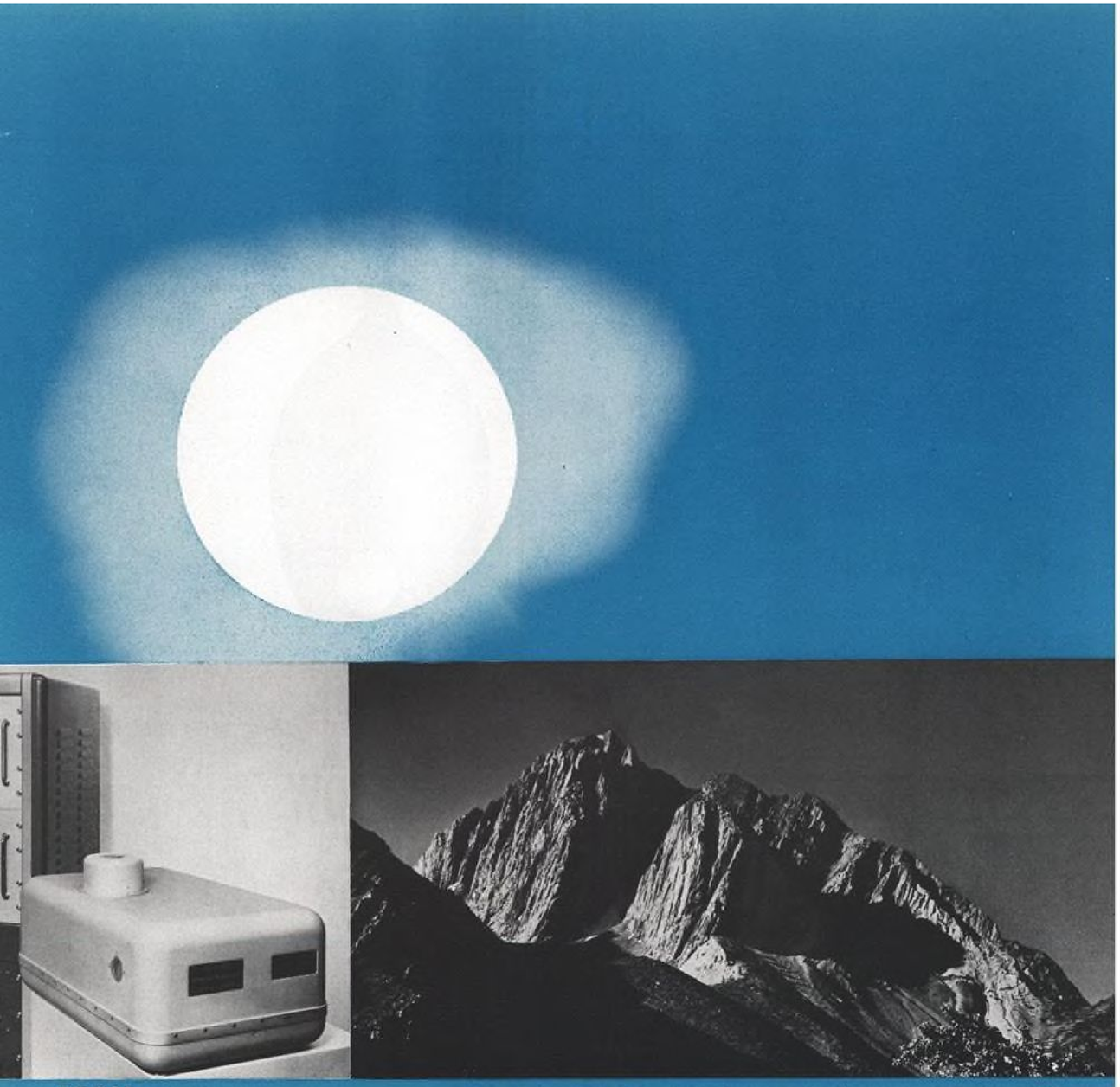
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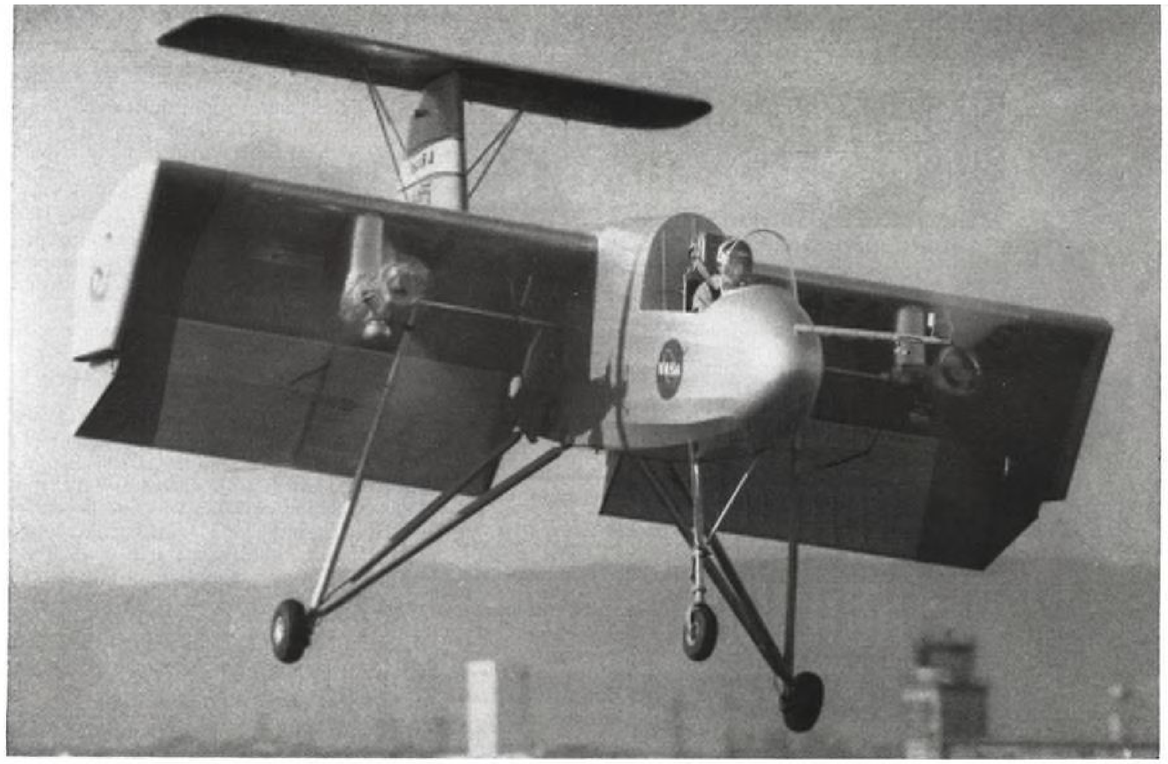
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RYAN VZ-3 deflected slipstream V/STOL flown with thrust axis declined 13 deg. to improve longitudinal trim characteristics.

Ames Studies V/STOLs, Mach 2 Transport

Moffett Field, Calif.—Aeronautical research at the Ames Research Center is exploring two important advanced requirements—V/STOL aircraft for commercial and military operations and the supersonic transport for the next generation of international passenger flight.

V/STOL research is investigating the feasibility of a vehicle to serve as an intercity carrier, in keeping with government thinking on methods to improve the nation's transportation system.

Ames' philosophy is that V/STOL aircraft in general will be operating most of the time in STOL configurations. The center's approach to this operational concept is to extend the helicopter's utility by capitalizing on the good high hovering efficiency of rotary-wing aircraft and increasing its cruising speed appreciably.

One specific approach is to use a tilting rotor concept. Previous flight studies involving the Bell XV-3 Convertiplane disclosed that this approach was feasible except for rotor stability problems in high-speed flight. The XV-3 has good hovering characteristics, low-downwash velocities, and good transition characteristics at low speed—hence Ames' approach is to improve rotor stability to extend operation into the relatively high-speed regime of 200-250 kt.

Rotor modifications have been made to the XV-3 and the aircraft will be tested in the Ames 40 × 80-ft. tunnel and in flight. If these modifications—increasing the Delta 3 value (flap-pitch coupling ratio) to as high as 45 deg., and the addition of restraint springs to the rotor system—are successful, Ames will consider extension of XV-3 performance by installation of a turbine engine to explore possible problem areas at higher speeds. But this turbine-version XV-3 would require support of the military services for a comprehensive operational test and development program.

Reverse Approach

Another approach to the intercity service configuration reverses the basic conditions of the XV-3 by starting with a good forward speed capability and designing a good vertical capability into the configuration. This scheme involves modification of conventional-type aircraft in successive steps to reduce the approach speeds and, as a consequence, the landing area requirements. First step is to improve the lifting system of the flaps and increase the thrust/weight ratio of the engines. Some progress in this direction has been made with the BLC (boundary layer control) version of the Lockheed C-130B (at Ames) and the Breguet 941 deflected slipstream-type plane.

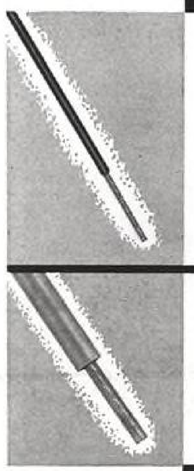
The BLC-version of the C-130B cuts the landing distance of the conventional C-130 by half, but tests have disclosed that handling qualities—controllability and steep approach capability—must be improved for operational use.

Ames researchers are examining the potential of the BLC-version with the use of a piloted landing approach simulator to determine which aerodynamic parameters require improvement and to what extent stability and damping augmentation will be required.

Simulator tests so far have indicated areas of modification. Incorporation of specific changes into the aircraft and flight tests are the next steps being considered. Target is to obtain landing speeds of the order of 50 kt. and landing rollouts of the order of 500 ft. This would be unusual low-speed performance for an aircraft of this size—120,000 lb. gross weight—which ordinarily uses an approach speed of about 100 kt., coupled with a landing roll of 1,200-1,500 ft.

Next stage with this configuration would be to improve wing lift and in-

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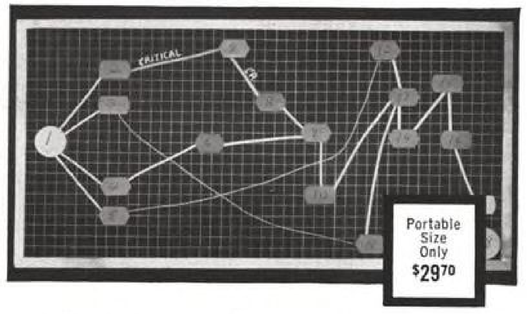
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crease thrust/weight ratios. This would require more sophisticated control—for example, the use of propeller pitch for lateral control, which might require shafting interconnection of propellers to eliminate asymmetry at low speeds.

A succeeding step for further improvement in takeoff and landing performance would be to provide a flapped-tilt wing with provision for slipstream coverage of the entire span. This effort is aimed at ultimately obtaining a vertical takeoff capability—possibly in a normal test and development period of about three to five years.

Successful development would permit a much larger gross weight V/STOL aircraft than the tri-service transport, which is projected for flight in 1963 but probably will not be operational until 1965. Ames will be performing simulation studies and 40 × 80 ft. wind tunnel tests of this tri-service configuration. It is likely that this work and the studies on the BLC version of the C-130B will produce data for reciprocal improvement of both.

Ryan, Bell Vehicles

Flight tests of the Ryan VX-3 deflected slipstream configuration are now under way at Ames to examine the stability and control problems in the low-speed regime.

Ames also has been using the Bell X-14A in its V/STOL studies. The aircraft employs the deflected thrust principle. This aircraft, which has been fitted at Ames with two General Electric J85-5 engines to increase performance and supply sufficient air for the reaction nozzles, also has been modified to include variable stability and control features. This configuration is expected to provide:

- **Exploration of possible problem areas** of a specific V/STOL design before it would be flown.
- **Derivation of acceptable control** characteristics applicable to any V/STOL aircraft.
- **Opportunity to evaluate** applicability of the X-14 principle in lunar landing studies. Feeling is that the jet lift and reaction-control concept generally is similar to that envisaged for lunar letdown.

As now contemplated, a possible program would consist of a trajectory study coupled with an investigation of control characteristics. The trajectory study would include an approach to touchdown from an altitude of 3,000 ft., in both vertical and near-vertical trajectories.

Time and fuel involved in descending from a given altitude to a point on the ground would be of interest, assuming that vertical velocity judgment would be left entirely to the pilot. Second phase of the study would consider the effect of the control char-

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Gordon Handberg, Aerospace Development

(Formerly of Fort Worth, Texas)

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Don Drung, Marine Systems

(Recently from Ohio)

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Dale Gunderson, Computer Systems Research

(Recently from New Jersey)

"The Aeronautical Division of Honeywell offers me a lot of opportunity for advancement in my field of interest . . . computers. Incidentally, Minneapolis is one of the leading computer centers in the country. Besides, we enjoy the advantages of this area: Uncrowded conditions (I live just 10 minutes from work in a really nice suburb), first rate schools, outdoor life."



Sheldon Sorensen, Data Proc. and Comp.

(Native Minnesotan)

"First, as a mathematician I felt Honeywell offered me challenging and financially rewarding work. Second, here the individual is important. Third, the area has all the cultural and social advantages of the largest cities in the country (big-league sports, symphony, art centers, top level schools, etc.) yet manages to maintain a warm, friendly atmosphere."



Norman Schamber, Evaluation Engineer

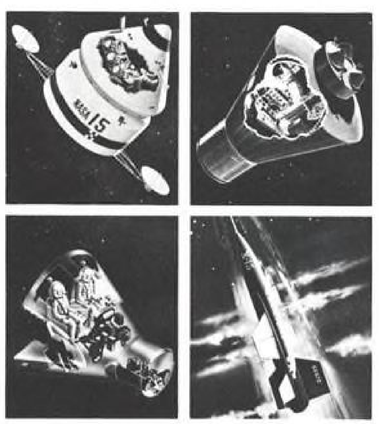
(Recently from Utah)

"I knew that at Honeywell I'd be working on challenging engineering problems. I also knew that if I could help solve them, this is the kind of company that would give me recognition and advancement. In addition, this is a fine section of the country to live in, especially from the standpoint of education facilities and the caliber and stability of the people."



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LOCKHEED NC-130B with blowing-type boundary layer control on wing and tail surfaces is tested at Ames. Tests with improved system indicate increased performance gains with flap deflections beyond 70 deg., need for stability augmentation.

acteristics (aircraft response-damping) on the ability to carry out the approach and landing.

Because the thrust required for hover in the lunar environment would be considerably reduced, the achievement of the given horizontal acceleration for a given mass would require that the thrust vector be tilted farther in the lunar environment, compared with the requirement near the earth.

The aerodynamic characteristics peculiar to a winged vehicle such as the X-14A could be eliminated in the earth tests by the variable stability and control features incorporated in the aircraft.

Supersonic Transport

Supersonic transport research at Ames is part of a coordinated NASA in-house effort, mainly in aerodynamics and structures, being done with Federal Aviation Agency funding under the joint FAA-NASA-Defense Department program. Research here is concerned with preliminary investigation of control characteristics of various configurations.

Prime objective of the joint program is to amass sufficient information by mid-1963 that the three agencies will be able to make a recommendation on the advisability of further government support for supersonic transport development, based on both financial and technical considerations.

Feasibility of the supersonic transport for flight at Mach 3 has been established. Research now is directed at defining components and integrating these into a transport configuration which would be a money-earning machine capable of safe operation.

Although the supersonic transport



BELL XV-3 in tests of effect of large flapping hinge deflection angles and flapping springs on dynamic stability at high speeds.

New lithium developments at Foote Mineral offer new boost to aerospace programs

The properties of lithium metal and lithium compounds have long received consideration in the field of aerospace technology. However, certain problems, including handling, containment and corrosiveness at high temperatures, have deterred its broad use.

Now, with assistance from new technological developments at Foote Mineral Company, it is possible to use the unique properties of lithium metal and lithium hydride in many areas of heat transfer, propulsion, heat shielding and radiation shielding. Some of the applications, and the available lithium compounds, are listed below.

First in importance is the development of a lithium metal of unprecedented purity, 99.98% pure. Because Foote has successfully reduced nitrogen in the metal to less than 40 ppm, corrosion is markedly lessened and the metal has been safely contained and circulated at temperatures as high as 1600°F. With use of refractory metals, or special alloys in container walls, operation at higher temperatures, up to the boiling point of lithium (2403°F), may be achieved in the future.

Second: problems relating to delivery of metal without contamination have been essentially solved. Now, new handling techniques retain the purity from production through utilization. Foote can supply high-purity lithium in special containers—or will fill your container, from which it can be transferred, molten but uncontaminated, to your system. We also offer special metal products of high-purity lithium. For example . . . machined shapes, wire, strip, rod, ingots, castings, dispersions.

A third major area is the development of many other types of lithium compounds of value to aerospace projects. For example: lithium hydride, also produced in high-purity form at Foote. Because it has excellent heat of fusion and vaporization properties, pure lithium hydride is of value as a heat sink and coolant. Its neutron cross section and its low density are important to radiation shielding, while its chemical properties find applications in fuel cell design. Because lithium hydride produces high specific impulses when used with certain oxidizers, it is a candidate for use in new propellant systems. Lithium is advantageous from an ignition standpoint since it ignites reliably with oxidizers under many conditions.

Our research and development programs embrace the applications listed in the chart below. If one of these areas is of special interest to you, please contact us. We will very likely be able to assist you. And you will also find these technical data bulletins of interest. A letterhead request will bring them to you. Bulletin 101, Lithium Metal; Bulletin 102, Lithium Hydride; Bulletin 110, High-purity Lithium Metal. Foote Mineral Company, Department 402, Route 100, Exton, Pennsylvania.

APPLICATIONS	Lithium Metal	Lithium Hydride	Lithium Fluoride	Lithium Chloride	Lithium Bromide	Lithium Aluminum Alloy	Lithium Oxide	Lithium Peroxide	Lithium Hydroxide	Lithium Perchlorate	Lithium Glasses*
FUEL GRAINS	●	●				●				●	
HEAT TRANSFER	●										
HEAT SHIELD		●	●								
FUEL CELLS	●	●		●	●						
RADIATION SHIELDS		●									●
ENVIRONMENTAL CONTROL							●	●	●	●	
HEAT SINK		●	●								
BUOYANCY TANKS	●										

*Neutron Absorbing

Partial list of applications for lithium-metal compounds shows how world of lithium is expanding. New applications and compounds are constantly being developed at Foote Mineral Co.

PROPERTIES	Lithium	Sodium	Potassium	NaK Eutectic
DENSITY (20°C)	0.534	0.9712	0.87	0.775
MELTING POINT °C	179	97.8	63.7	—12.3
BOILING POINT °C	1317	883	760	784
MOLTEN RANGE °C	1138	785.2	696.3	796.3
LATENT HEAT OF FUSION (Cal/gm °C)	158	27.1	14.6	17.5
LATENT HEAT OF VAPORIZATION (Cal/gm °C)	4680	1005	496	600±10
THERMAL CONDUCTIVITY (Cal/sec-cm °C) Liquid	0.09 (220°C)	0.195 (200°C)	0.107 (200°C)	0.059 (200°C)
HEAT CAPACITY (Cal/gm °C) Liquid 600°C	1.0	0.31	0.183	0.2092
VISCOSITY (Centipoises) 300°C	0.440	0.335	0.230	0.276
THERMAL NEUTRON CROSS SECTION (barns)	71±1	0.505±.01	1.97±.06	1.7

Key properties of lithium versus other alkali metals demonstrates its advantages as heat transfer medium. Liquid lithium has a very high heat capacity, making it an extremely effective coolant.

ANALYSIS	Reactor Grade High-purity Lithium	Commercial Lithium
LITHIUM	99.98%	99.88%
SODIUM	0.0030	.01
CALCIUM	0.0005	.0001
IRON	0.0014	.01
POTASSIUM	0.0029	.007
ALUMINUM	n.d.	.005
SILICON	0.0005	.001
CHLORIDE	0.0035	.01
NITROGEN	0.0037	.01

High-purity lithium costs very little more than conventional lithium. High-purity form is sold at approximately 10% premium over regular grades.

Theoretic Performance—Specific Impulse of Li-F_2 Versus H_2-O_2, H_2-F_2		
Fuel	Oxidizer	Specific Impulse, Sec
Li	F_2	335[a]
H_2	F_2	370[a]
H_2	O_2	363[b]
JP-4	O_2	262[b]

a 300 psi chamber to 14.7 psi ambient
b 500 psi chamber to 14.7 psi ambient

Lithium ignites reliably with oxidizers under many conditions.

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originally was projected as a Mach 3 intercontinental, 3,500-naut.-mi.-range design, Ames researchers now feel that data obtained since these guidelines were established point to initial operation at lower speeds—perhaps Mach 2 or slightly better—and over shorter, or continental stage-lengths.

This would permit earlier operation, possibly using interim engines which would be modifications of existing powerplants. This approach also would furnish some flight experience toward the Mach 3 capability, and a Mach 2 transport could be ready for operation in time—perhaps 1968—to meet foreign competition.

The Mach 3 transport begins to approach the limit of reasonable benefit with regard to time saved at high speeds, considering the flight ranges involved. Time spent in cruise becomes so small that the increased cruise speed would result in little reduction of overall flight time.

Engine, Stability Problems

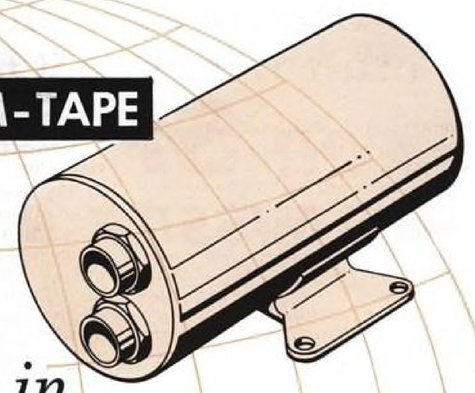
One major technical problem in the investigation at Ames has been development of an engine air inlet to provide the airflow required over a wide range of altitudes and flight speeds with a minimum penalty to the plane's drag characteristics. The problem boils down to a stringent matching compromise between inlet capability and engine demands.

Because basic aerodynamic damping of the supersonic transport will be less than that of its subsonic counterpart, some type of stability augmentation will be required. Ames researchers have established the aerodynamic damping levels through wind tunnel tests of supersonic transport models and this has provided data for the simulator program (AW Apr. 16, p. 52) in which Ames has investigated the problems a pilot would experience in controlling the aircraft, both with and without stability augmentation.

Other critical factors are landing approach and touchdown speeds. It's generally agreed that these will not be allowed to exceed those of the present subsonic jet transports, but the aim of the researchers is to reduce these speed values for the supersonic transport, if possible. Guideline has been that the transport would have to operate off runway lengths of existing major jet terminals.

To study the landing speed problem, Ames researchers have been conducting tests in the 40 × 80 ft. wind tunnel of representative configurations, to develop low-speed, high-lift capabilities. Preliminary results have been encouraging, indicating that it will be possible to hold landing speeds of the aircraft to the order required—about 140-145 kt.

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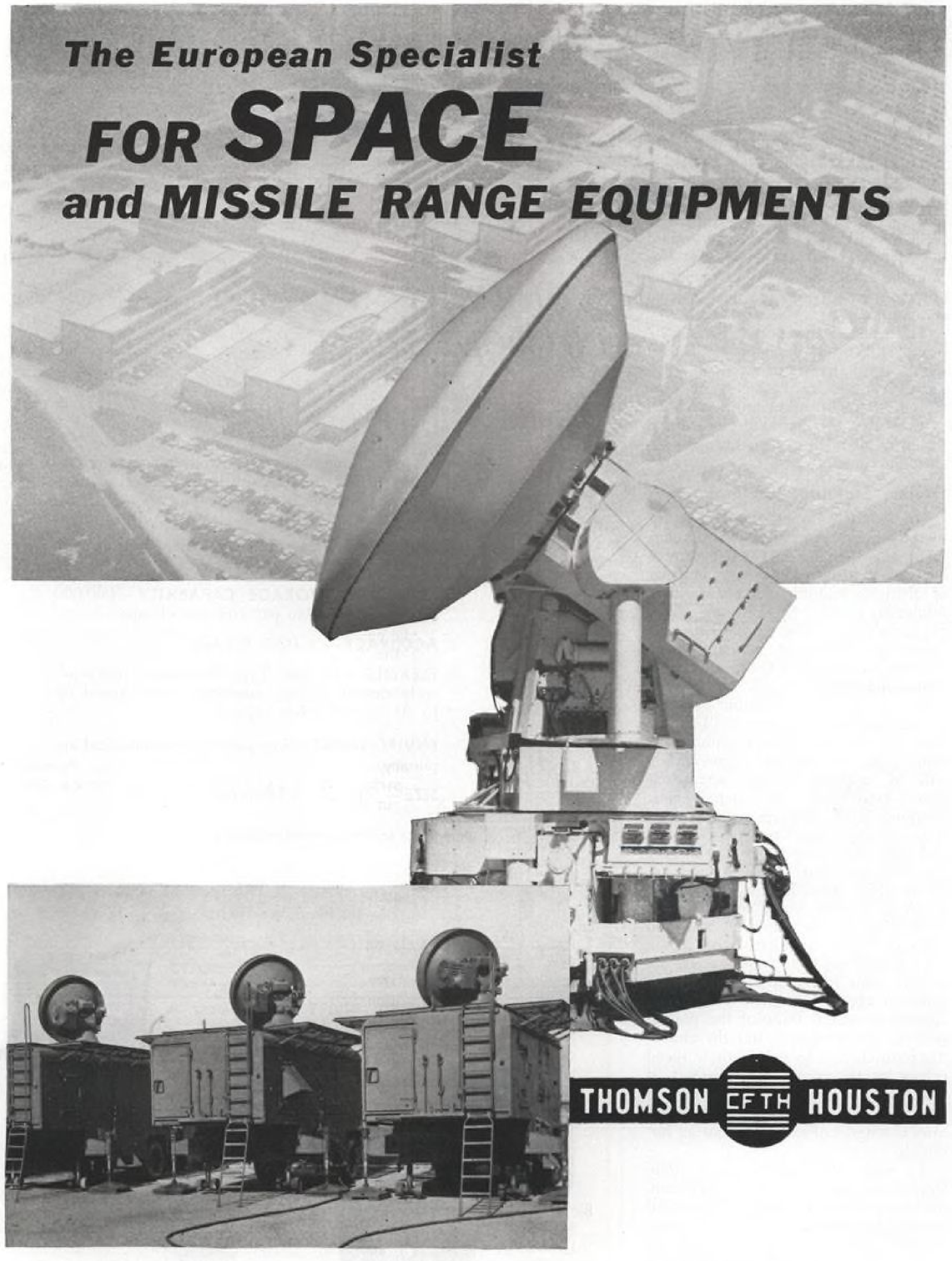
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Ames Advances Life Sciences Lead Time

Moffett Field, Calif.—Life Sciences Research Laboratory at Ames Research Center has responsibility for the major effort in this type of work for National Aeronautics and Space Administration. Goal is to develop a degree of competence in the life sciences, so that data generated through its research will be ready at least five years ahead of programs which require this new knowledge.

Laboratory's activities will span the fields of exobiology, environmental biology including physiological and behavioral sciences, and biotechnology, which will be the versatile function of crossover between biological and physical sciences.

One indication of the practical application of the laboratory's work will be in its responsibility for the "manned portion" of the guidance and control function and displays for the Apollo spacecraft. This manned portion includes analysis of psychological (performance), physiological (human system itself), and social aspects of the astronauts. Stress tolerance studies at Ames already have produced a technique for detecting physiological and psychological changes in man before they can be determined by his performance. This includes the ability for measuring a millionth unit of vasopressin, which is one of the first biochemical units to respond in a stress situation.

Research Program

Laboratory now is performing research programed to lead to development of selection and training criteria for succeeding groups of astronauts.

By the end of this year, the laboratory will have doubled its staff from a strength of about 80 to approximately 160 scientists. Although this might be considered a comparatively slow build-up, considering the extent of scientific investigations, the expansion of personnel has been programed solely on a basis of need.

Plan is to manage the responsibility for life science research in NASA in three ways:

- **Build an in-house** research capability in areas not presently covered in the U. S. national effort.
- **Transfer life science research,** on a task basis, to the three military services and other government agencies on the basis of what each is capable of performing.
- **Utilize, through research** contracts and grants, the entire national capability in universities, industry and research institutes. Through this medium, especially with universities, NASA hopes to stimulate education in space-relevant areas. About 90 grants and research contracts already have been issued to universities and other research organizations.

Major in-house effort for the next few years at Ames will be in the search for extra-terrestrial life (under Exobiology Division), brain mechanism research (Environmental Biology Division), and utilization of man and his display system (Biotechnology Division).

There also are miscellaneous related problem areas which Ames will study in-house. For example, one of these will be the effect of the heavy cosmic primary rays in space, which are not getting adequate evaluation elsewhere in government or private agencies, Ames researchers feel. While Atomic Energy Commission and Air Force will carry on the major portion of the nation's radiobiology program, their efforts do not include assessment of the effects of heavy cosmic primaries of the magnitude which is of specific interest to NASA.

Thus, for the past two summers, NASA life sciences activity has been carrying out a balloon flight program to study the biological effects of heavy cosmic primaries. This summer, four missions will be flown, each carrying about 500 lb. of experiments suspended from the balloon. The flights will be the longest (56 hr.) at the programed altitude (127,000 ft.) and latitude. Launch will be from Goose Bay, Labrador, and recovery is anticipated on the prairie country north of Edmonton (Alberta). Primary experiment will be exposure of simians to heavy cosmic primaries, with the brain as the target for investigation. The animals will be monitored physiologically. Other experiments on these flights will include microbiological specimens for study of genetic aberrations, biophysical instrumentation for the measurement of the components of the radiation spectrum. Universities and government agencies will conduct these experiments jointly.

Ames has submitted to NASA headquarters a development plan for carrying out recoverable orbiting biological ex-

Life Sciences at Ames

Life Sciences Laboratory, a relatively new activity at Ames Research Center, is programed to perform studies and experiments to develop data for over-all use in NASA in the following scientific regimes:

Exobiology
- Life on other planets
- Life synthesis
- Molecular biology
- Instrumentation for search and identification of extra-terrestrial life

Environmental Biology
- Effects of environments on earth organisms
- Ecology
- Bio and organic chemistry
- Bacteriology, virology, and immunology
- Zoology, botany
- Biological rhythms and performance
- Genetics

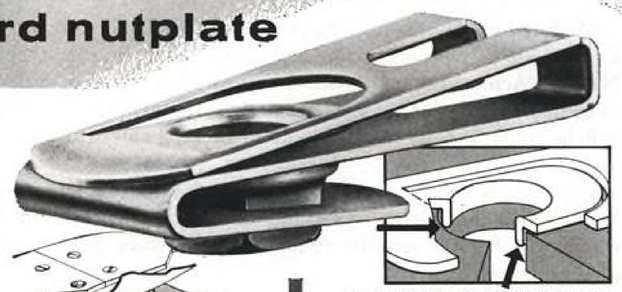
*Physiological and Behavioral Sciences
- Manned space flight research
- Performance and utilization potential of man
- General physiology
- Experimental pathology, endocrinology, neurology, psychology
- Brain mechanisms research

Biotechnology
- Man-machine integration
- Life support, personal equipment, crew accommodation, nourishment, gaseous and temperature control, radiation protection, waste disposal.
- Utilization of man, selection, training, integration, control, monitoring, maintenance, scientific observation.

* Work will be conducted under Environmental Biology

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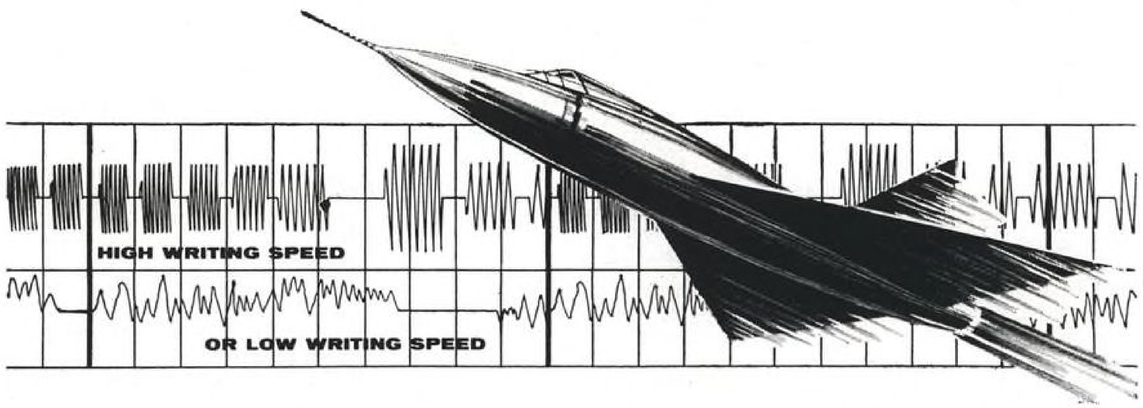
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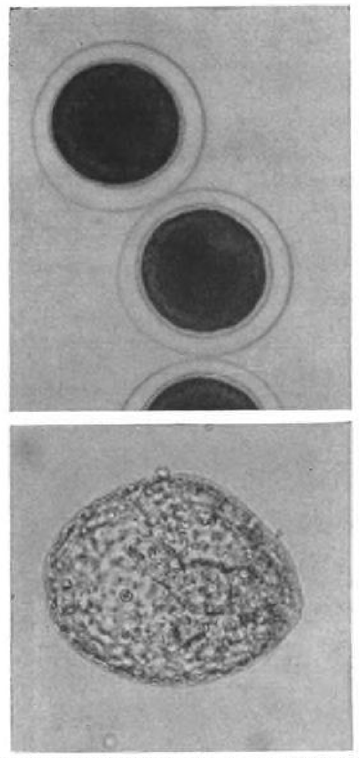


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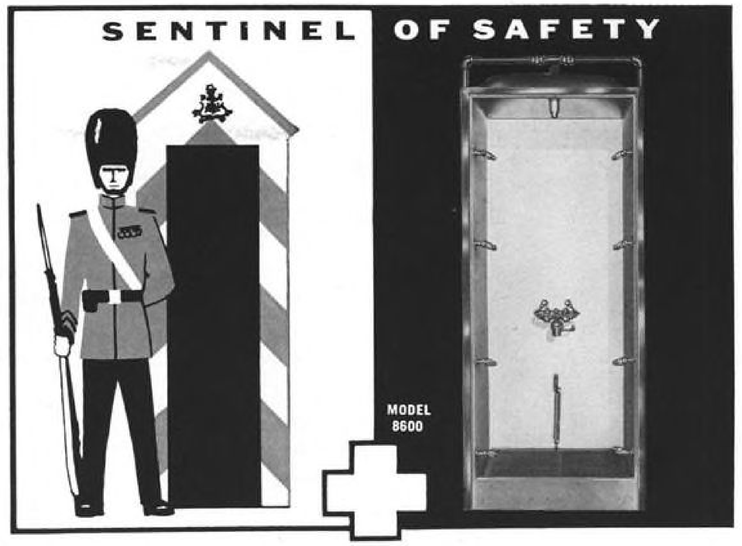
SEA URCHIN EGGS, shown magnified 400 times, are utilized in space probes to study the effects that zero-gravity has on fertilization and cell division.

periments. This would require an Atlas Agena boost vehicle for low earth-orbits of 7 to 14 days duration. The experiments are designed to be fully integrated so as to understand the complete effects of space environment on the biological system—essential for a sound manned space program. While the experiments have been approved by NASA, the spacecraft has not yet been approved. Two spacecraft are planned for the program. A chimpanzee is the first choice for the passenger, but if weight becomes critical a pigtail monkey will be utilized.

