# AIR FORCE

The Magazine of AMERICAN AIRROWER | Published by the Air Force Association

# SPACE WEAPONS

A HANDBOOK OF MILITARY ASTRONAUTICS

The Mission
The Battlefield
The Vehicles
Man in Space

Historical Office



# ARMA'S SECRET WEAPON

Bug hunting . . . failure testing . . . safety factors . . . flight testing—none of these traditional reliability concepts is sufficient to insure maximum performance of missile guidance systems.

We use them all at Arma-but the designer's

pencil is our "secret weapon," For true reliability must originate at the design stage—and then be implemented by a full-scale quality control and reliability program. ARMA . . . Garden City, N. Y. A division of American Bosch Arma Corporation. 4921 Asstorical Coffice,

Recon 160 Ble 717

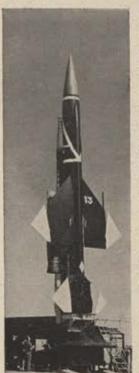




BUSTLING through the sky at supersonic speed, Boeing's Bomarc IM-99 interceptor missile is equipped with an electronic guidance system that keeps it on an interception course with the target.

Newest weapon for America's defense-

# the Boeing Bomarc interceptor missile



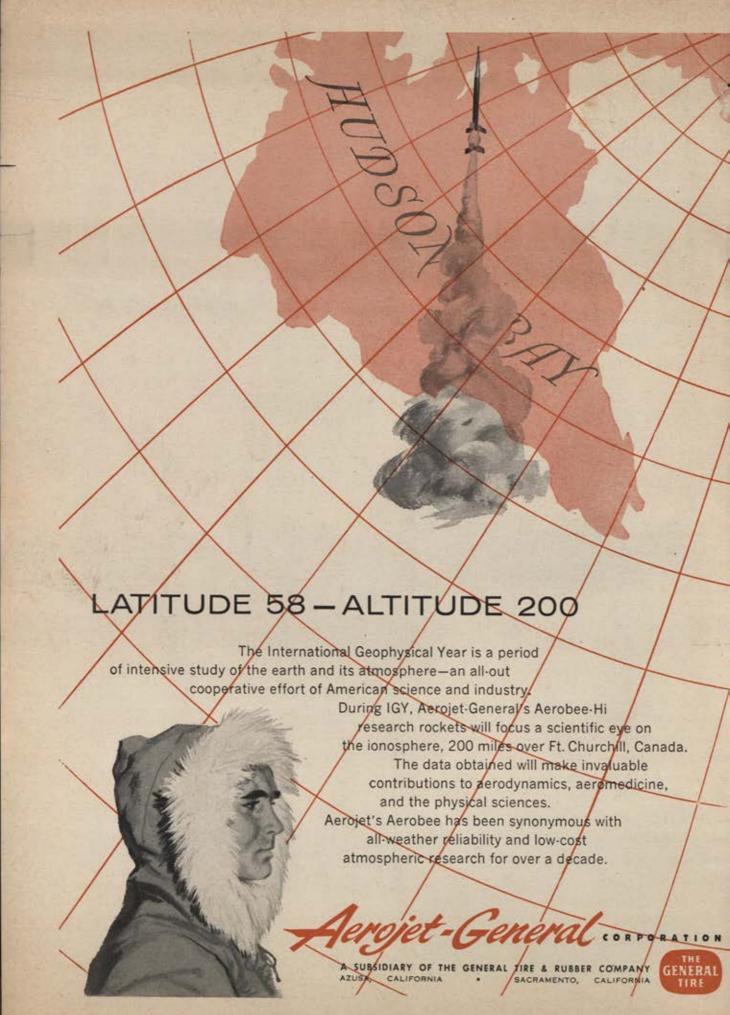
An advanced weapon is being added to the defense arsenal of the Air Force. It is the Boeing Bomarc IM-99, a supersonic rocket and ramjet-propelled long-range missile.

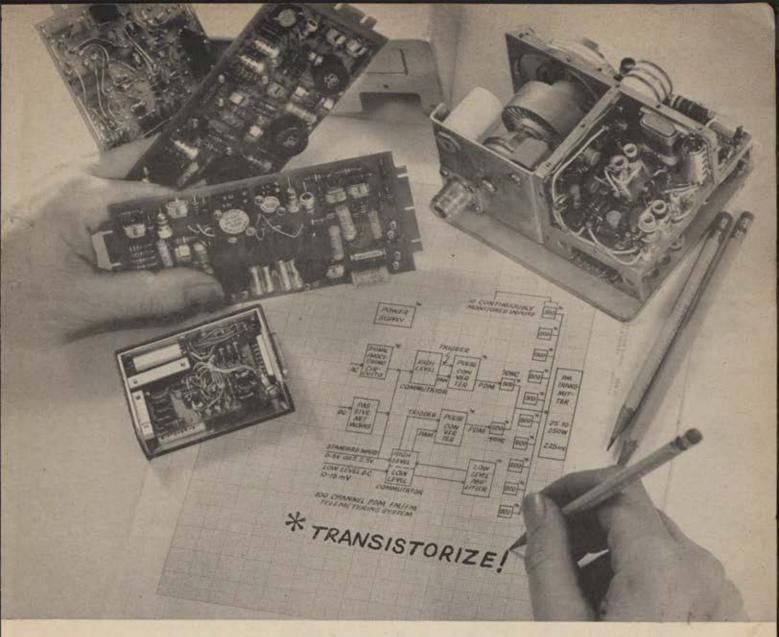
Bomarc bases are now being constructed, and the missile is in volume production by Boeing. Advantages of Bomarc include its quick reaction time, speed, range and atomic warhead capabilities, which combine to enable it to defend entire areas, rather than individual targets, from attack by manned bombers or air-breathing missiles. Bomarcs are unique in that they can be fired in multiple, and directed to intercept individual elements of a mass attacking force.

The Bomarc missile is the spearhead of an entire weapon system developed by Boeing for the Air Force. Bomarc will be operated by the Air Defense Command.

LEFT. A Boeing Bomarc in firing position. The missile is launched vertically by a liquid fuel rocket motor. When suitable speed is reached, the rocket cuts out and two ramjet engines take over to provide power for supersonic cruise speeds.

BOEING





# NOW...get more data on Strays and Long Shots with TI transistorized PDM/FM/FM telemetering systems

Out-of-sight missiles, particularly those off course or in the far reaches of terminal flight, can now send back signals loud and clear - providing data previously blocked by attenuation and noise. This promise can be made because TI-developed transistorized telemetering can now transmit 200 W and more without exceeding the space and weight previously required by most 50-W systems. Not "frozen" to old production designs, rugged TI systems and components will always represent the practical state of the art. This is the TI policy which resulted in the 200-W single package transmitter shown above.



Your requirements in telemetering systems or components can normally be met by existing TI equipment, but your most unique developmental problems are equally welcome. And fast, flexible production facilities will deliver on time.

\*TI Pulse Duration Modulation telemetering equipment shown, clockwise from lower left: Sub-Carrier Oscillator; Phase Discriminator; Low-Level Amplifier; Keyer; Single-Package 200-W Transmitter.

WRITE TODAY for more information on TI telemetering equipments.



# CAPABILITIES . . . Manpower, Tools and Experience



THIS UNRETOUCHED FIRST ACTION PHOTO RELEASED RECENTLY BY THE U. S. NAVY SHOWS THE BEECHCRAFT XKDB-I DURING A RECENT EVALUATION

Beechcraft's new target plane, pictured above as it leaves its special transportable catapult, offers maximum performance to all of the Armed Services of the United States. It is just one of an entire new family of rocket, turbo-jet, and supercharged powered craft being developed at Beech.

Here are just three occasions where this craft may be used: in procurement of information from behind enemy lines - either during the day or at night; for use as an operational target plane with ground or air launching - and with speeds up to 320 miles per hour; as a vehicle to deliver supplies to isolated combat units. It is now being delivered as the XKDB-1 to the Navy as a target aircraft.

Other Beech projects include research and development work on launching and recovery systems for missiles, drones, and manned aircraft; engineering test programs on aircraft emergency escape systems; and classified projects in the advanced fields of aerodynamics, cryogenics, thermodynamics, and aircraft range extension.

To put Beechcraft's capabilities to work to solve your research, development or production problems, telephone or write the Contract Administration Division today.



Beech Builds: U S Navy T-34 . USAF T-34 . U S Army L-23 . Bonanza . Travel Air . Twin-Bonanza . Super 18 Executive Transport



# AIR FORCE

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Volume 41, Number 3

March 1958

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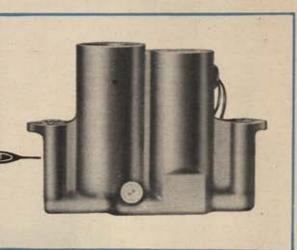
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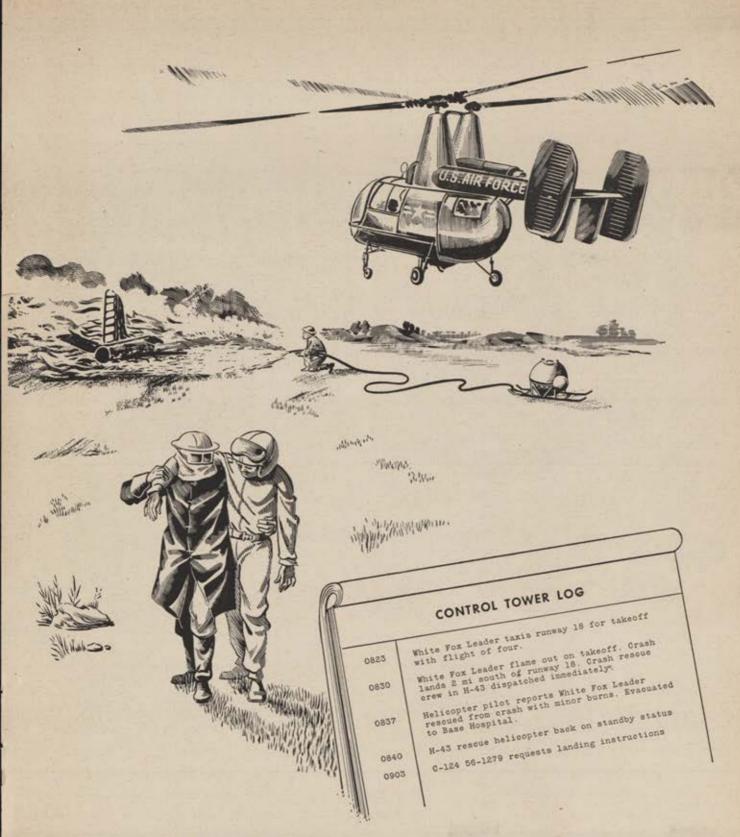
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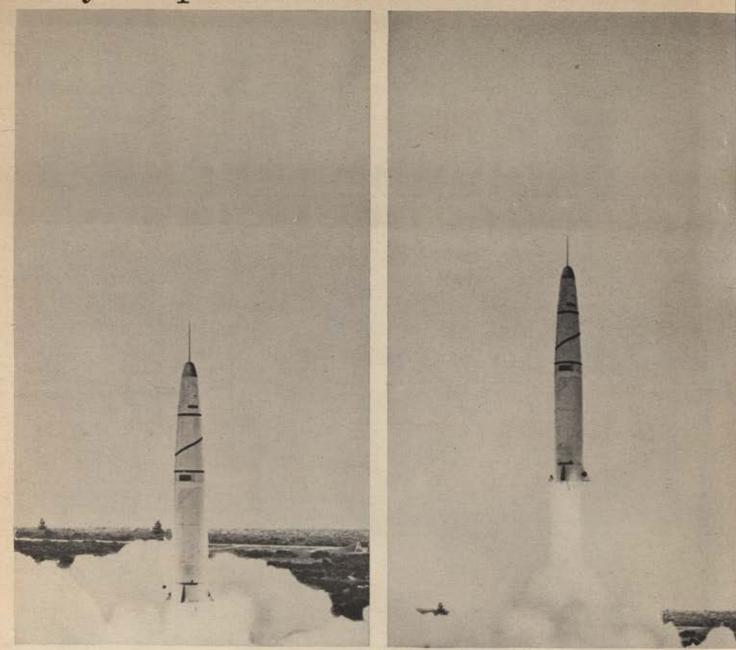


Electric Motor Driven Hydraulic Power Packages



THE KAMAN AIRCRAFT CORPORATION
BLOOMFIELD, CONNECTICUT

# Today's air power in action:\*



Thor starting one of its highly successful test flights from Cape Canaveral, Florida.

# Giant Air Force THOR — already in mass production -

Last November 27th the Defense Department announced that the Douglas *Thor* had been ordered into production as the Air Force's intermediate range ballistics missile.

America's defense is gaining more than just a highly successful missile. Thor comes completely equipped with a Douglas-engineered support system that is *immediately* ready for field operation. No hand-tooled prototype, the *Thor* test models fired for Air Force acceptance are built with mass production tooling. As a result, manufacture of *Thor* on a volume basis began the minute Air Force approval was given.

At the same time the science-industrymilitary team which cooperated in developing Thor readied the important systems required to make it operational...transportation, fuel-





# can strike anywhere in the world from U.S. bases!

ing, launching, training and parts replacement.

Such thoroughness is typical of Douglas where 19,000 missiles of all types have been produced since 1941. In fact, Douglas is the only U.S. manufacturer to have developed missiles systems in all categories...air-to-air, air-to-surface, surface-to-air, and surface-to-surface. And Douglas has an accumulation of missile experience unequaled in the U.S.





### A Research Project of Dr. Harry Nyquist, Senior Scientist, Stavid Engineering, Inc.

Dr. Nyquist is a pioneer in advanced areas of electronics such as Information Theory and circuit noise, and is credited with nearly 150 patents in the field of communications. He is now contributing his exceptional analytical ability to Stavid's work on a far reaching anti-missile system. Men like Dr. Nyquist are typical of Stavid's outstanding scientists and engineers who are working on advanced concepts . . . years ahead of actual systems development.

In Stavid's objective engineering atmosphere, scientific, development and manufacturing teams are producing a wide range of electronic systems for all branches of the military. Typical of such projects is the REGULUS missile command guidance system, designed, built and maintained in operational status by Stavid.

### PROJECTS INCLUDE:

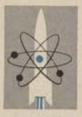
- Airborne Search, Bombing and Terrain Clearance Radar
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  Fire Control System
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Omaginative Electronics ...

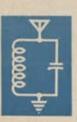
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### means experience

Parsons' success in the fields of missiles and high-energy fuels has been proven by an outstanding record of accomplishment on hundreds of completed projects.\*

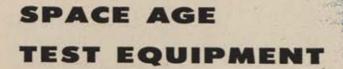
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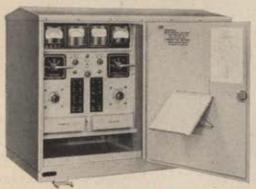
ANKARA BAGHDAD BEIRUT ZEDDAM KARACHI MADBID HEW DELHI ZARIE TORONTO



The age of super-sonic flight and space travel imposes new and more exacting demands upon testing and ground support equipment.

SUN is recognized as a leader in the development, design and production of testing and support equipment for aircraft, missiles, and "in-plant" testing applications. Hydraulic, pneumatic, electrical and electronic testing equipment-all come within the scope of SUN's fine engineering and production capabilities.

Write today for your free copy of SUN's new catalog of Test and Support Equipment.



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For testing hydraulic systems employing high temperature fluids. Gasoline engine or electric motor driven.



### PORTABLE GROUND POWER SUPPLY— Model LS-166 Supplies up to 500 amperes at 28 volts DC for

missile systems during testing and check-out.



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### Our biggest asset can't be photographed

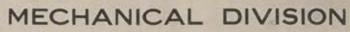
What's inside this engineer-scientist's head? A camera won't reveal that for 30 years a trained mind has been accumulating a vast fund of knowledge on gyroscopes and has come forth with sound original thinking on inertial guidance.

No photograph can tell that another man thoroughly grasps the present state of the art in infrared technology and has creative ideas for the future.