Although the Ames life sciences group is not charged with competence in life support systems, the group will develop this capability to the extent that it will be able to exercise responsibility for the integration of relevant data from industry, Air Force and Navy into any total manned system. Under this responsibility, Ames will award contracts for life support systems, monitor development of the prototypes and generally collate all life support data for industry and military service use.

Air Force and Navy have personnel at Ames to conduct liaison with the Life Sciences Laboratory so that these two military services and NASA may facilitate coordination of information.

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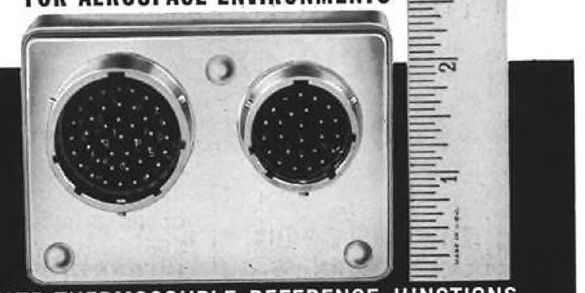
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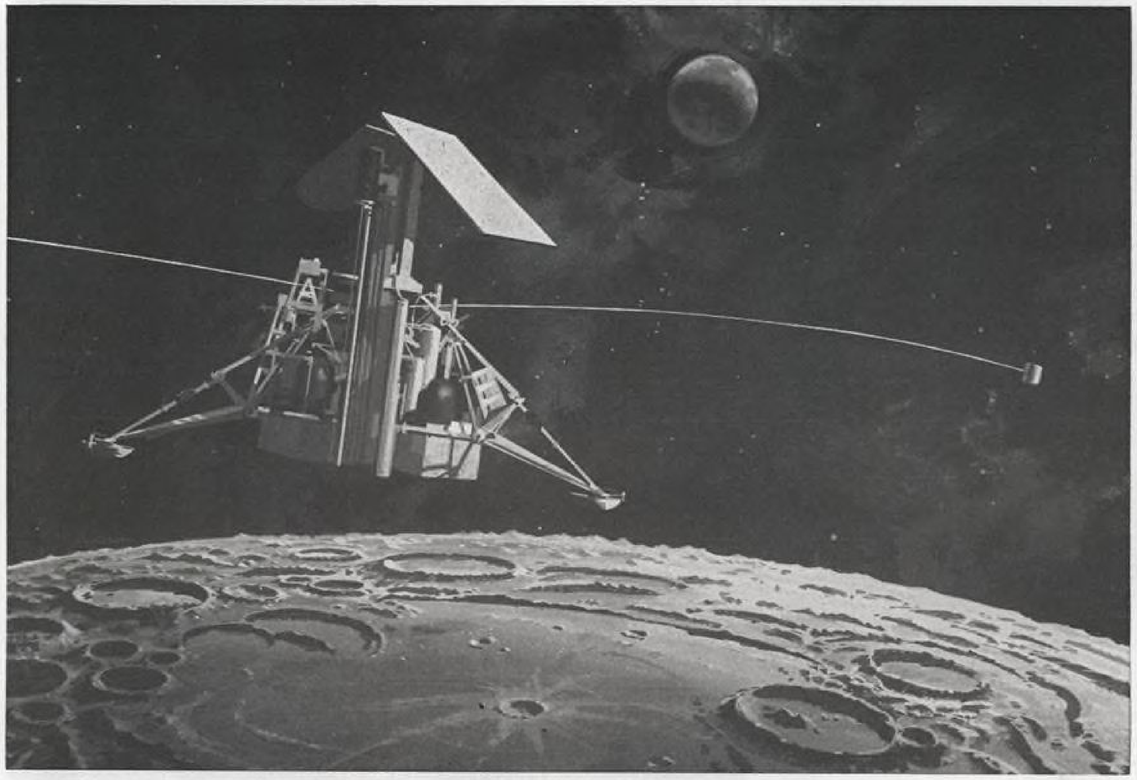
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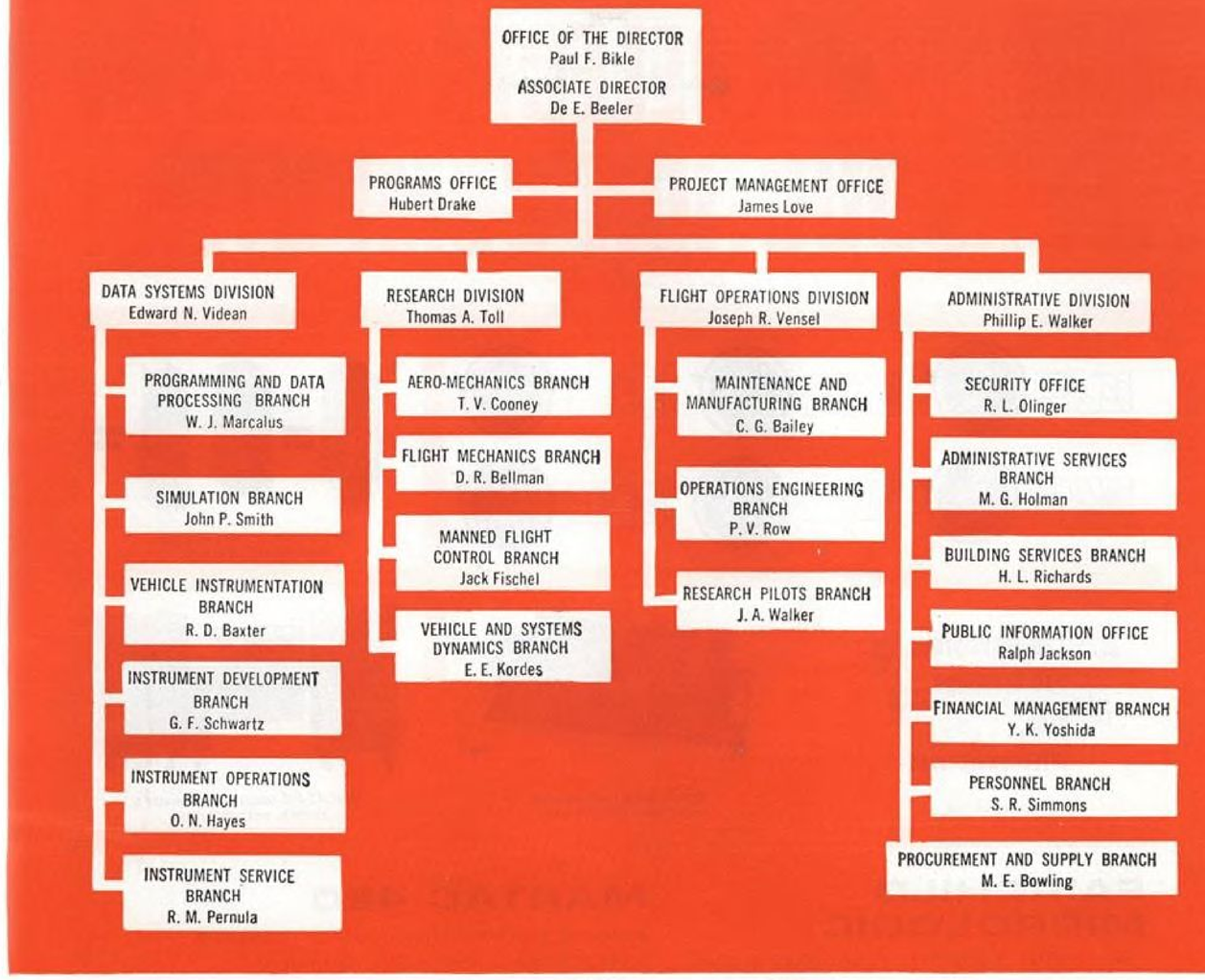
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Flight Research Center



Flight Research Spans Velocity Spectrum

Edwards, Calif.—Aerodynamic investigation of piloted aircraft at the National Aeronautics and Space Administration's Flight Research Center embraces both ends of the speed spectrum, from the hypersonic rocket-powered X-15 to the powerless paraglider, which so far has reached a maximum speed of 55 mph.

By far the bulk of the talent, energy and money expended here goes to support the X-15 project which is managed by NASA, although 80% of the project's funds are provided by the Air Force. Since the first powered flight of an X-15 by North American Aviation test pilot Scott Crossfield on Nov. 15, 1960, the three testbeds have been carried aloft by a modified Boeing B-52 bomber nearly 100 times and have made more than 50 powered flights.

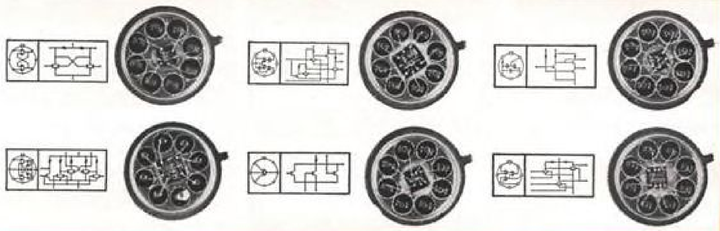
The performance envelope of the aircraft has been stretched to Mach 6.04 and to an altitude of 247,600 ft.—man's fastest and highest flights in a fully controllable vehicle.

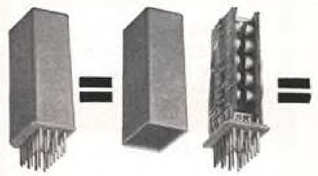
Still greater feats are in store for the X-15, and although NASA will not say how high nor how fast future flights will be, wind tunnel models of the aircraft have been tested to Mach 7 and unofficial estimates put the maximum altitude at 500,000 ft. (AW Nov. 20, p. 52).

Flights for the sake of exploring the behavior of the machine itself probably will be completed early in 1963 but the program has been so successful that 35 follow-on flights have been scheduled.

In addition to the basic research objectives—aerodynamic heating, operational and control problems, biomedical data on pilots, hypersonic aerodynamics and structures and exit and re-entry investigations—the follow-on program will use the X-15 as a platform for other engineering and scientific studies. Despite a per-flight cost of $300,000, the recoverable X-15 is cheaper to use than some of the unmanned probes that might perform the same tasks. Experiments will include ultraviolet stellar photography, tests on a horizon scanner to develop an attitude control system, use of an alphatron ionization gage for

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density measurements above 100,000 ft., and testing of an electric control stick and a letdown computer slated for use in the Air Force Dyna-Soar boost glider program, for which NASA provides considerable technical support.

The follow-on program will require continued use of the facilities built to support the current program. These include the High Range, a flight corridor extending from Wendover, Utah, to Edwards. Consisting of communications and tracking equipment for precise monitoring of X-15 flights, the High Range is maintained by Bendix Corp. under a NASA contract.

Periodic inspection must be made of the numerous dry lakes along the range, which are used as alternate landing sites in the event of an emergency. The effort expended in inspecting and maintaining emergency landing sites paid off last January when Navy Cdr. Forrest S. Petersen, unable to get engine ignition because of a faulty pressure switch after the drop from the B-52, jettisoned his propellants and landed the X-15 on Mud Lake.

Paul F. Bikle, director of the Flight Research Center, cites Cdr. Petersen's successful landing of the multi-million dollar research craft at a remote site as one example of the superiority of man over the computer in the still-raging battle of the manned machine vs. the "black box." Bikle probably is one of the industry's strongest proponents of manned machines, stemming from his long association with flight test activities that began at Wright Field in the early days of World War 2.

Bikle said he has "lost a battle but not the war" in the controversy over whether the pilot should be given control of the booster rockets used for ultra high speed flight. Proponents of completely automatic flight argued that if a pilot were put into the control loop, he would send too many control inputs to the thrust vector control system, increasing the probability of failure.

Bikle argued that a pilot could do the job smoother and with fewer inputs than an autopilot system. A simulator study of this problem, made by the Martin Co., bore him out, he said. Despite the vibration, noise and acceleration during the boost phase of flights in vehicles such as Mercury or Dyna-Soar, Bikle believes that pilots could control the flight path with fewer inputs than could an autopilot. He predicts that control of the boost phase eventually will be given to the pilot, perhaps with an autopilot backup.

Tests with the X-15 tend to support Bikle's faith in a pilot's ability to control. Flight profiles actually flown have come very close to planned profiles. This is especially impressive in view of the fact that a misalignment of one degree in attitude can result in a 10,000 ft. error in target altitude.

Flight Research Center

Edwards, Calif.—Flight Research Center's operating budget for Fiscal 1963 totals $9.7 million, an increase of $2.5 million over the previous year, and new construction valued at $1.8 million has been requested. The center occupies 170 acres under permit from the Air Force, and will employ 550 during the current year. This is 56 more than Fiscal 1962. Plant value is $9.9 million.

Nevertheless, pilot control over the aircraft under all flight regimes is not always possible without some stability augmentation. For example, tests revealed that at a high angle of attack, such as that experienced during re-entry at a speed of about Mach 3.5, the X-15 would enter into a divergent yaw maneuver that the pilot could not control if the stability augmentation system failed.

Simulator flights revealed that the maneuver could be controlled if the pilot put in aileron opposite to yaw. Control system parameters identical to this condition were put into a variable stability North American F-100, used by Flight Research Center for such purposes, and the pilots tried this technique. It did not work in the air as it had in the simulator, primarily because it required a maneuver alien to the pilot's natural reaction. As a result, a backup stability augmentation system was installed in the Number One and Number Two X-15s. Number Three already had an adaptive autopilot with backup systems.

Part of the increase in research and development will go for construction and operation of a dynamic lunar landing simulator, to be built by Bell Aerosystems Corp. NASA's Manned Spacecraft Center recently released $300,000 to the Flight Research Center as initial funding. The program is expected to cost $5 million over the next several years.

Simulator work generally is done by the Ames Research Center at Moffett Field, Calif., which has an extensive supersonic transport simulator program (AW Apr. 16, p. 52) or the Langley Research Center at Hampton, Va. However, the nature of the dynamic lunar landing simulator requires the natural geography of the Edwards AFB area.

Repeated tests will be made to investigate the piloting problems connected with landing on the moon. This will be simulated by making approaches onto the dry lake bed from an altitude of about 5,000 ft. Necessarily, the moon landing simulations will take place in clear weather on calm days, and Edwards presents the ideal topography for the mission. A vehicle such as the lunar landing simulator would hardly conform to airport traffic procedures, making the use of Edwards almost mandatory.

The 18-ft. high simulator will resemble an outsized foot stool. It will have four truss-type legs with shock struts attached. The pilot will ride in an encapsulated cockpit, in a zero-altitude, zero-velocity ejection seat, facing a display panel.

Initially the simulator will be a one-man vehicle, but brackets, etc., will be included so a second seat can be installed, making it a two-place trainer. Adding dual controls will be simple since the system will be fly-by-wire.

A General Electric CF-700 turbofan engine will provide thrust equal to 83% of the vehicle's weight. This is calculated to simulate the weight the vehicle would have under lunar gravity, which is 17% that of the earth's. The engine will be gimbaled so that its thrust vector is always directly opposed to gravity.

Typical moon landings will be simulated by starting a descent from an altitude of about 5,000 ft. Thrust of the engine will cause the descent velocity to approximate closely that which would be experienced on the moon. The pilot will control the simulator's attitude through a control system linked with four hydrogen peroxide attitude control jets, located on each of the four landing legs. Deceleration rockets will be used to brake the rate of descent at the proper time.

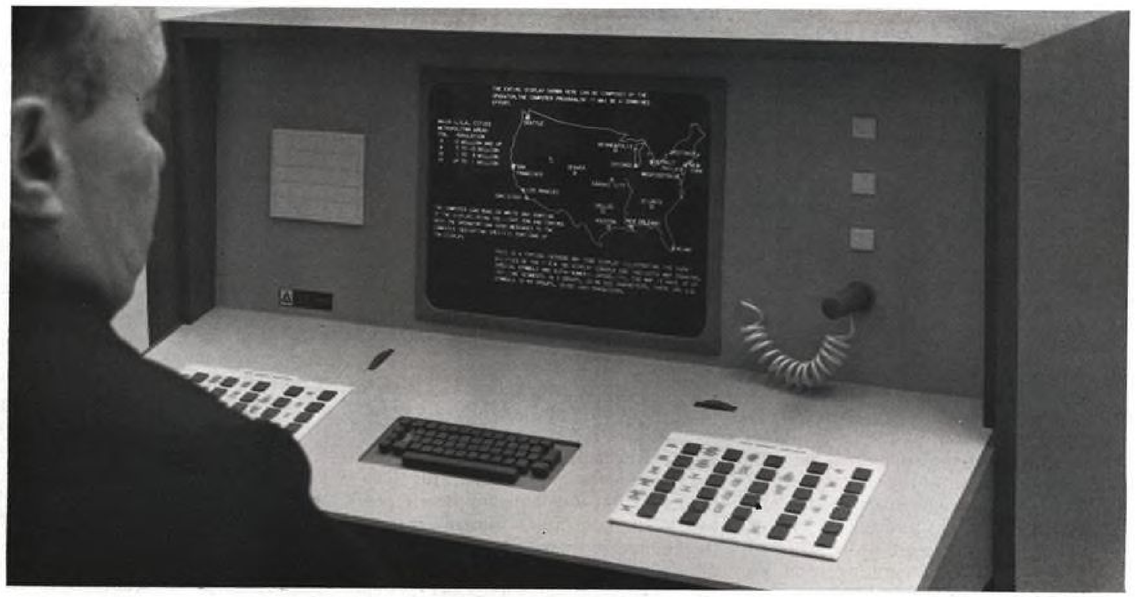
The lunar landing research test vehicle is expected to help answer many questions on such subjects as the type of display the pilot needs, how the control system should be built, what the cue should be for firing the deceleration rockets and how much stability should be required of the attitude control system. Bikle said some "black box" proponents in NASA suggested that building a lunar landing simulator should await decision on the final Apollo configuration, especially as to cockpit display and control system, but Bikle contends this approach tackles the problem from the wrong end. The best clues on what will be needed in cockpit display and how the control system should function probably will come from the simulator work itself, he believes.

In addition to experimenting with various control systems and displays, portions of the transparent cockpit enclosure can be masked, limiting the pilot's view to determine how much cockpit visibility is required.

At the other extreme of the speed spectrum explored by the center is the Paresev, or paraglider research vehicle. Built by Center personnel in their own shops, it is the only NASA-built aircraft in the inventory, and the simplicity of the approach to paraglider control and handling investigations is obvious. In

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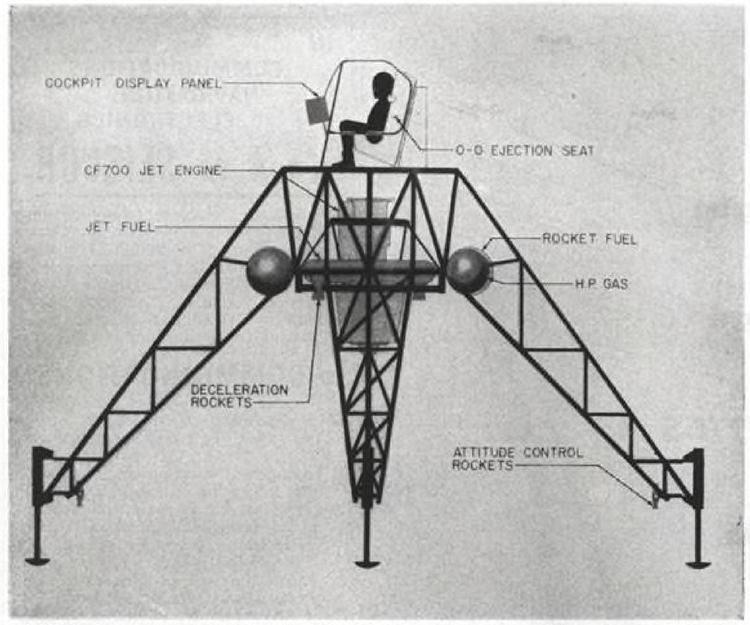
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SKETCH of the free flight lunar landing simulator planned for Flight Research Center. Pilot capsule initially will hold one man, and later will be enlarged to accommodate two.

fact, the Center has been accused of running a hobby shop because of the amateur-built appearance of the craft.

The Paresev now operating is the second model constructed here. The first was wrecked on takeoff because of the pilot's unfamiliarity with the technique required when being towed by another aircraft. A simple remedy was found by checking the prospective paraglider pilots out in a two-place sailplane, with Bikle doing the instructing. A couple of hours' instruction from Bikle, who has won numerous trophies here and abroad in his 23 years of soaring as a hobby, proved to be sufficient to teach the technique.

The present Paresev is a refinement over the first, chiefly from the control system standpoint. It is maneuvered by shifting the center of gravity of the whole machine through four cables linked to a control stick. Rudder pedals are provided but serve only to steer the nose wheel. Research pilot M. O. Thompson says the rudder pedals also serve as handy foot rests in the air and admits that he finds himself "coordinating" the rudder pedals with aileron inputs out of long habit.

Wing of the paraglider is formed by three spars braced to make a delta with 45-deg. sweep. The airfoil is made from 6 oz. Dacron formed into a delta with 55-deg. sweep. The excess material in the sail allows it to billow in flight, giving the airfoil the proper aerodynamic characteristics. The glider weighs 640 lb., including pilot Thompson, and has a wing loading of 4.25 psf. For lack of a specific category under which to license the craft, NASA obtained a Federal Aviation Agency experimental certificate, just as would someone with a home-built aircraft. Since there is no tail or fuselage on which a license number could be displayed, a special plate sporting the number N9765C was attached to the wing support strut.

Cautious Exploration

On typical test flights, the Paresev has been towed to 5,000 ft. by a Piper Super Cub, rented—with pilot—from a local airport. The obvious high drag configuration of the paraglider makes this quite a chore for the Super Cub, and a more powerful tow plane is being sought. So far, no great amount of maneuvering has been attempted with the Paresev, and exploration of its characteristics is proceeding cautiously. Despite its simple appearance and the wide publicity given to the Rogallo wing concept, the little craft has some rather tricky flying qualities.

At a forward speed of 35 kt., for example, the sink rate is 1,200-1,500 ft./min. Or, using the same dimensions for both speeds, a forward speed of 60 ft./sec. produces a sink rate of 25 ft./sec., a performance far worse than that of a jet fighter with a dead engine. Lift/drag ratio is about 3.0, compared with 3.5 for the X-15.

The paraglider does not exhibit stability characteristics similar to those of an aircraft. A pull force is required on the stick to maintain a constant airspeed if the airspeed is either increased or decreased from the trim point. In a more conventional aircraft, one expects to apply a push force when flying faster than trim speed and a full force if flying slower. Thompson also points out that very little energy is available for flareout on landing. The wing flies at a high angle of attack and obviously produces a lot of induced drag which, coupled with the profile and parasite drag of the cockpit, causes the speed to bleed off rapidly when the attitude is increased for landing flareout.

Program Pushed

Despite flying difficulties, the test program is being pushed because of the obvious uses of the Rogallo wing in capsule and booster recovery applications. First operational use of a Rogallo wing will be for landing the two-man Gemini capsule.

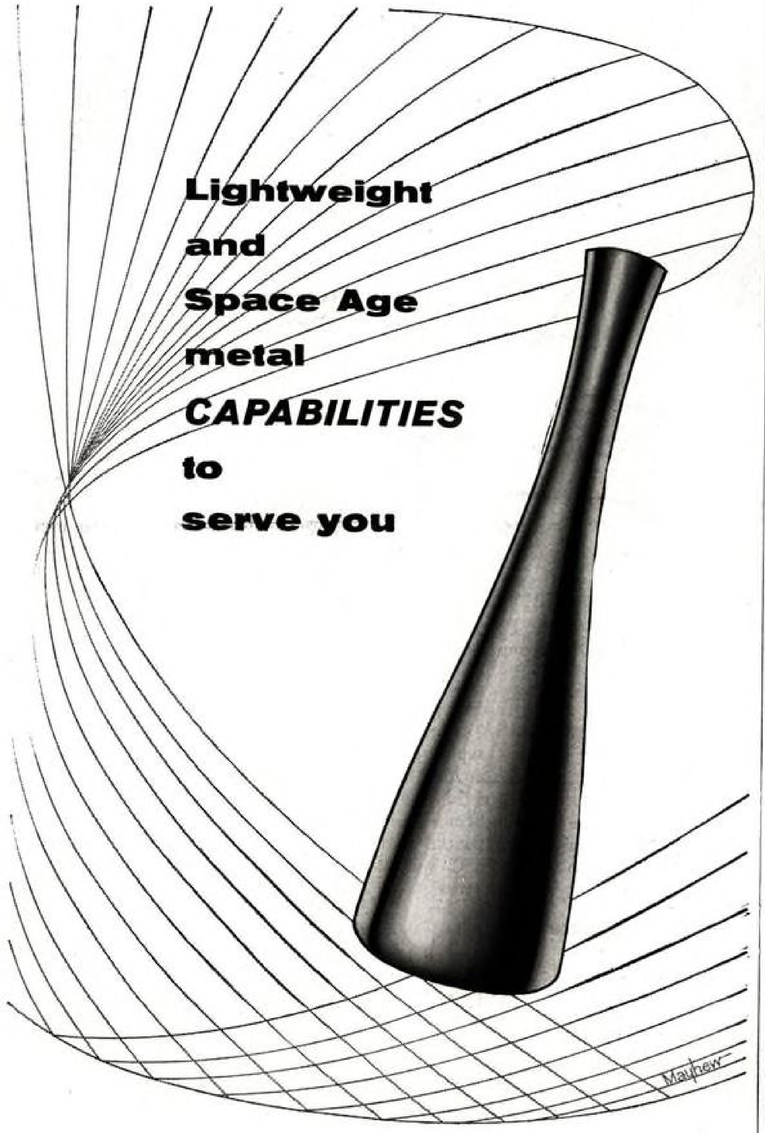
Once the test program here has been pushed far enough to establish the handling qualities of the paraglider, the next step will be to remove the wing support struts and make it a true Rogallo wing. The only remaining problem will be how to keep the wing from falling on the pilot after landing.

Lessons learned from the Paresev will be applied by the Flight Research Center in forthcoming tests of an inflatable glider being built by North American Aviation for possible application to both the Gemini and the three-man Apollo capsule.

Future projects include an extensive dual program to explore problems of operating supersonic transports, for which a Convair B-58 soon will be added to the Center's inventory. At the same time that NASA is conducting experiments to determine control system requirements, FAA personnel will be involved in obtaining data for Air Traffic Control and certification criteria.

One parameter which badly needs defining is stalling speed. Even today, FAA criteria regarding stall speed as applied to swept-wing jet transports is not adequate. In a swept-wing aircraft, stall speed is generally well below the lowest usable airspeed, and the latter is not adequately defined. What makes this worse is that stall speed is the basis for most landing and takeoff performance limitations. NASA will devote considerable time to correctly defining stall speed and minimum useful speed in the B-58 program.

Bikle said he also expects that NASA will let a contract in response to the several proposals that have been submitted on a supersonic transport dynamic simulator. Lockheed and North American are among the companies which have proposed the use of a Sabreliner or JetStar that could be equipped with flight control systems designed to duplicate the flying characteristics of any number of different supersonic transport designs.



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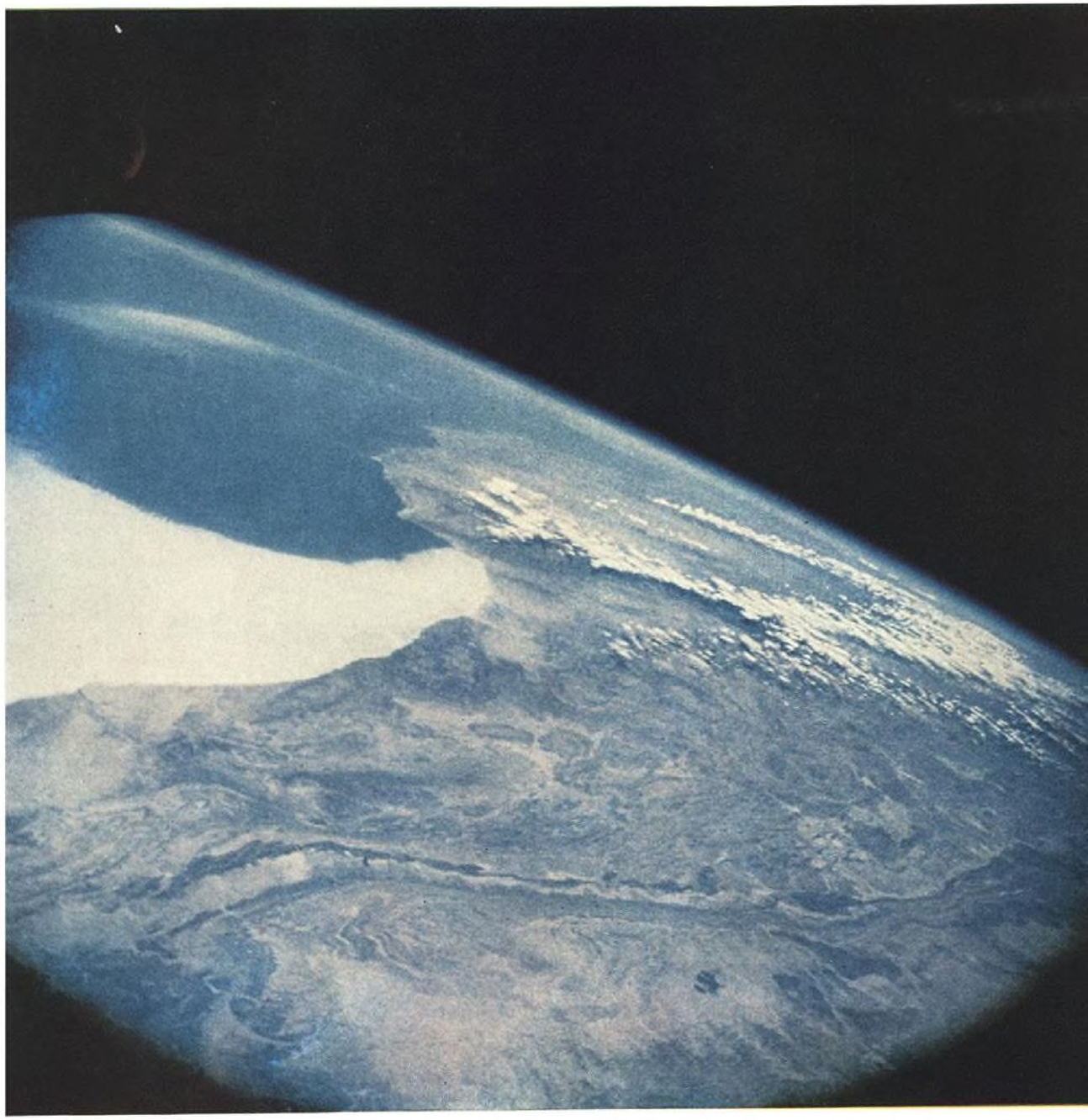
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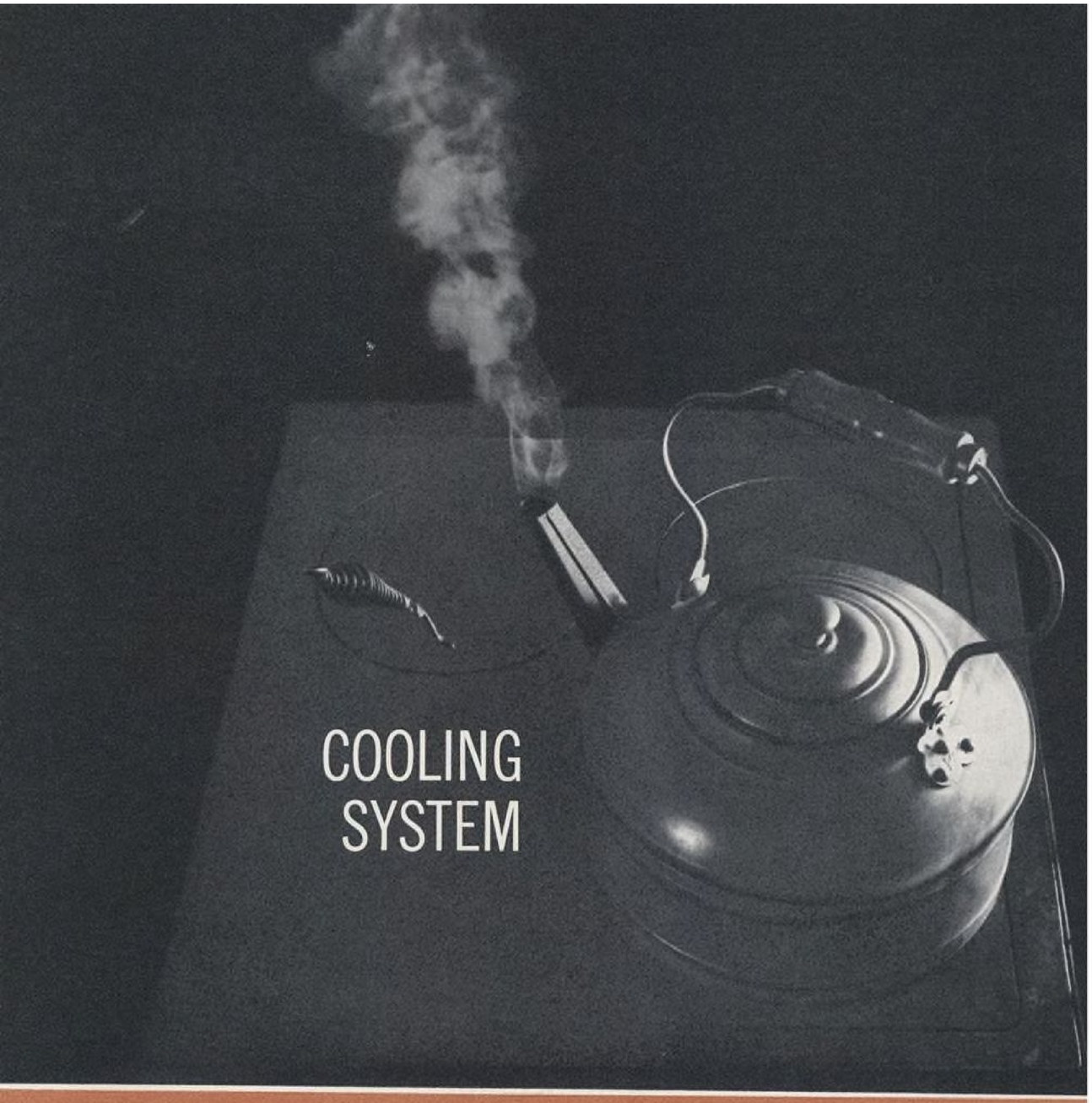
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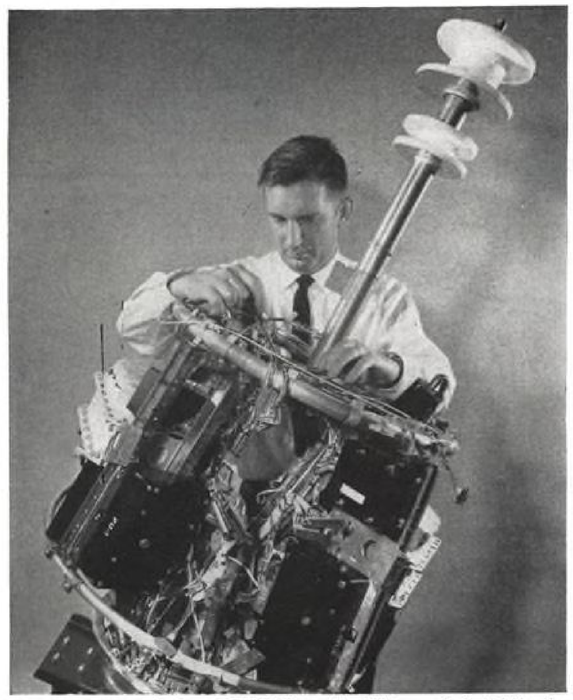
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NASA'S RELAY (left) and Bell System's Telstar, scheduled for launch this year, are part of broad communication satellite program.