We can't show pictorially the knowledge and reasoning ability other staff members bring to such subjects as radar, general electronics, semi-conductors, computation, mechanical design, and all the other fields of competence that go to make up a balanced research and development facility.

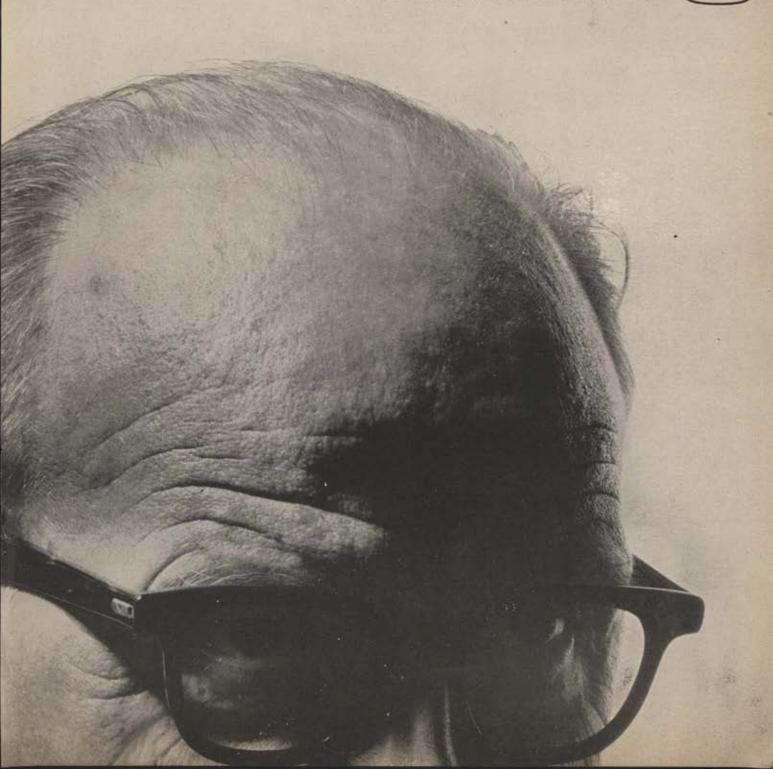
Nor can we show the special types of gray matter that make a first class systems engineer, a top production man, or a forwardlooking executive to keep these specialists functioning smoothly as an integrated organization.

But we can tell you what these people have done in the past, what they are doing now (where military security permits), and what we believe they can do for you. Write Dept AW, Mechanical Div., General Mills, 1620 Central Ave., Minneapolis 13, Minn.



Creative Research and Development + Precision Engineering and Production





NEW TOOL
FOR USAF's
NEW TRAINING
CONCEPT!

Air Force Cadets' proficiency
as they move into combat jets,
Cessna's T-37 jet trainer
is now in operation.
Advantages:
unique side-by-side seating,
slow landings
with high speeds
and high-altitude performance,
easy handling.
Cadets learn faster,
USAF saves time,
money.

CESSNA AIRCRAFT CO., WICHITA, KANS.



# 30,355 Feet UP!



# Sets New World Record, with Continental Power

When Capt. James E. Bowman of the U. S. Army Aviation Board flew the Cessna YH-41 to a new helicopter world altitude record of 30,355 feet, he added another to the long list of major performance records already held by Continental aircraft power. Capt. Bowman's mark, exceeding by some 3,400 feet the previous helicopter record, underscores again the wisdom of engineering the power to its job. The YH-41's Continental FSO526 engine is designed expressly for helicopter use . . . fan-cooled for efficient cooling in submerged installation . . . supercharged for maximum power. Its horizontal configuration permits the engine to be located forward, bringing the load directly below the rotors—an ideal situation in helicopter aerodynamics. Finally, the interchangeability of many parts with those of other models in the Continental aircraft engine line tends to simplify service, and reduce its cost.

# <u>Continental Motors Corporation</u>

AIRCRAFT ENGINE DIVISION



THE HISTORY OF FORD MOTOR COMPANY IN AVIATION

### HIS "WINGS" WERE LEFT BURIED IN THE SNOW

On November 25th, 1929, a lone tri-motored airplane soared over the desolate South Pole -its engines beating an interruption in the solitude of ages. Admiral Richard E. Byrd became the first man ever to fly over the South Pole. His plane was a Ford Tri-Motor. Byrd left his "wings" at Little America for

a year, encased by wind, snow and ice. Upon

his return, the Tri-Motor was hacked free, carburetor cleaned, batteries installed and it started with a roar.

Past events in Ford's history in aviation are no more dramatic or important than our production today of the mighty J-57 turbojet engine used in some of America's fastest and most powerful jet aircraft.



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A DIVISION OF MARQUARDT AIRCRAFT, SYMBOLIZES OUR ACCELERATED RESEARCH FOR PROPULSION SYSTEMS AND ACCESSORIES CAPABLE OF OPERATION IN THE ATMOSPHERE AND OUTER SPACE.

marquardt ......

VAN RUVE CALIFORNIA GODEN UTAH

# read'i.ness: when a fighter as new as tomorrow is in service with the Fleet today

There's a bright, new glint to our Fleet today.

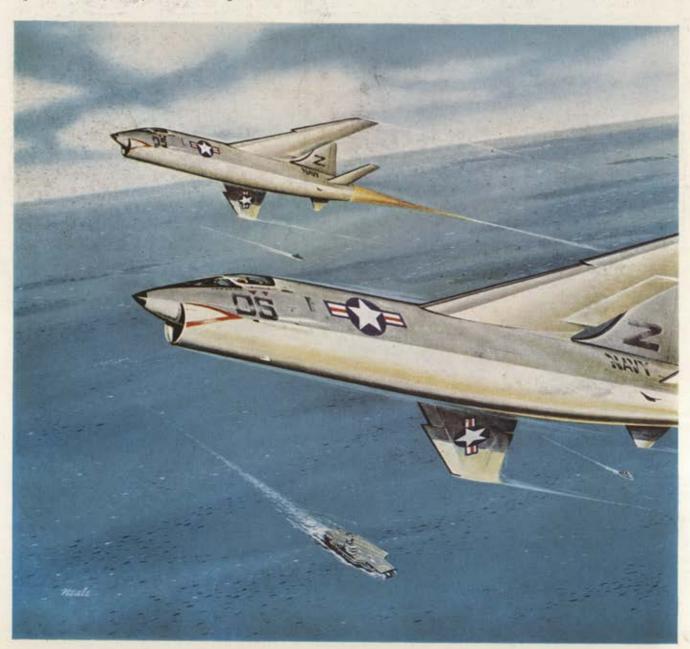
Chance Vought's 1,000-plus-mph Crusader has arrived – in strength! This potent fighter was designed a champion – in speed, ceiling and firepower. It was engineered, too, for swift production and for smooth introduction to pilots.

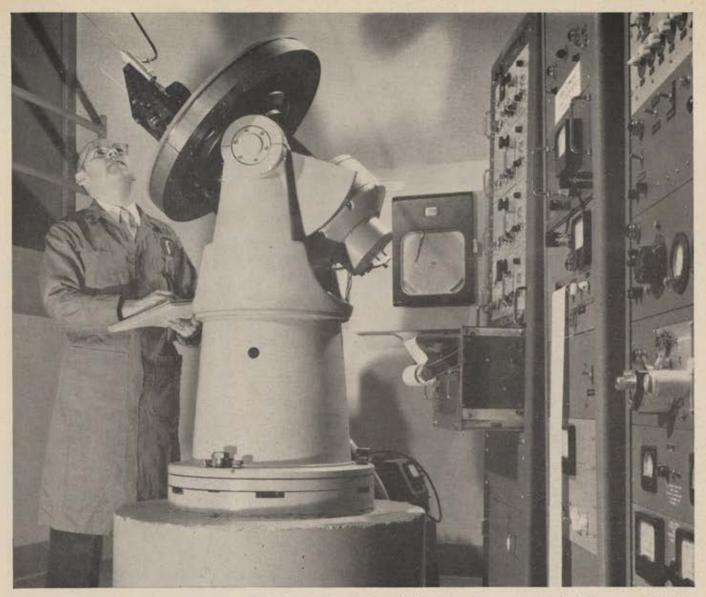
This sped the Crusader to duty faster than any modern jet. It brought to the Fleet in an age of peril a weapon that will hold its edge.

With the Crusader comes a new realm of four-figure speeds. Already, Navy and Marine pilots have used its performance to smash major world's records. Their unprecedented supersonic and carrier-to-carrier crossings of the U. S. signal a new chapter in manned aircraft speed and mobility.

Today, squadrons of *Crusaders* sweep the skies above the seas. Their trophy-winning performance adds unmatched combat strength to America's power for peace.







Ford Instrument Co. Engineer checks air-bearing gyro for angular drift on equatorial test stand. Test can show up drift rates as low as one revolution in 40 years. Tests like this . . .

## helped Army put "Explorer" into orbit

Some of Ford Instrument's current or recent programs include:

Inertial guidance systems . . . including Redstone and Jupiter

Missile launching and control order computers

Navigational and mission control systems and computers

Analog and digital computer systems

Fuzing, arming and other warhead control equipment

Plotting equipment

Nuclear systems and controls

Gunfire controls

Drone controls

A special guidance system for the Jupiter C, developed by the Army Ballistic Missile Agency, was used to launch the first U. S. artificial satellite into space.

Many components of this system were provided by Ford Instrument Co., prime contractor for both the "standard" U. S. Army Redstone and Jupiter guidance systems.

The fabulously-equipped, fantastically-clean gyro lab (above) is only a small part of the advanced research and development facilities available at Ford Instrument Co. They're used to create and produce the incredibly accurate control systems called for by modern technology in both government and industry.

And Ford Instrument's large-scale precision manufacturing facilities can turn even the most critical system requirements into working "hardware" on a quantity-production basis. Our Liaison Engineers are at your service to discuss your system requirements.

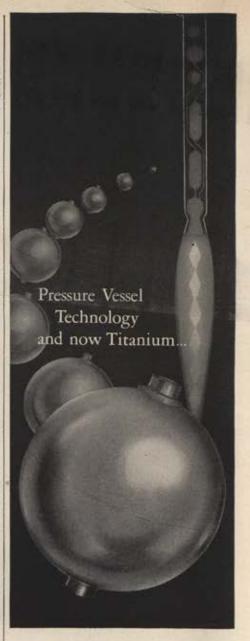
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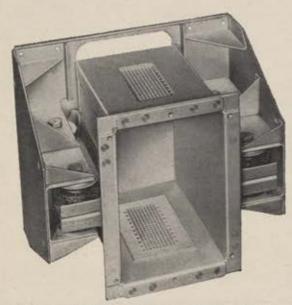
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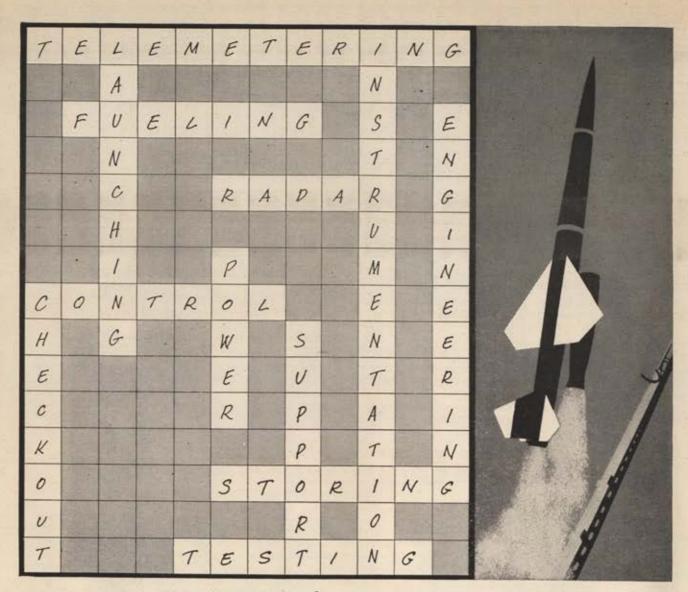
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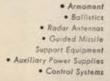
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Vickers 3000 psi Variable Dis-placement Piston Type Pumps supply power to the main control and utility hydraulic systems.



Vickers 3000 psi Constant Dis-placement Piston Type Pump operated by ram air turbine supplies emergency hydraulic power.

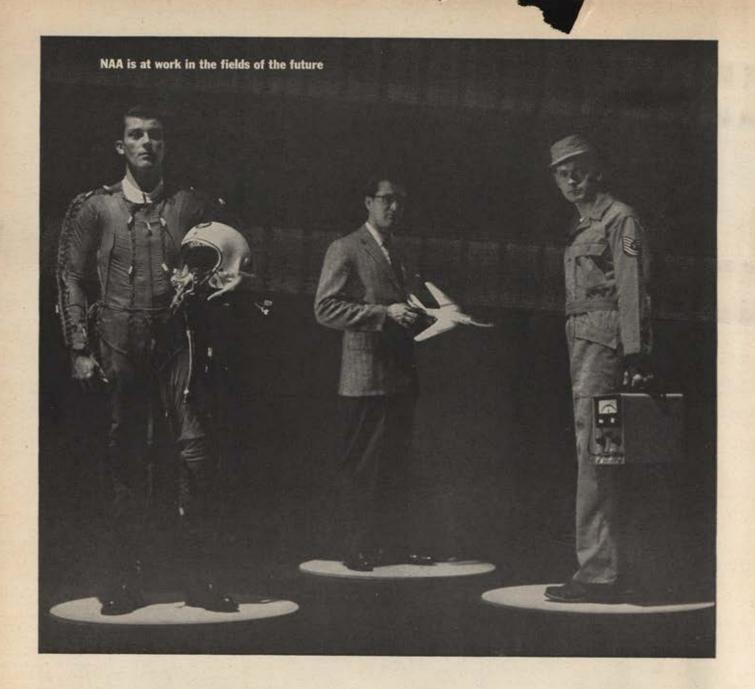


Vickers Constant Displacement Piston Type Hydraulic Motors perform critical functions requiring their high efficiency and distinctive control char-



Regulator permits emergency ram air turbine to generate needed hydraulic flow down to minimum airspeed.

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# On these three men depends America's conquest of Outer Space

Very soon now an American is going to ride a rocket ship to the edge of space—and back.

The success of this first flight—and of the others that will follow—depends on the teamwork of the men who build the rocket ship, the men who become its ground-support technicians, and the men who form its air crew. For only the closest coordination of America's industrial, technical, and military skills can achieve the conquest of space.

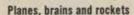
### The X-15: Space Ship No. 1

The craft that is being readied for this first flight into space is the X-15, a rocket-powered research plane for the Air Force, Navy, and National Advisory Committee for Aeronautics. So advanced in design it might be called a manned missile, it's the forerunner of the craft that will cruise through Outer Space.

The assignment to design, build, and test the X-15 is being carried out by North American.



Reliability Room. Automatic control systems for America's manned and unmanned weapon systems must do their critical tasks with unfailing reliability. Even a tiny fleck of dust might impair their vital accuracy. That is why Autonetics assembles its control systems with surgical precision in this dust-free room.



North American's key role in this great drive to put man into space is the result of its capabilities in the new technologies that make such a flight possible.

In supersonic aircraft, North American has had more experience than all other companies combined. In automatic controls—the elec-tronic "brains" that will guide and navigate the X-15-its Autonetics Division has pioneered some of the most significant advances in recent years. Its Missile Development Division-pioneer of America's missile technology-is at work on an advanced air-to-ground (or space-toearth) missile for the Air Force. And, in rocket propulsion, NAA's Rocketdyne Division is already delivering the great engines for America's major missiles-Atlas and Thor for the Air Force ... Jupiter and Redstone for the Army.

#### After the breakthrough

These divisions of North American are making many important scientific breakthroughs in this race to space. But even more important is the ability North American has demonstrated, time and again, to turn today's experimental flights into tomorrow's standard weapon system

-swiftly, surely, and at lowest possible cost. For every breakthrough is only a new beginning; it's the followthrough that gets the results.

### **Ground support for space**

One of the Armed Services' most difficult problems in the Space Age will be the increasing workload on their expensively trained technical manpower. That is why North American is designing a new kind of simplified maintenance into all airplanes, components, and automatic control systems.

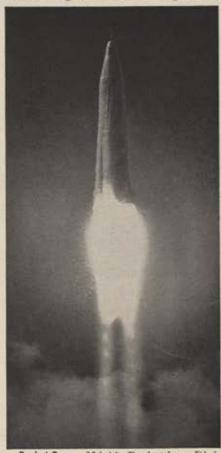
This program will pay off in three ways: more efficient use of special skills; more complete utilization of weapons; more defense for the taxpayer's dollar.

In the arts of peace, NAA's Atomics International Division has developed two nuclear reactors that show great promise as practical sources of electric power.

Today in North American Aviation and its divisions, you'll find as potent a combination of scientists, engineers, and production men as any in American industry. Because these men are constantly forging ahead into vital new technologies, much of their work holds great promise for science and industry.



Destination: Outer Space. A man will soon look out on space from cockpit of the X-15, rocket-powered research plane now being readied for its flight test.



Rocket Power. NAA's Rocketdyne Division builds rocket engines with thrust to drive Air Force's Atlas missile—or to launch an earth-circling satellite.

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### Revolutionary design...and accuracy to 40 per hour

In a fully maneuverable twin gyro platform utilizing completely new gyro design principles, Sperry has achieved unprecedented accuracies in heading information and all-attitude flight. The first of these new Sperry systems will soon be delivered to the Air Force's Wright Air Development Center.

This Sperry system provides azimuth drift rate as low as 1/4° per hour, and in the vertical axis, 1/10° per minute. The use of twin directional gyros and new design technique permits this extreme accuracy as it minimizes the disturbance torques inherent in conventional gyros. The low drift in the vertical axis minimizes turning error—permits freedom from erection control for longer periods of time.

Coupled with doppler radar navigators, the CEP (Circular Error Probable) is materially reduced due to exceedingly low drift inertial heading feature. The inertial heading output permits either Great Circle or Rhumb Line flight paths.

The compactness of the twin gyro system makes it extremely reliable and easy to maintain. No warm-up period is required due to the balanced thermal construction and the absence of fluids.

The twin gyro platform has been designed to provide control information for complete and full maneuverability of high-performance aircraft without limit. Its full stabilization in all attitudes makes it especially adaptable for Low Altitude Bombing Systems, fighter maneuvers and missile applications.

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### FEATURES

AERONAUTICAL EQUIPMENT DIVISION





-world's fastest, highest-flying operational airplane

Lockheed's ultrasonic "missile with a man in it" can outrace the sun from New York to San Francisco. When necessary, it can zoom into the upper stratosphere to perform its vital day-and-night missions.

Less than 55 feet long, with knife-sharp 7½-foot wings, the F-104 Starfighter packs awesome firepower. Each wing tip can carry a Sidewinder missile—which is guided to its target by an infrared track-

ing device (which "feels" the presence of other aircraft by the heat they radiate).

No other fighter plane in USAF history has been so thoroughly performance-proved before entering service. For over three years Air Force and Lockheed pilots, engineers and scientists have subjected the F-104 Starfighter, its electronic components and armament to the most punishing tests they could devise. This new pre-service

procedure assures maximum utilization of the F-104—starting with its very first mission for the Air Defense Command.

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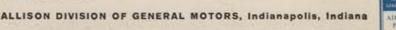
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Proving beyond doubt the operational readiness, flight dependability and superior economy of Allison Prop-Jet Engines and Aeroproducts Turbo-Propellers, Operation Hourglass clearly demonstrates why 11 airlines of the world have ordered 144 Allison Prop-Jet powered Lockheed Electras for medium- and short-range jet-age service.





LLISON PROP-JET POWER



Bendix-built Talos Guided Missiles on the Navy's "U.S.S. Desert Ship" at White Sands Proving Ground-Official U.S. Navy Photo.

# HOW THE MANY BENDIX MISSILE CAPABILITIES ARE IMPORTANT TO NATIONAL DEFENSE

Bendix\* has been meeting and solving missile problems for many years. In addition to building the Talos, a U. S. Navy ground-to-air missile, we engineered and developed many of the major systems used in other key missiles. These include warheads, target-seekers, propulsion devices, controls, guidance and telemetering systems. Telemetering systems enable missiles to send back reports from space. More than 500 different channels of information can be transmitted, such as speed, direction, acceleration, roll, vibration, temperature, etc.

The Talos, for which Bendix is prime contractor, has, according to a Navy statement, "demonstrated a remarkably high degree of accuracy and reliability". As a result, the Navy is making direct shipboard installations on first-line cruisers without the intervening step of evaluation. This has meant a considerable money saving and has advanced this missile as a fleet weapon. It will be the major armament of the United States cruiser Galveston and will also be installed on a number of other cruisers, including the nuclear-powered Long Beach.

Because of the accuracy and extreme range of the Talos, the U. S. Army is also studying the feasibility of incorporating it into the Continental Air Defense System.

In addition to missiles and missile components, Bendix manufactures important Ground Support systems and devices.

Looking to the future, Bendix is engaged in an intensive *long-range* program, designed to help keep America foremost in the development of weapons vital to the preservation of our security and world peace.



Bendix furnishes major elements for missiles of all types. This illustration represents no particular missile, but shows the general location of various airborne Bendix systems and their components. In addition, Bendix produces the Ground Support systems indicated above.

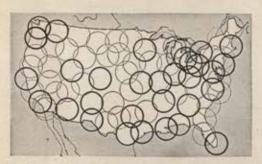
A thousand products



a million ideas



### Getting set for jet-age traffic at 27 leading U.S. airports



Raytheon radars at 27 of the 31 heavily circled areas will soon be operating as part of C.A.A.'s flight control network. Light circles indicate future coverage.

"More sky to fly in"—the goal of the Civil Aeronautics Administration—is near realization for both military and civil aircraft. The first of 27 new Raytheon Flight-Tracker radars ordered by C.A.A. is now being installed at Indianapolis. Installations at six other major cities will follow shortly and the nation-wide system will be tied in with Air Defense Command radars to link 31 airports by this fall.

Flight-Tracker radars help safeguard aircraft in every stage of flight. They detect and track planes in any weather—even in storms—pinpoint position of four-engine transports up to 200 miles distant, at altitudes up to 70,000 feet.

This new equipment, designed and built by Raytheon, will speed schedules, reduce airlane congestion. By readying the skyways for the Jet Age, Raytheon helps solve a major military and civilian transportation problem.



Excellence in Electronics

# Will ARPA Swim Upstream or Down?

Despite persistent and pained protests from the military and aircraft-industry men who will have to carry the cross, the Advanced Research Projects Agency is in existence. When Defense Secretary Neil H. McElroy announced the organization of ARPA on February 7 there was no mistaking that the Pentagon's boss had his own reservations about the action.

Mr. McElroy's formal directive does not mention the word "space," but it says that ARPA is responsible for any advanced projects handed to it by the Secretary. He acknowledges that space programs head the list, second only to the antimissile-missile on which some decisions already have been made. And he has promised Congress that ARPA programs will be developed in "full coordination" with the military departments,

On paper, ARPA is authorized to arrange for research and development work by other government agencies, including the Army, Navy, and Air Force. It can sign contracts with individuals, industries, colleges, and other institutions. And it is empowered to build its own facilities.

The idea of another layer of Pentagon bureaucracy, particularly in vital fields where the Russians seem to be ahead of us, has been condemned in many quarters. In most of these places nobody can do anything about it, but Congress is exceptionally alert these days and has its ears open.

Bob Gross, Board Chairman of Lockheed, told the Senate Preparedness Subcommittee, headed by Sen. Lyndon B. Johnson, how his firm built and flew the first F-80 jet fighter in 150 days. The reason, he said, was that the Air Force had only three officers on the project, and they had the power to say "yes" right on the spot. Mr. Gross said this saved millions of dollars and three years of time.

The Lockheed executive had high praise for Maj. Gen. Bernard A. Schriever and his USAF Ballistic Missile Division, but observed that this effort will pay off only if the General "does not have to swim through too much seaweed." The seaweed—committees, reviews, and other decision-delaying procedures— was assailed in a chorus by these witnesses. In this, Mr. Gross and his industry colleagues were joined by a list of distinguished military development and procurement officers. It is an incontrovertible fact that all of them fear ARPA will add to the seaweed.

Mr. Gross was not referring to ARPA. He was talking about the existing impediments to progress. So was Dan Kimball of Aerojet, another industry witness, who said, "There are too many layers of civilians." Kimball recommended that seventy-five to ninety percent of the watchdogs in the Pentagon be sent to the pound. All of them, he reported, "have the power of veto but they do not tell you to get going on something."

It seems clear to these men that ARPA will probably only add to the confusion. Mr. McElroy tried to reassure them. He named Roy W. Johnson, a vice president of General Electric, as director of the agency. He said ARPA "will do the planning." It will provide "direction and financing" for work now under way by the armed forces and not interfere with operations. On the other hand, if Johnson controls the purse it is clear he will have a strong voice in the selection of "upstream" weapon systems.

Here may be the rub. It does seem reasonable, or at least possible, that ARPA will find nuggets of information and know-how in its upstream swimming. They may include items that would not otherwise be brought to the attention of the military, like Dr. Edward Teller's conviction that it was possible to build an H-bomb. Dr. Teller stayed upstream. If ARPA can stay up there it could be useful.

But the provision for ARPA to have jurisdiction over contracts and build laboratories certainly is a license for it to come downstream far enough for alarm. Mr. McElroy has promised ARPA Director Johnson a "strong" technical team, but there is no promise that they will be scientists of as pure a strain as Edward Teller. Mr. Johnson, a top GE executive, will depend on this team to help him make choices when he starts to spend the \$340 million now being sought from Congress. The degree of competent military and industry advice available to the program is not clear. Some people see significance in the fact that the aircraft industry almost never is honored, if it is an honor, with an invitation to one of its top executives to fill a key Pentagon position.

Aside from military and industry skepticism, the organization of ARPA cannot be said to have a full blessing from Congress. At either end of Pennsylvania Avenue thought is being given to the idea of demilitarizing space. The Senate and House were forced into a compromise on the question, with the result that the Defense Department is slated for a one-year limit on its freedom to initiate new projects in the space weapons field. Meanwhile, both the Congress and the President, working with Dr. James R. Killian, the latter's scientific adviser, will try to decide how far to go in the effort to insure the use of space by scientists alone.

One of the fascinating aspects of the ARPA argument, raging since mid-November, is that nobody has mentioned the name of Dr. Paul D. Foote and his assignment as Assistant Secretary of Defense for Research and Engineering. Dr. Foote, undoubtedly qualifies as the most-forgotten member of the Defense hierarchy. He still has an Office of Aeronautics in his bailiwick and an Office of Planning. It is logical to assume that one of them, or both, would be concerned with astronautics, at least pending establishment of an Office of Astronautics. Well, there isn't any such office. Nor is there anything in the record to show that Mr. McElroy's top assistant in charge of research programming and coordination ever was invited to take part in the recent ARPA discussions.

Easiest interpretation of this side-stepping of an existing Assistant Secretary is that Mr. McElroy is facing a review of his entire organization, civilian and military. This goes back to the Johnson Subcommittee testimony and the constant reiteration that the Department of Defense is supposed to be an organization of about one hundred real policymakers. For administrative purposes it has grown, predominantly under Charles Wilson, to a 2,500-man monster.

The persistence of the senators and their counsel, Edwin Weisl, in chasing this subject and begging for opinions on it may be a growing cloud up above the Pentagon. Then (Continued on following page)

the Subcommittee has already come up with an interim report calling for "decisive action" in seventeen areas. One of them is the need for changes in the Department of Defense's own structure.

This is not by any means to be interpreted as a guarantee that the hierarchy will be pared down and that offices like that of Dr. Foote will be found as superfluous as it was in the two-and-a-half-month debate over ARPA. It is a well-known fact in Washington, as familiar as the monument, that a machine like this is pretty hard to tear apart and destroy. People thrown out of one door have a way of getting back in through another.

For real economy, however, the most effective place to start on a campaign of this type would be in the very area the Senate has been investigating-procurement. It has been pointed out that Dudley Sharp, Assistant Secretary of the Air Force for Materiel, has a staff of twenty-six persons, including the USAF panel of the Armed Forces Board of Contract Appeals. Looking over his shoulder as he spends USAF money is Perkins McGuire, Assistant Secretary of Defense for Supply and Logistics, and a staff of 250 persons. McGuire has been there a little more than a year, His predecessor, Thomas P. Pike, had the job two years. First man at the desk was Charles S. Thomas, who served nine months. He took the job on August 5, 1953, six months after Mr. Wilson became Secretary. Before that Secretaries Robert A. Lovett, George C. Marshall, Louis Johnson, and James V. Forrestal somehow did their job without an Assistant for Supply and Logistics and 249 aides.

In announcing formation of ARPA, Secretary McElroy paid tribute to the National Advisory Committee for Aeronautics, thereby recognizing that a good many observers can't understand why NACA did not figure in early planning for the space age. The Defense Secretary said "we have been very happy" in the relationship with NACA on aircraft development. Pressed by reporters, he refused to express a preference between his pleasure with NACA and his equally "satisfactory relationship" with the Atomic Energy Commission. The difference, of course, is that NACA does research in aerial weapon development and turns the results over to the military and industry. AEC does research, but it also is in the hardware business; it has a tradition of manufacturing similar in some respects to that of an arsenal.

As for the immediate future, McElroy says the space project proposals already submitted to the armed forces by industry will be evaluated and action taken as soon as possible. This will not have to await the arrival of Roy Johnson at his ARPA desk, expected about April 1.

There are a lot of things Secretary McElroy may change and they could include his early concept, expressed last November, that ARPA will develop new weapons, then turn them over to a chosen branch of the armed forces with orders to shoot. There is some evidence that the Secretary has gained new respect for the complexity of modern tools of war in his short tenure. Certainly Congress is preparing to strike a blow for urgency. Both the military forces and industry have reason to be thankful that ARPA is not in the coldly practical hands of Charlie Wilson. ARPA's effectiveness will depend entirely on how it is administered by Mr. McElroy, leaning heavily on President Eisenhower and Dr. Killian. There is hope that it can be held upstream and not add to the seaweed.

-CLAUDE WITZE

### Changes in AFA's Flight Pay Protection Plan

In setting up the Flight Pay Protection Plan, Air Force Association and 15,000 flyers have pioneered a new idea in military insurance.

Now, after eighteen months' experience, AFA announces adjustments in the program to balance the requirements of the 15,000 policyholders with good business practice.

Response to the Plan indicated a far greater need for such coverage than even AFA had expected. In the first eighteen months, money paid out in benefits or set aside for existing claims totaled some \$435,000. More important, letters from the men involved have proved beyond doubt that flight pay benefits have been critically important to family pocketbooks.

On the other hand, claims received have far exceeded the estimates on which the coverage and the payment rates were set up, so that adjustments become necessary if the Plan is to be permanently effective.

One of the best ways to save money on claims would have been to eliminate the three months' retroactive pay for groundings. On the other hand, this would have cut off income just when the grounded flyer needed it most—when expenses were high and before he could make any budget adjustments to allow for reduced income. So the three

months' retroactive pay feature has been retained, and is still effective.

One break was unanticipated. Compensation from the Plan has been declared tax-free. Consequently, AFA can now pay benefits at eighty percent of flight pay, rather than 100 percent, and still match the income from regular, taxable flight pay.

Benefits for groundings from non-aviation accidents, or from disease extend to a maximum of twelve months under the new Plan. Benefits for groundings resulting from aviation accidents extend to a maximum of twenty-four months.

To keep these benefits in effect, it has been necessary to move the rate up; a move which was considered preferable to the only other option, that of placing further restrictions on coverage. Consequently, the rate for coverage is now two percent of annual flight pay.