NASA Plans to Expand Comsat Program

Greenbelt, Md.—National Aeronautics and Space Administration will initiate two new active communication satellite projects this year—one an intermediate altitude (12,000 mi.) vehicle and the other an advanced synchronous orbit satellite, if present plans are approved by the Administrator and Congress authorizes the funding.

The new projects, together with the present Relay, Syncom and Telstar satellites scheduled for initial launch in the coming year, are complementary pieces of a NASA program to resolve technical unknowns and to develop the technology that will enable a commercial company to implement an operational system of maximum effectiveness at minimum cost.

Defense Department is working closely with NASA on the Syncom project, a lightweight, limited-channel satellite to be launched into a synchronous, non-stationary 22,300 mi. high orbit as the forerunner of an advanced satellite intended to be placed in a synchronous (equatorial) orbit.

The NASA communication satellite program is expected to play a more prominent role in military communications than contemplated earlier as a result of the realignment of Defense Department's own Project Advent communication satellite.

In recent testimony before the House Committee on Science and Astronautics, Assistant Secretary of Defense John H. Rubel said that Syncom, being developed by Hughes Aircraft Co. under NASA contract, will permit evaluation of a number of simplified control techniques.

If they prove out, "the possibility exists [that] it might . . . be more economical to put several of these relatively smaller and simpler satellites in orbit to accomplish a given communication capacity and function than to use the larger type of satellite contemplated under the Advent program," Rubel said.

Multi-Satellite Program

NASA is continuing its research and development efforts in passive communication satellites, with emphasis on inflatable structures, multiple satellite launching with a single booster and passive attitude stabilization, according to Leonard Jaffe, director of communications systems in the Office of Applications at NASA headquarters.

In the Fiscal 1963 budget submitted to Congress, NASA requested $85,377,000 for its communication satellite program, with funding as follows:

- **Project Relay**—$19,141,000.
- **Project Syncom**—$4,087,000.
- **Intermediate altitude satellite** (new)—$21,505,000.
- **Advanced synchronous satellite** (new)—$18,601,000.
- **Project Rebound** (passive satellite)—$16,747,000.
- **Project Echo** (passive satellite)—$135,000.
- **Advanced research**—$2,688,000.
- **Advanced technical development**—$2,473,000.

The first six projects, which involve launching operations, include the cost of boosters. Project Telstar is not included in the list because American Telephone & Telegraph Co. is underwriting its construction cost and will reimburse NASA for launch costs.

The Relay and Syncom satellites, which NASA is funding, and the Telstar, funded by the Bell System, are designed to explore a number of the present unknowns with a certain amount of intentional overlap.

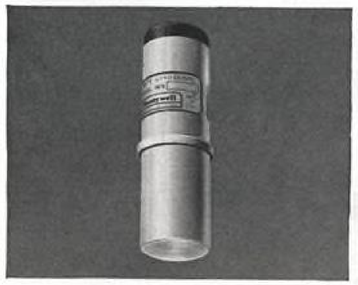
The communication satellite program is assigned to Goddard Space Flight Center and is directed by Robert Mackey in the Spacecraft Systems and Projects Division, headed by Daniel Mazur.

- **Project Telstar,** presently scheduled to be the first launched with an objec-

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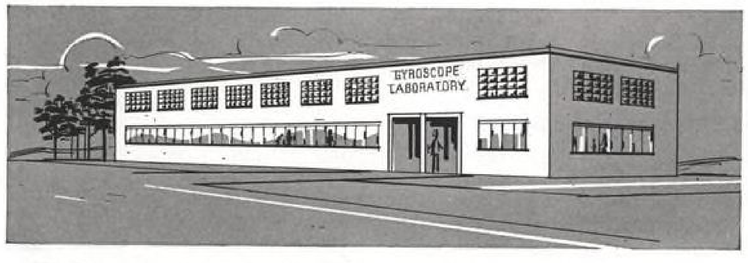
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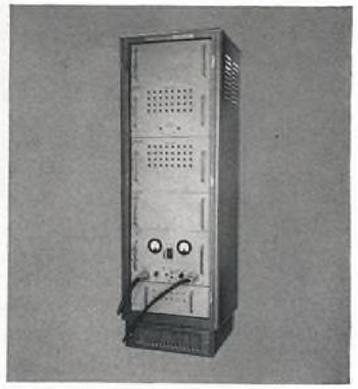
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tive of achieving an apogee of approximately 3,000 mi. and a perigee of 500 mi., will weigh about 170 lb. and provide bandwidth for transmitting one television channel or 600 one-way voice channels. It will transmit on a frequency of 4,170 mc., with an output power of about 2½ watts, and receive on 6,390 mc. The 34½-in. dia. spherical spacecraft will be spin-stabilized; therefore, the doughnut-shaped radiation pattern produced by its equatorially mounted antennas will illuminate the earth only for a portion of each orbit.

• **Project Relay,** being built by Radio Corp. of America, is scheduled for launch this fall into an orbit similar to Telstar. The 160-lb., top-shaped satellite will carry dual transmitters, receivers, telemetry receivers, command receivers and decoders, providing back-up service. Each satellite transmitter-receiver will have a bandwidth capable of handling one TV channel. Relay will transmit on a frequency of 4,170 mc., with an output power of 10 watts, four times the power of Telstar, and it will receive on a frequency of 1,725 mc.

This will permit comparison between Relay and Telstar to evaluate the different operating frequencies and radiated power levels. Relay, like Telstar, will be spin-stabilized so its doughnut-shaped radiation pattern will illuminate the earth only during a portion of each orbit. Relay will be equipped with a magnetic attitude control system, similar to that pioneered by RCA on the Tiros meteorological satellite, which can produce small changes in vehicle attitude through interaction with the terrestrial magnetic field.

• **Project Syncom,** slated for launch early next year, is expected to weigh about 60 lb., not including the weight of the built-in rocket intended to kick it into orbit when it reaches 22,300 mi. altitude. It will be the first U. S. attempt to put a satellite into orbit at this altitude, but it will not hover over a single location with respect to the earth. Rather it will sweep out a figure-eight pattern. Syncom will provide only a single two-way voice channel because of booster-payload limitations, but it will offer the first opportunity to evaluate time delay and echo problems resulting from such a long communication path. Additionally, it will permit evaluation of an unusual control system devised by Hughes Aircraft. The satellite will be spin-stabilized, but once it is in orbit small control jets will be actuated which are expected to cause the satellite to precess 90 deg. due to gyroscopic moments so that its spin axis is at right angles to the orbital plane. If this is successful, the satellite will spin like a wheel rotating around the earth so that its doughnut-shaped radiation will always be directed toward the earth—unlike Relay and Telstar. If the Hughes technique proves out, it will open the way to providing highly directional earth-oriented antenna radiation patterns without complex antenna stabilization systems. Syncom will carry dual transmitter-receivers and will transmit at 1,815 mc., with an output power of about 2½ watts, and receive at 7,360 mc. This will provide a third set of frequencies whose space performance can be evaluated.

Radiation Experiments

To obtain data on the effects of space radiation on payload performance and lifetime, both the Telstar and Relay satellites will carry modest radiation experimentation equipment. Syncom will not be so outfitted because of payload weight limits.

Telstar will carry four silicon diodes designed to measure protons at various energy levels between approximately two and 80 million electron volts (mev.) and electrons with energy levels of 0.25 to 1 mev.

Additionally, Telstar will mount three solar cells, each with a different amount of shielding, whose output will be telemetered back to earth. Also, six silicon transistors, specially fabricated with a wide base region to make them extremely sensitive to radiation damage, will be mounted on the skin in pairs, each pair shielded by a different amount. Their output also will be monitored in comparison with a seventh transistor which has been preradiated prior to installation, according to Charles P. Smith, Telstar project manager at Goddard.

The Relay satellite will carry an even more sophisticated radiation experiment, including four proton sensors, two electron sensors, 27 silicon solar cells and three gallium arsenide solar cells.

Some of the solar cells will be unshielded, while others will carry 30- or 60-mil thick protective covering, according to Joseph Berliner, Relay project manager at Goddard.

NASA hopes to obtain more comprehensive data on space radiation from its upcoming scientific satellite S-64, and from the Defense Department's Arents satellite, originally scheduled for launch by a Centaur.

Other Research Areas

To develop improved techniques required to implement a communication satellite system, NASA hopes to expand its research and advanced development in the following areas:

• **Attitude stabilization**—Major improvement can be achieved if extremely simple and reliable techniques can be devised for keeping the satellite's antenna or its radiation pattern continu-

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ously directed toward the earth. NASA is emphasizing techniques that do not require the use of expandable fuel to assure long life in orbit. Earth-attitude stabilization provides more effective use of satellite transmitter power by permitting the use of directional antennas. It also permits use of smaller antennas and lower-power transmitters in terrestrial stations.

• **Higher gain antennas**—When earth-attitude stabilization can be accomplished, antennas with higher gain can be used. In terrestrial applications, increased gain usually is accomplished by increasing the size of the antenna, but this approach poses problems for space vehicles because of payload size limitations. One promising technique for a satellite antenna with a gain of 18 db. and no rotating mechanical parts, currently under development by Hughes Aircraft, was recently reported at the National Aerospace Electronics Conference in Dayton (AW June 11, p. 88).

• **Improved modulation techniques**—As satellite payload weight limitations ease and/or improved electric power sources become available, different types of modulation techniques may prove useful. The choice also depends upon whether the bandwidth required is narrow or wide. NASA hopes to conduct side-by-side comparisons in a satellite to evaluate the relative performance of a variety of techniques, such as pulse coding and single sideband.

• **Improved power sources**—Dependable, long-lived electric power sources still are a much-sought objective, according to Jaffe. While others in NASA are responsible for developing advanced spacecraft power technology, the communications satellite group is sponsoring development of improved solar cells and is investigating radioisotope power packages for possible use in communication satellites, according to Jaffe.

Passive Satellites

The future role of passive communication satellites largely depends upon whether a simple, reliable technique can be devised for attitude stabilization to earth orientation of large, non-spherical configurations, Jaffe believes. An additional need is the development of techniques for fabricating extremely large, inflatable, non-spherical structures capable of maintaining their structural integrity for extended periods in space.

NASA recently awarded a contract to General Dynamics/Convair to conduct a parametric study of gravity gradient stabilization of a passive satellite which might be shaped like an inverted umbrella. The study seeks to determine whether gravity gradient stabilization would be seriously disturbed by solar winds and radiation pressure.

In the search for lighter weight inflatable structures, NASA is sponsoring programs at G. T. Schjeldahl Co. and Geophysics Corp. of America's Viron Division. Schjeldahl has developed a three-layer foil-plastic laminate in which the outer metal foil layers are photo-etched to form a honeycomb-shaped pattern which reduces over-all weight by about one-third without significant loss of structural rigidity, according to Herbert Eaker, who heads Goddard's passive satellite program. A somewhat similar result has been achieved by Geophysics Corp., using an expandable mesh foil which is encased in a sandwich of Mylar or polypropylene.

Project Rebound

Goddard scientists currently are analyzing the results of a Douglas Aircraft Co. study of the feasibility of multiple passive satellites launched from a single booster, known as Project Rebound.

An Agena-type second stage would serve as the carrier vehicle for three inflatable satellites, each housed in a canister equipped with three solid rockets and with a nitrogen vernier and associated controls. The carrier and payload, weighing about 2,800 lb., would be boosted into an elliptical orbit with an apogee of about 1,500 mi. Upon reaching apogee, the carrier vehicle would be spin-stabilized.

The three inflated satellites should end up approximately equally spaced in a circular orbit. But this requires precise control of carrier vehicle attitude and the instant of ejection of the canister.

NASA hopes to make another attempt to inflate a 135-ft.-dia. Echo 2 satellite at altitude this summer, as a prelude to placing the larger version of Echo 1 in orbit later this year. The satellite used for vertical launch inflation tests will be equipped with a new type of tracking beacon, which will also telemeter back data on the balloon's skin temperature. A more advanced beacon, intended to telemeter back both skin temperature and pressure, under development by Aero Geo Astro Corp., is planned for use on the orbital Echo 2. The company also is redesigning the beacon, which is powered by solar cells, to improve its efficiency and power output for use at higher altitudes, Eaker said.

A considerable number of ground stations in the U.S. and abroad are expected to participate in the forthcoming active communication satellite tests. The large AT&T facility at Andover, Me. (AW Apr. 16, p. 106), has been outfitted for use both with Telstar and Relay. Other Telstar terminals will be located at Pleumeur-Bodoy, France,

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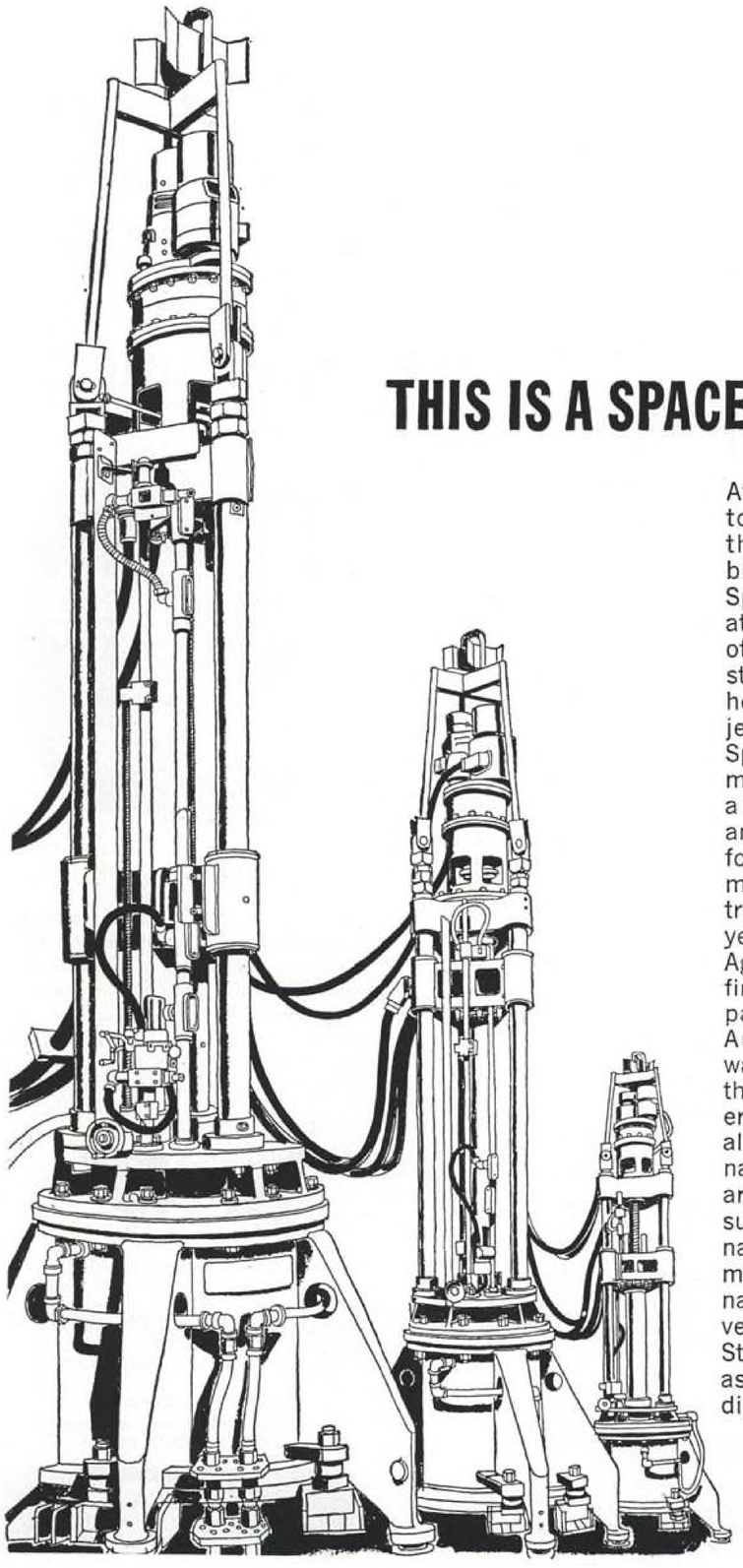
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and Goonhilly, England. Both stations also will be active in the Relay experiments.

Facilities in Germany, Italy and Brazil also will be used in the Relay tests and discussions have been held with India and Japan for their possible participation.

Transcontinental experiments using Relay will be carried out by NASA's Goldstone facility in California and its station at Wallops Island, Va., the AT&T Andover station and an International Telephone & Telegraph Co. station at Nutley, N. J. The ITT facility also will conduct narrow-band, north-south transmissions via Relay to a station at Rio de Janeiro, Brazil.

The facilities at Goldstone and Nutley will include command and telemetry for checking internal operation of the satellite as it comes over the horizon and turning its communications transmitter-receiver on and off.

NASA will be responsible for integrating the schedule of experiments run with Telstar, to prevent interference between it and Relay satellites and to avoid depletion of the payload batteries.

Plans for Telstar call for both objective and subjective types of tests, including transmission of tone signals, measurement of noise, transmission of one-way and two-way pulse-coded messages and one-way television type signals. Subjective tests will involve transmission of TV program material and both live and taped voice messages.

Tests planned for Relay include measurement of teletype error rates, using both digital and frequency-shift-keying, quality of voice and television transmissions, gain and phase stability, distortion, and noise-interference.

Present plans call for Syncom to be launched into a 30-deg. inclined orbit, which will station the satellite at approximately 40 deg. west longitude, over the mid-Atlantic, according to Alton Jones, Syncom project manager at Goddard. The satellite will make figure-eight tracks with respect to a point on the earth between 30 deg. north and south latitudes. To prevent drift of the satellite, Syncom will be equipped with a small control jet which will be actuated as required upon radio command.

The Syncom will be launched by a Thor-Delta and will contain a solid-propellant rocket, making total pre-orbit payload weight to about 125 lb. The launch will aim for a highly elliptical orbit whose apogee is approximately 22,300 mi. When the payload reaches this altitude it will separate from the second stage and the rocket in the core of the satellite will be fired to provide the additional energy needed to place it in orbit at the apogee altitude.

At separation from the booster second stage, the satellite will be set to spinning at approximately 180 rpm. with its spin axis aligned with the orbital plane. Shortly afterward, hydrogen peroxide jet controls on board the satellite will be actuated to maneuver the vehicle into the desired longitude. When this has been accomplished, cold nitrogen gas jets will apply a torque in such a direction as to cause the satellite spin axis to precess through a 90-deg. angle until it is at right angles to the orbital plane so that the antenna radiation pattern is directed along the orbital plane toward the earth.

With the coming availability of larger boosters, such as the Atlas-Agena B, NASA can overcome some of the limitations imposed on first-generation communication satellite tests. The Atlas-Agena B can place a 600-lb. payload into orbit at altitudes up to about 12,000 mi., compared with the 150-175 lb. payload and lower altitude limit of the Thor-Delta. It also should permit payloads up to 500 lb. in synchronous, 22,300 mi. orbits.

The larger payloads will permit the use of earth-oriented attitude stabilization, increasing the percentage of the time that a satellite can be used. The larger payload also permits carrying increased power supplies which makes possible increased bandwidth.

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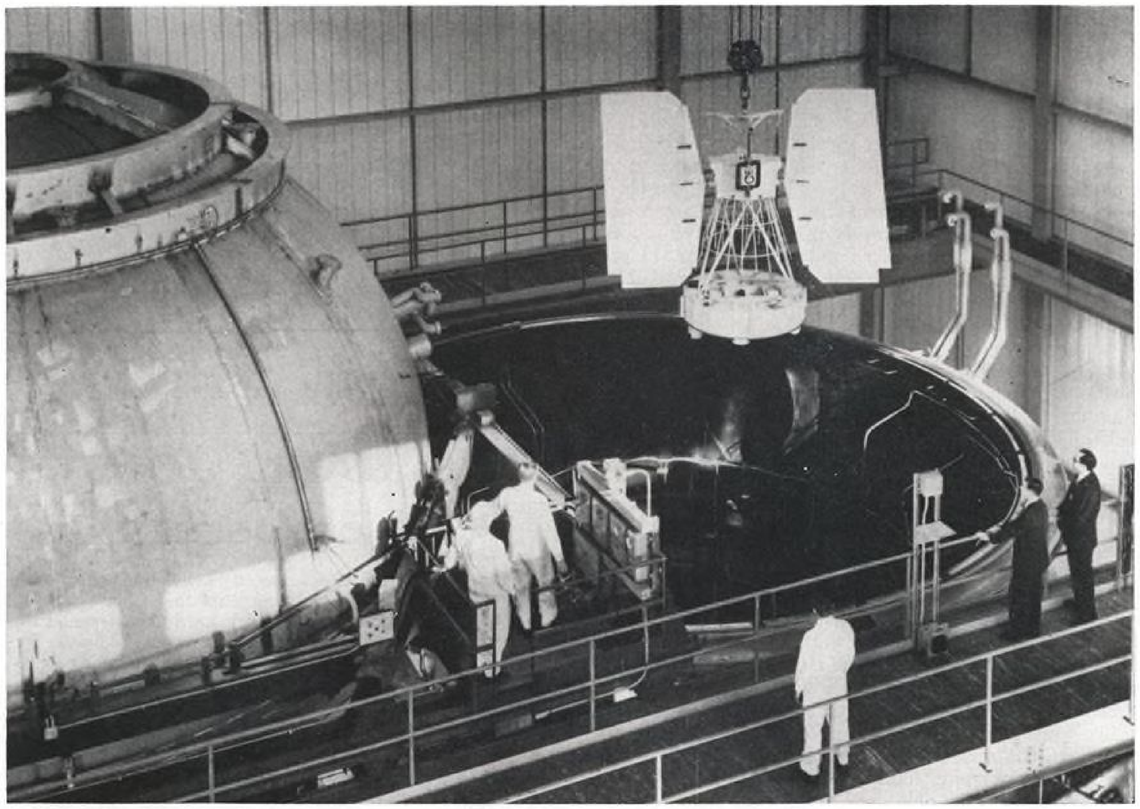
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NIMBUS meteorological satellite prototype is placed in 39-ft. vacuum chamber at General Electric for qualification tests.

Weather Satellite System Due by 1965-66

Greenbelt, Md.—National Aeronautics and Space Administration hopes to launch next spring its first Nimbus weather satellite, prototype for a multi-satellite operational system that is expected to bring the entire world's weather under regular and frequent surveillance by 1965-66.

National Operational Meteorological Satellite System is being developed for use by the U. S. Weather Bureau in a joint agency effort. But the system could well become an international one in its ultimate use. Other potential users, such as the Defense Department and Federal Aviation Agency, make their needs known through a coordinating committee.

With a Nimbus satellite in a circular, near-polar orbit at 500-600 mi. altitude, the Weather Bureau should obtain two pictures of weather conditions over every spot on the earth every 24 hr., one a television picture made during daylight hours and the other a cloud-cover map made by infrared sensors. Present plans call for launch of the first Nimbus at approximately noon so that its pictures will be taken at local noon and midnight over each location throughout the orbit.

Because hurricanes and cyclonic storms have lifetimes which usually exceed 12 hr., a two-Nimbus system which would provide one television and one infrared picture every 12 hr. should permit detection of the birth and growth of such storms. Satellites would be spaced to provide TV pictures at approximately 9 a.m. and 3 p.m. local time, with infrared maps made at 9 p.m. and 3 p.m. local time, according to H. I. Butler, associate chief for projects of the Aeronomy & Meteorology Division at Goddard Space Flight Center.

To detect the birth and development of thunderstorms and tornadoes, which have much briefer lifetimes, more frequent observations would be needed. This could be accomplished by placing more Nimbus satellites in orbit at any one time, but an alternative approach under NASA study would use a different type of satellite, known as the Aeros, to complement Nimbus coverage.

Aeros would be placed in a synchronous equatorial orbit (22,300 mi. altitude) where it could scan almost one-third of the earth's surface. Three such satellites, suitably spaced in longitude, could view almost the entire earth continuously, except for the polar regions.

Each Aeros would be outfitted with both a wide-angle camera and a telephoto camera. When meteorological conditions of special interest were disclosed by the wide-angle camera or by a Nimbus low-altitude picture, the appropriate Aeros satellite would be commanded to aim its telephoto camera at the area of interest.

Aeros currently is only in the preliminary study stage. Earliest likely date for an Aeros launch is around 1966, according to Dr. Morris Tepper, director of meteorological systems at NASA headquarters. Development is likely to wait until synchronous-orbit-station-keeping techniques have been developed and proven for other uses, such as the communication satellite.

Present NASA hopes for early implementation of an operational weather surveillance system result from the extremely successful Tiros program, originally started by the Army and later transferred to the space agency. Tiros, developed and built by Radio Corp. of America's Astro Electronics Division, is one of the most complex payloads put into orbit, but it has been one of the most reliable.

First Tiros launched operated for 2¼ months, producing nearly 23,000 weather photos. Tiros 2 operated for 10 months and Tiros 3 for 4½ months, each turning out more than 35,000 pictures.

Tiros 4, which was launched last February, is still operating and produced more than 30,000 pictures in the first three months of operation.

New Set of Tools

Tiros satellites have given the Weather Bureau scientists an entirely new set of tools, some of which require more research before they are fully understood and can be effectively applied. For example, infrared radiation patterns from clouds and the ground measured on successive Tiros passes show certain characteristics in the plots of equal-value radiation which may serve to pinpoint the breeding grounds for tornadoes, according to Dr. F. W. Reichelderfer, Weather Bureau chief. These patterns also may enable forecasters to locate pools of warm water in the oceans which are inhabited by certain types of fish, for use by fishermen.

Although it is premature to talk of controlling the weather, Dr. Reichelderfer ventured the prediction that information from weather satellites might permit man to break up hurricanes before they reach full growth.

Joint Program

Under the terms of a NASA-Weather Bureau agreement, the space agency is responsible for developing the satellites, ground data and control stations, for data acquisition from the operational models, as well as for satellite launching. The Weather Bureau is responsible for processing the meteorological data, analyzing and disseminating it to users and for storing the data. Both agencies are jointly responsible for data analysis and processing during the research and development phase to assure that Weather Bureau requirements are being met.

Under the terms of the agreement, NASA bears the cost of developing and launching the development model Nimbus satellites and of developing and installing data acquisition and transmission facilities, while the Weather Bureau will fund the procurement of operational satellites.

NASA now has two developmental Nimbus satellites on order and negotiations are under way at present for two more satellites, tentatively identified as operational models, for launch in 1964. If the first two developmental Nimbus satellites go into orbit and perform without major difficulties, the third and fourth Nimbuses will retain their operational satellite designation (OS-1, OS-2)



PUMP PRIMERS

ARTHUR A. NICHOLS

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► Engine designers have been recently strongly attracted by Gerotor pumps which permit the incorporation of an extra pumping element in a separate chamber of the lubricating pump to provide fluid pressure for a control function or other use.

► **The Gerotor is a form of internal gear pump consisting of only two moving parts: an inner toothed element and an outer, meshing toothed element. The inner element has one less tooth than the outer and the "missing tooth" provides a chamber to move the fluid from the inlet port to the outlet. Pump capacity is measured by the volume of the "missing tooth" multiplied by the number of driver teeth and RPM.**



FIG. 1

► The unique construction of the Gerotor type pump permits aircraft systems designers to combine *several pumping functions* in a single pump housing mounted on a single pad and driven by a single shaft. Diversified systems such as lubrication, scavenging, low pressure hydraulic servo systems and motors up to pressures of about 1000 psi may be centralized in this manner.

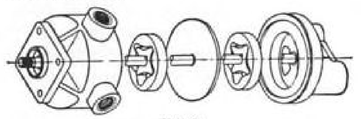


FIG. 2

► **The designer has several variables to secure a given capacity within his space limitations: Gerotor *diameter* which governs the area of the pumping chamber. Gerotor *thickness* which, taken with area determines chamber volume and Gerotor *RPM*. Thus, it is possible to vary the diameter, length and speed to secure the needed capacity.**

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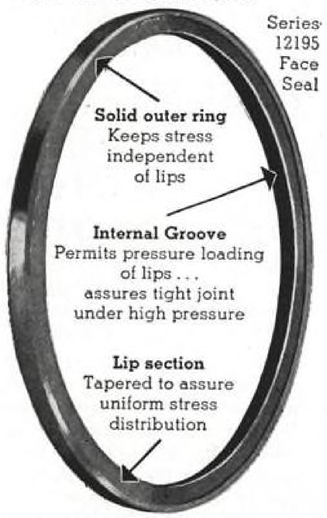
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and become the first elements of Weather Bureau's operational system.

If, however, the first two models encounter difficulties requiring major redesign, then the third and possibly the fourth Nimbus satellites will revert to developmental status to prove out the attempted fixes. In this event, the fifth and sixth satellites would take on the OS-1 and OS-2 designations.

Naturally the Weather Bureau will make use of weather photos obtained from the developmental Nimbus, much as it has done with the experimental Tiros satellites.

For the upcoming year, NASA's budget request for its meteorological satellite program totals $51,185,000. This total includes the cost of launching vehicles, but not the cost of Weather Bureau operational models which are funded by that agency. The breakdown of this total is as follows:

- **Tiros 4, 5, 6, and 7—$3,390,000.** Tiros 5 was launched successfully last June 19 and the two subsequent satellites are scheduled for launch at roughly five-month intervals. If all are successful, an additional back-up payload may also be orbited.
- **Nimbus 1, 2—$17,854,000.** These are the first two development models, sometimes referred to as Nimbus A and B.
- **Nimbus 3, 4—$17,060,000.** These are tentatively identified as the second pair of development satellites, unless the first two Weather Bureau Satellites must be diverted for such purpose, in which case these satellites would probably be transferred to the Weather Bureau.
- **Meteorological sounding rockets—** $1,468,000.
- **Advanced research—**$1,808,000.
- **Advanced technical development—** $9,605,000.

Figures shown above for Nimbus do not represent the cost of the two spacecraft because NASA uses incremental funding spread over several years, and the launch costs also are included.

When NASA can provide the Weather Bureau with a Nimbus of the required performance and reliability, it will turn its attention to evaluating new types of sensors for possible use on later models of the operational Nimbus. The base of the Nimbus structure, in which sensors and other payload elements are located, was designed to permit substitution of different subsystems.

One presently planned future experiment involves the use of a weather radar, with its antenna mounted directly underneath the spacecraft, to measure precipitation content of clouds. Small holes in the antenna would permit the television cameras to have an unobstructed view.

Second planned future experiment will carry an infrared spectrometer which will measure infrared radiation in narrow spectral intervals in the 15 micron carbon dioxide absorption band, from which it should be possible to determine the temperature of the atmosphere at different altitudes.

The concept, originally proposed by L. D. Kaplan of the Jet Propulsion Laboratory, assumes that carbon dioxide is uniformly mixed through the free atmosphere. On this basis, data from radiation measurements in 10 spectral intervals, each less than 10 wave numbers wide, could be used in 10 simultaneous equations to compute temperatures at each of 10 different pressure altitudes, Kaplan suggested. The experimental model, using a four-interval spectrometer, is being developed by Barnes Engineering Co. under Weather Bureau sponsorship.

Other planned future experiments include the evaluation of radio sferics detectors for tracking thunderstorms and evaluation of an electrostatic recording television camera under development by RCA, which would eliminate the need for a magnetic tape recorder to store television pictures between passes over ground stations.

NASA expects that Nimbus satellite research and development costs will begin to taper off in Fiscal 1964, when the total Nimbus research and development effort will have cost slightly more than $100 million.

Ideally, a ground station located at the North or South Pole could interrogate a Nimbus satellite and read-out its stored weather pictures on every pass, but such a location is impractical from a construction and logistics viewpoint.

Most convenient compromise location which NASA has selected is a site near Fairbanks, Alaska, which should permit contact with Nimbus satellites in their 80-deg. inclined orbits during 10 or 11 out of every 14 orbits each will make daily.

To supplement this coverage, the U.S. currently hopes to work out arrangements with Canada for installation of a similar facility in the Canadian northeast. Discussions are under way.

Goddard Space Flight Center has just completed the installation of its new Alaska Data Acquisition Facility, a $5 million unit near Fairbanks, which will be used with the first Nimbus and for far-ranging scientific earth satellites, such as the Eccentric Geophysical Observatory (EGO) and the Polar Orbiting Geophysical Observatory (POGO). The Alaska facility is equipped with an 85-ft.-dia. antenna.



ALUMINUM wire mesh sphere developed by Geophysics Corp.'s Viron Division to explore passive satellite structures.

Because the operational meteorological satellite system will require a full-time data acquisition facility, Goddard plans to construct a similar facility, with an 85-ft.-dia. antenna, at Fairbanks. The dual facility will also enable one station to serve as a back-up to the other in an emergency.

Fiscal 1962 NASA budget provided $12.1 million for initial work on the ground stations required for an operational weather satellite system. For Fiscal 1963, the agency has requested an additional $5.5 million. It also is seeking $1.1 million for wideband communication facilities capable of transmitting weather photos from these stations to the National Meteorological Center and to Goddard, both located just outside Washington, D. C. The communications link is to have a bandwidth transmission capability of 96 kc.