These changes became effective February 1, 1958. Other provisions of the coverage remain substantially unchanged; AFA will continue, as in the past, to absorb the bulk of administrative and clerical costs in handling and processing the coverage—the factor which enables the underwriters to make such normally expensive protection available to AFA members at extremely low cost.—End



READY NOW—Not a dream of the future, but "hardware" today, the Northrop Snark SM-62 is now being produced in limited quantities for the Strategic Air Command. Air Force ground and technical crews are in training and an accelerated production schedule of this relatively low-cost missile can be our strongest deterrent to enemy aggression. Years in development, the Snark has repeatedly proved its ability to deliver nuclear warheads on targets more than 5,000 miles away at speeds in the sonic band. The Snark is automatically guided to its target by a self-contained guidance system that defies jamming or misdirection by the defender. Enemies of the free world are well aware that the U.S. has this fully developed intercontinental guided missile—capable of flying from concealed mobile launchers to hit a target anywhere in the world. A formidable companion to the long-range bombers of the Strategic Air Command, the Snark is another reflection of Northrop Aircraft's "security with solvency" philosophy of delivering more air power per dollar.





#### THE ROOT OF THE MATTER

Orenda is pioneering many new concepts in jet engine design. The IROQUOIS supersonic turbojet, now producing over 20,000 lbs. (dry) thrust in its early development, incorporates several. The outstanding performance of the IROQUOIS, combined with inherent low weight, is the reason it has been selected for the Avro Arrow, Canada's new supersonic interceptor.

Illustration shows stress patterns in a jet engine blade root under load, using color photography and photo-elastic stress analysis.



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a handbook

of military astronautics

#### USAF AND THE SPACE AGE

AN ancient vaudeville joke ends with the punch line, "Watch that first step. It's a long one." That is what we discovered when we decided to devote the entire contents of this issue to space. Space itself is literally limitless, and what you can say about it very nearly so. We have attempted to stay within the bounds of our title, "Space Weapons," in an effort to provide for those interested in the United States Air Force and its mission a basic compendium of knowledge for the transition into the Space Age. We decided to concentrate on those items directly bearing on the USAF space mission—the history of the Air Force's already considerable penetration into space, the vast technological contribution being made through the Air Force ballistic missile program, and the unique foundation of Air Force experience and doctrine through which the ultimate goal of man in space can be achieved. Many complex subjects have, of necessity, been touched on comparatively lightly and will be discussed in greater depth in future issues.—The Editors.





Stepping stone to the stars. The moon, our nearest neighbor and potential USAF base in the heavens, as seen by a high-powered telescope.



#### BY THE END OF THE CENTURY ...

James H. Doolittle

THERE has been exploration since the beginning of mankind, since the beginning of curiosity. The airplane has made well known most of the remote spots on this globe, but exploration will continue.

The new exploration will be in science and in space. We, as a nation, must have vision and must work hard if we are to be leaders in this new type of exploration.

I am a conservative, but I believe that before the end of the century the following events will occur and that they will occur more or less in the following order:

 A rocket will go to the moon. Somewhat more propulsive power will be required than for an intercontinental ballistic missile or for a satellite, but the guidance in actually hitting the moon will be easier than hitting a specific target from 5,000 miles.

Scientific instruments will be landed on the moon.
 There is no atmosphere on the moon, so reverse thrust will be required in order that instruments may land on the moon lightly, softly. There may be deep dust on the moon, no one knows, so it may be necessary to send up several scientific instruments before one will operate.

• A manned satellite will go around the Earth and will return to the Earth. This will lead to the possibility of transcontinental or transoceanic travel in half an hour. San Francisco to New York, New York to London, New York to Paris—in half an hour. The determinant as to whether people travel this fast will be not technology, but economics.

· A trip around the moon and return; an opportunity,

first to look at the far side with radar or television, unmanned, and then a trip around the moon and return to Earth with a man aboard.

- · A man will be landed on the moon and brought back.
- A space platform will be established.
- · Instruments will be landed on Mars or Venus.
- A man or men will be landed on Mars or Venus and brought back.

If I weren't a conservative, I would say that before the end of this century two more events will take place: a permanent observation station on the moon, and interplanetary travel as a common thing.

This is only the beginning. What will happen next, I cannot even conceive. I am only sure that the rate of scientific progress will continue to increase.

The eight or ten things I have enumerated can be done. I am satisfied that before the end of the century—and maybe long before the end of the century—they will be done.

We, the United States of America, can be first. If we do not expend the thought, the effort, and the money required, then another and more progressive nation will. They will dominate space, and they will dominate the world. There is a nation with this ambition. We must not let it prevail!

From remarks by James H. Doolittle at the Aero Club of Washington's Wright Memorial Dinner, Washington, D. C., December 17, 1957.



#### AIR AND SPACE ARE INDIVISIBLE

Gen. Thomas D. White CHIEF OF STAFF, UNITED STATES AIR FORCE

N LITTLE more than a decade, the nature of international relations has been radically altered by the concurrent development of thermonuclear weapons, intercontinental bombers, and missiles. International relations soon will be further complicated by man's capability to travel in the far reaches of space. This era of rapid technological progress could benefit all mankind or it could result in a holocaust which might destroy the civilized world. The United States Air Force intends to do everything within its power to prevent war and to enhance the peaceful benefits that knowledge of space could bring.

To assure peace, the United States has no current alternative but to maintain powerful military forces in a state of constant readiness for war. Since the prime purpose of our military forces is to deter war, our deterrent forces will have accomplished their purpose if they never have to be used in battle. Should the United States be required to use its military forces, however, they must be strong enough to achieve victory.

The basic philosophy of the United States Air Force as concerns military airpower is the requirement for flexible offensive forces second to none. These forces must be capable of *selective* operations anywhere in the world in support of our national objectives. Possession of a strong defense, particularly a strong air defense, is important, but our possession of first-rate offensive forces is the principal deterrent to enemy attack.

The idea of deterrence through possession of strong military strength is not new. In years past, the deterrent stature of the United States existed in its reserve and mobilization potentials and in the protection afforded by its oceans—as well as in the size and quality of its forces in being. But this has changed. Deterrence can no longer be measured in terms of distance or mobilization potential. The potency and flexibility of powerful striking forces

which can retaliate on a moment's notice, compose the only real deterrent today. This deterrent power can be sufficient only so long as it convinces potential enemies that aggression against the United States and its allies would not pay. The most important responsibility of the United States Air Force is to maintain its deterrent power strong and modern, with forces that are sufficiently flexible to meet all situations in which they are likely to be needed.

#### Missiles

Air Force capabilities have always been developed in accordance with assigned responsibilities and are always projected into the future on the same basis. The reason the Air Force builds weapon systems of any type is to produce better combat capabilities. As the state of the art has improved, so have the weapon systems of the Air Force improved. The technological progress evidenced in a comparison between the B-29 atomic bomber of 1945 and the global B-52 jet nuclear bomber of 1958 is obvious. The sciences of aeronautics and astronautics will combine to bring progress that is even more significant and astounding in the years to come.

The Air Force embarked on the intermediate- and long-range missile programs because the combat potentialities of missiles offered certain advantages in comparison with manned systems. This is true even with early models of missiles, which will be much less efficient than those we expect to obtain later on. The Air Force has made considerable progress in the research and development of missiles, in detailed planning for their operational use, and in the provision of logistic support of missile systems when they became operational. Building a missile capability has been the number-one priority project of the Air Force in recent years.

There are many reasons why ballistic and guided missiles are compatible and complementary systems to manned aircraft. The alert potential, quick reaction time, and reduced vulnerability to enemy attack of operationally reliable missile systems will result in more effective and economical performance of many Air Force missions. However, weapon selection and the determination of proper force structure will also depend on many other factors such as reliability, accuracy, warhead weight, carrying capability, range, cost, and the type of targets to be attacked.

Although there are many advantages to be gained from exploitation of missiles, care must and will be taken to avoid the danger of going overboard on missiles or, for that matter, on any single weapon system or weapon. USAF studies indicate that even with vastly improved missiles, the strongest force structure, the one providing the best survival insurance, will be one in which missiles and high-performance manned systems are used together in complementary roles. Aircraft, missiles, and spacecraft are mutually supporting systems. They are compatible in development and operational strategies designed to gain and hold a superior advantage in air and space. They are a functionally complete system.

This factor of system completeness must be kept in perspective if the future patterns of airpower are to be seen clearly. Manned aircraft, missiles, and piloted spacecraft which are responsive to the command and control structure of the Air Force are parts of a continuing integrated system. From an operational viewpoint they are a single instrument. Operating under the same control structure, missiles, manned aircraft, and spacecraft will provide great flexibility. If circumstances should rule out mission accomplishment with one method, another method will be responsive to the mission. If more than one method is required, they can be applied simultaneously to the target objective.

#### Astronautics

Ballistic missiles have sometimes been erroneously referred to as the ultimate weapon. It is extremely doubtful whether there ever can be an ultimate weapon, although experience has shown that a single weapon or weapon system can be decisive at a certain time or place. Missiles should be considered as but another step, albeit a very important step, in the evolution from manned aircraft to true piloted spacecraft.

In discussing air and space, it should be recognized that there is no division, per se, between the two. For all practical purposes air and space merge, forming a continuous and indivisible field of operations. Just as in the past, when our capability to control the air permitted our freedom of movement on the land and seas beneath, so, in the future, will the capability to control space permit our freedom of movement on the surface of the earth and through the capability attended to the capability of the capab

the earth's atmosphere.

The Air Force has been pioneering in the fringes of space for several years with manned aircraft. The Bell X-2, a rocket research plane, carried Capt. Iven Kincheloe up to approximately twenty-five miles above the earth at 1,900 miles per hour. The X-15, which is now in the development stage, is designed for speeds and altitudes much greater than those of the X-2. The next step is the Air Force program to fly at hypersonic speeds, circumnavigating the globe many times before reentering the Earth's atmosphere. As a weapon system, this program will represent the first major breakthrough in sustained piloted space-flight. With this system it will be possible to resolve many of the problems involved in either placing man on a continuous orbit around the earth or sending him soaring into outer space and to nearby planets. At the rate things are

going, it is technically feasible for manned spaceflight to become routine in a very few years. The current technological race is producing technological advances at an unprecedented rate. Engine thrust has been increased many times over what was considered excellent a few years ago; and personal equipment has been improved to a point where it will be adequate for manned spaceflight to the moon.

#### Air Force Experience Factor

It is natural for the Air Force to have a major operational interest in the integration of air and space capabilities. Since the beginning of controlled flight in a heavier-than-air machine over fifty years ago, the Air Force has used the airplane as its basic system. During these years it has accumulated a vast amount of development knowledge, operational experience, and practical skills. Today, as the United States Air Force stands on the threshold of the space age, this know-how . . . the Air Force maturity in the science of flight . . . is a tre-mendously valuable and important asset. Through constant exploitation of the range, speed, altitude characteristics, and carrying capability of aircraft, the Air Force has developed techniques of air warfare, which were brought to a high state of perfection in World War II and which were improved even more during the Korean War. Strategic air warfare, the capability to penetrate deep within an enemy's defenses and attack his vital sources of power, is but one product of Air Force imagination, skill, and experience.

Today, the operational structure of the Air Force reflects this intensive experience in excellent equipment and a dedicated body of professional airmen. Predominant characteristics of this structure are quick reaction, flexiblity, firepower selectivity, mobility, and penetrative ability. With an infinite number of combinations of range, speed, routes, altitudes, and tactics, and operating in a medium that is undivided, unobstructed, and unlimited, the United States Air Force can accomplish an infinite number of tasks. The forces can be shifted rapidly from task to task or from one locality to another. They can be adapted quickly to various requirements for firepower in war and to employment for humanitarian, political, and psychological purposes in peace. Missiles can be exploited most efficiently and effectively when combined with this extensive operational experience.

Missile development and the probing of piloted craft into the fringes of space have been tremendous undertakings, surpassing even the Manhattan Project in scope and goals. In the not too distant future, efficient ballistic missiles and true piloted spacecraft will enter our forces as operational weapons. The Air Force will be ready to receive them and use them effectively, although new prob-

lems and challenges can be expected.

The United States and its allies must maintain the capability to exert a steady unremitting pressure against war in the years ahead. This can be done if United States airpower is the best airpower. To be the best it must be ready night and day, for every day of every year, to execute a counterstroke which is powerful, swift, and deadly. Such a force will make an aggressor reluctant to attack. The Air Force is dedicated to creating for our country the best airpower it is possible to produce.—End

The above material is the preface by the Air Force Chief of Staff, from the forthcoming book The USAF Report on the Ballistic Missile, edited by Lt. Col. Kenneth F. Gantz, Editor of The Air University Quarterly. The publisher of the book is Doubleday & Co., Inc. The appearance of this material in Air Force is with special permission.



"To me every hour of the light and dark is a miracle, Every cubic inch of space is a miracle,"

-WALT WHITMAN

## THE SPACE FRONTIER

THE United States Air Force, having penetrated space with its ballistic missile program and having probed the fringes of space with its manned aircraft, has been termed the logical agency to carry out the operation of manned vehicles in the vast reaches beyond Earth's atmosphere. The military space mission, which had been up for grabs ever since Russia's Sputnik I jarred this nation, may now be officially placed where it obviously belonged all along.

Defense Secretary Neil H. McElroy, in a press conference on February 7, indicated that he considered the operation of manned spacecraft as an Air Force responsibility.

This makes sense, and the decision should accelerate the nation's space program. For, as Gen. Thomas D. White, USAF Chief of Staff, points out on the preceding pages, "For all practical purposes air and space merge, forming a continuous and indivisible field of operations." At one point, in the almost hysterical reactions to Sputniks I and II, it appeared likely that space operations would somehow be considered an entirely new kind of military mission. Such an approach could have had only one of two results—either a new, and fourth, military service for all practical purposes; or fierce competition among the existing services for the space mission.

Either alternative would have been a disservice to the nation. For through its Air Force, the United States already has a tremendous investment in space operations, and assignment to any other agency would have inevitably resulted in delay, duplication, and waste.

In the Air Force's ballistic missile program, the developmental and production springboard into space is already

Left, the great nebula in the constellation Andromeda, one of the most distant objects in the heavens visible to the naked eye. It takes light some 2,000,000 years to reach Earth from the galaxy containing Andromeda. Yet Andromeda's is one of our own galaxy's nearest neighbors.

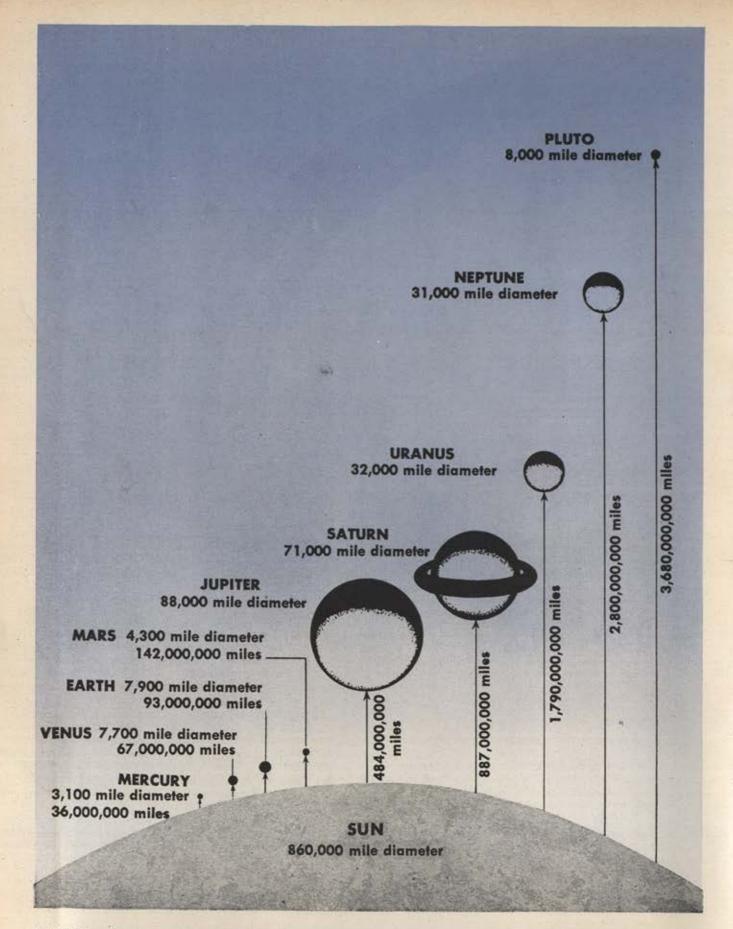
in existence, as will be discussed later in this publication. Its space medicine program has laid the physiological foundation for manned flight into space (see page 109). But beyond that is the all-important experience factor, also discussed by General White. For it is a far cry from a piece of hardware to an operational capability, a long step from a chunk of unmanned metal circling the Earth to an operational capability in manned spacecraft. And only in the Air Force does the nation possess an organizational and doctrinal base on which such a capability can be built.