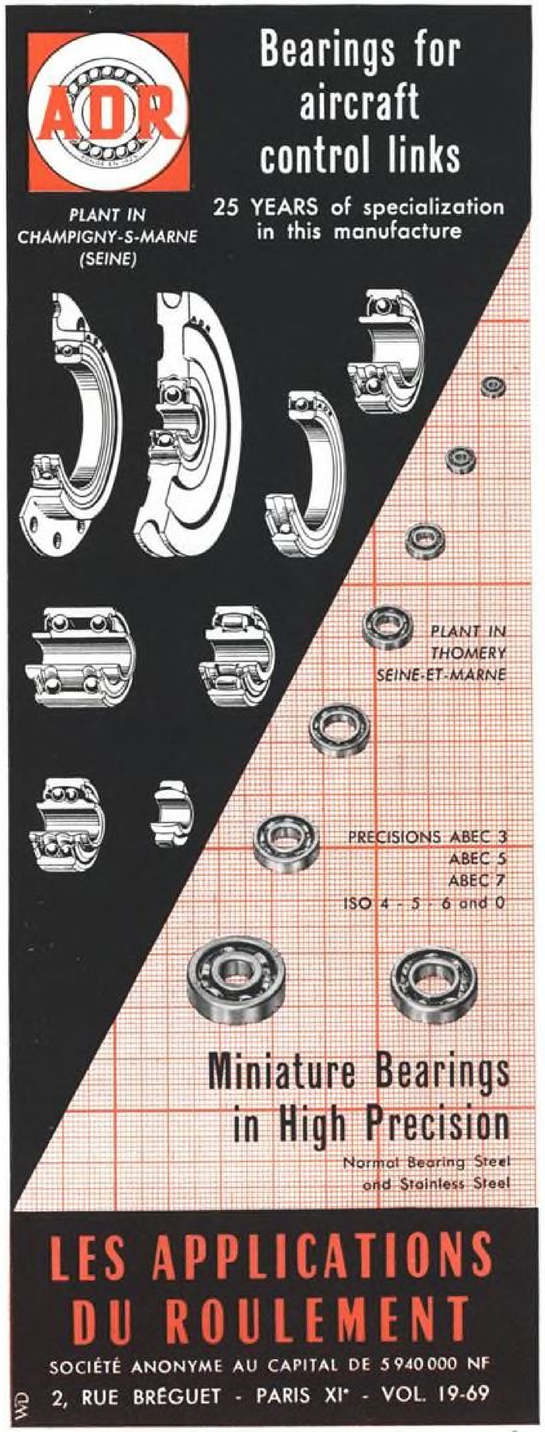
Nimbus Complexity

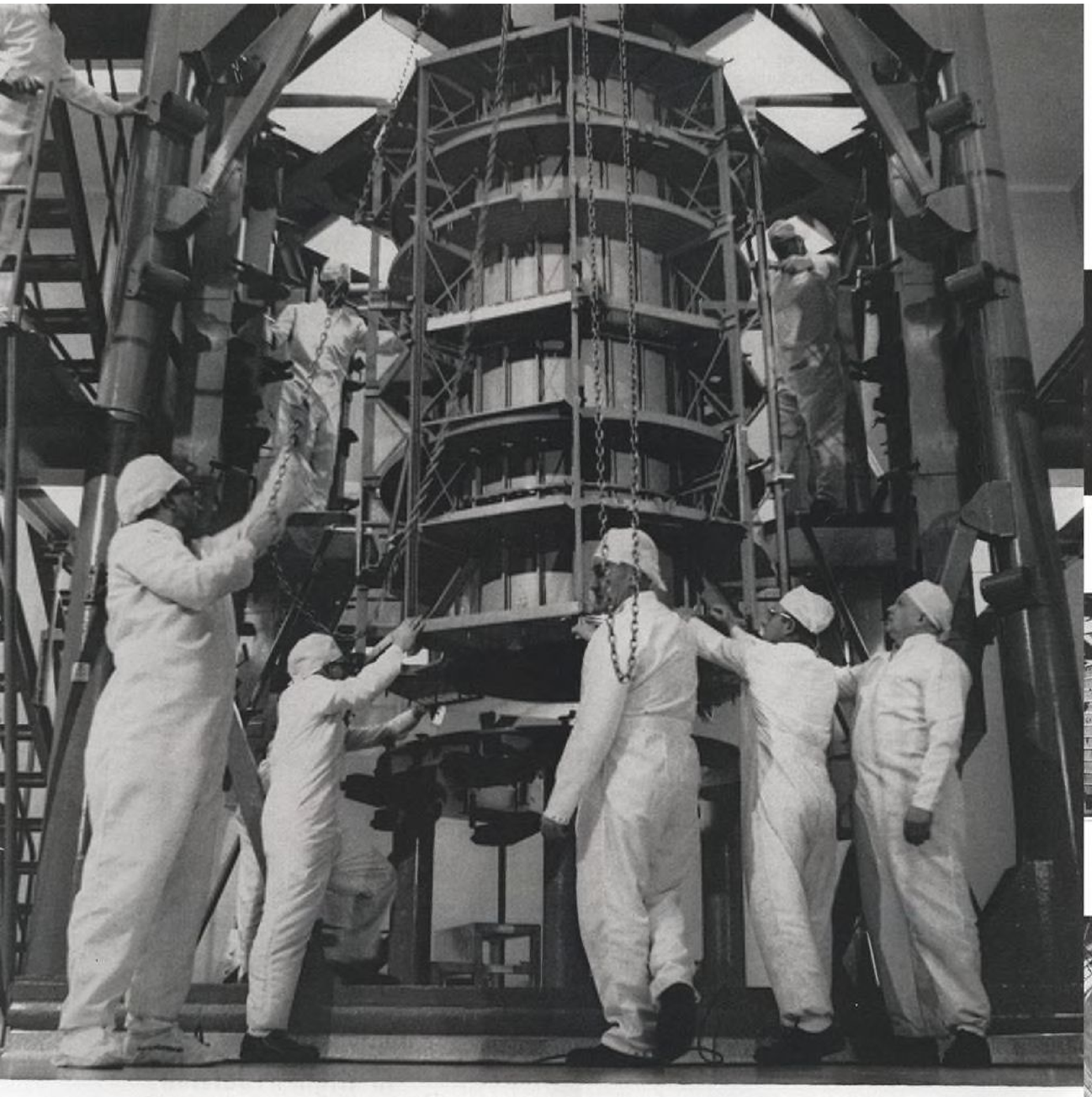
Nimbus is a far more complex spacecraft than its Tiros predecessor. The first model, scheduled for launch in the second quarter of 1963, is expected to weigh about 700 lb., more than twice the weight of Tiros. Launch vehicle will be a Thor Agena B, fired from the Pacific Missile Range.

NASA is studying the Atlas Agena B or a modified Thor Agena B as launch vehicles for later models of the Nimbus to permit greater payload weights, according to Harry Press, Nimbus project manager at Goddard Space Flight Center. The first model will not carry the dual camera packs and other redundant circuitry which Press believes are needed to achieve the desired operating lifetime of six months or longer.

One example of the increased complexity of Nimbus is its attitude stabilization. Where Tiros was spin stabilized so that its cameras aimed at the earth only for about 20% of the time, the Nimbus will be earth-oriented by means of horizon sensors so that its cameras always are directed toward the earth.

Tiros solar cells are mounted along the surface of the drum-shaped spacecraft which exposes only a fraction of the total cells to direct sunlight, producing an output of about 20 watts. The Nimbus solar cells are mounted on two large paddles which automatically are titled about their pitch axis to aim the cells at the sun. The paddles also are directed toward the sun in azimuth by





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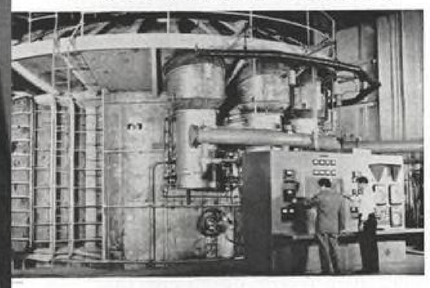
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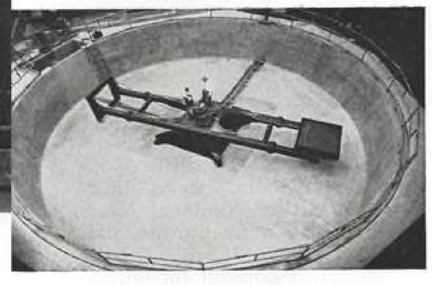
Frictionless conditions encountered in space are simulated by Grumman's airbearing attitude table. Supported on a 1/1000-inch-thick air cushion, the table is capable of holding five men, but would tilt at the drop of a feather.



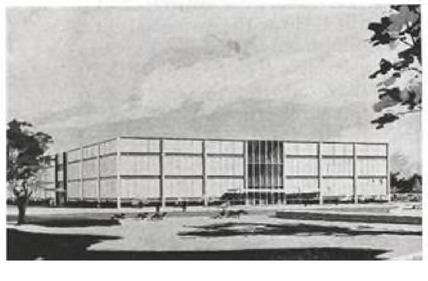
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Drawing of new Space & Missile Center which will further expand Grumman's aerospace activities, providing accommodations for a larger scientific, engineering and support staff.



means of sensors on the spacecraft which orient it in yaw. Output of the Nimbus solar cells is about 400 watts, or 20 times that of the Tiros.

Where the late model Tiros satellites carried two wide-angle television cameras, the first Nimbus will carry a pack of three cameras and later models are expected to carry two such packs, or a total of six cameras. The second pack is intended as a back-up, but probably will be used on alternate orbits to exercise the equipment and keep a check on its operability.

Within each camera pack, the three videcons will be trained to provide slightly overlapping coverage. Combined area of surveillance from the pack will be approximately 1,500 naut. mi., at right angles to the satellite direction of motion, and 350 naut. mi. deep, at an altitude of 600 mi.

Photos will be made at approximately 100 sec. intervals during daylight passes, providing modest overlap of successive pictures in the direction of motion. During the course of each orbit, a Nimbus camera pack is expected to produce approximately 1,300 individual pictures.

Videcons used in Nimbus will have an 800-line scan per frame, compared with 500 for Tiros. This will give a resolution of about one-half mile, compared with approximately two miles for Tiros.

Infrared Sensors

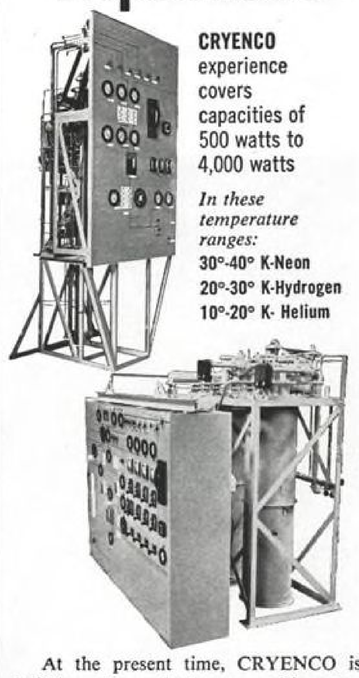
Increased sophistication of Nimbus also shows up in its improved infrared sensors, to provide finer-grain detail on nighttime cloud cover and earth heat balance. Presently planned infrared radiation sensors include:

• **High-resolution infrared radiometer,** sensitive in the 3.4 and 4.2 micron region, will serve as the eye of the Nimbus for night passes to map the temperature of clouds or of the ground and ocean, in cloud-free areas. Resolution expected is to within approximately 5 mi., compared with 30-mi. resolution obtained from Tiros sensor.

• **Medium-resolution infrared** radiometer, will measure radiation in five infrared and near-infrared bands. These include: 0.2 to 4.0 microns, earth-reflected solar radiation; 0.55 to 0.75 microns, solar energy reflected from daytime cloud cover; 6.5 to 7.0 microns, water vapor absorption; 10 to 11 microns, atmospheric window; and 7 to 30 microns, thermal radiation from the earth.

Another interesting difference between Tiros and Nimbus programs is that Goddard is acting as prime contractor and system engineer for Nimbus, a role which RCA performed for the Tiros. The basic Nimbus spacecraft configuration and structural design was done by Goddard, and it has

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selected the suppliers of Nimbus subsystems and is following the suppliers' efforts.

General Electric's Missile and Space Vehicle Department is the major Nimbus contractor, with responsibilities for detailed design of the spacecraft and its fabrication, and for integration of all subsystems into the spacecraft. GE also is developing the attitude stabilization control system.

Major Contractors

Other major contractors on the Nimbus satellite program include the following:

- **Radio Corp. of America:** Vidicon camera pack and solar cell paddles. RCA also is providing clock receivers, a tape recorder for the high-resolution infrared sensor, and is developing the advanced electrostatic recording camera.
- **ITT Industrial Laboratories:** High-resolution infrared radiometer.
- **Santa Barbara Research Center:** This Hughes Aircraft subsidiary is developing the medium-resolution infrared radiometer. Hughes itself has the job of building the PCM/AM telemetry transmitter.
- **Radiation, Inc.:** PCM telemetry.
- **Texas Instruments, Inc.:** Transmitter for medium-resolution sensor.
- **General Electronics:** S-band transmitter.
- **Raymond Engineering:** PCM telemetry and medium-resolution sensor data recorder.
- **Aero Geo Astro:** Medium-resolution sensor electronics package.
- **California Computers:** Clock command package.
- **Stanford Research Institute:** Data utilization studies.

Nimbus Slippage

First Nimbus launch date has slipped from the last quarter of this year to the second quarter of 1963, largely the result of troubles encountered by GE in the design of its horizon sensor for the attitude control system (AW June 4, p. 32).

The major problem has been the difficulty of determining earth horizon to required precision when there are clouds present whose radiation distorts the apparent position of the earth horizon.

General Electric is redesigning its horizon sensor to make it sensitive to longer wavelengths in the 12 to 18 micron region, reducing horizon sensor scanning speed and developing lower-noise preamplifiers in the hope of solving the problem, Press said.

There have been problems and delays with other subsystems for the Nimbus. But Press said this is characteristic of spacecraft and their payloads. He concedes that the qualification tests which Goddard requires for its spacecraft and payload subsystems are extremely demanding, higher even than those that are usually imposed for military equipment.

Project Office

Nimbus project office divides its program into four major areas: spacecraft, launch vehicle, data acquisition and data utilization. The data utilization office is headed by a Weather Bureau representative, while the head of the data acquisition office is a member of the Data Systems Division of the Goddard tracking and data systems directorate, assigned to the Nimbus project. The launch vehicle office provides liaison with the Marshall Space Flight Center, which is responsible for providing boosters.

Majority of the Nimbus project office manpower is applied to the spacecraft itself, with individuals assigned to monitor development of the many payload subsystems.

Bulk of the subsystem contracts, and the one with GE for the spacecraft, are on a cost-plus-fixed-fee basis. Program Evaluation Review Technique (PERT) is being used on the major Nimbus contracts, including those with General Electric, Radio Corp. of America and Radiation, Inc.

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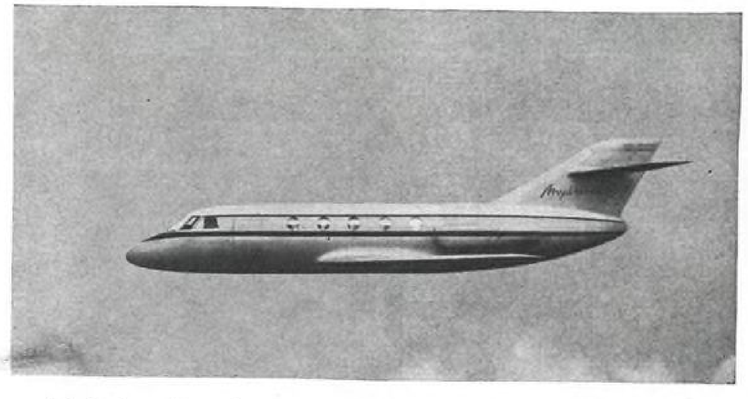
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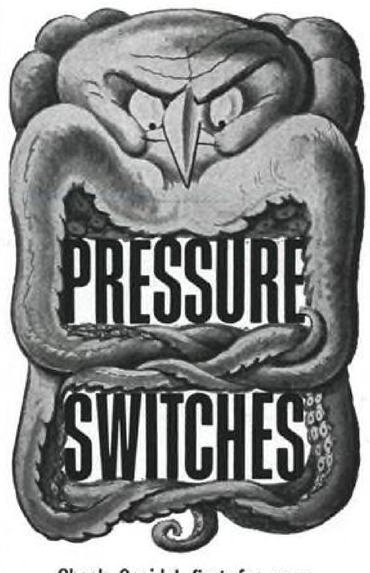
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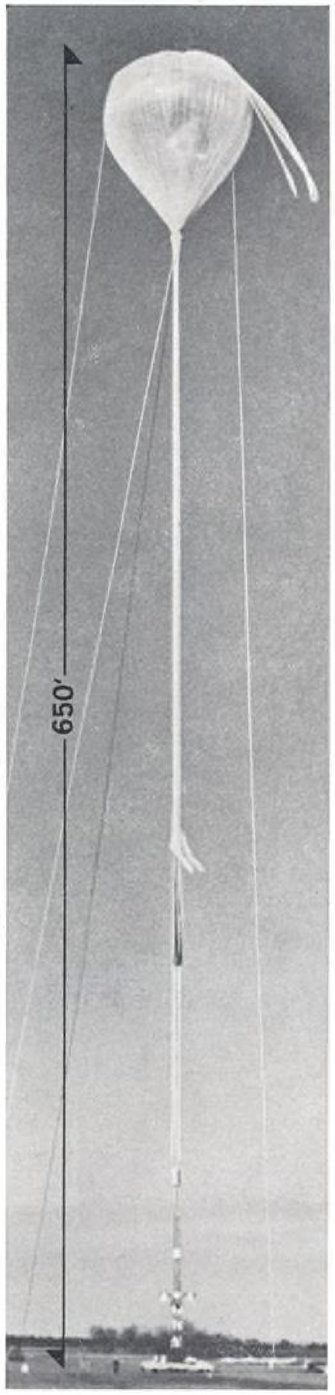
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Polar mount antenna at JPL Echo site. Older antenna (rear) is being moved to Venus site.

Tracking & Data Acquisition



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GODDARD COMPUTING CENTER, shown during MA-7 Mercury flight, performs launch, orbital and re-entry computations which are instantly transmitted to Cape Canaveral Mercury Control Center for display. Critical launch, orbital and re-entry parameters are shown in illuminated display at left, while status of all network stations is shown at right.

NASA Expands Tracking, Data Acquisition

Washington—Advanced manned spacecraft missions and the vastly increased amount of data that will come from scientific satellites such as the orbiting geophysical and astronomical observatories are requiring National Aeronautics and Space Administration to continue expanding its tracking networks and data acquisition facilities.

For Fiscal 1963, NASA has requested $224 million for operation and expansion of this umbilical cord which has enabled man to extend first his senses and more recently himself into the hostile space environment. Of this total, $74.6 million is intended for equipment and components, $67.8 million for network operation, $16.0 million for systems development and $65.6 million for construction work.

The space agency operates three tracking and data acquisition networks around the globe, from Alaska to South Africa and Australia, each designed to perform a different mission. But like an iceberg, only a fraction of the total is apparent. Generally unseen are the extensive data processing, reduction, computation and communication facilities at the Goddard Space Flight Center and the Jet Propulsion Laboratory, which form an essential part of the overall system.

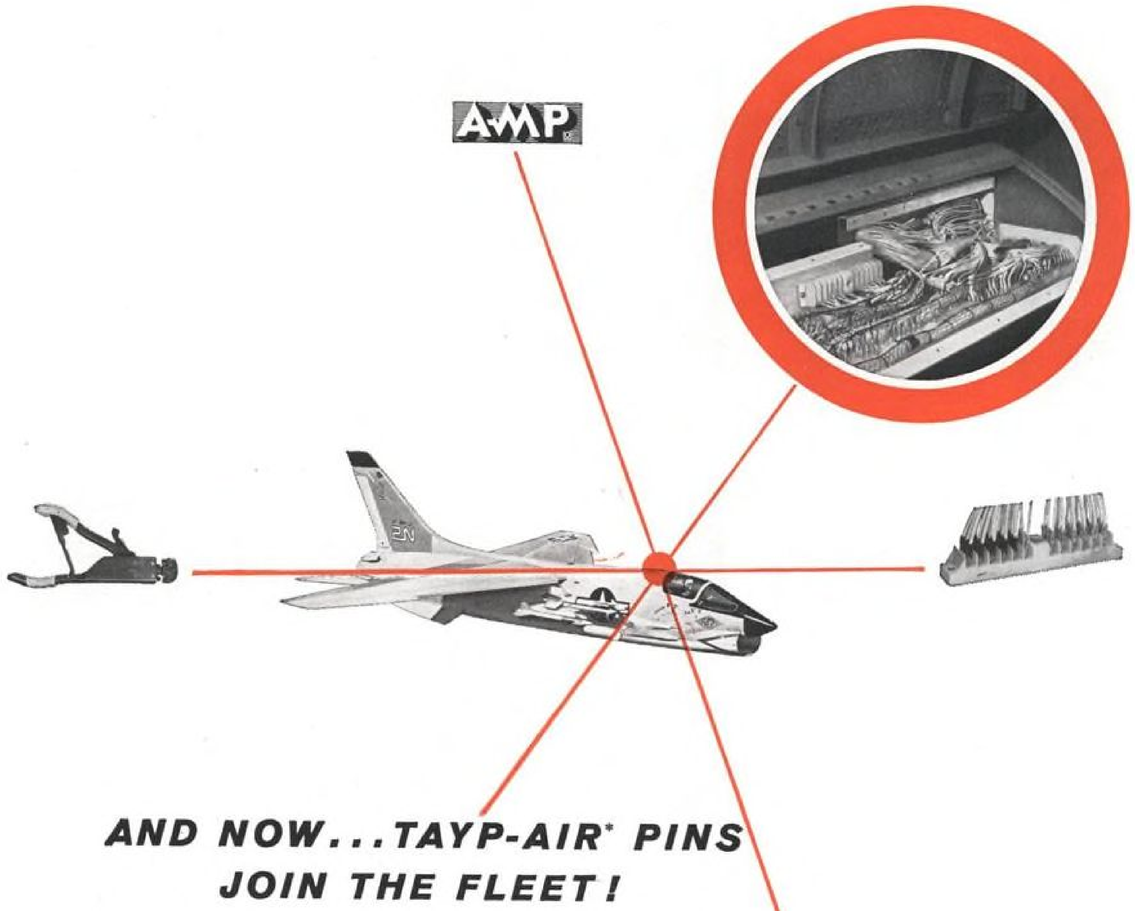
The three networks are:

• **Manned space flight network,** sometimes called the Mercury network, consisting of 16 stations, two of them ship-based, plus two down-range stations of the Atlantic Missile Range. Land stations outside the U.S. are at Grand Canary Island, Nigeria, Zanzibar, Canton Island, Mexico and two in Australia.

• **Earth satellite networks,** presently consisting of 13 Minitrack stations with three new facilities under construction or planned. Stations outside the U.S. include Ecuador, Peru, Chile, Australia, South Africa, Newfoundland and England. There also is a 12-station optical tracking network, with stations outside the U.S. located in Argentina, Aus-

Tracking and Data Acquisition Facilities

	S-Band Radar Tracking (Verlort)	C-Band Radar Tracking FPS-16	Telemetry & Capsule Communications	Command Control
Woomera, Australia	—	X	X	—
Canton Island	—	—	X	—
Kauai Island, Hawaii	X	X	X	X
Point Arquello, Calif.	X	X	X	X
Guaymas, Mexico	X	—	X	X
White Sands, N. Mex.	—	X	—	—
Corpus Christi, Tex.	X	—	X	—
Eglin, Florida	X	X	—	—
Cape Canaveral, Fla.	X	X	X	X
Grand Bahama Island	—	—	X	—
Grand Turk Island	—	—	X	—
Bermuda	X	X	X	X
Grand Canary Island	X	—	X	—
Kano, Nigeria	—	—	X	—
Zanzibar	—	—	X	—
Indian Ocean Ship	—	—	X	—
Muchea, Australia	X	—	X	X
Atlantic Ocean Ship	—	—	X	—



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tralia, India, Iran, Japan, Peru, South Africa and Spain.

• **Deep Space Instrumentation Facility** for lunar and interplanetary spacecraft missions, consisting of stations at Goldstone, Calif., South Africa and Australia (see p. 175). The stations are sited approximately 120 deg. apart in longitude to enable at least one to view a space probe at all times despite the rotation of the earth.

With a list of station sites that sounds almost like a roll-call of the United Nations, NASA officials responsible for the selection of station locations and their subsequent operation must keep eye on the international situation and internal political situations in countries where stations are located. This requires close liaison with the State Department. NASA seeks to prevent a decision to expand or change the role of a particular station, based entirely on technical factors, from becoming an internal political issue, according to Edmond C. Buckley, director of the Office of Tracking and Data Acquisition at NASA headquarters.

NASA's policy is to employ nationals to operate and maintain stations outside the U. S. to the maximum extent possible consistent with the availability of required skills. Stations in Australia, Canada, England and South Africa are managed by nationals.

In most instances, the land for the station is provided by the host government at no cost to NASA. The land for the NASA station at Guaymas, Mexico, was donated by a small farmer with a keen interest in space exploration. For nearly half of the foreign stations, the local government provides some financial support for station operation, Buckley said.

Responsibility for the three networks is divided as follows:

• **Manned space flight**—Goddard Space Flight Center's directorate for tracking and data systems, headed by John T. Mengel, is responsible for design and operation as a support service to NASA's Manned Space Flight Center at Houston, Tex.

• **Earth satellite**—Mengel's group has similar responsibilities for this network in support of Goddard's own scientific, communication and meteorological satellite programs. Personnel of the tracking and data systems directorate number approximately 530, representing about 23% of the total at Goddard. Approximately 40% of the group are professionals.

• **Deep space**—Responsibility for design and operation of the deep space probe network is assigned to Jet Propulsion Laboratory in support of its own unmanned lunar and planetary spacecraft programs (see p. 175).

Although the three usually are re-



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ferred to as separate networks, at some stations which service more than one network—for example, Woomera, Australia—common communication facilities are used. As earth satellite missions move out in distance and the lunar program develops, the lines of demarcation between the three networks will become less distinct.

Manned Space Flight Network

Proof that the decision to construct the manned space flight network from existing, proven equipment, particularly the radars used for tracking, was sound came with the extremely successful network performance during both the Glenn and Carpenter manned Mercury flights according to Buckley. Mengel said there has not been a single "hold" during a Mercury count-down due to failure in the tracking-data network, although fluctuating power from a diesel generator at Bermuda during the MA-6 countdown did cause a brief hold.

When plans were prepared for the Mercury network several years ago, there was pressure on NASA to use newer, higher-performance radars. But the agency took the position that a potentially high-risk experiment should not take on the added risk of using newly-developed hardware, Buckley said.

The 16-station network has at least one radar installed at 11 of the sites for tracking the capsule and instantly sending back data on its position to the Goddard computer center for calculation of orbital parameters and capsule impact point during re-entry.

Two radars, a precision AN/FPS-16 operating at C-band, and an S-band radar, are installed at key stations where orbit injection and re-entry normally occur. These are Cape Canaveral, Bermuda, Hawaii, Pt. Arguello, Calif., and Eglin AFB, Fla. The stations at Woomera and at White Sands, N. M., have a single FPS-16, while stations at Grand Canary Island; Muchea, Australia; Guaymas, Mexico and Corpus Christi, Tex., have the S-band radar. This provides overlapping radar coverage in key areas to assure necessary coverage in the event of a failure at one or two stations.

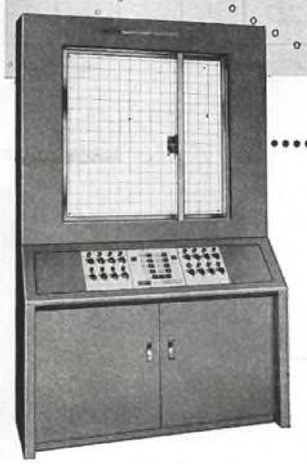
A number of stations in the Mercury network are military facilities, operated by private firms under contract to the Defense Department.

All stations except those at White Sands and Eglin are equipped to receive telemetry data from the capsule and to conduct voice communications by UHF when the capsule is in line-of-sight range. The readings of approximately 100 sensors, measuring both the state of the astronaut's well-being and the capsule equipment status, are telemetered down and in-

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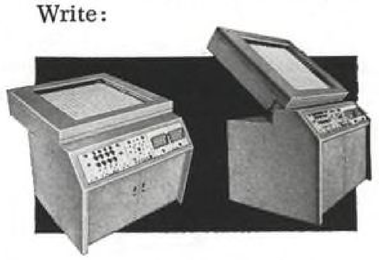
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stantly relayed to the Mercury Control Center at Cape Canaveral. Approximately 30 of these are displayed on meters or charts instantaneously. The remainder are recorded for later analysis.

Six stations are outfitted with command and control equipment, to enable them to initiate re-entry or other capsule functions if necessary. Five are clustered around the injection, re-entry or retro-fire areas—Cape Canaveral, Bermuda, Hawaii, Pt. Arguello and Guaymas—and the sixth is located at Muchea.

Hotline Network

These stations are linked into a hotline network by 141,000 circuit miles of telephone, teletypewriter and high-speed data circuits, using land lines, submarine cables, microwave links and point-to-point radio.

Capsule position information is automatically converted at each site into a form suitable for transmission by teletypewriter circuits and routed instantly to Goddard. Output from the Goddard computers is transmitted instantly to the Mercury Control Center at Cape Canaveral via high-speed data circuits, operating at a 1,000-bits-per-second rate.

Eleven of the 16 stations in the Mercury network, plus the two Atlantic Missile Range down-range stations, are now interconnected by voice circuits. The remaining five stations, presently linked only by teletype, will soon be connected to the voice network.

The communications network, built by an industrial team headed by Western Electric and including Bell Telephone Laboratories, Bendix Corp., Burns & Roe and International Business Machines Corp., was designed to assure the reliable communications so vital to manned orbital missions.

For example, two separate circuits are provided between the computation facility at Goddard and the control center at the Cape, either of which can provide required service. If both should fail, a similar pair of circuits using a different geographic routing are provided. Duplicate communication channels are provided to all key stations, with alternate routes available on a standby basis.

Computing Center

Four large digital computers, two IBM 7090s at Goddard, one IBM 709 at Bermuda and an Atlantic Missile Range 7090 at the Cape form a network during an orbital mission.

The Goddard computing center functions throughout the mission to provide the Mercury Control Center at the Cape with a running display of important launch, orbital and re-entry information. It is located at Goddard because that is the center of the NASA world-wide communications network into which tracking data flows, but it is linked to the Cape by the previously mentioned high-speed data circuits.

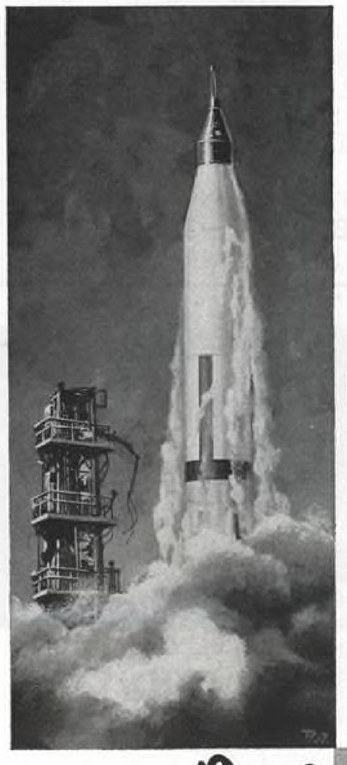
USAF 7090

The Air Force 7090 located at the Cape is used by the range safety officer during initial portion of the launch to predict the booster's impact point in case the booster should deviate from flight plan. It is therefore referred to as the IP-7090. At lift-off, data on booster position is obtained initially from the AN/FPS-16 radar at the Cape which feeds into the IP-7090. The IP-7090 output also is transmitted instantly to Goddard for use in initial launch computations for display at the Mercury center.

When the booster reaches an altitude sufficient that it can be tracked by AMR's Azusa Mark 2 system, the IP-7090 changes over to receive its data on booster position and velocity from the Azusa system, which usually is more accurate than data from the FPS-16.

Approximately 20 to 60 sec. after lift-off, the General Electric/Burroughs guidance system takes control of the booster, providing position and veloc-

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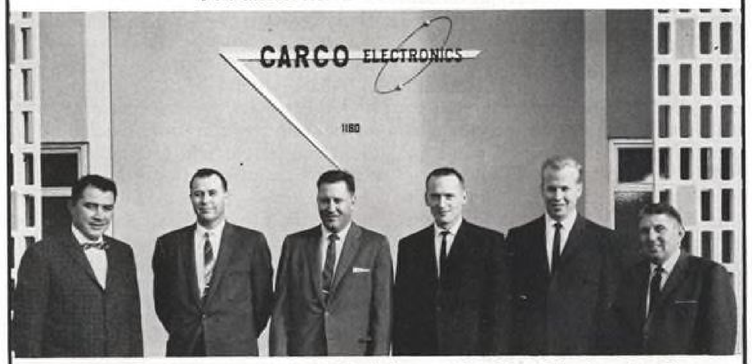
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ity data similar to that available from the IP-7090. This also is transmitted instantly to Goddard.

When both IP-7090 and GE/Burroughs data are available simultaneously, a data quality monitor at the Mercury center determines which is better and by remote control selects the data source which Goddard computers will use.

As the booster heads down range, it comes within view of the Bermuda radars. When the Mercury network was first installed, the only link with Bermuda was by radio, which did not permit transmission of radar data at high speeds and ran the risk of propagation interference. Because the Bermuda data is obtained during the critical injection or abort decision period, NASA decided to install an IBM 709 at Bermuda to make independent calculations on the spot.

Recently a submarine cable has gone into service between the U.S. and Bermuda, permitting transmission of radar data directly to Goddard. While the 709 remains in use, NASA is now considering shifting this function out of the Bermuda station.

Normally the data from the Bermuda radars will be more accurate than that from the Cape because of their closer proximity to the booster at this period in flight. But the choice of data source used by the Goddard computers is made by Mercury Control Center.

Once the control center determines that the capsule has been injected successfully, it switches the Goddard computers to their orbital computation mode.

Both Goddard computers run through identical orbital computations, using the same data, and compare answers as a check procedure. But only one machine is on line, feeding its output to the Cape for display and to the Goddard center display.

Power Sources

One computer operates from commercial electric power, while the other operates from a diesel-powered generator located at Goddard. This assures that loss of normal power will not disrupt the operations.

During the entire mission, the Goddard computers continuously calculate and display there and at the Cape the estimated impact point for the capsule if it should suddenly become necessary to initiate re-entry. (There is a 30-sec. built-in time delay between the instant an astronaut or ground station initiates re-entry action and the time the retro-rockets fire).

The computers also continuously estimate the time at which the retro-rockets will need to be fired to bring the capsule into the intended recovery area after completion of the present orbit, and after the final planned orbit. They also continuously calculate retro-rocket firing times to bring the capsule in at one of five contingency recovery areas if an emergency develops. Only the firing time to the next possible contingency recovery area is displayed, however.

When the Mercury center receives a signal that retro-rockets have fired, the Cape instantly advises Goddard of the time and the number of rockets that fired. Goddard operators insert this information manually into the 7090s and the machines then compute the estimated impact point.

A number of factors can cause the actual impact point to deviate from the first estimate, however, as the recent MA-7 orbital mission dramatically illustrated.

This is why the first radar report on capsule position after retro-rocket firing is so eagerly awaited, since it gives the first data on the actual re-entry flight path and permits a more realistic impact point calculation.

During the MA-7 flight, the first radar data received after retro-rocket firing came from Pt. Arguello. Based on this, the Goddard computers came up with a new impact point which differed from the early estimate by about 240 mi.

Initial reaction at both the Cape and at Goddard was that "the computer must have slipped a cog," according to one Goddard spokesman, because the mission had previously proceeded according to plan except for capsule fuel consumption. During the entire flight the computer-calculated time for retro-rocket firing had not changed by more than two seconds.

Goddard re-ran the calculation based on Pt. Arguello's radar data and came up with the same answer—a 240-mi. overshoot. This later was confirmed by radar data received as the capsule came within range of the Corpus Christi, Eglin and Cape Canaveral stations.

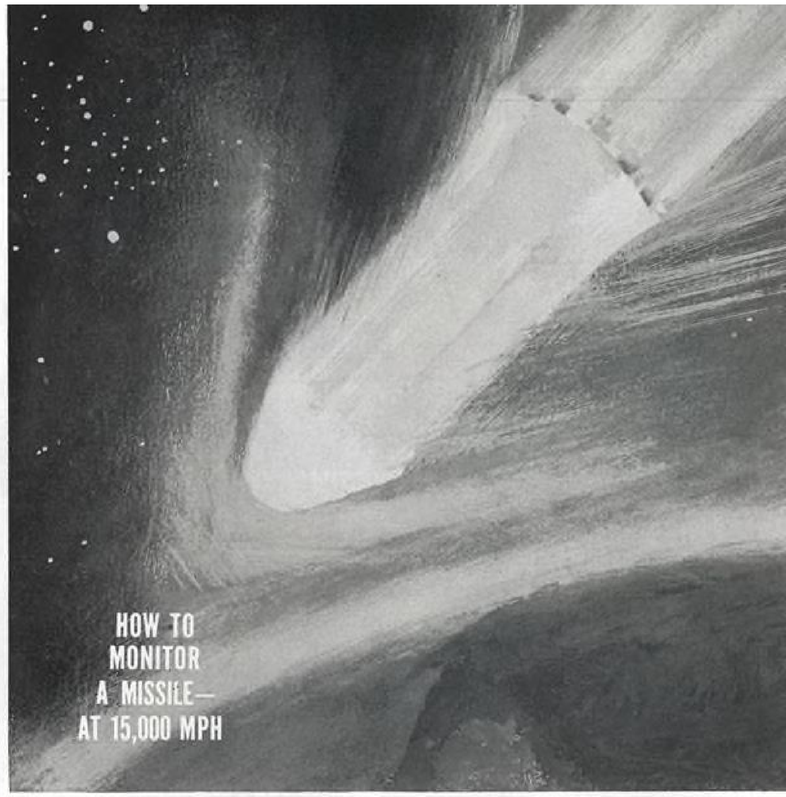
Astronaut Carpenter was picked up within 10 mi. of the impact point predicted from the Pt. Arguello radar returns as nearly as can be determined from the position report made by the aircraft which first sighted the capsule, according to a Goddard spokesman.

Reliability No Accident

The excellent reliability of the Mercury network to date is the result of a long and rigorous program which includes extensive exercising and preflight testing before each mission.

The network is operated, checked-out, maintained and continuously improved by the Manned Space Flight Support Division, one of five divisions reporting to John Mengel. Division chief is N. R. Heller.

The two 7090 computers and other



Spectacular as it is, a Titan take-off from Canaveral is only one end of the story. Moments after the shoot, nine thousand miles downrange, an airborne monitoring team is alerted to record the other end of the story as the re-entry vehicle plunges into the atmosphere at 15,000 mph.

Aboard the re-entry monitoring aircraft, a battery of photographic, photoelectric, and radiometric devices captures the dramatic end of the flight. A P.I. instrumentation tape recorder, operated by an Avco-Everett Research Laboratory monitoring team, is used to preserve on magnetic tape a precise record of important radiometric and time-sequence information...data which is essential in the development of advanced re-entry vehicles and in the country's anti-missile program.

One reason a P.I. recorder was selected for this program is that it provides full-size instrumentation performance in a fraction of the space. You'll be interested, if you record any type of scientific data, in other characteristics of P.I. recorders. For details, write for our current brochure.



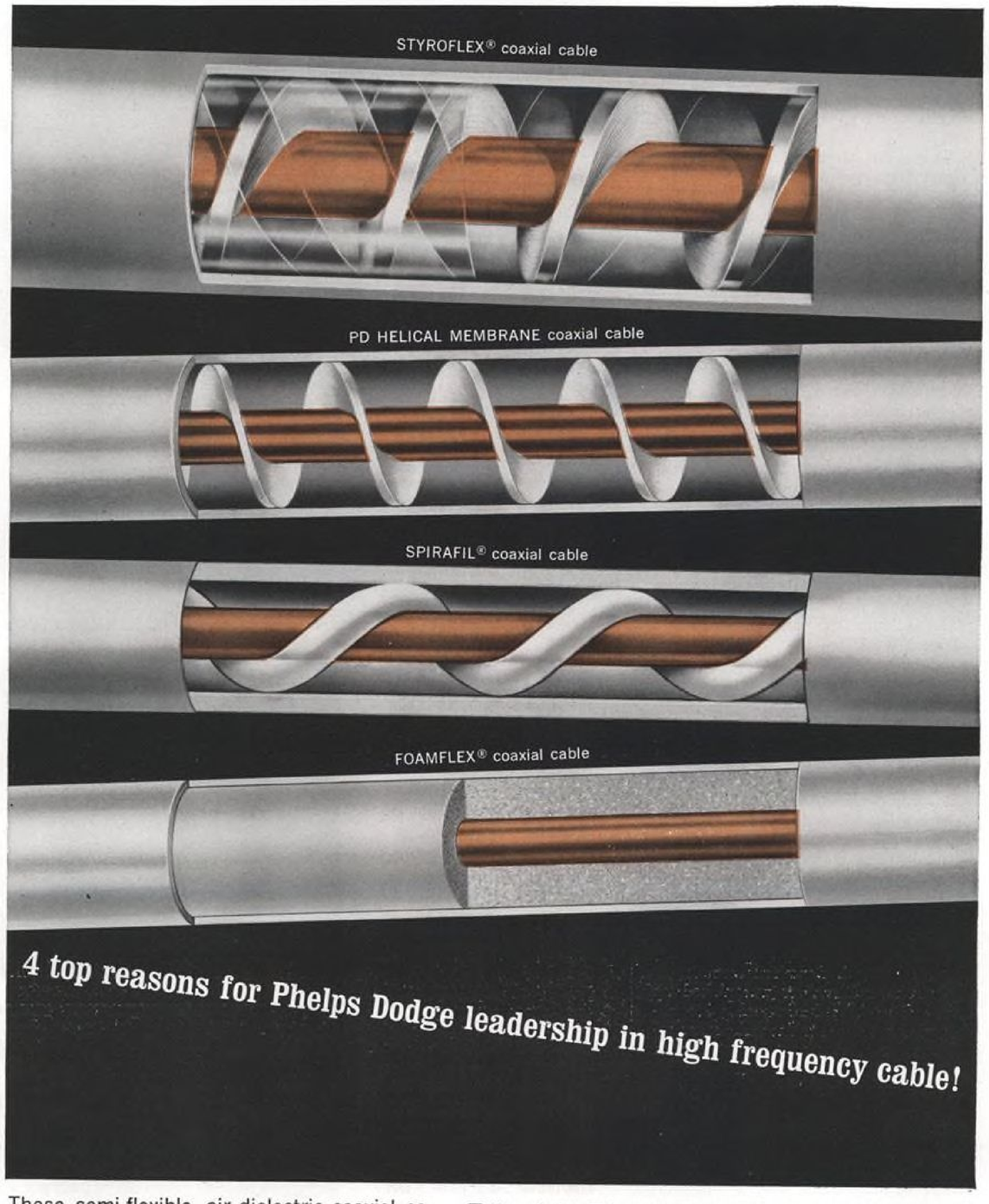


Above — Photo of Titan missile re-entry. Below — Recorder installation aboard the monitoring aircraft. Photos courtesy of Avco-Everett Research Laboratory.

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computers at Goddard used for related tasks normally are under the cognizance of the Data Systems Division, also under Mengel. Dr. Joseph W. Siry is acting director of the division.

Shortly before an orbital mission, the operational responsibility for the Goddard computer center shifts to the Manned Space Flight Support Division to centralize all of Goddard's responsibility for the network's operation.

At that time, the Goddard center comes under James J. Donegan, known as the Goddard operations director, who works for the Manned Space Flight Support Division.

Approximately 10 days before a scheduled orbital mission, the launch monitoring subsystem, involving facilities at Bermuda, AMR and Goddard, begins an extensive test simulation, using pre-recorded tapes, according to E. P. Odenwalder, Jr., executive engineer of the division.

Roughly a week before the scheduled launch date, flight controllers from the Manned Spacecraft Center arrive at each station in the network, which is then placed under the Mercury Control Center's cognizance.

Flight controllers bring pre-recorded tapes which will simulate a complete orbital mission for each station. In an effort to achieve realistic simulation, the tape program includes faults and troubles, such as a telemetry signal from the capsule which indicates it is running out of fuel, or an equipment failure at one or more stations.

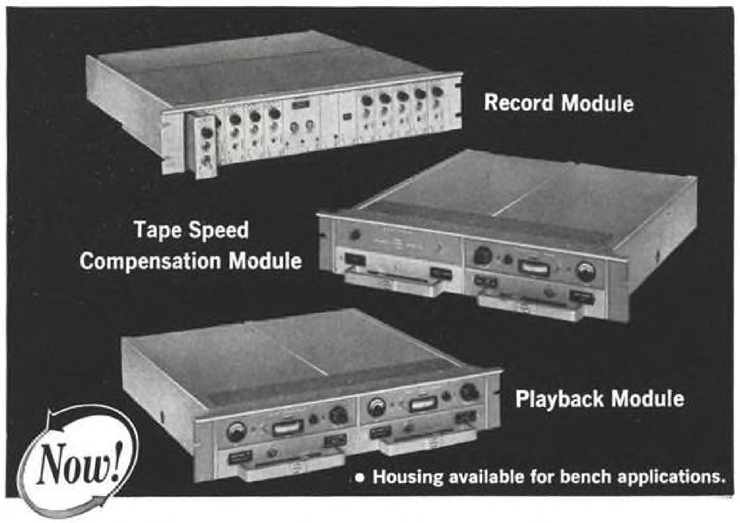
All positions are manned as they would be for a regular flight and the entire network runs through the mission, complete with exchange of voice and teletype messages. Station maintenance personnel also run both detailed and brief systems tests on all equipment.

Pre-Launch Preparation

Approximately nine hours before a scheduled lift-off, usually at around 10 p.m. the night before a launch, Goddard begins its countdown. First a group of IBM specialists comes in to carry out a preventive maintenance program on the two 7090s. They are followed shortly after midnight by a second group of IBM specialists who check the data flow throughout the network.

Radars at each station are boresighted against targets of known position and range to check performance and accuracy. Each radar then is positioned at a prescribed azimuth and elevation angle, to provide an input to the Goddard computers to simulate tracking the capsule in orbit. This assures that data from all radars are being processed at the site and transmitted to Goddard. High-speed data links to Bermuda and to the Cape also are tested.

Approximately four hours before lift-



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• All above are nominal 1% accuracy systems, subject to terminal equipment employed. • Full range of accessory calibration and test equipment available.

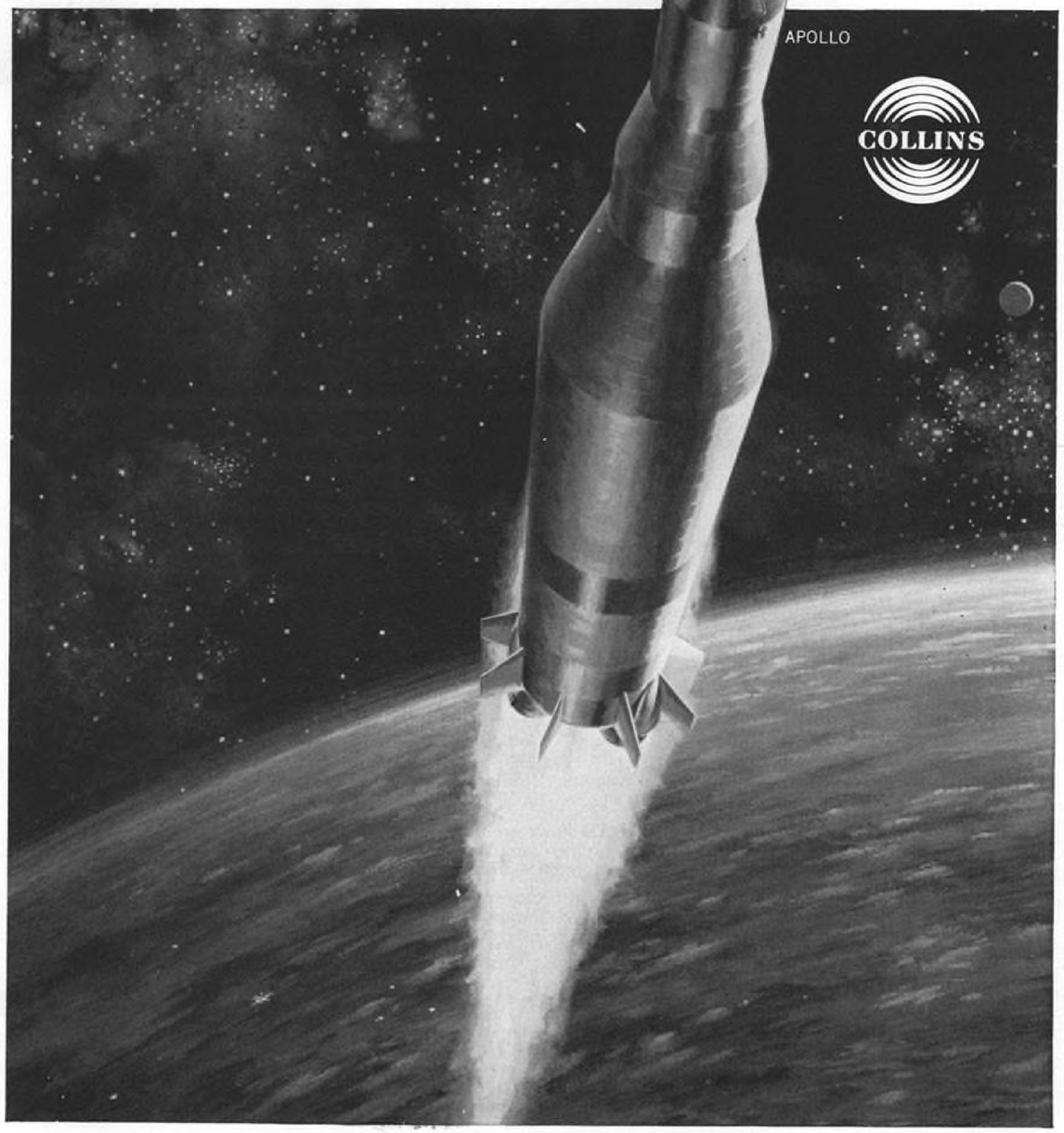
If you're concerned with magnetically recorded data for any purpose, you'll want to know more about UNIDAP's unique capabilities. For more information, address: Dept. AW-1-7.

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Every American voice from space — from the X-15 and Mercury — has been carried by Collins communications. Now, with the accent on reliability, Collins is readying extensive systems for the next and most ambitious U.S. space effort, NASA's Apollo manned lunar spacecraft. ☐ To further extend this leadership in space communications, Collins requires specialists in HF, VHF, UHF equipment, digital communications, spacecraft antennas, TV, radar, modulation techniques, tracking and ranging, information theory, and ground systems. If interested in this challenge, write Mr. L. R. Nuss, Cedar Rapids, Iowa; Mr. C. P. Nelson, Dallas, Texas; Mr. E. Montano, Newport Beach, California.



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off. Goddard conducts a computer and data flow integrated subsystem test. The Goddard computer, using a specially prepared program, transmits a "cue" to each station, which should evoke a prompt response with the appropriate reply. If the station gives the wrong reply, no reply, or takes too long in responding, something is wrong.

These computing center tests, under preflight director Walter Adams, normally will be completed by approximately 2½ hr. before scheduled lift-off, at which time Calvin Packard, the flight director, takes over. Both men report to Donegan.

Trajectory Confidence Run

The next test is the trajectory confidence run, in which the Bermuda radars, the FPS-16 and Azusa system at the Cape and the GE/Burroughs guidance system simulate a launch sequence, with their data being used by Goddard to compute the trajectory.. On days when no mission is scheduled, a similar test can be run using pre-recorded tapes. Mercury flight controllers participate in the simulated lift-off, which takes about 30 min. and checks out the entire complex.

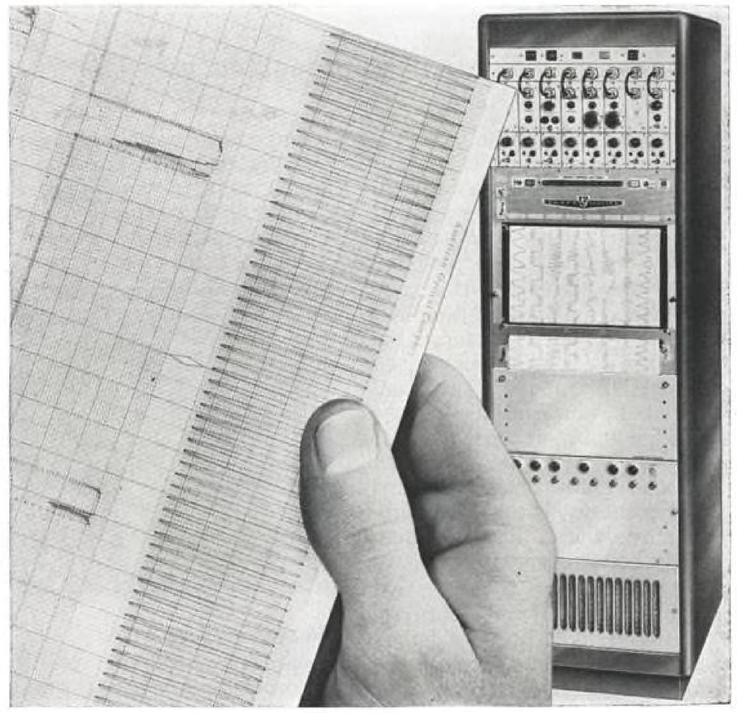
Approximately an hour before lift-off, the trajectory confidence run is repeated, except that tapes of radar data made during the first run are used.

At about 20 min. before lift-off, Goddard begins to exercise one 7090, using a cycling program in which the computer activates displays at the Cape which can be checked by the control center there. Approximately five minutes later, the second 7090 begins its cycling tests. These continue until launch time.

When the actual launch has taken place and the capsule is in orbit, Goddard automatically sends a teletype message to each station advising the expected capsule azimuth, elevation and range during its next pass over that station so that tracking and telemetry antennas can be properly oriented in advance. Each message gives four different "look angles" (azimuth, elevation, range and time for these coordinates) in case the station fails to acquire the capsule when it first comes within range. The first message is sent 45 min. before the capsule is due to pass over and is updated 25 and again 5 min. before the pass.

When the mission is finally completed, the Goddard center does not shut down and take the afternoon off. It immediately launches a post-mortem analysis of network performance and processes orbital data for transmission to the Mercury control center.

The network is continuously undergoing improvement. For example, the Atlantic ship-board station recently has been outfitted to give it a command



High recorder "Q" means more information on the chart!

BAP and MRP, the most important figures of merit for direct-writing recorders, help establish the "Q" for the Tracemaster systems by expressing performance *from the record*.

BAP: Band-Amplitude Product—a figure of merit that relates bandwidth to the maximum peak-to-peak amplitude. Tracemaster "250" provides a bandwidth of DC — 140 cps (3 db pt.) at 40 mm; i.e. BAP = 140 cps x 140 mm (5,600 mm — cycles/second).

MRP: Maximum Resolving Power — the product of BAP and the definition expressed in line-cycles per second. Tracemaster "250" produces 55 distinctly separable lines, per centimeter (5.5 lines/mm); i.e. MRP = 5,600 mm-cycles/second x 5.5 lines/mm (30,800 line-cycles/second).

An advanced pen motor design plus the completely transistorized circuitry and the exclusive direct-carbon-transfer writing method all combine to give the AO Tracemaster "250" a "Q" never before available in this class of recorders.

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FREQUENCY RESPONSE: DC to 110 cps. ± 1% at 40 mm. peak to peak. Down 3 db at 140 cps.

BAND AMPLITUDE PRODUCT: 5600 (i.e. 40 mm. x 140 cps.)

SENSITIVITY RANGE: 10 Microvolts to 100 v/cm

CHART SPEEDS: 0.2 to 500 mm/sec.

CHART CAPACITY: 1000 ft. roll

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Memorex scientific approach to magnetic tape making benefits users

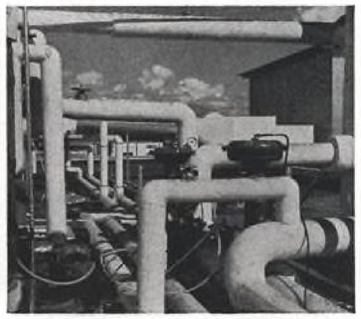
Too frequently, the best available magnetic tapes have not been good enough for many tape users. The reason: lack of consistent quality and reliability — the result of tape-making practiced as an uncertain art.

Memorex approaches tape-making as a science. Manufacturing processes and techniques uncommon in the industry have eliminated the uncertainties in tape-making and their consequent distressing effects. The result: Memorex magnetic tapes not merely incrementally better than products available to date, but materially better in important parameters.

In early 1961, Memorex Corporation undertook to turn the art of tape-making into a science. It put together a team of highly qualified people affording a diversity of talent and breadth of experience unique in the industry. Significantly, the group possesses unusual depth in chemistry, process engineering and automation, as well as in magnetic recording technology and data processing.



Within the white walls of the plant, which bespeak Memorex emphasis on cleanliness, are the most advanced tape manufacturing facilities in the United States. A conspicuous feature of the plant is its control and elimination of dust and other possible contaminants of production. Extreme emphasis upon freedom from airborne dust particles provides for Memorex tape users a like freedom from incipient drop-outs which could otherwise result from encaptured dust. Memorex uses dust filtration equipment similar to that employed in atomic energy facilities to prevent the escape of radioactive particles. The photo below shows a portion of the complex system of air filtration, humidification, de-humidification, heating, and cooling which provide the special environment for Memorex tape manufacture.



Memorex Research

Acute awareness of tape users' problems is one key to product development at Memorex; deeper understanding of the many parameters of tape is another.

Knowledge of tape users' problems — tape wear, oxide shed, head contamination, head wear, and obtaining better short wavelength performance and pulse response — derives from earlier experience of many Memorex researchers. Working with equipment manufacturers and sophisticated tape users, they obtained insights useful in developing meaningful solutions to many tape problems.

The aim of much Memorex research is to develop vital fundamental knowledge, lack of which continues to limit product improvement in the magnetic tape industry. The research staff has extensively investigated the problem of tape wear and the exact way in which wear influences tape reliability. Basic causes of different types of drop-outs have also been determined. Factors affecting the response at very short wavelengths and high packing densities are under study. Other study areas include the significance of the condition of tape edges and the electrostatic behavior of tape.

To establish a true technological basis for magnetic tape development and improvement, it is also essential to obtain critical measurements of the electrical, chemical, and physical properties of tape. Memorex, therefore, has set up one of the most thorough and accurate testing facilities in the world for tape analysis. It encompasses a number of new tests and techniques, which go well beyond the specifications of the most critical commercial and military users, and it utilizes advanced Memorex-developed test instruments, which achieve a degree of sensitivity and precision otherwise unobtainable.



An unusual degree of accuracy in measurements on magnetic materials is made possible with the use of a vibrating sample magnetometer, designed by Memorex research engineers. Below, as a part of a durability test which Memorex makes on every production run, a performance check on a digital tape handler provides the permanent photographic record of a computer tape's pulse output.



Memorex Manufacturing

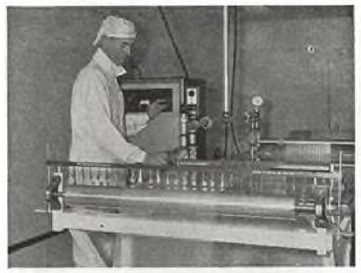
The strength of Memorex manufacturing people derives from their extensive experience in process engineering and chemical and pharmaceutical production. This background has enabled them to obtain for Memorex the consistency and reliability of quality production which is its objective.

Throughout the manufacture of Memorex tape are employed the principles and techniques of automation, production-line monitoring, and process control. As a consequence, you will find extreme consistency in the quality of Memorex tape, both within-a-reel and reel-to-reel. Also borrowed from the pharmaceutical industry are the standards of cleanliness and the techniques of sterile-room manufacturing which help insure consistency and freedom from drop-outs.

The Memorex manufacturing process incorporates many innovations, in the areas of formulation dispersing, treatment of backing material, coating, drying and curing, slitting, and even in packaging. Traditional processing methods were held suspect, not because of any desire to be different, but because innovation was considered essential to overcome quality limitations inherent in commonly used methods.



Access to clean room areas is through change rooms where street dress, jewelry, and cosmetics are removed. Lint-free clothing, caps, and boots are donned from another locker across the barrier-bench. Below, an ultrasonic cleaning system, designed by Memorex engineers, removes foreign matter from film base material prior to coating.



Memorex Quality Assurance

Memorex standards of quality, which exceed the specifications of commercial and military users, are established by its Quality Assurance Laboratory, an independently constituted function which cannot be subjected to delivery schedules and other pressures of a manufacturing operation. The Lab also has the responsibility for continuous audit and enforcement of its standards in the drop-out checking and other quality control activities of manufacturing. At least one tape slit from each production run is comprehensively tested.

It is not necessary for Memorex customers to engage in extensive and costly testing of Memorex products, because of this high order of quality control and this quality assurance philosophy. We conceive it to be our responsibility to know and to certify the quality of Memorex products without reservation. Our warranties reflect our integrity in practicing what we preach.



Slitting of rolls of the coated web into narrow tape widths is one of the several operations carried out in a completely controlled environment. Below, infra-red spectrophotometer and gas chromatograph analyses are used to monitor the resin binder systems used in coatings.



Type 22 Computer Tape and Type 33 Instrumentation Tape

Memorex manufactures only precision magnetic tapes for computers, data acquisition and analysis systems, telemetry and instrumentation recording systems, and exacting audio frequency applications. Memorex precision tapes are now available in widths, lengths, and reel sizes for all commercial tape drives.

Type 22 Computer Tape sets new standards of wear and durability. Users will find Type 22 gives performance comparable to premium tapes at substantial savings.

Type 33 Instrumentation Tape offers performance and cost advantages to analog recording users.

Write for comprehensive specification sheets. Upon request, we shall also send you literature describing Memorex research and manufacturing capabilities.



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and control capability that will be needed for six- to eight-orbit missions. The ship probably will be stationed near Guam for such missions.

The two ship-board stations plus those at Nigeria, Zanzibar and Canton Island, which formerly had only teletype communications with the rest of the network, are being outfitted for voice communications.

Telemetry data from the capsule during the critical injection phase, now received and displayed in the Bermuda station and relayed by voice to the Cape, soon will be relayed automatically and displayed at the Cape.

For the one-day (18-orbit) Mercury flights, where more information is needed on the ground to monitor the status of the astronaut and the capsule, wideband telemetry equipment will be installed at all stations.

The original Mercury network was laid out to assure that voice/telemetry contact with the capsule could be maintained for approximately 5 min. out of every 15 min. in orbit. During the 18-orbit missions, there will be some orbits in which contact with the capsule is available only once during an orbit. But by that time NASA expects its knowledge of capsule and astronaut performance to be sufficient to tolerate this.

By stationing the modified ship near Guam and moving the Indian Ocean ship-board station west to near Madagascar, NASA expects to modify present coverage to enable it to handle the one-day missions. For Gemini capsules outfitted for land recovery, additional precision radar near the recovery area may be needed, depending upon the site selected.

But the relatively low-altitude coverage of network radars will not be suitable for Apollo lunar missions. For circumlunar and lunar landing missions, elements of the present deep space probe network probably will be used.

Earth Satellite Network

The earth satellite network is an outgrowth of the original 11-station Minitrack network and the associated optical tracking network designed and built for Vanguard satellites as a part of the International Geophysical Year program in 1957-58. At that time orbit altitudes were expected to be low, payload sensors and output data were modest and economy was an overriding consideration.

NASA now is expanding the network's capabilities, already improved from its original configuration, to handle extremely high data rates from sophisticated scientific satellites. Goddard has developed an improved accuracy tracking system, called range-and-range-rate system, which is scheduled for initial field tests next year.

Operation and maintenance of the earth satellite tracking network is the responsibility of the Operations and Support Division, headed by F. J. Friel, Jr.

Minitrack is an interferometer type of system which determines satellite position in a north-south direction by comparing the phase or signals received from a satellite transmitter at each of two fixed antenna arrays oriented in a north-south direction. A similar phase comparison made by two east-west oriented antennas establishes satellite position in that plane. By using two or more pairs of antennas, each at different baseline distances from the center of the site, increased accuracy without ambiguity can be obtained.

The 11 original Minitrack stations operated at 108 mc., a frequency assigned for the IGY Vanguard program. Antenna configurations were layed out with highest accuracy for satellites in low-inclination orbits, the only ones then planned.

Since then, two stations have been added and several stations in Latin America have been moved to provide sites in England, Alaska, Newfoundland and Minnesota for improved coverage of high-inclination orbits, according to

EYE IN THE SKY



Official NASA Photograph

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Harold Hoff, assistant director of the Operations and Support Division.

The tracking frequency has been shifted to a permanent assignment of 136 mc. and new receivers have been designed which can be tuned to any frequency in the 136-137 mc. band, instead of being fixed at 108 mc. as before.

When 136 mc. arrays were installed, an additional pair of fine-resolution antennas were included with switching provisions which enable them to be used for either polar or low-inclination orbit tracking.

Separate Antennas

The Minitrack stations employ separate antennas for receiving telemetry data and transmitting command signals to the satellite. Present facilities include a nine-element Yagi for command-telemetry at 136 mc., with a similar antenna for operation at 108 mc. There also is a 16-element Yagi for 136 mc. operation which provides higher gain for use with high-altitude satellites.

Industry proposals are being evaluated now for an upcoming procurement of a self-tracking Yagi antenna, with a gain of about 22 db. at 136 mc., which will automatically track satellites from their radiated beacon signal. The new autotrack antennas are expected to provide a significant improvement in the quality of telemetry data, according to C. A. Schroeder, chief of the Tracking Systems Division, which is responsible for development of new network hardware and techniques.

While the Minitrack network has been undergoing a continuing program of improvement, an order of magnitude or greater increase in tracking accuracy and data rate handling is needed for some of the more advanced scientific satellites on the horizon. These include the Orbiting Astronomical Observatory and the solar, eccentric and polar orbit geophysical observatories (OAO, OSO, EGO and POGO).

The planned EGO orbit calls for an apogee of about 50,000 mi., which will give it an orbital period of about 40 hr. With the present Minitrack network, many hours would elapse between satellite sightings, taking far too long to establish its orbital parameters.

Also, the Minitrack interferometer technique is based on measurement of angles, which means that its inherent accuracy decreases as satellite altitude increases. The present Minitrack can determine angle to the satellite to within approximately 20 sec. of arc, but this corresponds to a possible error of nearly half a mile at a distance of 50,000 mi.

The new range and range-rate tracking system developed by Goddard's Tracking Systems Division is expected to be able to determine the distance to the satellite with an error of about 75 to 150 ft. and measure its change of altitude (range-rate) with an error less than 1.5 fps. or better, according to Schroeder.

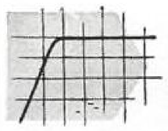
By triangulation of range and range-rate signals from three ground stations, separated by a suitable base length, the position of the satellite can be calculated accurately. For missions where it is desirable to determine orbital parameters quickly, the three ground stations must be located within several hundred miles of one another so that all can view the satellite simultaneously. But if continuous surveillance is more important, each of the three stations should be located approximately 120 deg. apart in longitude to track the satellite sequentially with precise time data used to correlate each station's measurements.

The three Goddard range-and-range-rate system stations, which Motorola is building under contract, will be installed in mobile vans so they can be shifted for specific missions. Initial field tests are scheduled for next year.

The new system requires that the satellite carry a transponder which retransmits the signal received from the

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Individual drawer type modules for solid state modulator

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DESIGN FEATURES OF THE 50 WATT AMPLIFIER UNIT:-
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Output Impedance - 50 ohms unbalanced
Input Impedance - 600 ohms balanced
Frequency Response - 300-4000 cps 3DB
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Control - local or remote control. On remote, up to 3000 ohms of loop resistance may be tolerated
Power Source - 115 volts 50/60 cps single phase OR 220 volts 50/60 cps can be provided on special order
Panel Space Required - standard 19" relay rack panel mounts. Only 28" is required for 50 Watt A3 model



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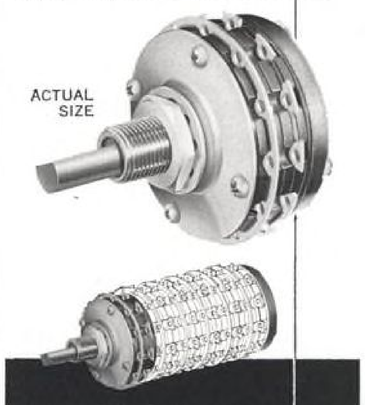
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ground terminals. Distance is determined by measuring the phase shift that occurs during transit to and from the satellite, while range-rate is determined from the resulting Doppler shift. The transmitted carrier wave contains a number of different frequency modulated subcarriers to provide high accuracy phase delay measurement without ambiguity.

The new system is intended to supplement, not replace, the Minitrack stations. It will be used only where the increased accuracy is needed and the satellite can afford the added weight of the transponder.

Large Antennas

To handle the increased bandwidth data requirements of the OAO, OSO, EGO and POGO scientific satellites, Goddard is building two new tracking and data acquisition stations with 85-ft.-dia. antennas and has requested funds for two more in Fiscal 1963.

The first, the Alaska Data Acquisition Facility near Fairbanks, is nearly completed and will be operated by the University of Alaska under NASA contract.

A second facility now under construction at Rosman, N. C., is slated for completion early in 1963.

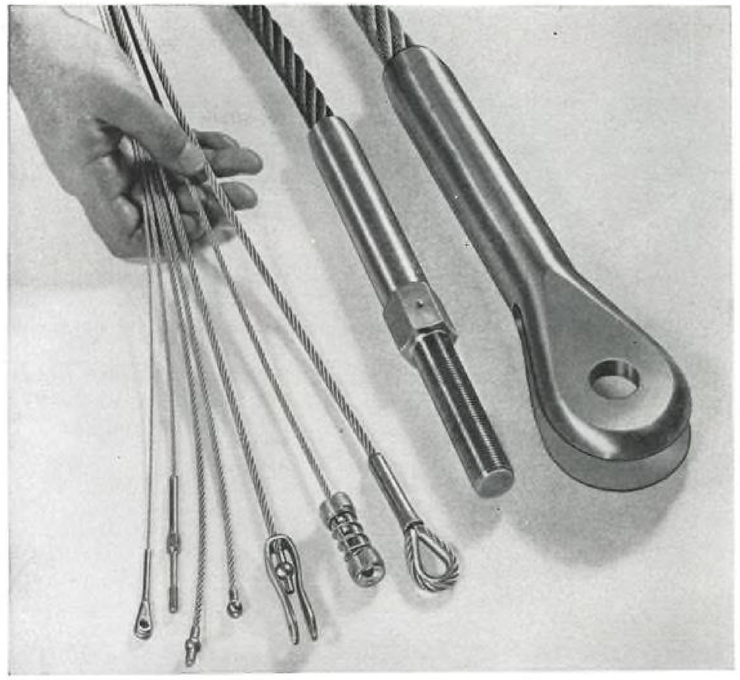
Because of the heavy usage required to control and receive data from the orbiting observatories NASA has asked for funds for another 85-ft. dish at Rosman and a fourth antenna to be located in the Far East. Sites under consideration include Japan, Okinawa and The Philippines.

To illustrate the heavy work load which requires the new facilities, the Eccentric Geophysical Observatory is expected to be in its high-altitude apogee, producing much-sought data, for 20 hr. out of every 40-42 hr. orbital period. The lower orbit OAO, OSO and POGO will be producing data and requiring command instructions from the ground for 15 min. out of every 90-min. orbit.

The Fairbanks antenna, standing 120 ft. high, is the largest yet built in which the dish moves in north-south and east-west coordinates rather than in azimuth and elevation. This enables the antenna to track a satellite passing directly overhead without having to swivel 180 deg. in azimuth.

The antenna has multiple feeds which enable it to receive at 136 mc., 400 mc. and 1,700-2,200 mc. Although it can be used both for tracking and telemetry at all three frequencies, the nearby Alaska Minitrack station probably will be used for tracking at 136 mc. The EGO and POGO satellites will transmit data at 400 mc. while the prototype Nimbus will transmit at 1,700 mc.