Thus the Air Force finds itself, in the beginning of its second half-century of existence, on the threshold of the space frontier, with possibilities that kindle the imagination and challenge the intellect. Fortunately, it is able to approach the task with a solid background of experience, technology, doctrine, and philosophy. Conquering the space frontier will not be easy, but it is mandatory to the peace and security of the planet from which, paradoxically, we must escape in order to preserve our earthly liberties.

As a result, a heavy educational requirement has been laid upon Air Force shoulders. At a time when the transition from piston-engined aircraft to an all-jet force is still incomplete, when guided missiles are taking over the pilot's cockpit for many missions, the Air Force man must simultaneously project himself beyond even these startling developments into space itself.

For in space, the Air Force flyer once again comes into his own. Sometimes bewildered and often embittered by the black boxes which appeared to threaten technological unemployment, men who love to fly have new and exciting vistas open to them.

The sweep of technology is putting the pilot back into aircraft—or spacecraft, if you will—even before the missiles have edged him out of the flight plan. Missiles, even intercontinental ballistic missiles, are emerging not as the



VAST DISTANCES OF OUR SOLAR SYSTEM and the diameters of its nine planets are illustrated here. To a Plutonian, more than 3,680,000,000 miles away, the sun would look like not much more than a star, while to a Mercurian, "only" 36,000,000 miles away, the sun would appear as a huge fiery orb in the heavens. Of all the planets, Earth seems to be ideally situated, just far enough away from the sun (93,000,000 miles) to provide balanced and comfortable temperatures, radiation, and light ranges to nurture the life that has developed on this planet over the ages.

ultimate weapon, but only as the necessary interlude between manned flight in the Earth's atmosphere and manned flight in the vast reaches of the solar system and beyond.

As a result, it behooves the airman of today, the spaceman of tomorrow, to begin now to know the medium in which he will be operating. He will leave old problems behind him: drag (there is no drag in space); gravity in the usual sense (one cannot crash in space because there is no place to fall to); weather (there are no clouds or thunderstorms in space). He will encounter a range of new problems: environment (he must take his food and atmosphere with him); navigation (he must learn to astrogate rather than navigate—his checkpoints are the stars); and he may spend weeks, months, or even years, instead of hours between blastoff and landing.

Space is big. Its vastness is all but incomprehensible to the human intellect. But there are homely examples

which convey some imagery to this vastness.

Sir James Jeans, the British astronomer, gives us an inkling. He says there may be as many stars in the universe as there are grains of sand on all the beaches of the world. And our sun, the center of our solar system, is merely one of these stars.

Our own solar system, with the sun as its star, is but a pocket of the vast galactic star system we call the Milky Way, which in turn is only one outpost among the myriad

star systems of the universe.

Our system's planets all revolve in the same direction in their orbits around the sun. These orbits are all nearly circular and all lie in about the same plane. The so-called "Inner Planets"—Mercury, Venus, Earth, and Mars—are relatively small and dense and have few satellites. The "Outer Planets," on the other hand, with the probable exception of Pluto, about which little is yet known, are large, have low densities, and run to larger numbers of satellites. Jupiter, for example, has twelve moons; Saturn, nine (the sixth of which, Titan, with a diameter of about 3,500 miles, is the largest satellite in the solar system and the only satellite that we know has an atmosphere); Uranus, five; and Neptune, two. The relative sizes of all the planets and their distances from the sun are shown on the chart on the opposite page.

It takes a man eight hours to drive his car 400 miles, and about the same length of time to walk twenty miles. But miles become relatively meaningless in any discussion of space, if only because of the unwieldy number of zeroes required for figures over the billions. And in terms of billions of miles, a space traveler hardly finds himself beyond our own planetary system. So new units of

distance measurement have been devised.

One of these is called the "astronautical unit" and is based on the average distance from the sun to the Earth

(about 93,000,000 miles).

A second unit of measurement, a much larger one, is the "parsec." This is a contraction of what scientists call a "parallax second," and indicates the distance at which the mean radius of the Earth's orbit would subtend an angle of one second of arc. Each parsec is equal to 19,150,000,000,000 (or 19.15 trillion) miles.

The most familiar unit of space measurement, of course, is the "light year." This is the distance light (traveling at the rate of 186,284 miles each second) would travel in one year. Each light year contains 5,880,000,000,000 (or 5.88 trillion) miles. There are 3.26 light years in

every parsec.

None of the planets in our solar system is so far from the sun that light takes as long as a year to cover the distance. Earth, for example, is only eight light minutes from the sun—that is, it takes sunlight eight minutes to travel the 93,000,000 miles from sun to Earth.



This dazzling sight, visible through high-powered telescopes, is the spiral nebula in Virgo, one of the constellations in the southern hemisphere of the sky. Our own galaxy, the Milky Way system, would have a somewhat similar disc-shaped appearance to observers in Virgo.

# The Distances of Outer Space



Left, the large disc represents the size of our sun, with the planets Jupiter, Earth, and Saturn shown on its surface at the same scale. The broken line represents the orbit of Earth's moon, a distance from Earth of some 239,000 miles. Below, some idea of the size of the universe may be gained from realization that it takes more than 26,000 years for light (which travels at 186,-000 miles each second) to travel from our sun to the center of our galaxy, or the system of stars on which our sun is a member. Outside are many "extragalactic nebulae," one of the nearest and largest of which is the galaxy containing the great nebula Andromeda.

#### THE DISTANCES OF THE UNIVERSE

From the Sun to the Earth, 93,000,000 miles.

Light takes 8 minutes to travel this distance, traveling at 186,000 miles per second.

From the Sun to Pluto, outermost planet of our Solar System, 3,680,000,000 miles.

Light takes 5¼ hours to travel this distance, traveling at 186,000 miles per second.

From our Sun to Proxima Centauri, the star closest to our Solar System, 25,000,000,000,000 miles.

Light takes 4½ years to travel this distance, traveling at 186,000 miles per second.

From our Sun to the center of our galaxy.

Light takes 26,080 years to travel this distance, traveling at 186,000 miles per second.

From the center of our galaxy to the center of the galaxy containing the great nebula Andromeda.

Light takes 2,262,000 years to travel this distance, traveling at 186,000 miles per second.

SUN

Pluto, the outermost planet, some 3,680,000,000 miles from the sun, receives its sunlight about five and a quarter hours after that light leaves the sun. So we say Pluto is five

and a quarter light hours from the sun.

All around our solar system-that is, our sun with its nine known planets-lie the countless other stars of our galaxy. A "galaxy" is a system of stars. Our galaxy can best be visualized as a disc standing on end. Our solar system is fairly far down the "disc" and situated in an outer "arm." Looking up through the disc, observers on Earth see what appears to be a huge, tight-packed, irregular band of stars. This is what we call the Milky Way and is, in reality, the aggregation of stars seen through the deep length of the galactic disc.

Some idea of the size of our galaxy may be obtained from examination of the chart on page 46 which shows that it takes light four and one half years to travel from our sun to its nearest neighbor-the star Proxima Centauri. And light must travel some 26,080 years to reach the

center of our own galaxy from our sun.

But there are other galaxies outside the one which contains Earth and her sister planets. One, which the astronomers call "Messier 31," contains the constellation Andromeda (or the "Chained Lady"). The center of this galaxy lies more than 2,000,000 light years from the center of our galaxy. Andromeda's galaxy is famous as one of the most distant heavenly objects that can be seen with the naked eye. Yet what appears to an observer on Earth as a faint pinpoint of light is an enormous cluster of stars whose galactic diameter alone is nearly 100,000 light years.

And beyond Messier 31 are still countless other galaxies, Man's most powerful telescopes now have probed as far as 1,000,000,000 light years into the heavens. No one can now say if these vast reaches of nothingness extend on indefinitely or if, as Einstein's General Theory of Relativity suggests, space is finite and curved so that a beam of light projected into space at the 186,284-mph "speed limit" would eventually (after more than 200,000,000,000 Earth years) return to its starting point-but from the opposite "direction."

Einstein's theory, in an interpretation that staggers common sense, also suggests that time "shrinks" when measured within objects which are moving at very nearly the speed of light. This phenomenon has led such persons as the eminent physicist Dr. Edward Teller to speculate that, given a space vehicle capable of such fantastic speed, an Earth spaceman could travel to points a million light years distant and return-all within his lifetime!

In terms of these almost unbelievable times and distances, our sun's planetary system suddenly seems a

smaller, friendlier place.

The flight to the stars is the "day after tomorrow," pending unimagined new knowledge of propulsion systems geared to the speed of light. But today, airmen are on the threshold of near space. They are facing "space equivalent" conditions now within the Earth's atmosphere, and they will enter "true space" in the neighborhood of 400 to 500 miles "up" or "out." On the way out of our atmosphere, they will pass through the ninety-nine percent of it that lies below 100,000 feet. They will pass through the five layers of atmosphere (see chart, page 48):

 The troposphere-lowest air region extending up about ten miles, is pretty much the extreme operating altitude for today's conventional aircraft. Its upper boundary is the tropopause, ranging from 54,000 feet at the equator to about 28,000 feet at the Poles and 36,000 feet at the middle latitudes. This variance is due to the elliptical shape of the earth. Only about twenty percent of the troposphere is oxygen, the remainder largely nitrogen.

The stratosphere—extending from about ten to six-

teen miles up. There a reciprocating engine's power output would reduce to zero as absolute pressure fell below 212 pounds per square foot. Halfway through the stratosphere-at about 63,000 feet-an airman's blood would boil. A sealed cabin is imperative. Outside temperatures are seventy degrees below zero, Fahrenheit.

• The mesosphere-extending from the stratosphere extremity to about 250,000 feet, or about fifty miles. Here there is a concentration of ozone which absorbs a large part of the sun's ultraviolet radiation, increasing temperatures but helping shield the earth from cosmic rays. USAF Maj. David G. Simons spent thirty-two hours in a balloonborne cabin in this area last year, but did not reach its warmest part, above 150,000 feet, where outside temperature is about fifty degrees above zero, Fahrenheit. Beyond the fifty-mile level, just out of the mesosphere, the mercury

tumbles to 104 degrees below zero.

 The thermosphere-starting at about 250,000 feet or about forty-eight miles, this area extends up to somewhere around 200-300 miles, with experts not in agreement. Here the temperature curve goes up again, reaching 2,200 degrees above at 300 miles. There is no sound here. The thermosphere is also called the ionosphere because of its intense electrical activity. Atoms and molecules in this layer are bombarded by powerful electromagnetic waves from the sun and become electrified or ionized. The thermosphere is made up of four different layers of these ionized particles, each more concentrated than the next. Lowest is the "D" region topped in order by the "E," "F<sub>1</sub>" and "F<sub>2</sub>." The ionosphere has strong influence on radio transmission.

• The exosphere-the upper limits of this top layer of the Earth's atmosphere blend into outer space to a possible 1,000 miles, although there is, of course, no actual delineation or "boundary," and there are some experts who believe that bits of Earth's atmospheric gases are found much farther out.

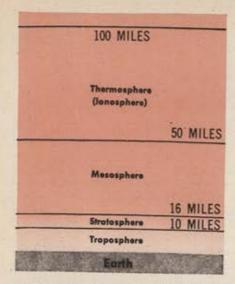
Apart from the theoretical discussions of scientists and the active, often scientifically sound, imaginings of sciencefictioneers, man's efforts to conquer time and distance via the air have led him inevitably to the fringes of space. In his attempts to fly farther and faster, he flew ever higher, where the air was "thinner" and where there was less drag.

Here man found limitations, or "ceilings," both physical and mechanical. Man and his engine had to breathe air to continue functioning, and both rather quickly reached a point where there was not enough air to keep either functioning without outside assistance. Above 15,000 feet the pilot in an open cockpit could not function without supplementary oxygen, and so the oxygen mask and later the pressurized cabin were devised. Above 25,000 feet the engine began to run short of oxygen, and the supercharger was developed.

Operating altitudes continued to climb. In World War II the Air Force was flying and fighting at from 15,000 to 35,000 feet. Doglights over MIG Alley in Korea sliced through the thinning air at 45,000 feet. Today we have operational aircraft in our inventory that can reach altitudes of over 50,000 feet, and others in the program

designed to fly over 70,000 feet.

On the experimental side, Air Force efforts to pierce the sonic barrier pushed experimental aircraft to new heights where there was not enough air for either man or machine, and the engine carried its own oxygen with it just as did the pilot. These aircraft included the Bell X-1 in which then Capt, "Chuck" Yeager became the first man to fly faster than sound. He did it in October 1947 at 73,000 feet. In 1954 Maj. Arthur "Kit" Murray climbed to a new ceiling for manned powered flight-94,000 feet in the X-1A. Capt. Iven C. Kincheloe currently holds the



At the 100-mile level, which will be surpassed by the X-15, we are in conditions of physiological "space equivalence," although still well within the gravitational grip of the Earth.

world's altitude record of 126,200 feet set September 7, 1956, in the Bell X-2.

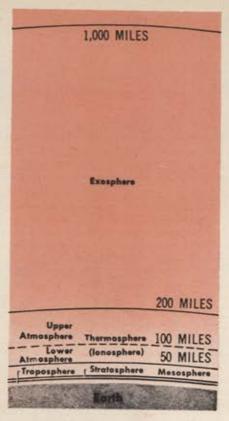
For all intents and purposes these men have been in space. Both they and their aircraft were operating independently of what little atmosphere there is at those altitudes.

Concurrently with these experiments with manned aircraft on the edge of space went other probing forays into the practical upper limits of the atmosphere. It has been ten years since the joint military Aerobee programs were established. These rockets have carried instruments, mice, and even monkeys, well into the mesosphere (95,000 feet). USAF's Moby Dick meteorological balloon project has regularly carried instruments over 75,000 feet high, with the advantage over the research rockets of being able to stay aloft much longer.

Another Air Force spaceman, of course, is Balloonist Simons, who reached 102,000 feet in a sealed capsule gondola beneath a balloon (see "Man in Space," page 120).

The most recent USAF space study, and the most spectacular, has been Project Farside. Sponsored by ARDC's Office of Scientific Research, Farside used a balloon-borne, four-stage rocket, fired at 100,000 feet, to carry a three-and-one-half-pound package of instruments still farther up—or out—to an estimated minimum of 2,400 miles—the very farthest known foray into space by a man-made, man-directed object. Farside furnished telemetered information on cosmic-ray activity and the grip of the Earth's gravity at that distance.

But these manned and unmanned ventures into space are but the prel-



From the 200-mile level to an estimated 1,000 miles extends the last layer of the atmosphere, the exosphere. The US satellite Explorer is ranging, at its farthest point, beyond this level.

ude to true spaceflight. And spaceflight, like atmospheric flight, is subject to certain basic physical laws, although not necessarily the same ones. In fact, there are certain essential differences which the airman must learn as he transforms himself into a spaceman.

Just as aeronautics is the science of air travel, so astronautics is the science of space travel. The differences between the two, so far as the machine is concerned (physiological problems are discussed in the section "Man in Space," beginning on page 109), deal with propulsion and control. And in each case it is the absence of air that causes the difficulty.

#### Propulsion

In 1686, Sir Isaac Newton stated his laws of motion, the third of which was, "For every action there is an equal and opposite reaction." This is the fundamental principle on which all propulsion is based—propeller, jet, or rocket. The propeller aerodynamically transfers the energy of the engine to the surrounding air. The jet does it thermodynamically, by scooping in air, compressing it, heating it by burning fuel, and ejecting the heated air and exhaust gases. Either way, the



Beyond the atmosphere—the beginning of the road to the moon. This is "near space" in celestial terms. USAF's Operation Farside rocket has penetrated this area more than 2,400 miles.

forward thrust is obtained by accelerating air rearward. But in space there is no air, hence no medium. The engine has no air to breathe to oxidize the fuel. And there is no air to "push against."

As a result, for space travel, man must return to an ancient propulsive device—the rocket. The rocket can breathe in space because it carries its own air with it, so to speak. That is, it contains both fuel and oxidizer. It can propel a vehicle through space because it develops its propulsion solely through reaction, in accordance with Newton's third law, rather than "pushing." Dr. Robert H. Goddard, American rocket pioneer, demonstrated this fact experimentally as early as 1919.

But until comparatively recently the state of the rocket art did not

War II has been told many times. But it was here that the basic advances were made in rocketry that will eventually permit manned spaceflight. The Germans were after range, enough range to carry a warhead to England. And they wanted speed, speed to avoid the detection and interception that were knocking down the lower-flying, slower, air-breathing V-1 missiles. The needed combination could be obtained by propelling a rocket into a high trajectory and letting it literally fall out of the sky onto its target.

Today's intercontinental and intermediate-range ballistic missiles have thus become the springboard into space (see page 73). For the quickest way to get a hydrogen warhead from one point on the Earth's surface to another as much as 5,000 miles away is via space. Thus the military requirement for long-range ballistic missiles has led to development of engines powerful enough to send payloads into space. As physical evidence we have seen three man-made satellites-Sputniks I and II and the US Explorer-circling

Earth.

In fact, putting a satellite into orbit-once the necessary propulsion has been achieved-is a relatively simple matter. It is much simpler, for example, than putting a warhead on target halfway around the world. The guidance problem is

not nearly so critical.

Basically, you put a satellite into orbit by accelerating it to somewhere above 18,000 miles an hour but less than 25,000 miles an hour. This range of speed is known as orbital velocity. That is, the satellite is projected far enough and out at a fast enough speed so that Earth's gravity does not pull it back. Yet its velocity is not great enough to release it from Earth's gravity and cause it to fly on out into space until it is picked up by the gravitational pull of some other body, such as the moon. The familiar analogy is that of swinging an object around your head on a string. Centrifugal force keeps it in a circle-or orbit-the string (representing gravity) keeps it from flying away.

Earth's escape velocity is 25,000 miles per hour. At this speed, the vehicle would be able to overcome Earth's gravi-

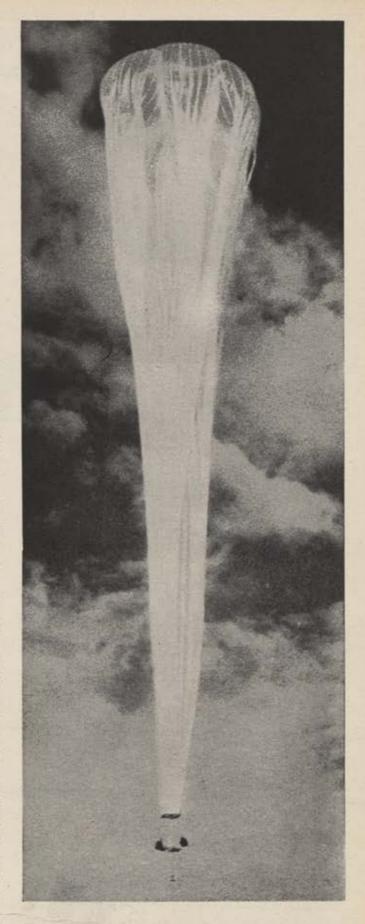
In passing, it might be noted that the elliptical orbits of the Sputniks and Explorer indicate errors in guidance. A perfect orbit would be very nearly circular, and, in such an orbit, a satellite would theoretically stay up-or outindefinitely. In an elliptical orbit, however, the satellite will eventually be pulled back into the atmosphere and disintegrate through friction, just as did Sputnik I.

If our eventual object is to get man into space, why fool around with satellites? One answer is that we can learn much about the conditions which man will encounter in space. Another is that, unlike man, an inanimate object can easily withstand the stresses of acceleration and other physical stresses the human body would encounter in blasting out of the Earth's atmosphere. An unmanned satellite, of course, does not have to breathe or eat, both matters which present certain difficulties for man in space.

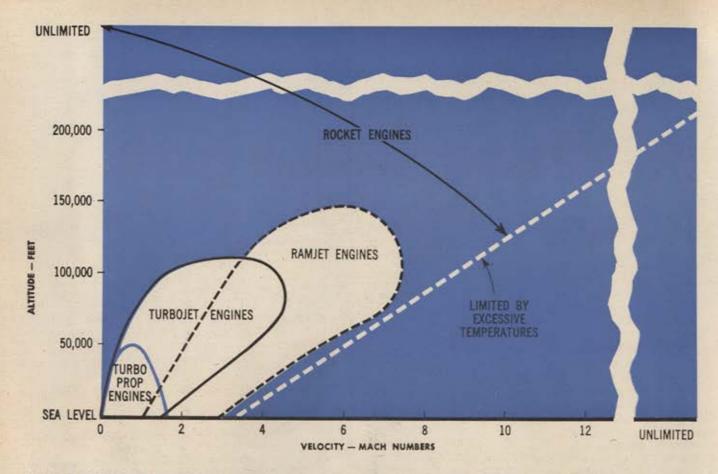
From a purely military point of view, there are certain things which can be done with an unmanned satellite without waiting for all of the physiological problems of manned spaceflight to be solved. The most obvious is that of reconnaissance. This is the purpose of the Air Force advanced reconnaissance satellite project, known as Pied Piper. Reconnaissance satellites will circle Earth, at altitudes of from 300 to 1,000 miles, and could carry photographic and television equipment, infrared, or radar. The data accumulated can be transmitted to Earth electronically.

However, we will see manned spaceflight for short periods of time and even orbital flight, again for short periods of time, before Pied Piper gets into space.

As pointed out previously, several Air Force men have already gone through ninety-nine percent of the effective



USAF Operation Farside rocket, carried aloft by this huge balloon, starts its ride to an altitude of 100,000 feet, from which the rocket was fired to a height of some 2,400 miles, marking the farthest push into space yet recorded for a man-made object. The launching was at Eniwetok Atoll.



THE LIMITS OF AIR-BREATHING CRAFT Powered flight has taken man and his aircraft to ever-higher altitudes, and finally to the limits of the most advanced airplanes, powered by ramjets, which run out of air to "breathe" and push against at about 150,000 feet. At this point rockets take over, carrying their own "air" with them and offering the mechanical approach to spaceflight because their ability to operate in the vacuum of space is theoretically unlimited. After today's chemically powered rockets will come nuclear, ion, and even photon propulsion.

atmosphere. One of these, Capt. Iven Kincheloe, is scheduled to venture more than four times as far into space as he did in his record-breaking Bell X-2 flight. In the experimental craft, the X-15, built for the Air Force by North American, Kincheloe will rocket to 100 miles or more (some reports say as high as 300 miles) and glide back into the atmosphere. He will be dropped from a B-52 and shoot upward under the X-15's rocket power. On his way up he will hit 3,600 miles per hour at about twenty-four miles' altitude. Somewhere above this point his aerodynamic controls will have no air to grab onto, and for this purpose the X-15 is equipped with so-called "ballistic" controls. These work on the reaction principle, like tiny rockets, and are strategically located so that Kincheloe can make the craft go where he wants it to.

As he begins to penetrate the effective atmosphere Kincheloe will be able to again utilize his aerodynamic controls to direct his gliding descent and from then on the flight will be quite similar to that of the X-2.

Thus, Kincheloe's trip in the X-15 will be a flight into space, rather than true spaceflight. He will be in space but for far too short a time to be called true spaceflight (see page 121 for artist's conception of the X-15 and diagram showing how the projected flights into space will be accomplished in this vehicle).

A USAF follow-on project is an extension of the X-15 concept and gets the Air Force a step farther toward true spaceflight. This is the boost-glide vehicle, which will be lifted to speeds and altitudes sufficient to orbit the globe several times. It will reenter the atmosphere and be directed aerodynamically just as the X-15.

However, the hypersonic speed of such a vehicle may require several trips in and out of the atmosphere to guard against aerodynamic heating that could occur during too fast a descent.

Both the X-15 and the projected boost-glide vehicles are but one step away from true spacecraft. They are hybrids—half airplane, half spacecraft.

And there are other Air Force space projects in the mill. One is to utilize an existing missile, such as Thor or Atlas, and substitute a small satellite for the final stage. There is no reason why such a vehicle could not be recovered safely, using reverse jets, or high-lift, high-drag areodynamic shapes, or even parachutes.

Another way to use existing technology is in the beginning of scientific exploration of the moon. The basic Thor missile, with other existing rockets as additional stages, could take a payload to the moon this year. The payload could include transmitters to send data to the Earth during the flight and a spotter charge so that we could see the vehicle actually hit the moon.

Only a few years ago such talk would have sounded fantastic to all but a relative handful of space *aficionados*. Yet even these exploits, present and projected, are but relatively primitive ventures into the vast cosmos which lies beyond our thin envelope of air,

If we can put unmanned satellites into orbit, if we can literally "shoot the moon," then the space frontier becomes limited only by man's imagination.

The obvious next step will be the establishment of a permanent base in space—that is, a manned satellite. This (Continued on page 55)

100,000 MILES

CISLUNAR SPACE

Atmosphere



Well beyond the limits of the atmosphere, the area between Earth and the moon is called cislunar space and covers the approximately 239,000-mile distance to our neighbor in the sky.

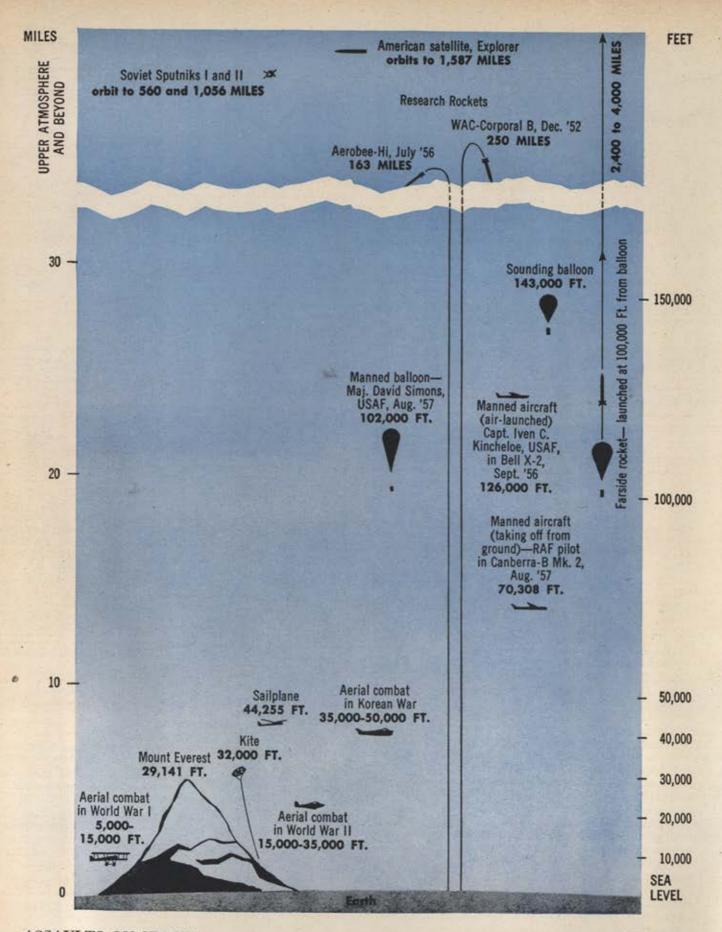
permit enough thrust to pierce the atmospheric envelope. A rocket fired from Earth has to fight its way through the drag of the atmosphere, and has to overcome the very considerable force of gravity. If a rocket is fired straight up, gravity alone will slow it twenty miles an hour every second. Add aerodynamic drag, and final velocity can be cut to around seventy percent. As a result, enormous initial thrust is required.

Like many another technological advance, the rocket art was accelerated by the impetus of military needs. The story of the German work with the V-2 at Peenemünde during World 1,000,000 MILES

TRANSLUNAR SPACE



THIS VAST DISTANCE from the moon and beyond the 1,000,000-mile range is called translunar space. Although, in the vastness of the universe, it marks but the start of even interplanetary travel, its conquest will be the result of a series of giant steps that today stagger the imagination. Scientists say trips to the inner planets of our solar system will require all of man's skills.



ASSAULTS ON SPACE Almost since the invention of the airplane, and even before that, man has been thrusting upward toward and finally into space. As early as World War I, combat-aircraft range reached 15,000 feet, and during World War II, combat planes attained 35,000 feet. In Korea, jets fought as high as 50,000 feet. In 1956, Capt. Iven C. Kincheloe, Jr., attained man's highest powered flight, 126,000 feet, in the Bell X-2. Maj. David G. Simons a year later, in "Man High," ascended in a balloon to 102,000 feet. Now satellites have accomplished orbits in near space.



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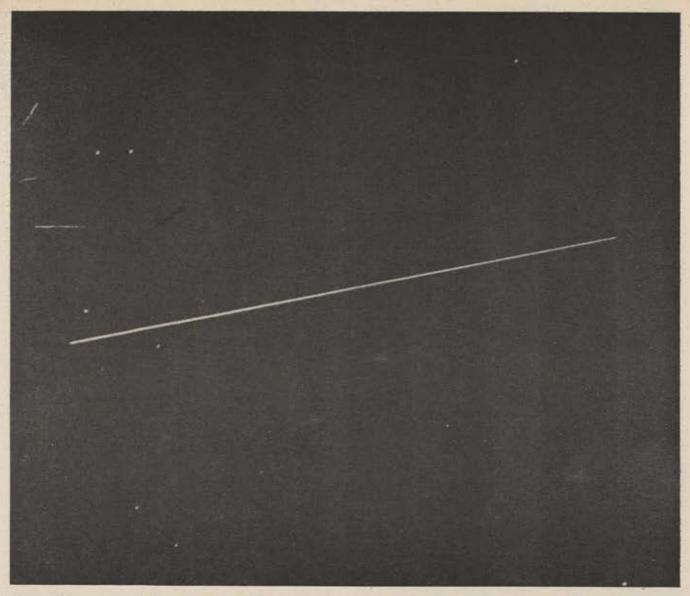
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The satellite seen round the world. Sputnik I, or more scientifically "Alpha 57-1," was photographed from Elmendorf AFB, Alaska, as it crossed the sky soon after the Russians launched the world's first Earth satellite last October 4.

would perform all of the military functions of the unmanned version, with the important addition of human judgment and monitoring.

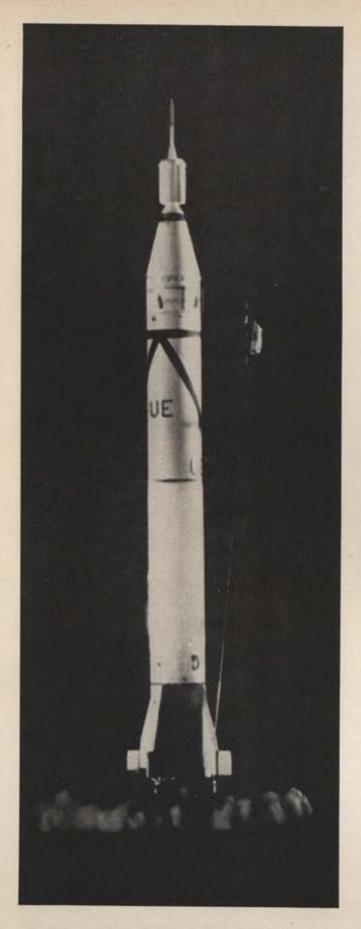
There are several possible ways to establish a permanent and manned satellite—all of them difficult under the present ground rules. One would be to simply fire a vessel containing a man and considerable equipment into orbit. Although this seems the easiest and most direct method, it may not yield the most fruitful results. There would be the terrible necessity to choose a single airman volunteer who alone would have to carry the burden of the launching from Earth and be subjected to the terrific physical and psychological strains of this assignment. And further, once in orbit, his manned station would necessarily be small, which would prove a further complication, pychologically, for the inhabitant of the satellite to cope with.