The antenna tracks the satellite automatically, using an amplitude



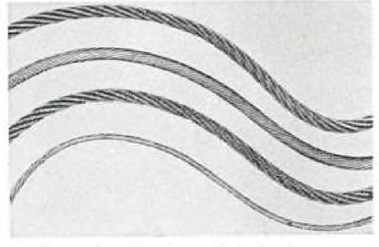
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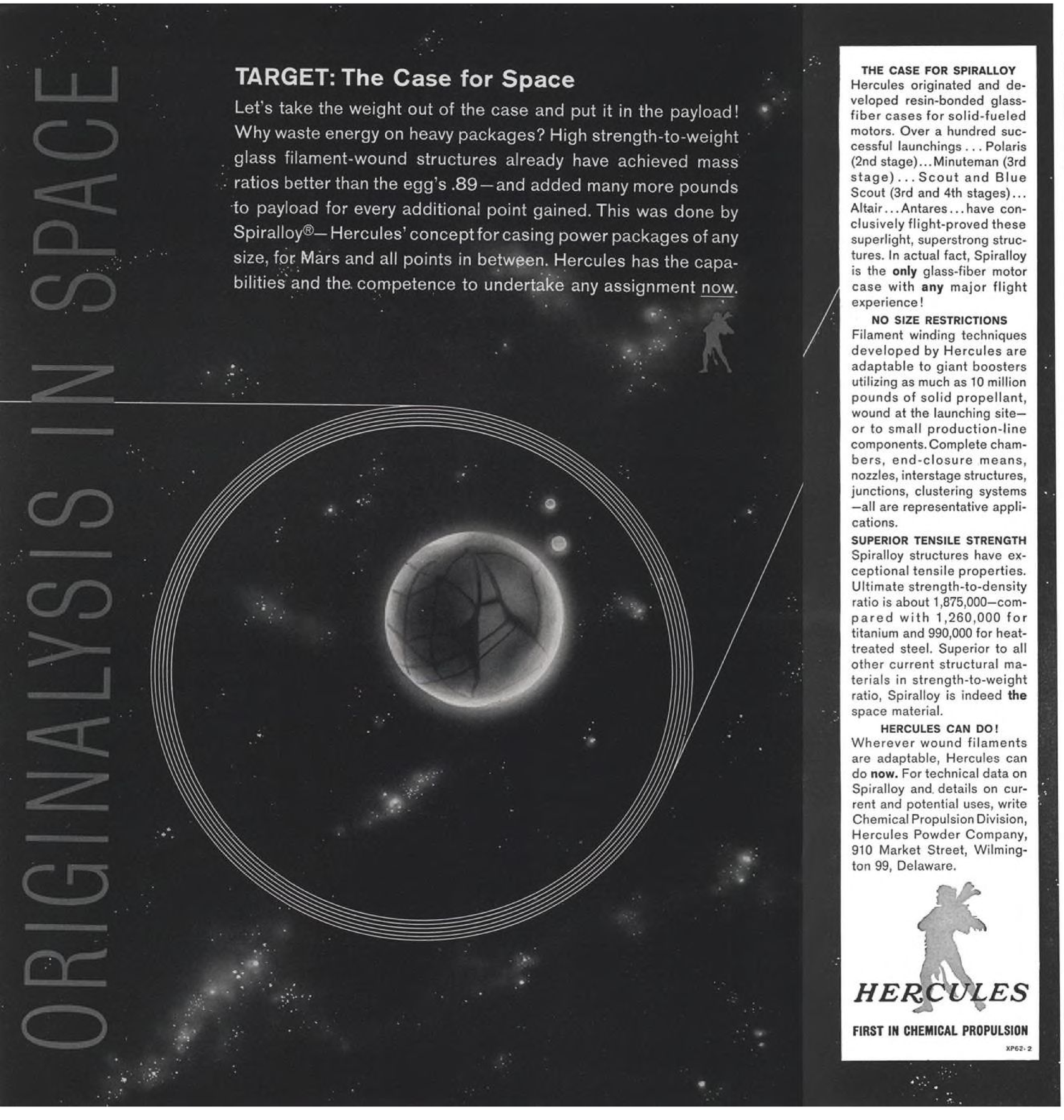


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XP62-2

monopulse auto-track system built by Collins Radio. The Alaska antenna was built by Blaw-Knox, while the one at Rosman is under contract to Rohr Aircraft.

New Developments

The Tracking Systems Division, under Schroeder, is responsible for developing new techniques and equipment to improve the satellite tracking net.

Approximately 25% of the division's development program is carried on in-house, while the remainder is contracted.

The new range-and-range-rate tracking system was developed here, and a working breadboard model was constructed in-house to evaluate feasibility before the contract was awarded to Motorola. A similar procedure was followed for a new digital PCM/AM-AM command system, expected to be more secure than the presently used tone command system. The new system also provides 70 commands, many more than are available with the existing system.

Generally speaking, the division is intentionally conservative when it comes to applying new techniques whose feasibility is questionable, preferring to emphasize reliability, low power consumption and long life.

Soon, Goddard will call for industry proposals for a new 136-mc. telemetry receiver with all solid-state construction, which can also be used for 400 mc. and 1,700-2,200 mc. by substituting different front ends. The objective in changing over from the present vacuum tube receivers is based on the practical advantages which solid-state equipment provides, Schroeder says. The lower power consumption is an important factor at remote sites, which must provide their own electric power, and the lower heat dissipation eases the burden on air conditioning power load.

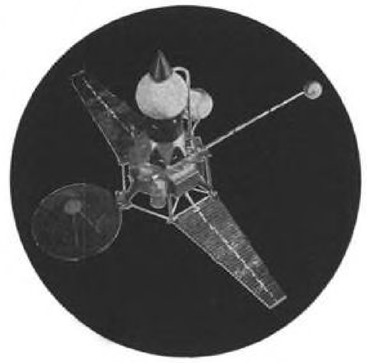
The solid-state equipment also should be smaller, and this is important as the amount of equipment needed at stations grows. Perhaps most important, however, is the improved reliability which solid-state equipment promises.

An antenna range near Goddard is expected to be operational this fall, enabling the division to increase its in-house capability in antennas. Some modest outside study contracts in side-lobe suppression and low-noise designs are planned, Schroeder said.

The division also has a modest outside program in low-noise amplifiers of the diode-parametric type. Maser amplifiers are not being used at present because of the problems of cryogenic cooling, and probably will await the development of a suitable closed-cycle cryogenic system suitable for use at remote sites.

A major effort is under way to im-

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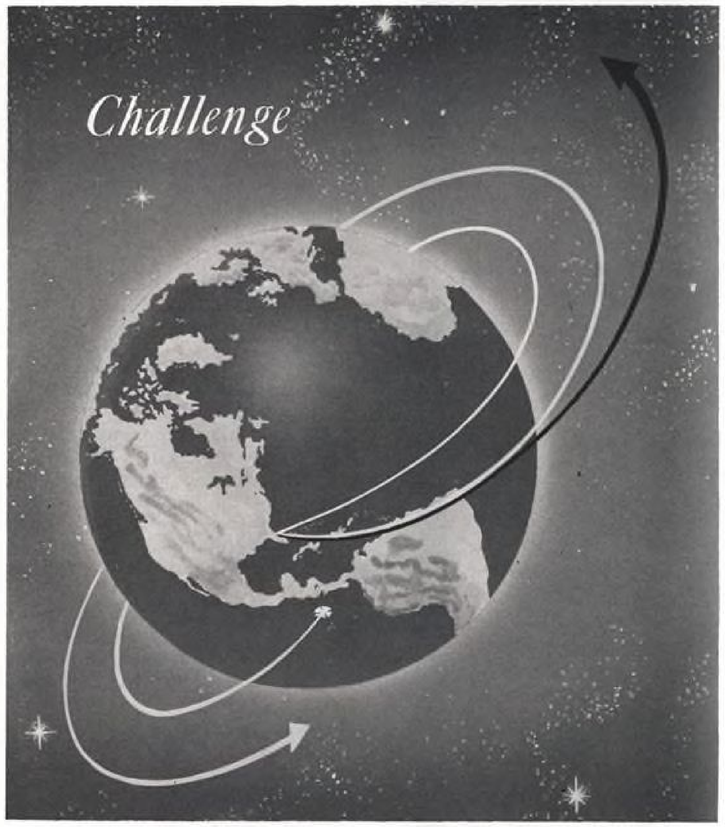
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prove the timing reference used throughout the Goddard networks for more precise correlation of measurements made by several stations. The present system uses high-frequency broadcasts by the National Bureau of Standards' station WWV, to provide both a reference frequency for daily calibration of the crystal oscillator at each station, which serves as its clock, and an accurate time marker.

Because of propagation characteristics in the HF band, the present WWV signal provides marker timing which is accurate to within approximately one or two milliseconds, Schroeder says. While this is adequate for the present Minitrack network, the new Goddard range-and-range-rate system will require an order of magnitude improvement.

A two-step improvement program is under way here. The first phase calls for using a transmission at very low frequency (VLF) in combination with a receiver having a long time constant (integration time) to set the station oscillator at the correct frequency, perhaps once a day. But the WWV transmission still will be used to obtain the time marker. This should provide a time reference accurate to within about one-half millisecond, Schroeder believes.

Meanwhile, Goddard is sponsoring work at NBS to develop techniques by which a brief time marker can be transmitted at VLF. If this can be developed, VLF would then be used both for oscillator calibration and time marking, with an error of perhaps 0.1 millisecond.

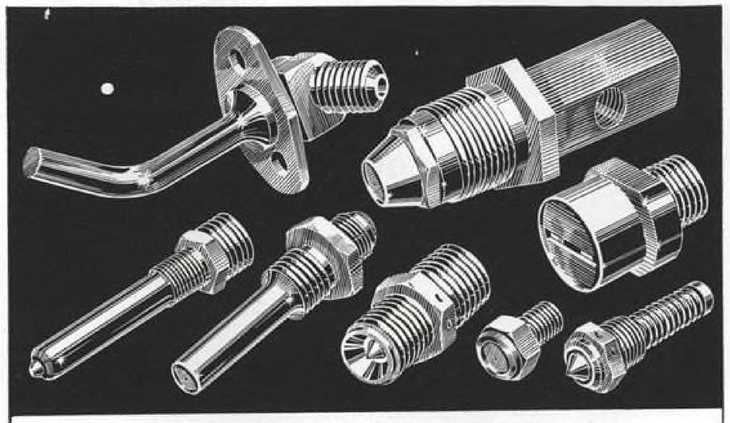
Although radio and radar tracking systems have the advantage of being able to operate in all types of weather, optical trackers are more accurate and have a built-in calibration because of the star background.

One of the biggest shortcomings of present optical trackers is the many hours of labor required to analyze tracking films and calculating satellite position.

The Tracking Systems Division is negotiating a contract for development of an automatic optical tracker which is expected to be able to lock onto a non-cooperative satellite and track it in daylight and twilight hours.

If this can be achieved with required accuracy, the azimuth and elevation aiming point can be read out directly in the same manner as with an automatic tracking radar, greatly expediting the data analysis and giving optical tracking a big boost.

The division here is investigating, in an in-house program, other sensors which might be used for automatic tracking during complete darkness. Some outside contracts in this work area appear likely.



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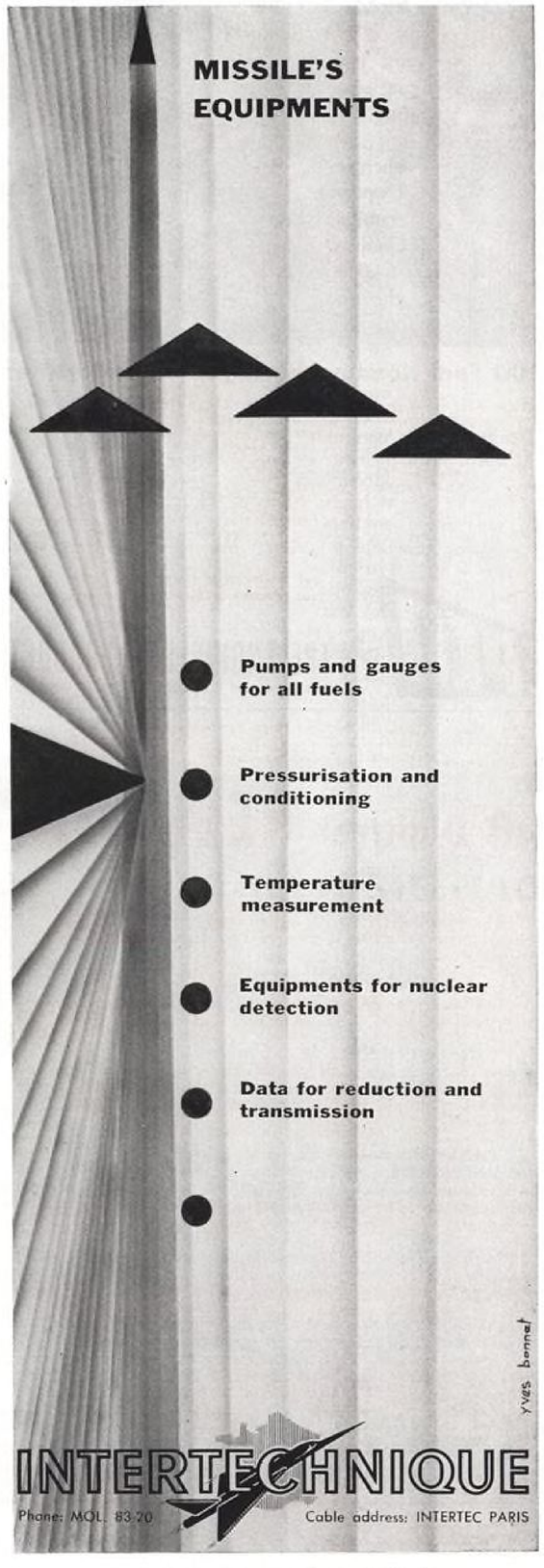
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Goddard Data Processing Role to Increase

Greenbelt, Md.—Goddard Space Flight Center is preparing for the avalanche of data that will be telemetered back from the coming series of sophisticated scientific satellites, such as the orbiting solar, astronomical and geophysical observatories.

Explorer 12 (S-3) provided a sharp warning of things to come when it produced some 6,000 reels of telemetry tape in its three months of operation. But Explorer 12 transmitted data at the rate of 350 bits per second, high compared to many previous satellites, whereas the Eccentric Geophysical Observatory (EGO) will be designed to transmit at rates up to 64,000 bits per second, or 180 times as fast, with a corresponding increase in the amount of data collected.

Although interest sometimes centers on the more glamorous aspects of National Aeronautics and Space Administration's scientific satellites, the end objective of the whole program is to obtain new information and reduce it promptly to a form suitable for use by the scientists whose experiments are in orbit.

The matter of controlling and selecting experiments in sophisticated satellites such as the Orbiting Astronomical Observatory is a related problem. These experiments will be designed to permit the ground station to select the next experiment conducted, but this must be planned carefully to permit maximum useful data acquisition with minimum expenditure of spacecraft fuel and power.

These are some of the challenging problems assigned to the Space Data Acquisition Division, headed by Dr. R. J. Coates. It is one of five divisions in Goddard's tracking and data systems directorate, under John T. Mengel.

This division was created almost a year ago to centralize in one group all of the command, control and data acquisition functions which previously had been divided among several divisions.

Spacecraft Responsibility

The division's responsibility with regard to the spacecraft is limited to the encoder, which converts experiment sensor measurements into the required digital format for transmission to earth, and the decoder, which receives ground commands and converts them into suitable form for operating satellite controls and experiments. Responsibility for the spacecraft telemetry transmitter and receiver is assigned to the Spacecraft Technology Division under the directorate for space sciences and satellite applications.

This division of reponsibility assures that the digital coding format used to transmit data to and from spacecraft is compatible with ground data processing facilities. Within the division, the spacecraft function is assigned to the space electronics branch. While current scientific satellites are using pulse frequency modulation (PFM), the trend is to pulse code modulation (PCM) for higher data rates in the more complex payloads, according to Dr. Coates. The branch carries out paper design and builds breadboards to evaluate feasibility, but flight hardware usually is built by outside contractors.

Responsibility for design and prototype construction of ground-based data processing and display systems, operating in real time to give NASA ground control stations a running status report on the operation of a satellite and its payload, is assigned to the space data control branch. For example, the OAO will telemeter back approximately 200 status-report items on the state of its own temperature, power and internal conditions plus data on sensor measurements.

These must be processed in real time, automatically compared with expected values and any discrepancies displayed so that ground controllers can take necessary corrective action and transmit new commands to the spacecraft.

The advanced systems implementation branch supports the space branch when a new equipment is ready for production by a contractor. This support includes monitoring the contractor's efforts, supervising subsequent equipment installation, training station crews in its use and evaluating performance during initial use.

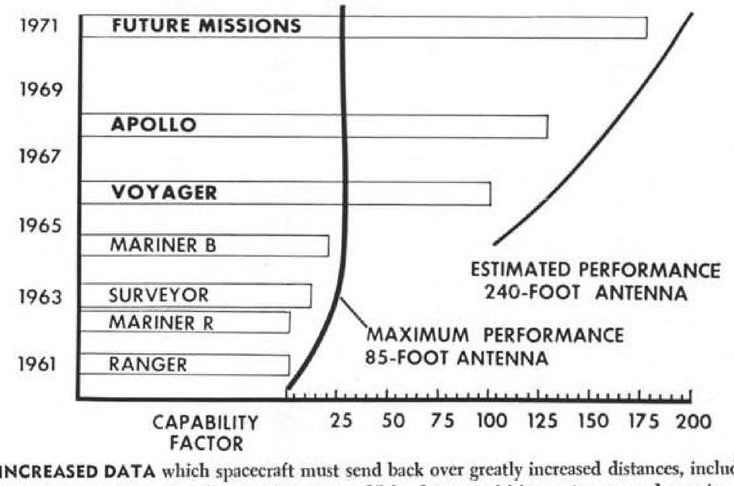
Experiment Data

The telemetered experiment data as recorded on magnetic tapes at various acquisition stations in the satellite network requires extensive processing and correlation before it is in a form suitable for use by the experimenters. This function is assigned to the data processing branch. First step in the processing is a quick-look examination of the raw data to check its quality and suitability for subsequent processing, as well as checking on ground station equipment performance.

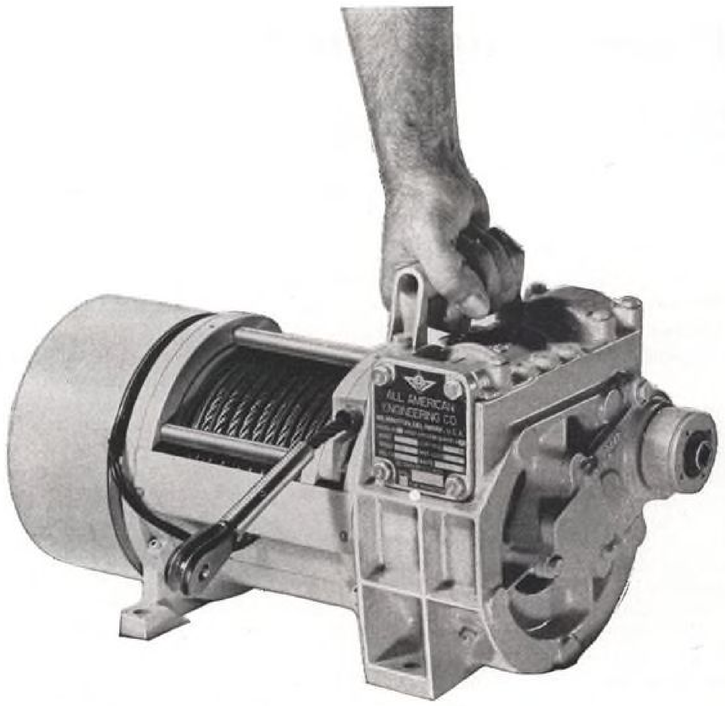
The raw data signals often are buried deeply in noise and must be reconstituted into idealized pulse form, a step carried out by a signal conditioner. The data then is converted from its original multiple channel parallel format into a digital serial form compatible with the digital computers which will perform subsequent steps.

The revised format data tapes then are processed by a CDC-160 or an IBM 1401 to detect momentary loss of data or inconsistencies in the data.

Finally, after the digital format tapes have been cross-checked against the original telemetry tapes for accuracy, they are run through a computer which adds information on satellite position, altitude and attitude, if it is available, for each set of telemetered data. The data, now in final format, can either be printed out in hard copy form or the



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data on each experiment can be extracted and recorded on separate magnetic tapes, which can be sent to individual experimenters for their own detailed analysis.

Much of the equipment used by the data processing branch is designed initially by the data instrumentation development branch. For example, the latter group has designed and built two of the present systems for processing telemetry data, known as STARS, an acronym for Satellite Telemetry Automatic Reduction System, and two more are under construction.

Three of the four prototype STARS are designed to accommodate pulse frequency modulation data, currently being used for scientific satellites such as Explorer 12. The fourth is designed to accommodate the newer PCM, planned for use on more advanced satellites.

Specifications currently are being prepared for an outside procurement of a general purpose STARS which will be able to handle both PFM and PCM, and process the data on a continuous production-line basis instead of in separate stages as is now done.

On-Board Processing

Dr. Coates says there is growing interest in the use of on-board data processing in the spacecraft to reduce the amount of data that must be telemetered and subsequently processed, with significant savings all around. The recently launched United Kingdom S-51 was one of the first satellites to use on-board data processing.

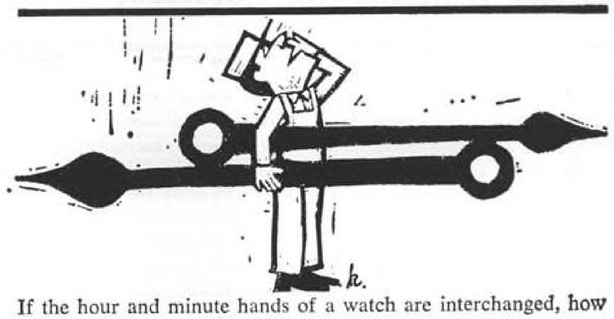
The decision to use this technique in S-51 was born of necessity. Because of originally planned ground station coverage, data from desired measurements had to be stored in the satellite's tape recorder, but it lacked sufficient capacity. Experimenters conceded that the many data points were needed only to obtain the slope of a curve. This could be obtained from measured data by a small on-board processor so that only a single value (slope of the curve) needed to be stored in the recorder, permitting a 50 to 1 reduction in data storage requirements.

Multi-Data Results

During times when the satellite was over a ground station, so that measurements could be telemetered down directly without storage, it was possible to compare the multi-data results with those obtained by on-board processing. The agreement has been so close that on-board processing will be used entirely for this function in the next U. K. satellite, the S-52, Coates says.

The Orbiting Astronomical Observatory is so complex an experiment, and its control will involve so many factors, that Goddard hopes to use a ground-

PROBLEMATICAL RECREATIONS 125



If the hour and minute hands of a watch are interchanged, how many different possible times could the watch show?

—Contributed

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Practical Dimensional Control of Large Missile Cases

Dimensional control in missile cases has in many instances been a perplexing problem requiring a solution beyond normal metal fabricating techniques. This is especially true in the larger missiles which are made up of two or more plates which, after bending, are longitudinally welded together to form a cylinder and then two or more cylinders are girth welded together to form a complete missile stage. Although the problems of dimensional control are more easily recognized in missiles fabricated by the roll and weld technique, the same problems are found to be as acute when forgings are spun out to the desired wall thickness.

The most satisfactory approach to dimensional control has been through the incorporation of the Grotnes mechanical expanding technique. Grotnes has developed a metal forming machine tool which on a 16-foot long missile case is capable of tolerances within .006" of the geometric definition of a cylinder.

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based computer to automatically program OAO operations, based on stated desires of the experimenters.

The Data Systems Division, one of five under the tracking and data systems directorate, is attempting to devise the required OAO computer control program. The objective is to enable a ground computer to simulate the OAO, with the same built-in constraints that exist for the spacecraft itself. For example, if one experimenter wants to scan a particular portion of the heavens during the next orbit, the computer will quickly determine whether the OAO can be maneuvered into this attitude in the required time, whether the desired stars will be obstructed by the sun, moon or one of the planets, and whether the spacecraft power supply can tolerate the experiment at this time, according to Dr. Joseph W. Siry, acting director of the division.

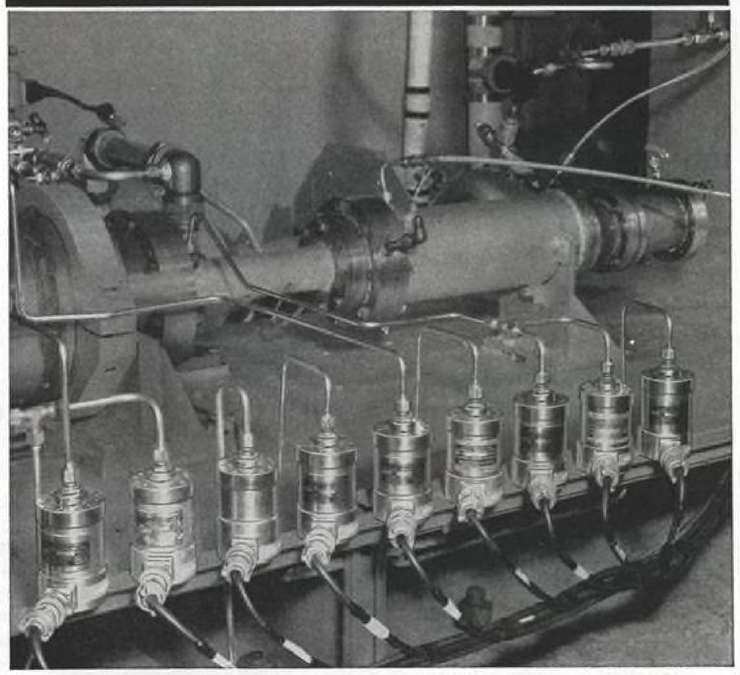
The division, which might better be called the computation facilities division, is responsible for operating most of the digital computers at Goddard, including the two IBM 7090s used in the Mercury computing center. The division also operates a third 7090, two IBM 1401s and an RCA 301, the latter used primarily as input-output processors for the larger 7090s. The stable of computers also includes a CDC-160 and CDC-160A, used primarily for editing Minitrack tracking data. Present plans call for the purchase of another 7090 and 1401 for use with the prototype Nimbus meteorological satellite.

Within branches of this division are the men who program the 7090s for the manned space flight missions, and operate the computers during a Mercury mission, working alongside engineers from IBM.

Another function of the division is to carry out orbital parameter determinations such as apogee, perigee and period. For satellites such as Tiros, whose attitude can be controlled to a limited degree through the application of current to a coil aboard the satellite, this division computes the amount and timings for such attitude corrections, based on an analysis of Tiros attitude data. Calculation of the optimum launch window periods for different types of satellites is another responsibility. This division also does considerable scientific computation for other divisions and directorates at Goddard, Siry said.

Within the last several months, Goddard invited 14 computer manufacturers to brief its scientists on their latest machines and new technology. In the near future, Goddard expects to brief a group of computer manufacturers on its own requirements for a new machine to be used for program control of the

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- Positive visual lock indicators afford inspectability for correct connector assembly and engagement.
- Millivolt drop, measured by the latest specification techniques, is 50% below the minimums before and after corrosion testing. And insulation resistance is at least four to five times higher at 300°F. than the specification's minimum at room temperature.
- Insertable and removable contacts are crimp terminated to military standard geometry, and are held in place by mechanical devices that insure retention, contact alignment and are replaceable if damaged.
- MIL-C-0026482 electrical performance ratings, at altitude, are met and exceeded at 110,000 ft. instead of at the specified 80,000 ft.

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OAO. Siry said his division often is pressed to give orbital parameters on a newly launched satellite before it has obtained sufficient data from the existing Minitrack network. He points out that when the original network configuration was laid out, Vanguard satellites were expected to be launched only in a low-inclination southeastern orbit, but today satellites are launched in a variety of other trajectories.

But with additions to the satellite tracking network now programed or requested, the situation should become improved.



TIROS 5 satellite is launched by Douglas Thor Delta from Cape Canaveral. Satellite and vehicle are managed by Goddard, which also collects, processes data.



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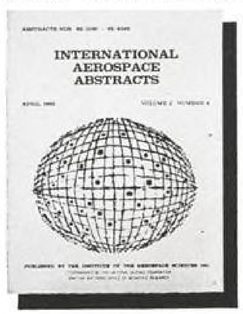
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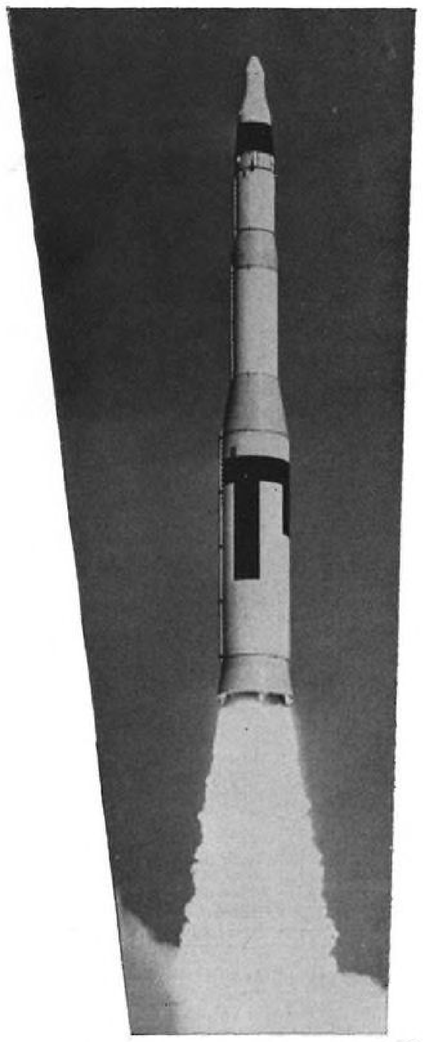
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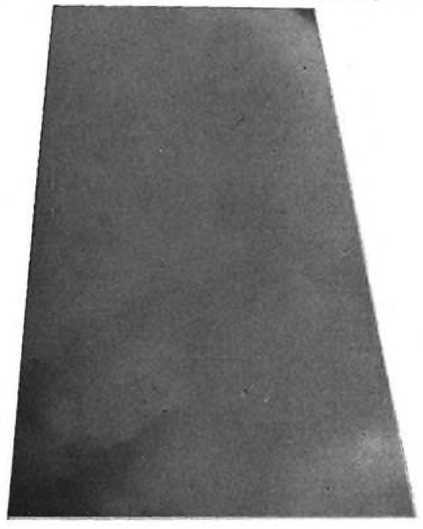


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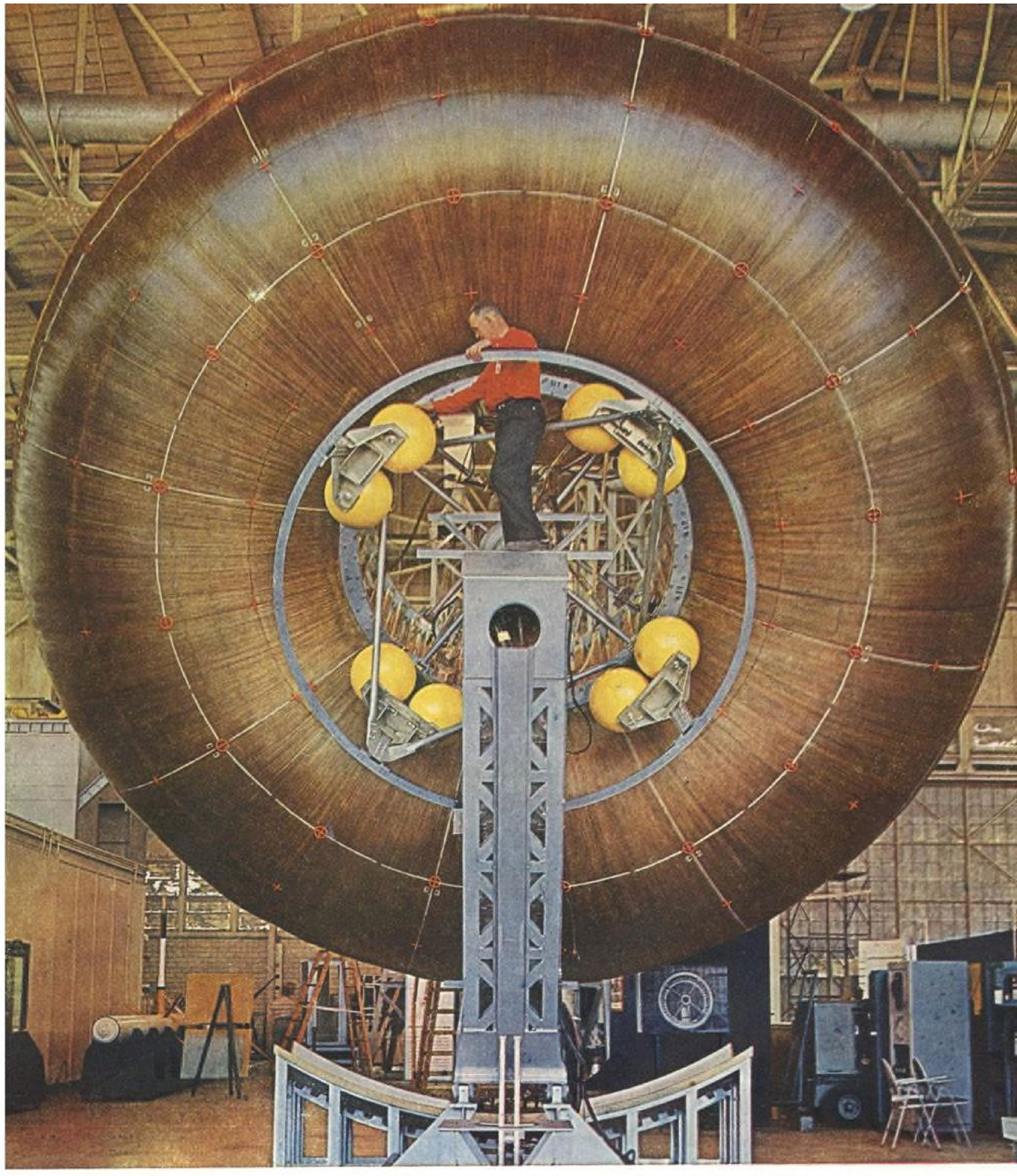


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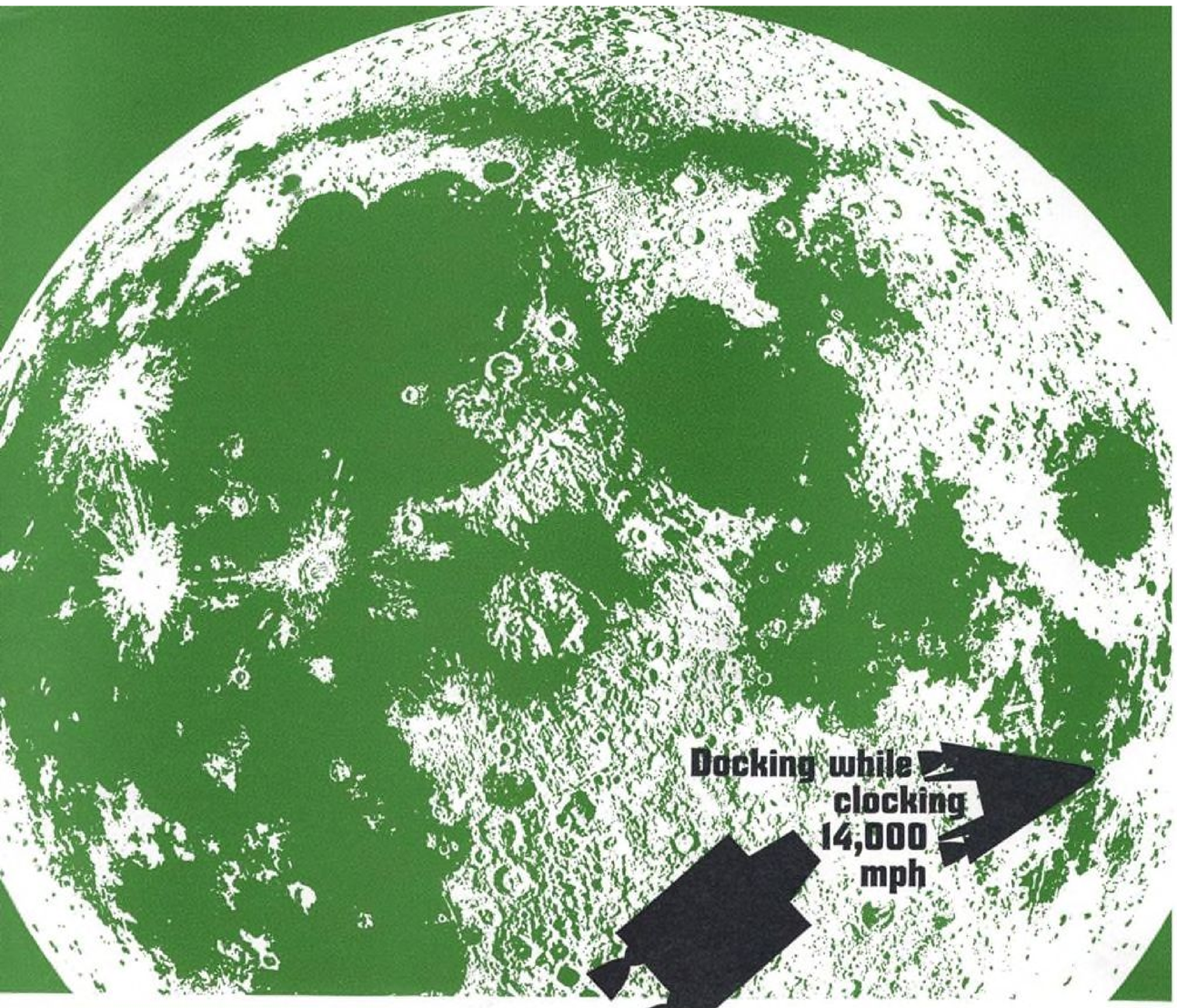
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NASA Strives for Procurement Flexibility

Washington—National Aeronautics and Space Administration, less than four years old and still a business neophyte by government procurement standards, is developing a financial acumen keyed to a philosophy that money is a dynamic tool for reaching national technical goals rather than a limiting element.

Dollars are considered in combination with the national technical capability and together these determine the total resources to be committed to space.

With this approach, the space program avoids the handicaps of an overriding desire to balance the books. Instead, it is designed to be flexible enough to underwrite a significant breakthrough or a new project that was not programed, and strong enough to eliminate any project that has reached a dead end.

NASA is young enough to take calculated risks in the way it does business, but most of its innovations are in technique and not in basic procedure. Complications that have arisen have stemmed mostly from the fact that its prime contractors are the same industrial firms that work chiefly for the Defense Department.

NASA Departures

By law, NASA's procurement procedures closely follow the Armed Services Procurement Regulations. But the agency is developing its own character, and industry is finding significant departures in the emphasis that NASA places on such areas as quality assurance, on-time delivery and performance.

The impact of these departures will become pronounced in Fiscal 1963, when NASA expects more than 150,000 different procurement actions involving contracts valued at more than $3 billion. NASA intends to write formal contract clauses covering many of the quality and performance requirements that previously were only implied.

Although the agency can experiment with its procurement techniques, it cannot do so in its flight program, where man-rating and reliability of hardware must be near-absolute no matter how complex the system. Unlike the missile development program, where scores of Atlas or Titan vehicles could be launched before the system was considered operational, much of the wringing-out process for the large Saturn C-5 and Nova space boosters will have to be accomplished before first firing.

It is within this framework of monumental cost per item, a few of each kind to be produced and a need for the utmost in reliability that NASA sees the demand to improve greatly on classical government procurement practices.

NASA has completely decentralized its procurement. Contracts are written at headquarters and at 10 field installations (see chart, p. 350). One objective of decentralization is to broaden the base of sources. Each center has its own bidders' and suppliers' lists and conducts its own competitions for equipment, construction and research and development.

NASA also is interested in unsolicited proposals in all scientific disciplines. This program is managed by the Office of Research Grants and Contracts at headquarters here (see p. 357).

Selection Process

Centers initiate all research and development contracts on the basis of programs approved by project chiefs at headquarters. Source evaluation boards are formed for all projects costing $1 million or more. If the estimated cost is below $5 million, the contract is written by the centers and headquarters does not become involved in the procurement process.

When the estimated cost is above $5 million, the center having the technical responsibility for a project prepares background work and forwards it to headquarters as the basis for requests for proposals and specifications. Ordinarily, the project chief in headquarters becomes the chairman of the source evaluation board, which will include headquarters and field experts in both management and technical areas.

An evaluation board establishes criteria and develops a request for proposals, which is sent to a preferred list of companies that NASA considers qualified to perform the job. Bidding is not restricted to this list, but NASA has found that it very seldom receives bids worth serious consideration from companies that were not on the original list for a particular competition.

This is the beginning of a two-step competition designed to help reduce the need for what NASA calls "brochuremanship"—the preparation of elaborate and costly proposals by a large number of companies when only one or two will be awarded contracts.

Pre-Proposal Briefings

Pre-proposal briefings are held to acquaint potential bidders with the complexity and difficulty of the job to be tackled. In most cases, the majority of companies that attend pre-proposal briefings drop out of the running by the time the formal bidders' conference is held.

Requests for proposal are distributed at the bidders' conference.

For competitions involving more than $5 million, evaluation board reports are

NASA Contractor Statistics

National Aeronautics and Space Administration's largest contractor is North American Aviation, Inc., California leads all states in dollar value of NASA contracts, and the Marshall Space Flight Center is the agency's biggest spender, according to the most recent fiscal summary issued by NASA.

The report, covering the six-month period which ended last Jan. 1, shows North American received payments totaling $47.6 million; McDonnell Aircraft, $37.4 million; Douglas Aircraft, $21.7 million; United Aircraft, $18.4 million; Ling-Temco-Vought, $11.4 million; Grumman, $10 million; Aerojet, $9.5 million; Radio Corp. of America, $7.3 million, and Chrysler and Bendix, $6.7 million.

Contractors whose components were purchased through Defense Department are not included. These purchases totaled $169 million for the period. If these contractors were included, companies such as General Dynamics, which supplies Atlas boosters, and Lockheed, which supplies the Agena upper stage, would outrank some firms now high on the NASA list.

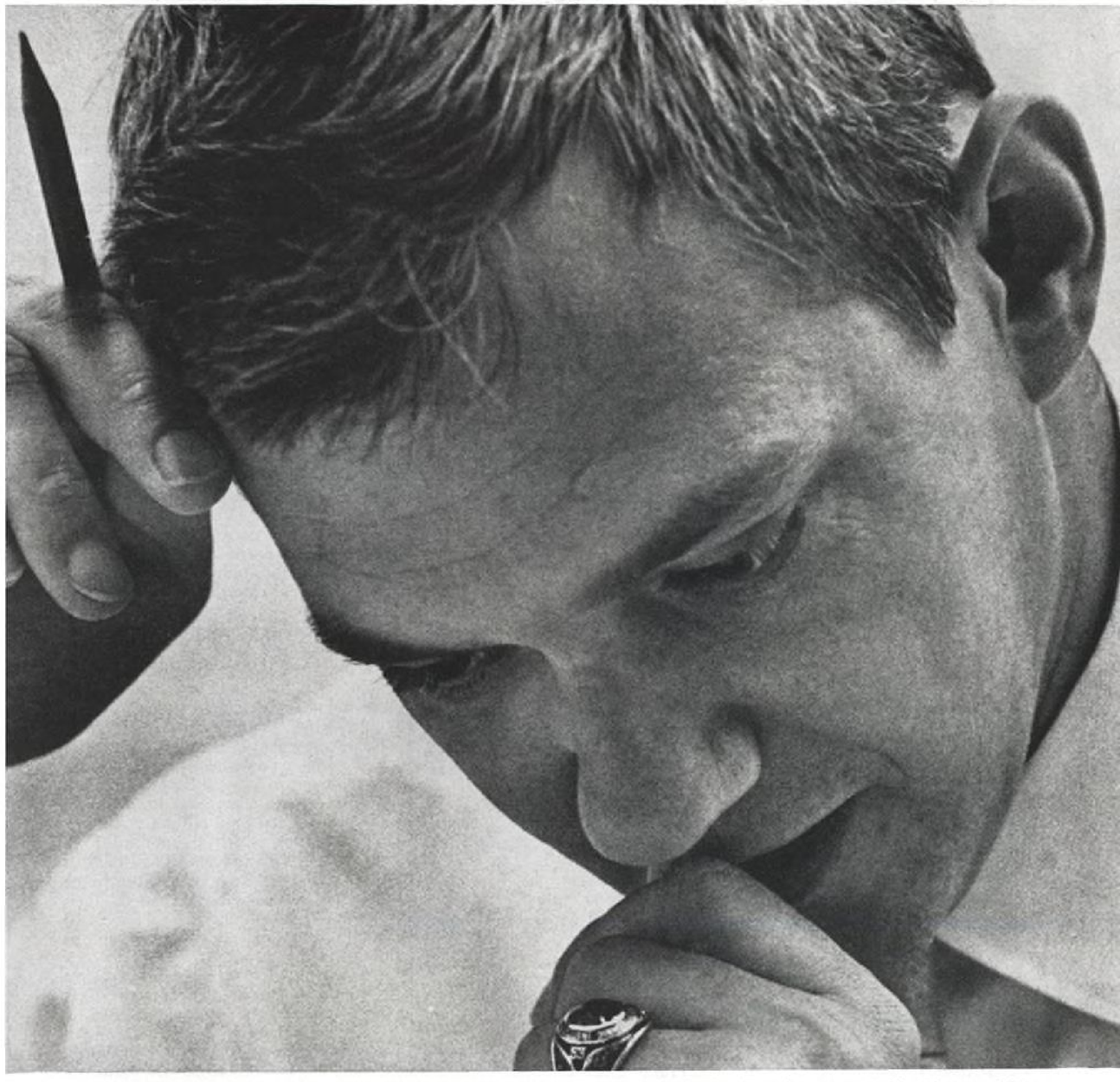
For the same period, California companies received $100 million; Missouri, $38 million; Alabama, $27.6 million; Florida, $27.3 million; New York, $23 million; Texas, $13 million and Maryland, $12.2 million.

Marshall Space Flight Center had 11,300 procurement actions during the six-month period, obligating $257.3 million. Western Operations Office had 500 actions involving $154.2 million; Goddard Space Flight Center, 8,800 actions involving $73.6 million; Manned Spacecraft Center, 1,100 actions and $47.2 million; Langley Research Center, 11,000 actions and $32.9 million; headquarters, 3,300 actions and $30.9 million; Lewis Research Center, 10,900 actions and $12.9 million; Ames Research Center, 5,000 actions and $6.7 million; Wallops Station, 1,800 actions and $6.5 million and the Flight Research Center, 2,500 actions for $1 million.

NASA Procurement Directory

Installation	Procurement Officials	Specialty Areas
NASA Headquarters Washington 25, D.C.	Albert A. Clagett, procurement officer E. W. Quintrell, small business specialist	Foreign government and foreign commercial contracts; studies and surveys in research and development and management.
Ames Research Center Moffett Field, Calif.	A. S. Hertzog, procurement officer Donald E. Davis, small business specialist	Re-entry physics, environments, exobiology, biotechnology, environmental biology, guidance, stabilization and control.
Langley Research Center Langley Station, Hampton, Va.	Sherwood L. Butler, procurement officer Joseph F. Braig, small business specialist	Aerodynamics, heat transfer, materials, structures, fluid mechanics, guidance and control, development of prototype simulators and research instrumentation.
Goddard Space Flight Center Greenbelt, Md.	Gordon H. Tyler, procurement officer Harry T. O'Toole, small business specialist	Complete systems in space sciences and satellite applications and in tracking, data acquisition and data reduction. Theoretical program in astrophysics, celestial mechanics, plasmas, lunar surface, earth and planetary atmospheres.
Jet Propulsion Laboratory Pasadena, Calif.	T. W. Candee, procurement officer G. R. Lawrence, small business specialist	Propulsion, aerodynamics, chemistry, guidance, communications, physics and mathematics relating to complete unmanned lunar and interplanetary spacecraft.
Western Operations Office Santa Monica, Calif.	Earle Sample, procurement officer Alex Mirosav, small business specialist	West Coast contract monitor for industry, research organizations, NASA installations.
Flight Research Center Edwards, Calif.	Morris E. Bowling, procurement officer Lloyd J. Walsh, small business specialist	Aircraft aerodynamics, heating, operating problems, simulation and flight support.
Wallops Station Wallops Island, Va.	Louis T. Birch, procurement officer Robert H. Bradford, small business specialist	Rocket-propelled vehicle experiments, including satellite payload prototype instruments. Scout-launched satellites and probes.
Marshall Space Flight Center Huntsville, Ala.	Wilbur S. Davis, procurement officer James S. Morrison, small business adviser	Development and prototype construction of Saturn-class launch vehicles, including aeroballistic and related sciences, simulations and data reduction, research in manufacturing, guidance and control systems, vehicle checkout and launch.
Lewis Research Center Cleveland, Ohio	John Biggs, procurement officer Norman C. Prahst, small business specialist	Chemical and nuclear rockets, electric propulsion systems, power generation and space environmental systems.
Launch Operations Center Cape Canaveral, Fla.	Gerard A. Michaud, procurement officer Carl J. Dahl, small business specialist	Construction, supplies, materials and services for vehicle preparation and launch.
Manned Spacecraft Center Houston, Tex.	Dave W. Lang, Jr., procurement officer H. T. Christman, small business specialist	Mercury, Gemini and Apollo manned spacecraft, with some advanced technical development studies under contract.
Space Nuclear Propulsion Office Germantown, Md.	George Kimball, procurement officer	Project Rover and the Nerva nuclear engine, advanced technology, test facilities, reactor and vehicle development.

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ILLUSTRATED RIGHT:
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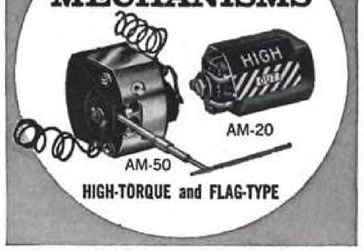
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forwarded to NASA Associate Administrator Robert C. Seamans, Jr. He and Deputy Administrator Hugh L. Dryden then review the reports and make a recommendation to NASA Administrator James E. Webb, who makes the final decision.

Top NASA officials insist that there has been no case where a contractor was selected solely for political reasons. They concede that the political facts of life have been taken into account, but they say that so far they have never been placed in the position of awarding a contract to a company that did not have full technical capability to handle the job. Technical considerations are given top priority; then management considerations; and finally, NASA's desire to bring new companies into space work to broaden the base of technological competence is weighed.

Increasingly, NASA is trying to cut down cost and manpower and improve the selection process in highly complex competitions such as Apollo and Nova by awarding several conceptual design study contracts before it picks a hardware developer. This is the first phase of the two-phase competition. It is probable—but by no means guaranteed—that one of the study companies will be selected to develop the hardware for the space agency.

NASA relies primarily on two types of contracts:

• **Cost type,** either straight reimbursement or with a fixed fee. During the six months ending last January, 82% of NASA's contracts were cost-plus-fixed-fee, which is considered the most attractive type when technical unknowns are involved. By law, fees are negotiated in dollars, and they average 6 to 7% of the total job cost.

• **Fixed price,** which account for 17% for NASA's contracts. This type is used when the item or services to be procured can be clearly defined. It is the type usually used for conceptual studies in which negotiations are in terms of man-hours.

Inserting new twists into classical government procurement practices has been difficult at a time when NASA's budgetary expansion has paralleled the agency's growth in responsibility. NASA began its life as an agency a quarter of the way through Fiscal 1959 with an appropriation of $300 million. Its budget for Fiscal 1963, which began July 1, amounts to $3.6 billion—about 70% of which is earmarked for research and development.

Most of the major contracts in the future will contain new clauses covering:

• **Quality assurance**—with provisions for inspectors, prime systems contractors and suppliers. The quality assurance provisions were developed beginning more than a decade ago by the former Army Ballistic Missile Agency research and development team, most of whom transferred to NASA to form the nucleus of the Marshall Space Flight Center.

• **Program Evaluation** and Review Technique (PERT)—A computer analysis method for reporting critical program events, modeled after Navy's Polaris PERT system.

• **Financial reporting**—Budget Bureau recently approved a NASA program which requires that contractors report monthly their total costs to date and a projected total project cost. This will be the first use of such a technique in government procurement history.

NASA is aware that the innovations will add to the complexities and costs of projects. It has already heard complaints of over-management and government red tape. But the agency feels the expense of space projects and the requirement for reliability, particularly in manned space flight, makes formal contract provisions in these areas logical and necessary.

Emphasis on quality assurance is designed to eliminate flight failures by microscopic inspection during production and checkout. PERT will focus management attention on existing problem areas and on activities that are likely to become critical. Financial reporting will help to rectify one of the most overwhelming research problems —cost estimating.

One NASA official put it bluntly: "We are not satisfied with out own cost estimates. We are damned unsatisfied with our contractors' estimates."

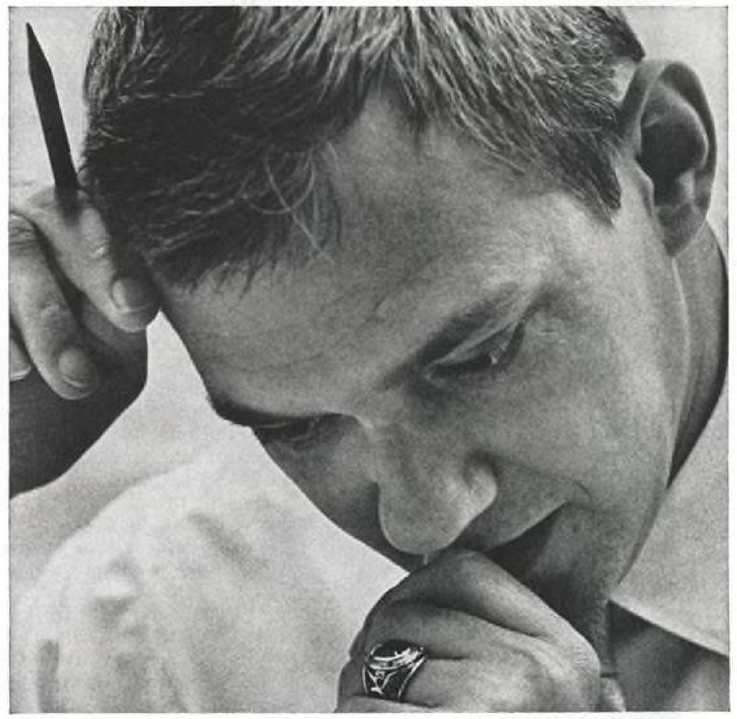
Incentive Contracting

Along with tighter management controls, NASA is seriously attempting to find ways of adding incentives to contracts. Wesley Hjornevik, director of administration for the Manned Spacecraft Center, said it is difficult to find a "handle" on which to base research and development incentives when an item has never been made before. The target, he said, must be objectively measured, but it cannot be subject to adjudication after the job has been finished.

Herbert L. Brewer, a headquarters procurement officer, pointed out that the incentives problem is complicated by the small number of items NASA makes under one contract—for example, the Apollo spacecraft. Even though this contract will be sizable in dollars, numbers of spacecraft to be produced will be relatively low.

NASA is willing to pay premium fees if performance is good, and performance may be the optimum base for research and development incentives. Ernest W. Brackett, procurement director, said the agency is considering a system of contractor performance evaluation which will take into account the general qual-

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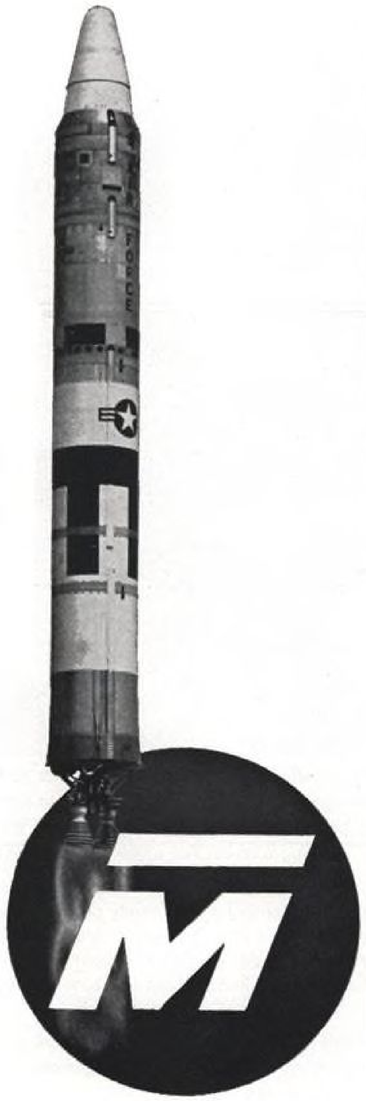
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When a launch is successful, the outcome of this evaluation is obvious. But the drawbacks are obvious, because when a launch fails because of a minor switch or valve, it will be hard to penalize contractors whose components did not have an opportunity to perform.

The new quality assurance provisions are designed to eliminate such random failures, however, and they require that contractors and suppliers, large and small, document their inspection plans as part of their contracts.

Quality Assurance

The quality assurance program consists of three parts:

- **Inspection agency provisions,** which spell out inspection plans and methods of monitoring and reporting on the contractor quality assurance system. Essentially, it is the guide to be used by Defense Department representatives who monitor NASA contracts, and by NASA plant representatives.
- **Major contractor provisions,** describing requirements for relation of quality to reliability, the quality program plan, design control, qualification tests, control over subcontract quality, fabrication and process controls, documentation, corrective action and quality auditing.
- **Supplier provisions,** which call for documentation of the company's inspection plan and defect-prevention methods for components it buys from others.

Within 45 days after the award of a contract, the prime contractor must provide a plan which shows how his quality program will operate and what changes are necessary in his program to meet NASA contract requirements. He is then required to maintain and document control over design and development, including review of drawings and specifications and qualification tests; materials which he procures and inspections and standards for tests and measures; government-furnished materials inspection; articles which he fabricates; calibration and maintenance of his test equipment, and packaging, handling, storing and shipping.

NASA's major contractor quality assurance provisions also require a training program for employes involved in quality control inspections and those who purchase and fabricate parts.

The provisions call for a monthly status report along with immediate reports on any failures or difficulties. NASA will retain the prerogative to review the qualification status list, end-item test plan, and end-item test and inspection procedures.

The contractor, subject to NASA review, establishes his general quality program plan, test and inspection procedures, process control procedures, storage procedures for end-items and special sampling plans.

Provisions for suppliers, many of which are small businesses, are considerably less stringent than those for prime systems contractors. Suppliers' inspection system clauses generally spell out responsibility for control of procurement source material quality, inspection and test of their own components, and process control.

NASA PERT System

NASA's PERT system is similar to the basic Navy PERT system in that it uses data processing equipment, it establishes a network of activities in a dependent sequence flow array, and it determines critical path and slack determination. NASA PERT uses a single time estimate for network activity, while the Navy system has a three-time estimate. Another variation is that NASA PERT uses the milestone, or top level event, as the master schedule.

The system was established in-house last September as a management tool for project and systems managers in the field, and two months ago it was extended to contracts that are adaptable to PERT.

Contractors and NASA centers work as a team in accomplishing PERT, with NASA defining the number and scope of contractor networks and the contractor developing these networks, identifying events and activities constituting the networks, and estimating direct labor involved with each activity.

Project chiefs receive the following PERT information bi-weekly from the NASA-contractor team:

- **Summary outlook**—an assessment for meeting milestone dates on the master schedule, any changes in outlook from the previous report, and reasons for the change.
- **Significant progress**—describing milestones reached.
- **Pacing tasks**—identification and discussion of critical paths derived from the latest computer input.
- **Corrective action** taken, and its effect on resources.

One of the best ways NASA has found to spread the base of space procurement has been to enlarge the opportunities for small businesses—firms employing 500 or less. In addition to some "set-aside" actions, on which only small businesses can bid, the agency recently began a policy of carrying names and addresses of prime contractors invited to bid on projects in the Commerce Department synopsis. This policy is for contracts of $100,000 and over.

Wright/Sperry



Temperature Compensated Servo Motor Tachometers

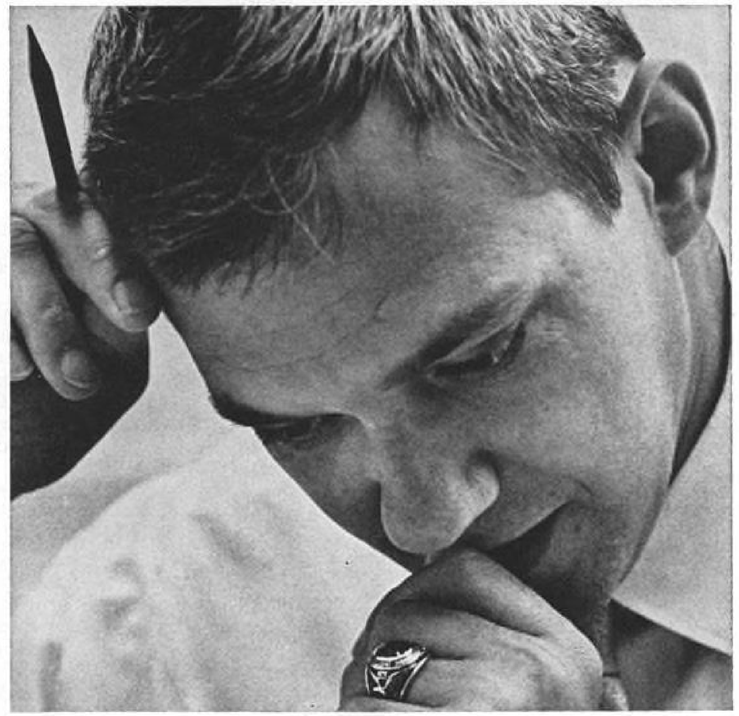
Now available are servo motor tachometers which operate reliably over a wide ambient temperature range. For example, from 0°C. to 85°C., this Size 11 will maintain a speed sensitive voltage to within 0.3%, a phase shift to within 1°, and a tachometer linearity of 0.07% from 0 to 3600 rpm.

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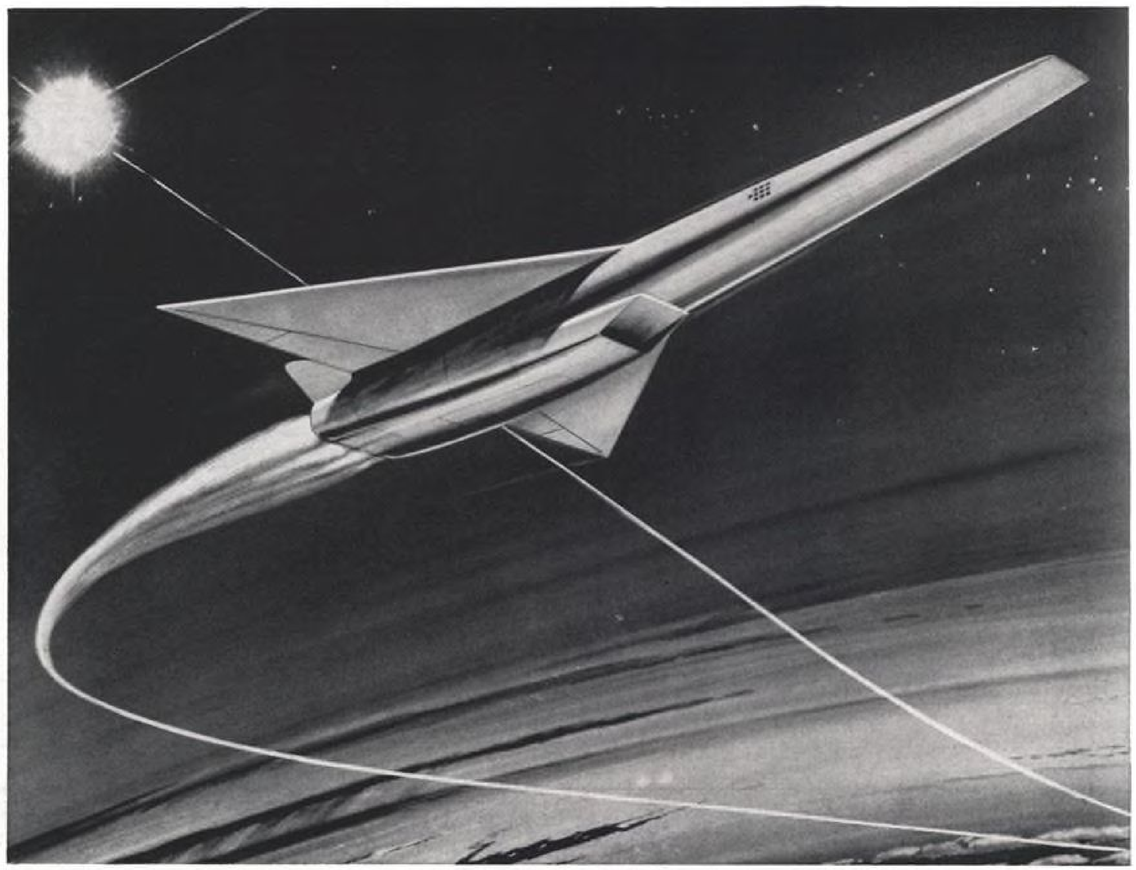


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Engineers to work in data reduction.
Scientists who know structures research and dynamics.
Scientists who have done supersonic aerodynamic research.
Scientists experienced in working with information and sensing systems, platforms, infrared, sensors, flight controls, airborne computing and data handling systems.
Engineers familiar with programming, operations, and instrumentation for ballistic missile flight test.
Reliability Engineers to assess the reliability and to optimize the configurations and mission profiles of space systems.
Chemical Engineers to work on the development and applications of structural adhesives for aerospace vehicles.
Metallurgical Engineers for research and development on materials and joining.

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Contract Research Reflects NASA Growth

Washington—One of the most significant indicators of the National Aeronautics and Space Administration's growth is the amount of research the agency buys and supports to complement research being done in its own centers.

When NASA was established almost four years ago, it had a budget of about $1 million to support research conducted under grants and contracts. In Fiscal 1963 it will spend $100 million, directly and indirectly, for sponsored research.

The agency's research interests run across the entire scientific spectrum. An estimated 500 grants and contracts were funded in Fiscal 1962. This is more than one-third of the proposals submitted during the year, and the space agency obligated about $50 million to support them.

Research Philosophy

Philosophy behind NASA's research support is to let people with ideas come to NASA, according to Dr. Thomas L. K. Smull, director of the Office of Research Grants and Contracts. In this way, the scope of new ideas does not become restricted and the probability increases that the space agency will underwrite most research projects that have merit.

Objective of the program is to tap the best minds in the country, in universities, industry, non-profit organizations and government laboratories. An obvious fallout is the stimulation of training and interest in universities, which will furnish scientists and engineers to both industry and NASA in the future.

Dr. Homer E. Newell, director of space sciences, recently pointed out the critical role that universities play in the space program. "The government laboratory, industry, the research foundation, all use up trained talent without reproducing this vital resource," he said. "The university alone replenishes the resource by the production of new engineers and scientists."

NASA will attempt not to set up activities that tend to draw strength away from the university or draw the researcher away from his teaching, Dr. Newell said.

First Contact

First contact for a researcher with a proposal is Dr. Smull's office. The proposer does not have to follow a standard format. What NASA wants to know essentially is the problem, how it will be attacked, what will be accomplished, and the effort that must be expended.

If the proposal comes from a university or non-profit organization, it becomes a candidate for a grant. If the originator is a company, the proposal will be funded by a contract.

Research grants can be made active for as long as three years, and NASA encourages proposals for long-term projects.

Research contracts normally are awarded on a cost-plus-fixed-fee basis because costs cannot be accurately forecast.

Once a proposal is received from any source, it is diffused throughout the NASA organization wherever the specific interest lies. If it is an idea for an instrument to be carried on a satellite, the proposal is documented and presented to the Space Sciences Steering Committee for consideration. This committee selects all NASA satellite and probe experiments.

If the proposal is in a field in which NASA is expert, the proposal review may be conducted completely in-house. In areas where the agency has limited competence, Dr. Smull's office convenes a panel of consultants, which recommends action.

Program Financing

Smull directly administers the program, but financing can come from a variety of offices. In the lunar and planetary program, for example, the Office of Space Sciences will fund sponsored research projects from which it will benefit. University participation in this program is sizable, and it is indicative of fairly widespread national interest. Of the total Ranger project participation, 39% is furnished by universities. The percentage goes as high as 59% in Mariner and 64% in Surveyor.

Research that is mission- or project-oriented will account for about $90 million in Fiscal 1963, and NASA has about $10 million available for generalized, fundamental research.

Research activity should not be confused with hardware development, however. Once a research project reaches the flight hardware stage, it transfers in administration from the Office of Research Grants and Contracts to the headquarters program office most directly concerned.

Fundamental Studies

The Isomet Corp. of New Jersey, for example, has been conducting fundamental studies for the past four years on closed chemical systems for the reduction of carbon dioxide into oxygen and carbon. NASA has funded these studies in the amount of $404,000. Although the research may require production of some hardware, this is in the category of laboratory instrumentation and not flight hardware. If Isomet is successful, funding will shift to the Office of Manned Space Flight when NASA decides to buy the system for a spacecraft.

Smull's office awarded the Massachusetts Institute of Technology a $400,000 grant in 1960 to develop a laboratory prototype of the Apollo guidance and control system. Manned Spacecraft Center approved MIT's design last May 31, and at that time, the funding shifted from headquarters to the center.

In the most recent tabulation of active grants and contracts, NASA was doing business with 67 colleges and universities, 27 companies, 21 non-NASA government laboratories and 11 non-profit organizations. About 80% of the dollar is awarded in grants to universities and non-profit organizations. The remainder goes to industry and government laboratories in contracts.

Although there are many small schools and companies represented in the active list, NASA feels any pattern of geographical distribution is accidental—the agency is basically interested in quality research rather than an attempt to sponsor as much research as possible.