The more complicated approach to establishing a manned station—by firing the components and a team of specially selected men into orbit and then having them put together the pieces in space—is considered much more logical and productive by many experts.

With this method, a multistage rocket containing the men and the lightweight pieces of the station would be fired into orbit. These parts would provide a basic living quarters for the crew, with more elaborate components to be sent up later. When the final stage of the rocket arrived at its orbital position, the team, clad in spacesuits, would unload the components in space and pull them together to build initial living quarters, filling them with oxygen and supplies. As they worked with the components, the men could maneuver in space by use of small rocket guns. Everything would be moving together at the same speed, and parts could be pushed around easily in space since they would be weightless, as would the men. Once living quarters were hooked together and filled with oxygen and supplies, part of the team would be left in the station and the rest would return to Earth in the last portion of the vehicle that had been launched into orbit and which would have been designed to permit reentry. Later new rockets could be sent with additional parts, supplies, and crews into the same orbit to expand the station.

The assembly-in-orbit method might also be effected—some experts suggest—by first firing the components into orbit and later sending the assembly team up to rendezvous with the parts. This approach might enable initial construction of a larger and more sophisticated station.

Once in its circular orbit, any manned USAF satellite



On January 31, the first American satellite, Explorer, was launched into orbit from the Air Force Missile Test Center, Cape Canaveral, Fla. Fired by a modified US Army Jupiter-C rocket (above), Explorer circles Earth in an orbit that varies in altitude from 219 to 1,587 miles.

launched with today's chemical propellants would have emptied its fuel tanks by the time it reached its position in space. It would be moving around the Earth at about 18,000 mph. Supplying it would be the problem of the successors to today's USAF inflight refueling personnel.

Although fraught with some unearthly dangers, supplying a manned satellite would not be much different from today's refueling in the air; it would be easier in some ways. So long as the refueling "ferry" were in the same orbit as the satellite, it would be traveling at the same speed. Extremely heavy equipment could be moved from supplier to satellite with little effort in zero gravity, and visibility would be unmarred by such factors as atmosphere, bad weather and the like,

The manned USAF satellite, invaluable for observation and reconnaissance, can be the steppingstone to the first true interplanetary flight—the landing and establishment of a permanent base on the moon. Our nearest neighbor is only 239,000 miles away. The trip would take five to seven days.

Some definite ideas have been proposed about the strategic value of lunar bases. Some are convinced that control of the moon can mean control of the Earth, and that this nation's forces should establish themselves on the moon as soon as possible.

In the words of Brig. Gen. Homer A. Boushey, USAF Deputy Director of Research and Development, the moon is an almost perfect example of what a military man means by "high ground." From the moon, excellent reconnaissance is possible, with amazing close-up views of Earth through the airless "atmosphere" of the lunar surface. The moon's high ground could, General Boushey suggests, serve as a launching point toward Earth for retaliatory missiles with only about twenty percent of the thrust needed on Earth. These missiles could-thanks to the lack of resistant atmosphere-be launched from shafts sunk into the moon's surface, perhaps even catapulted, with no internal propellant. Once a missile was launched Earthward, the moon-based crew could track and guide it. The reverse process from Earth is not possible because of atmospheric resistance, weather, and numerous other factors.

With a gravity one-sixth that of Earth's, movement of heavy equipment would be much simpler on the moon, allowing easy construction of military facilities. Another lunar advantage is the concealment possibility afforded by the fact that one side of the moon is never visible from Earth—making it ideal for launching sites. Thus the "reception committee" for enemy missiles and landing parties could be located on the near or "light" side to Earth and retaliatory facilities on the far or "dark" side.

To get from Earth to the moon will get us into true space navigation—or astrogation. It consists of hurling a craft from one body's orbit to another's at a carefully selected time and speed so that the vehicle arrives at a point on the other orbit where the spaceship and the planet are traveling at about the same speed. This enables contact.

After the craft has escaped the Earth and its rockets are shut off, it is in a state of free fall—it is being pulled back to Earth still but at a decreasing rate as its inertia carries it away from the Earth. Thus, to send a ship to the moon, rockets must push it far enough from the Earth, so that its inertial speed takes it from the Earth's gravitational field into that of the moon.

As it approaches the moon's gravitational field, it will begin to speed up again, coasting rapidly into the moon's orbit. And at that point it will be necessary to slow the ship down to avoid crashing headlong onto the surface of the moon. This would be done by reverse jets of rocket power which would slow the ship and brake it as it touches down on the lunar surface. When one goes beyond the moon, to other planets, the problem becomes even more difficult. One reason is that, although the planets of our solar system are generally on a plane, there are slight differences in the planes of their individual orbits, differences of a few degrees. But a degree "up" or "down" in space could mean thousands or millions of miles, depending on distance. Therefore, it would be necessary at intervals to "take a reading" of the ship's spatial position to make sure it would arrive at the correct plane 'as well as the correct position in the destination planet's orbit—to allow it to meet the planet.

This would be accomplished by using the sun and nearest heavenly bodies as reference points. Position would be fixed in all three spatial dimensions as well as in time, the fourth dimension in the Einsteinian conception of the universe. Then with control rockets the necessary corrections in course would be made. In this vacuum of space, the astrogator could always see his reference points with perfect visibility.

Possibly almost all of the course could be planned by computers at the time of launching, but these answers will come as space travel itself comes closer to reality. In space, it is not a matter of fancily turning left or right but rather of adjusting the spacecraft's path to make sure the spaceship is headed toward its destination orbit at the proper speed and on the correct plane.

To conquer the giant distances in space and time from Earth to the edges of our solar system and beyond to the stars, entirely new propulsion systems will have to be developed. Spaceships could never carry the enormous quantities of chemical fuel necessary to build the fantastic speeds needed for trips beyond the solar system.

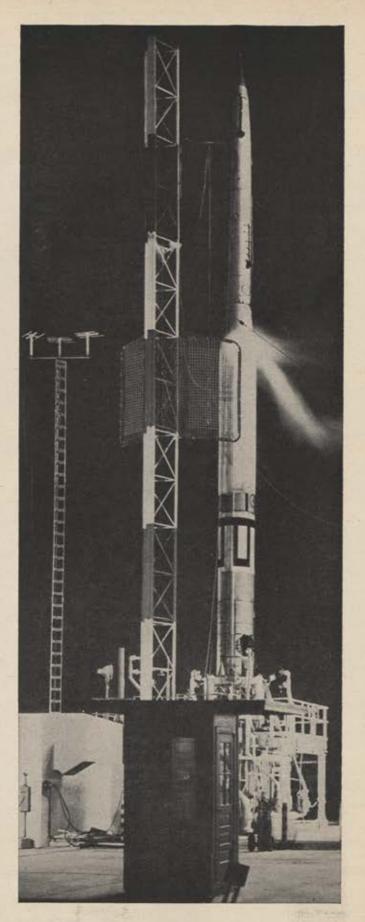
As matters stand now, we could—after building up the necessary 25,000-mph velocity to escape Earth—"coast" to the moon at that speed in five to seven days, or to Mars in around eight months. But beyond these relatively near destinations, greatly increased speed and better control will be necessary, available only through exotic new propulsion methods. Mercury, nearest planet to the sun, may mark the practical limits of chemical fuel in terms of speed and weight.

The first of these new propulsive methods is nuclear, either a nuclear pile using heated fluids, which might suffice to carry Earthmen as far as Jupiter or Saturn; or nuclear fusion, which would have unlimited range across the solar system. The next jump might be to ion propulsion, that is, obtaining thrust through ejection of a stream of ionized particles. This method is under study today, and theoretically might supply enough thrust for unlimited space travel. In fact, many authorities consider it more feasible than a nuclear fusion drive.

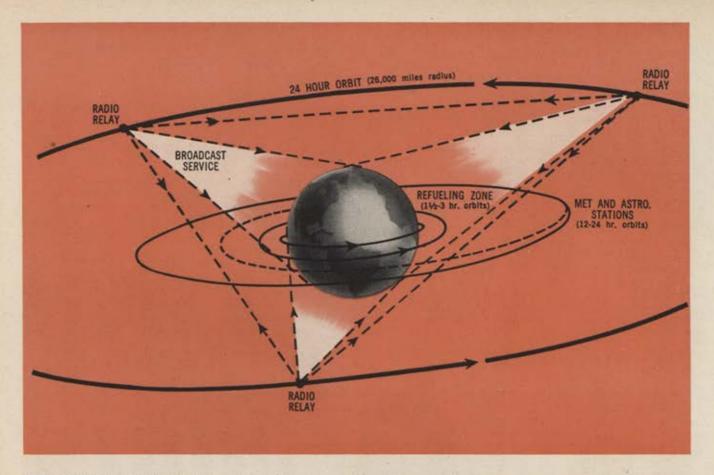
Also being considered is photon propulsion, which would propel spaceships by the actual pressure of light particles, but at a slow initial rate of acceleration. Photon propulsion could enable travel from our own galaxy to others. Time itself to traverse such distance would by then be the only problem. And there may be an answer to that dilemma in the Einsteinian theory that time "shrinks" in a relative way as we approach the speed of light.

Since the invasion of space first by Russian satellites and now our own, there is growing sentiment for some sort of system of international control, or demilitarization. President Eisenhower has made a serious proposal to the world that this be done, and other Administration and congressional leaders have done likewise. One proposal is that the United Nations form a special commission on space.

Without questioning the worthiness, or even the ultimate necessity, of such a move, there are serious questions of sovereignty and international law involved.



Technical difficulties caused the first two attempts to launch an American satellite to end in failure. The launching vehicle was the three-stage Martin Vanguard rocket shown above. The satellite program is one phase of American participation in the International Geophysical Year.



ORBITING SATELLITES could provide enormous boons for scientific observation, refueling of outward-bound spaceships, and worldwide radio and TV reiay. Closest-in satellites would serve as "filling stations" for outbound vehicles, whose launching from orbit would take far less thrust than a start from Earth. Satellites for scientific observation would be in middle orbits, while outermost three satellites, in line of sight of one another, would always stay over the same point on Earth, which would turn on its axis, 26,000 miles away, at exactly their orbital rate.

It can be logically argued that the International Geophysical Year marks the beginning of a new era in international law, holding that "outer space" is not a part of a nation's "airspace." This has been suggested by John Cobb Cooper, Canadian air-law expert and legal adviser to the International Air Transport Association. Cooper points out that neither the US nor the USSR asked permission to put satellites into space when they announced their IGY programs. The fact that no nation has protested the satellites' invasion of space, Cooper says, has already established a precedent for freedom of space. He interprets the present situation as follows:

 That present national boundaries extend upward only to a point where the atmosphere ceases to provide lift for airplanes or balloons.

 That "outer space," which he defines as where there is not enough atmosphere to create drag or otherwise affect flight, is now beyond the sovereignty of any state or nation of the world.

 That the "fringe area" between these two still awaits a definition of sovereignty through some sort of international agreement.

The desirability of a demilitarized space and its implications for a peaceful world is difficult to deny. But while the debate goes on, the United States cannot let space go by default to the Soviet Union.

It is worth pointing out here that although the United States should work hard to prevent a Soviet monopoly on space achievements, deep space itself could not be the site of battle, as man has always known it, between giant fleets or armies of opposing war vehicles. Instead—as a battlefield—space would serve as the "high ground" for reconnaissance and missilry, as envisioned in the earlier suggestions of General Boushey.

As we approach the reality of space travel, the sciencefiction buffs among us will have to leave much of our romance behind. For it would be difficult indeed, if not impossible, for great space fleets to meet in combat, unless they both left from the same place at the same time in the same predetermined paths. This is hardly likely. Otherwise, moments after they had "passed" each other in space, they would be thousands of miles apart, and the weapons, again in the classic use of the word, they ranged at each other would be utterly useless.

This does not, of course, preclude combat in near space between orbiting satellites of opposing nations. It would be possible, indeed quite simple, to demolish or puncture a manned satellite with a missile fired into its orbit. And there could, of course, be combat on the moon, a battle to gain sole control.

Dr. Edward Teller gave a hint of that prospect during his testimony at a recent congressional hearing. He was being asked why man would want to go to the moon. And he answered that it would be interesting to find out what was there.

Asked later what he thought we might find when we did get there, Dr. Teller answered, "Russians!"

The above material represents the combined efforts of the staff of Am Force Magazine and was written by William Leavitt, John F. Loosbrock, Richard M. Skinner, and Claude Witze.

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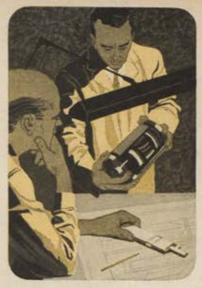


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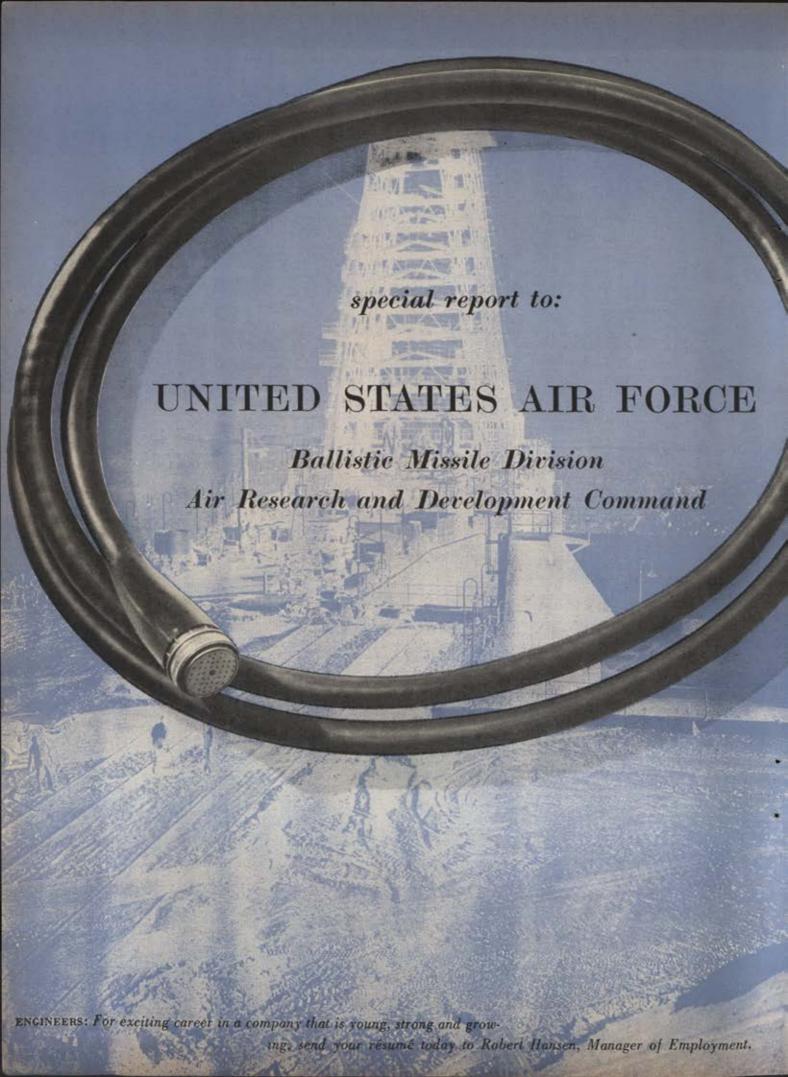
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If you are a graduate engineer with experience in the fields of mechanical or electrical engineering and believe that you have something to offer to this important program—and, if you are not now a member of the armed forces—write the personnel section of AC in Milwaukee.