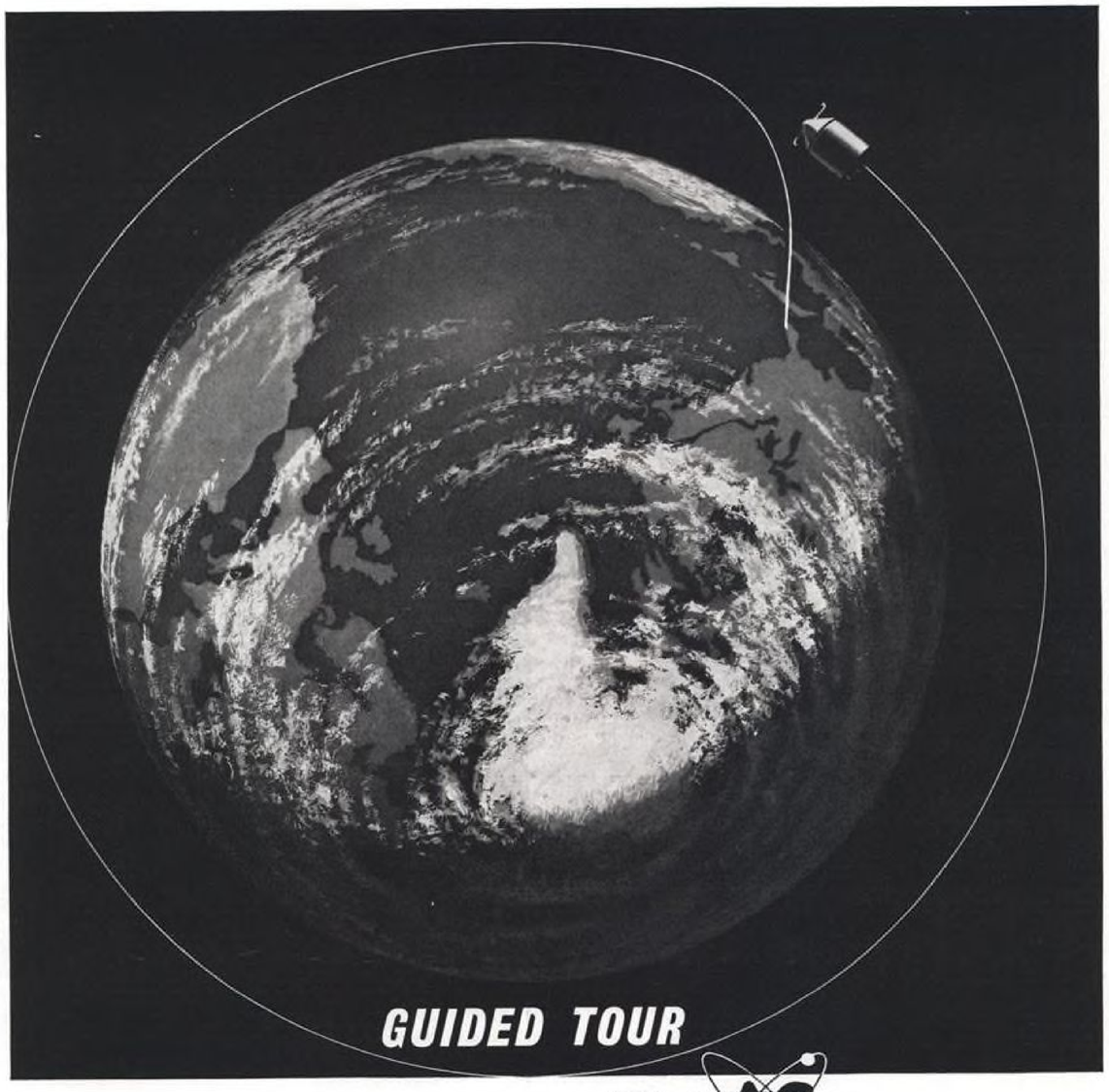
Indicative of the scope of NASA's re-

Role of Universities in Space Research

"Accomplishing the space mission requires the strong and vigorous participation of our universities and colleges," according to Dr. Homer E. Newell, director of National Aeronautics and Space Administration's Office of Space Sciences. NASA's responsibility in this relationship is to bear "its fair share of the support" so that universities and colleges can participate in the space program, Dr. Newell said.

Although NASA cannot meet all demands, the agency "stands ready to invest an appreciable fraction of its resources" in the university grants program, and to a limited extent in provision of buildings and facilities, he said.

Universities "must bear their share of responsibility to the space program and allocate an appropriate fraction of their material, as well as human, resources to the effort," he said.



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AC Spark Plug, The Electronics Division of General Motors, has accepted an exciting new challenge: the development and production of a navigational-guidance system for the first phase in NASA's APOLLO project of manned flight to the moon. This new assignment is another significant step in the progress that is being made at AC . . . progress achieved through the knowledge of AC's highly skilled, highly respected staff of creative engineers.

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search interest is this general summary of areas open to support:

• **Fundamental research**—Basic and applied research related to aeronautical and space sciences. It includes physical sciences, either theoretical or experimental, in areas such as materials, chemical and energy transformations, extreme temperature processes and phenomena, and mathematics as it applies to control theory, trajectories and information theory.

Engineering Sciences

In the engineering sciences, NASA is interested very broadly in development of new techniques and exploitation of scientific knowledge. Critical problem areas include energy production and conversion; electronic processes in measurement, guidance, control and communications; mechanics of orbits, trajectories, guidance and structures; hypervelocity fluid dynamics, and system analysis and control.

Areas of research open in cosmological sciences include astronomy, astrophysics, geophysics, geochemistry, material particles and energies. Socio-economic studies emphasize assessment of the effects of space technology on man.

• **Space flight research,** covering generally the sciences involved in launch vehicle and spacecraft development. Critical areas include most aspects of scientific space investigations using sounding rockets, satellites and lunar and planetary spacecraft.

NASA also is interested in determining specific future application potentials, such as those under way in communications and meteorological satellite programs.

Other Areas

Other broad areas of interest in space flight are operational problems of manned space flight, research in trajectory determination, data acquisition and processing, fundamental studies of advanced vehicle systems and booster recovery techniques and fundamental studies of chemical rocket propulsion, nuclear and space power technology.

• **Life sciences research,** concerned with man in space and the search for extra-terrestrial life. Categories of interest are flight medicine and biology, involving biotechnology and the operational aspects of biomedical experiments; space medicine and behavioral sciences, which concerns physiology, metabolism, radiology, psychology and sociology as it applies to manned space flight; space biology, involving research in life on planets and in space, and the effects of space on biological phenomena.

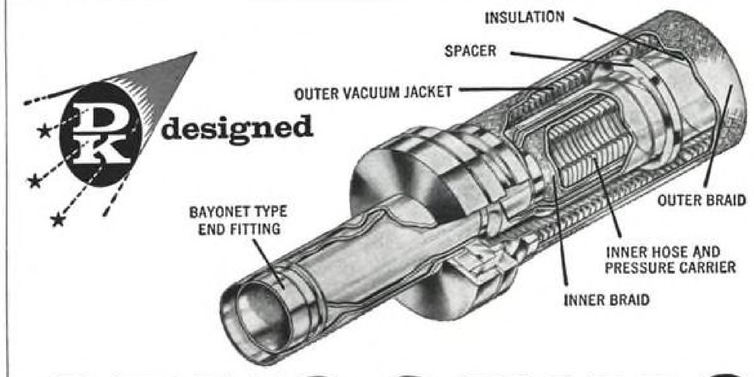
Smull emphasized that categorizing has many shortcomings because it appears too restrictive. Unsolicited proposals are evaluated as to how they relate to NASA's objectives—but since long-range objectives encompass most of the scientific and engineering disciplines, this relationship is interpreted very broadly.

NASA Program

This fall, NASA will begin a practical program of stimulating the flow of new scientists to meet industrial and government needs of the expanded space program. The program, also to be administered by Smull, involves training 100 pre-doctoral students at 10 universities. Students will receive stipends and allowances totaling $3,400 annually, as well as tuition and fees.

Universities are selecting candidates for the program on the basis of their academic records and ability to complete the necessary work for doctorates in three years.

Because the research which NASA supports should have some relevancy to the total agency objectives—even though it can be remote—one of the major requisites for those interested in the program is knowing the objectives. For this reason, NASA encourages publication of reports of its sponsored research in a form identical to that used for its own in-house technical notes, technical memoranda and research reports.



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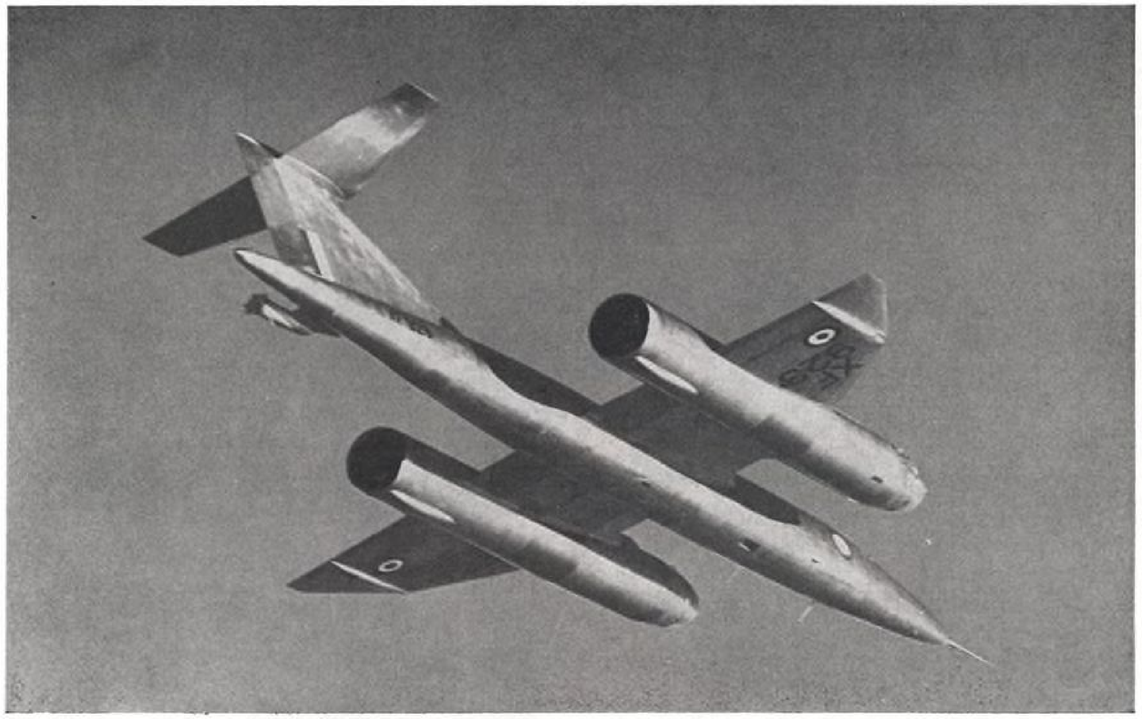
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Flight Photo Shows Bristol T.188 Test Details

First air-to-air photo of Bristol T.188 stainless steel research aircraft (AW Apr. 30, p. 58), made during pilot handling trials at Boscombe Downs flight research facility, shows square aperture on bottom of fuselage which is vent for dumping air from air conditioning system. Probes on port side opposite roundel insignia are radio antennas and pod at rear holds auxiliary parachute; second parachute is contained in tail cone of the stainless steel research aircraft.

Nuclear Missiles Sought for Submarines

Navy has requested the Atomic Energy Commission to develop a configuration of the Project Pluto nuclear ramjet engine compatible with a missile for launch from Polaris submarines.

The nuclear-powered missile would have the advantage over Atlas, Titan, Minuteman, and Polaris of unlimited range, omnidirectional strike capability, and substantially greater payload. USAF is actively studying three missile configurations for the Pluto engine.

AEC witnesses, reporting the proposal for a submarine version in testimony before the House appropriations committee released last week, also said that beyond the immediate goal of an offensive weapon, an adaptation of the nuclear ramjet engine for a reconnaissance vehicle is also being considered.

Funds Increased

Air Force plans to increase its funds for Pluto from $7 million in Fiscal 1962 to $24 million for Fiscal 1963. AEC, which has already invested almost $100 million in Pluto research and development since 1956, has earmarked $25 million for Fiscal 1963.

AEC estimated that a total of $640 million will be required over the following three years, 1964-66, to bring Pluto through flight test: $500 million by Air Force and $140 million by AEC.

Dr. Glenn T. Seaborg, AEC chairman, told the committee that as a result of highly successful tests last fall of Tory 2A-1—the first engineering test device in the Pluto program—AEC dropped Tory 2A-2 and proceeded directly to Tory 2C, designed to bridge the gap between the engineering test device and a flyable powerplant. Tory 2C testing is scheduled to begin in 1963. The design, power, operating temperature and size of the Tory 2C reactor approximate the requirements for a propulsion system needed for flight at sea level, Seaborg said.

Management Planning

AEC and Air Force are now considering the type of management which should be established for the follow-on program to Tory 2C, including development of reactors for ground test and flight test, Seaborg reported. "The varied and inter-related functions of the follow-on program, including the development of an airframe and reactor and propulsion systems, will require close coordination among the participants," he said.

On other weapons projects, Seaborg reported:

• **Project Rover** for nuclear rocket propulsion. AEC will start design and fabrication of reactors in Fiscal 1963 for Project Phoebus—AEC's advanced effort to develop high power levels required for sophisticated space missions. The Nerva nuclear propulsion system, the first phase of Project Rover, preceding Phoebus, is scheduled for flight demonstration in 1966-67. AEC contracted last July with Aerojet-General Corp. and Westinghouse to develop the Nerva engine. Seaborg said AEC hopes to determine the reactor design for adaptation into the Nerva engine during Fiscal 1963.

• **Snap space nuclear** auxiliary power program. AEC will start procurement of long lead-time items in Fiscal 1963 for the advanced Snap 50 program for development of large nuclear-electric space plants in the megawatt range to serve as sources of power for communications, television, and radar satellites. Seaborg noted that Snap 50 will require advanced technology in materials and reactor coolants.

Technical Problem

To explore the severe technical problems involved, he said, a lithium cooled reactor experiment is planned for 1965. AEC has earmarked $5 million for facilities at the Idaho National Reactor Testing Station for testing this experiment, and $1.4 million for modification of facilities at Pratt & Whitney Aircraft Division at Middletown, Conn., for fabrication of large columbium components to be utilized in the experiment.

New NASA Moves

Charles H. Zimmerman, associate chief of the aerospace mechanics division of National Aeronautics and Space Administration's Langley Research Center, has been appointed director of aeronautical research for the space agency (see NASA headquarters organization chart, p. 78). He succeeds John Stack (AW May 28, p. 37).

NASA also announced formation of a directorate for biotechnology and human research under its Office of Advanced Technology and Research (see p. 141). Dr. Eugene B. Konecci, chief of the life sciences section of the Douglas Aircraft Co.'s Missile and Space Systems Division, will head the new unit effective July 9.

Advanced OSO

As many as three parallel study contracts for an advanced Orbiting Solar Observatory (OSO) are expected to be awarded shortly by National Aeronautics and Space Administration's Goddard Space Flight Center. The company which performs the best of the three studies will then get continued funding through flight hardware without going through reproposal efforts.

Oral presentations are being made now to Goddard by 10 bidders including Airborne Instruments Laboratory, Ball Bros., Bendix, General Electric, Grumman, Radio Corp. of America, Republic Aviation, Space General, Space Technology Laboratories and Westinghouse.

Advanced OSO will be a more sophisticated vehicle than the NASA Ball Bros. OSO which performed well recently, possessing extremely high pointing accuracies (AW May 21, p. 23).

West German F-104 Operations Resume

West German air force resumed F-104 flight operations early last week after grounding the aircraft for five days following the tight-formation air-to-air collision of four F-model trainer versions on June 19 (AW June 25, p. 35) that touched off a new political storm.

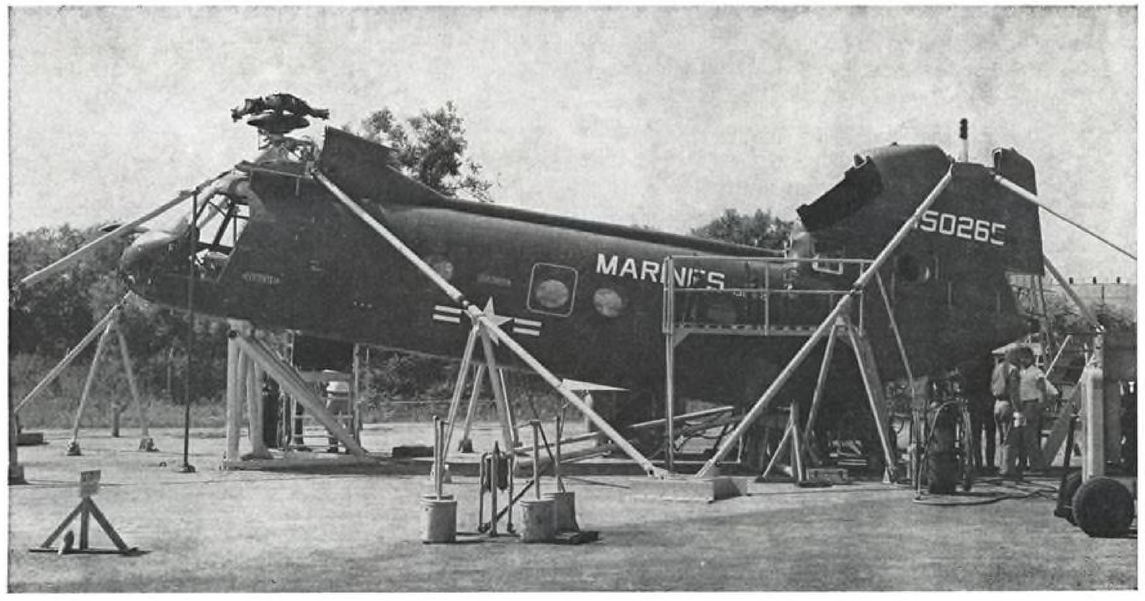
The accident which resulted in the grounding order, wiped out approximately half of the Luftwaffe's effective F-104 instructor corps and prompted charges and debates within parliament and the West German press over the 18-month-old decision to purchase the advanced aircraft. A special target was Defense Minister Franz Joseph Strauss.

Air Force and Defense Ministry also were criticized for permitting the formation of an acrobatic team using the high-performance F-104, and some members of the opposition Socialist Party last week were demanding a full-scale parliamentary investigation of the incident.

At the time of the accident, the four aircraft were practicing on the eve of a planned ceremony designed to still much of the earlier parliamentary criticism over the status of the program—the formal dedication of the air force's first F-104G fighter wing at the time and date specified in original plans.

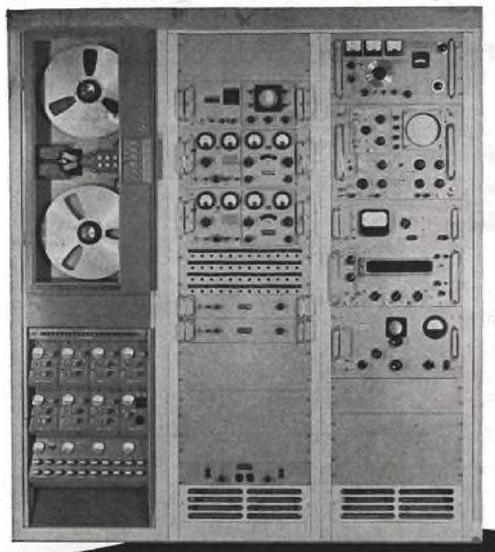
After the accident, which apparently occurred when two of the aircraft brushed wingtips as the group swung into a turn and then collided with the other two, the ceremony was closed to the public, and the aircraft subsequently were grounded to avoid any risk of a further incident until the protests had subsided to some degree.

Three of the pilots killed were German air force instructors, at Noervenich Air Base near Bonn; the fourth was a U.S. Air Force captain.



First Production HRB-1 Begins Tie-Down Tests

Marine Corps has accepted the first production model of the Boeing-Vertol HRB-1 Sea Knight medium transport helicopter. Following roll out of the first aircraft and an inspection tour headed by Col. Marion E. Carl, deputy chief of staff (air), the ship was placed in a tie-down rig for testing. Powerplants for the helicopter, the same basic aircraft as the civil Vertol 107-2, are two General Electric T58-8s.



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CAB Examiner Asks End to Schedule Study

Civil Aeronautics Board Examiner Edward Stodola has recommended that the Board end its investigation of a regulation requiring foreign flag carriers to file schedules with the U.S. for CAB approval.

In his initial decision on the investigation, which began early in 1961 (AW Jan. 30, 1961, p. 43), Stodola found that the frequency and capacity issues raised by the proposed regulation are "primarily a legislative and political problem which should be reviewed and passed upon" by both the Congress and the President.

Examiner Stodola said, however, that limitations on capacity and frequency can be imposed upon foreign flag carriers under section 402 (f) of the Federal Aviation Act of 1958.

In this respect, he said, should the Board, after consulting the State Department, decide not to urge or to wait for action by Congress on frequency and capacity problems, the Board should institute individual proceedings under section 402 (f) of the act against foreign air carriers which the U.S. suspects of providing excess capacity.

Stodola expressed doubts that the difficulties the U.S. is encountering with foreign flag carriers justifies a "regulatory control over foreign flag carriers of the magnitude implicit in the proposed regulation." He added that, even were the need for such a regulation manifest, the Board is not "the proper forum for the disposition of the serious issues raised by this proceeding."

The proposed regulation called for an amendment of foreign air carrier permits to require them to furnish traffic data and schedules to the Board for approval.

Such information would provide the Board with information on which to base the restriction of seat capacity offered by a foreign airline.

Tax on Airline Fares To Drop 5% on Nov. 16

Congress last week passed a compromise bill reducing the tax on airline fares from 10% to 5% effective Nov. 16. The Senate originally made the reduction effective Oct. 1 while the House-passed measure called for a Jan. 1 effective date.

Both the Senate and House rejected the Kennedy Administration's proposal to couple any airline tax reduction with new levies on turbojet fuels and air cargo.

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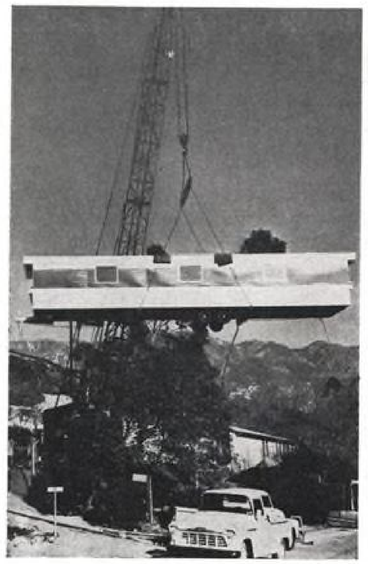
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Settlement of FEIA, Airline Dispute Slowed

Attempts to settle the jet crew complement issue were slowed last week as Flight Engineer International Assn. members weighed a settlement proposal at Trans World Airlines (AW June 25, p. 45), and Pan American World Airways won extension to July 6 of a federal court order blocking an FEIA strike there. Eastern Airlines was shut down by an engineer strike June 23.

Judge George Rosling delayed making a final ruling on the temporary restraining order issued June 26 after the National Mediation Board offered its services.

Eastern Air Lines, which did not seek similar court relief, was forced to furlough 18,000 employes. Eastern spokesmen said last week that the airline may seek an injunction to halt the FEIA strike, which was triggered by membership rejection of a settlement proposal made by Labor Secretary Arthur J. Goldberg and approved by FEIA headquarters officers.

FEIA said it was considering an appeal to Judge Rosling's order. Since the NMB has already failed in attempt to mediate the dispute at Pan American, FEIA contends that all provisions of the Railway Labor Act have been complied with and that NMB has no further jurisdiction in the dispute.

Settlement of the crew complement issue under the Goldberg proposal brought immediate protest from rank and file union members at Trans World Airlines because H. S. Dietrich, the TWA chapter president, agreed to drop FEIA demands for retention of a mechanic's license requirement in the union's contract. FEIA members on both Pan American and Eastern immediately voiced the same objections to the proposed settlement and called for protest strikes.

Six Airlines to Ask Coach Fare Increase

Six trunklines late last week had indicated they intend to ask the Civil Aeronautics Board for what would amount to a 3% increase in present coach fares as a means of reducing the diversion of passenger traffic from first-class to coach.

The proposed tariff, which will ask a 6% increase to replace the temporary six-month 3% raise granted Feb. 1, would bring coach fares to about 85% of first-class rates. At present, coach fares average about 75% of first-class rates, which, the CAB feels, is the proper relationship for the development of new traffic.

Each of the six carriers seeking the increase—Braniff, Continental, Delta, Eastern, National and Northeast—complained that revenues were declining as more passengers switched from first-class to take advantage of the low coach fares. For example, Eastern said that its percentage of coach traffic rose from 55.1% in the first four months of 1961 to 57.4% in the same period of 1962—excluding Air-Shuttle and Air Bus traffic.

JPL Reorganization

Los Angeles—NASA's Jet Propulsion Laboratory has combined its Space Sciences and Physical Sciences Divisions into a single group to strengthen its space sciences activity without de-emphasizing fundamental physical science research, according to William H. Pickering, director of JPL (see p. 156).

The combined technical division, comprising the eight sections that previously functioned within the two divisions, will be the second largest at JPL, with over 300 professional and supporting personnel and a budget expected to be in excess of $30 million annually.

Previously, Physical Sciences devoted itself to basic physical sciences work, Pickering explains, while Space Sciences activities were geared to flight missions. The combination of the two is intended to strengthen both, eliminate much of the overlap in interest and techniques.

Robert V. Meghreblian, formerly chief of the Physical Sciences Division, will hold that position in the combined division which will retain the name Space Sciences Division. Manfred Eimer, previously acting chief of Space Sciences, will be deputy chief, Pickering says.

News Digest

Boeing-USAF Dyna-Soar manned space glider last week was re-designated the X-20. The change is intended to emphasize the experimental nature of the project.

Navy Cdr. Walter M. Schirra, Jr., has been selected to pilot the Mercury-Atlas 8 flight late this summer which will be planned for as many as six orbits, National Aeronautics and Space Administration said last week (AW June 4, p. 26). USAF Maj. L. Gordon Cooper, Jr., will be backup pilot.

NASA headquarters is expected to authorize the addition of five Ranger spacecraft (RA-10 through 14) to its unmanned lunar exploration program (see p. 160) to take up slack between end of current Ranger series next year and start of the Surveyor program.

Parallel six-month study contracts for comparative analysis of rocket systems for advanced earth-lunar transportation systems (AW Apr. 2, p. 16) to establish and supply permanent lunar base have been awarded by NASA's Marshall Space Flight Center to Lockheed Missiles and Space Co. ($144,596) and Ling-Temco-Vought ($148,897).

Last of 744 B-52s built by Boeing rolled out at Wichita Div.'s final assembly area June 22nd. The B-52H will enter flight test in July and be delivered to Strategic Air Command in September. Of the total Stratofortress production, 466 have been built at Wichita. At peak B-52 production at Wichita, employment totaled about 35,000. It is now approximately 21,500 and is expected to be about 2,000 less by year's end. Nearly 4,000 subcontractors in 43 states were involved in the B-52 effort.

Sir Leslie Rowan, managing director of Vickers, Ltd., has been appointed Deputy Chairman of British Aircraft Corp. A former British treasury secretary, he succeeds Maj. Gen. Sir Charles Dunphie, new Vickers chairman. New BAC vice chairman is Royal Air Force Marshal Sir Dermot Boyle.

New Iroquois Purchase

House appropriations committee last week approved purchase of 41 additional Bell Iroquois helicopters by the Army, to be financed by transfer of Fiscal 1962 funds from other Army accounts.

Army's original Fiscal 1962 budget earmarked $67.6 million for purchase of 242 Iroquois, and its Fiscal 1963 program includes $95.4 million for Iroquois procurement.

New York-Florida Renewal Case hearing will resume July 9 at the Civil Aeronautics Board in Washington, D.C. The examiner had postponed the case until the Hughes Tool-Northeast Control Case was decided (AW June 25, p. 40). The renewal case will determine whether Northeast continues to operate in the Florida market or reverts to being a New England regional carrier.

James J. Kerley will become vice president-finance and treasurer of Trans World Airlines in mid-July, replacing A. V. Leslie. Kerley, now vice president and controller of Ling-Temco-Vought, formerly held financial posts with Ford Motor Co. and Crosley Division of the Avco Corp.

Aero Commander last week asked Civil Aeronautics Board to conduct a full-scale investigation into the need for third level air service to provide adequate transportation for smaller communities. The firm asked that the probe include possible revision of existing economic and operating regulations, airport utilization problems, cost of various aircraft types, estimated traffic response, and defense, postal and subsidy needs.

Political uproar over the BOAC-Cunard joint venture (AW June 11, p. 41) began last week in London with Minister of Aviation Peter Thorneycroft denying charges of monopoly and defending the association of a public company with a private one. Opponents in Parliament charged Thorneycroft with "conniving" to place independent airlines inside a monopoly at the expense of the Air Transport Licensing Act of 1961, designed to give independents a larger share of the market.

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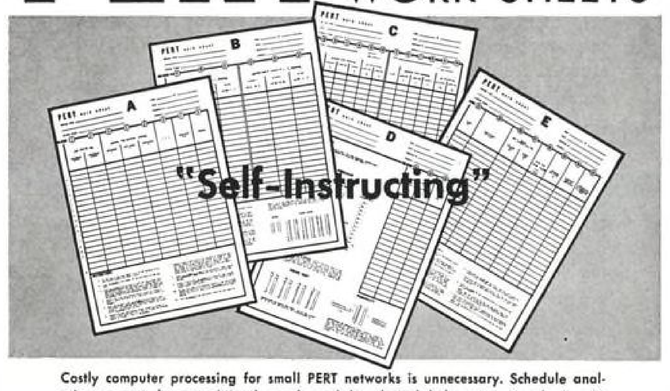


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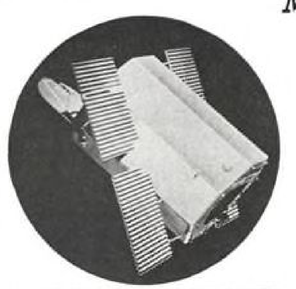
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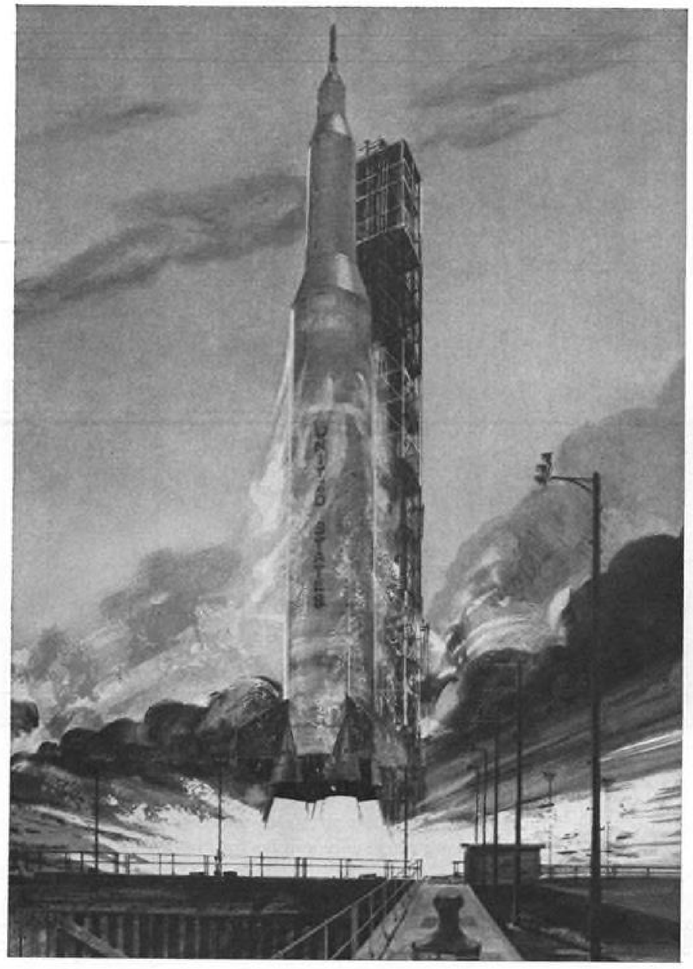
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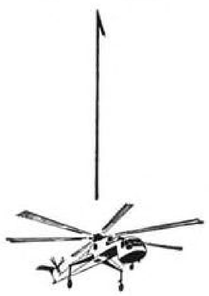
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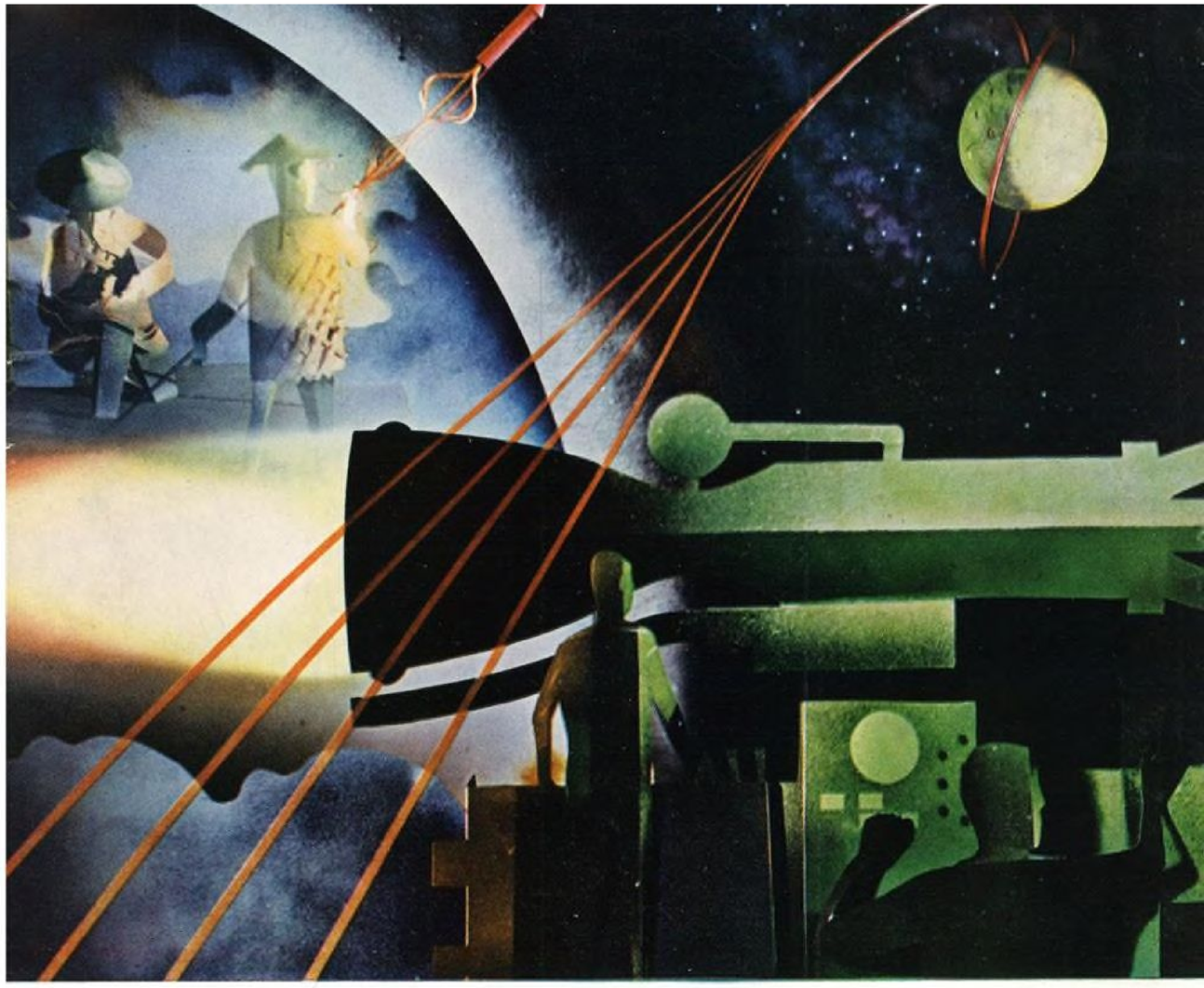
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