AC SPARK PLUG ST THE ELECTRONICS
DIVISION OF GENERAL MOTORS





SUBJECT: REFERENCE: PACIFIC AUTOMATION PRODUCTS, INC. Systems Cabling Program

Fall 1955 forecasts by PAPI of benefits to be derived from establishment of sole responsibility for missile site cabling and activation.

ACTION:

The validity of our subject forecasts has been thoroughly tested by our service to USAF and Convair (Astronautics) a Division of General Dynamics Corporation. We have provided the services described below\* for test and launching sites of the ATLAS intercontinental ballistic missile, with the following results:

- 1. All sites are being completed on or ahead of schedule.
- 2.14,000 cables are now in service, with no malfunctions due to cabling.
- 3. Substantial savings are indicated by comparison of actual costs with predictions based upon former techniques and methods.
- 4. Superior design and simplified operational characteristics of completed sites are due to our integrated approach to cabling and activation.

Original estimates of the benefits to be derived from PAPI services have proven to be conservative actual performance warrants extension of PAPI services to other missile projects of USAF.

\*HERE IS THE COMPLETE SYSTEMS SERVICE OF PAPI-THE SERVICE WHICH WE ARE NOW FULLY PREPARED TO OFFER TO ALL MISSILE AND MISSILE SYSTEMS CONTRACTORS



SYSTEMS DESIGN: Test Instrumentation, Launch Control SYSTEMS FABRICATION: Cable Components, Special Hardware and Checkout equipment SYSTEMS INSTALLATION: Instrumentation, Recorders, Transducers Controls, Consoles, Accessories, Inter-Unit Cabling SYSTEMS CHECKOUT: Conformity to Circuit Specifications, Instrumentation operation (by systems), Fire and Launch Control Validation SYSTEMS DOCUMENTATION: Complete Operational Information in Approved Form

Address Inquiries to Arthur P. Jacob, Executive Vice-president

#### PACIFIC AUTOMATION PRODUCTS, INC.

1000 AIRWAY, GLENDALE 1, CALIFORNIA

Phone: CHapman 5-6871 or Cltrus 4-8677

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BIG 13-TON AIR CONDITIONER Vitally necessary cooling for electronic equipment ground checks is available from the MA-3's modern air cycle unit.

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**EXTRA LARGE GAS TURBINE COMPRESSOR** Hot weather is never a problem. This compressor provides

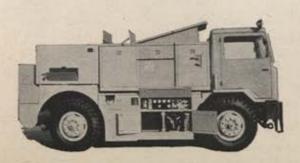
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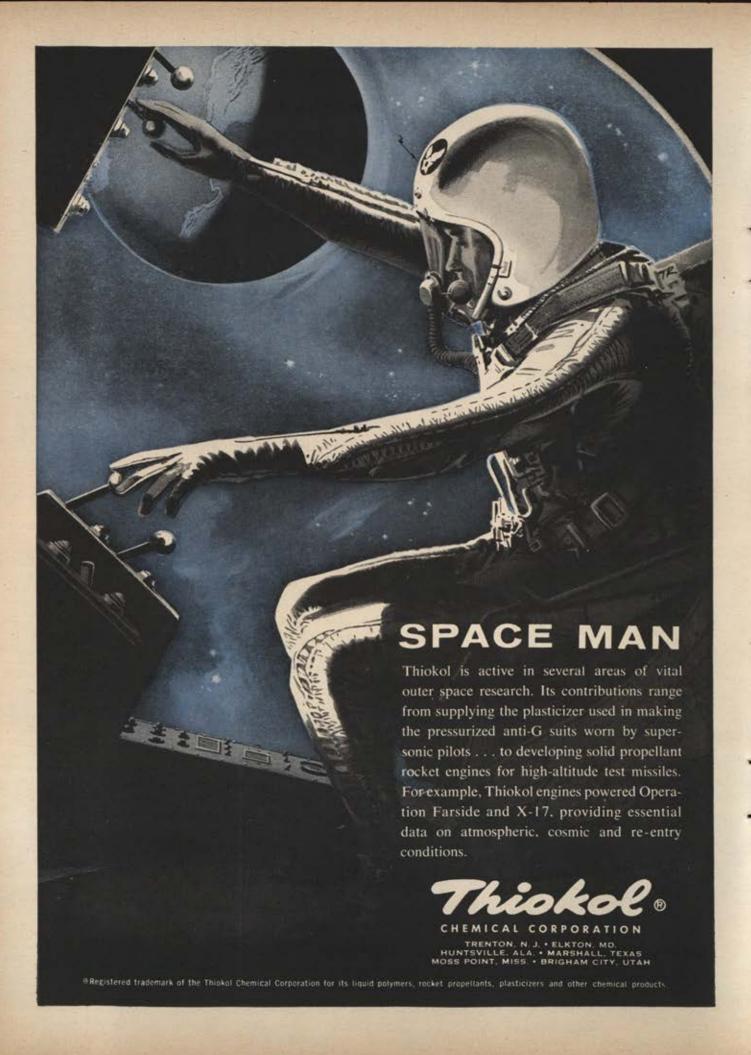
Space Navigation
Space Flight Control
Space Armament
Space Communication
Space Guidance
Space Reconnaissance

For information on Air Arm's Space Systems Engineering Group, write: Air Arm Division, Westinghouse Electric Corporation, P.O. Box 746, Baltimore 3, Maryland, or contact your nearest Air Arm representative.

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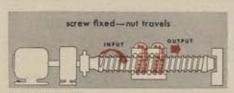
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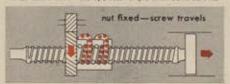
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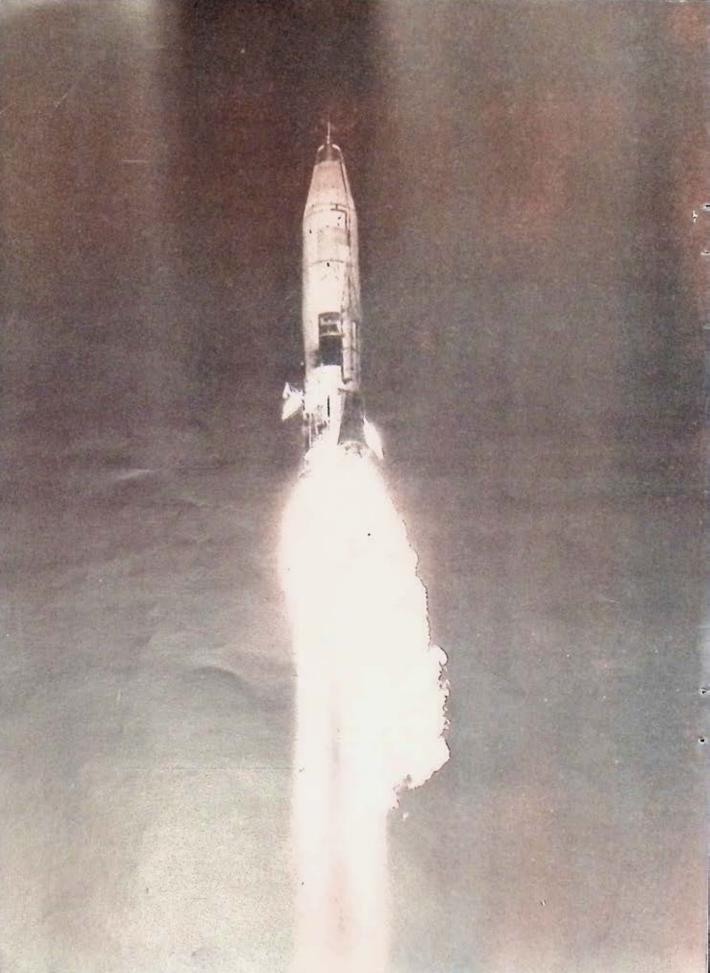
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-WALTER DORNBERGER

#### **Ballistic Missiles**

#### SPRINGBOARD TO SPACE

The quote at the top of this page was written by Dr. Dornberger in his book V-2, referring to the first successful flight of a V-2 missile from the German facility which he commanded at Peenemünde. Implicit in these words is the recognition that the ballistic rocket had unlocked the key to successful exploration of space. Recent events—the Russian Sputniks and the American Explorer—have driven this fact home. Fortunately, in its space endeavors, this nation is in a position to call upon the resources of the mightiest single military project the country has ever known, exceeding in magnitude even the Manhattan Project, which produced the first atomic bomb.

This is the Air Force's ballistic missile program, a logical springboard into space. Ballistic missiles can be considered the first true space weapons, since they are outside the atmosphere for some ninety percent of an intercontinental flight. As an introduction to our discussion of the USAF ballistic missile program we could find no better source than its boss, Maj. Gen. Bernard A. Schriever, who runs the show from his position as Commander of the Ballistic Missile Division of the Air Research and Development Command

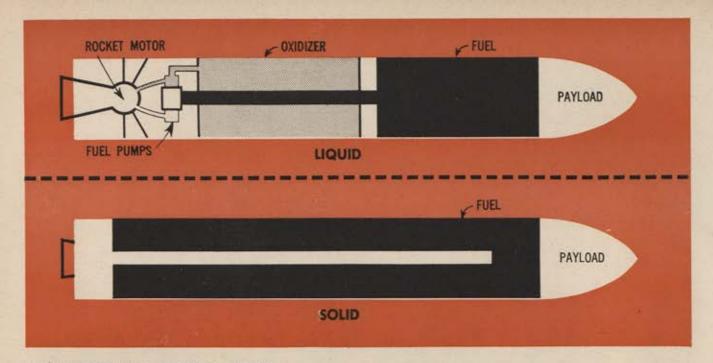
The following excerpt is from an address by General Schriever, made long before the various satellites—Russian and American—had sullied the virgin reaches of outer space. The occasion was an Astronautics Symposium, jointly sponsored by the USAF Office of Scientific Research and Convair at San Diego, Calif., in February of last year. We think it remains the best explanation of the important implications of the USAF ballistic missile program in the US conquest of space and serves as a fitting introduction to our examination of the program in its historical, developmental, and operational context.—The Editors.

The dawn of space-age weaponry is represented by such advances as USAF's Atlas intercontinental ballistic missile, shown dramatically rising from its launching pad at the AF Missile Test Center, at Cape Canaveral, Fla. The more advanced Martin Titan ICBM will back up Atlas.

OW have the ICBM and IRBM programs contributed to the conquest of space? They have contributed in a very concrete sense from the standpoint of hardware that has been developed or is being developed for this program. A tremendous industrial capability is being built up and production know-how is being established in many new areas. These airframe, propulsion, and guidance subsystems development and the data which will become available as ballistic missile test flights are made, will make possible a whole gamut of follow-on projects,

Take, for example, the propulsive unit. The same propulsive unit that boosts a heavy nose-cone warhead to 25,000 ft/sec, could boost a somewhat lighter body to the escape velocity of 35,000 ft/sec or to an orbital path around the Earth. Using the same number of stages, the ratio of thrust to weight would be greater by using a lighter payload, and higher accelerations and velocities could be reached before burnout. Or with our present state of knowledge, it would be relatively easy to add another stage. We have already done that successfully on our reentry test vehicle, the X-17. The same guidance system that enables the warhead of a ballistic missile to reach its target within a permissible accuracy would also be sufficiently accurate to hit a target much smaller than the moon. Or, if we are talking about circular orbits around the Earth, errors in guidance could be easily observed over a period of time and corrected, and the satellite kept on an accurate orbit. And, of course, these same propulsive and guidance components could also be used for surface-to-surface transport vehicles of various sorts to experimentally carry mail or strategic military materiel to critical sites. The same applies to structural advances of the ICBM that have brought us to new heights in the ratio of total weight to structural weight. I would be willing to venture a guess that ninety percent of the unmanned follow-on projects that one could visualize for the future can be undertaken with propulsive guidance, and structural techniques, presently under development in the Air Force ballistic missile program.

It is reasonable to expect that it will not be too difficult



TWO TYPES OF PROPELLANTS Top cutaway shows liquid-propelled rocket's two chambers, one for fuel and the other for an oxidizer to enable the fuel to "burn" in the rocket motor, forming the powerful exhaust thrust. Storing the volatile liquids and the time required to prepare liquid rockets for launching are factors why second-generation ballistic missiles will probably all be solid-repellant (lower), whose oxidizer is contained in the fuel. In solid rocket, fuel burns uniformly out from central core. These rockets can, when operational, be fired on short notice.

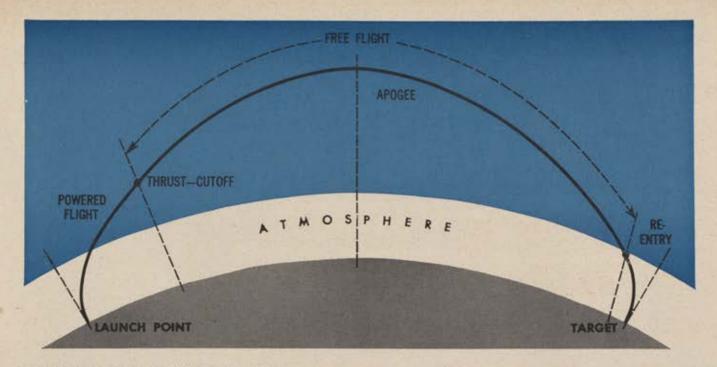
to extend these present developments to surface-to-surface transport of personnel by rocket propulsion, or space travel of personnel at some time in the future. However, before man can be committed to space vehicles, a tremendous amount of human factors research will be necessary. . . . Granted this research, there are other problems as well. A specific example of the kind of advanced development probably necessary for manned spaceflight to distant planets is sustained thrust through space. This will permit us to reach higher velocities and cut down the flight time which would otherwise be impractically long for a human passenger even to the closest planets. Such 'ong sustained thrust, at a small enough magnitude level to be tolerable to a man, requires a type of propulsion technique that is not well suited to takeoff thrust and general ICBM requirements. The successful achievement of the required propulsion system is clearly indicated by today's science, but it has to be developed as a program beyond the current ICBM program.

Space technology, probably for some decades, will not revolve primarily around apparatus for controlled movement of vehicles from one point to another in empty space. Perhaps not only initially but for all time, space technology will include as its most characteristic problem the need for going from the surface of one terrestrial body to another with successful passage through the atmosphere of each. The first big problems, then, are how to bring a substantial mass up to empty space with velocity sufficient to continue interbody space travel, with adequate precision in the velocity vector control, and how to bring it back through an atmosphere without disintegration. In each of these respects, if one for the moment bypasses human cargo ambitions, the ICBM is attaining the necessary capability and, even for manned flight, the ICBM flight-test program will provide experimental data of direct interest.

Granted then that the ICBM program is a major pioneering and foundation step for space technology, what appears to be a logical future program? The answer is not easy. It is very difficult to make a firm prognosis on military need during a twenty-year period for something as new and revolutionary as ballistic missiles, Earth satellites, and space vehicles. We are somewhat in the same position today as were military planners at the close of the first World War when they were trying to anticipate the employment of aircraft in future wars. Consequently, my prognoses will go from those which are reasonably firm to those which might be considered visionary. Fortunately, there is a considerable overlap between the advances in the state of the art which are required for the firm needs and those now considered visionary.

First, we should consider those changes in the operational and technical characteristics of our long-range ballistic missiles to make them superior, reliable weapons. Almost any military planner would agree that if we can increase the range, increase the payload, reduce the gross weight, increase the accuracy, reduce the cost, or simplify the operational procedures, we will have made a worth-while contribution. Now, in order to achieve any or all of these objectives, it will be necessary to advance the state of the propulsion art, the structures art, or the guidance art, or perhaps all three. When these advances are made, they will be applicable also to the more visionary projects. The basic science underlying these engineering arts has been well surveyed in the past two years. It tells us that considerable advance is possible on all fronts.

A word is necessary on the relationship between military need and scientific feasibility in space technology. In the long haul our safety as a nation may depend upon our achieving "space superiority." Several decades from now the important battles may not be sea battles or air battles, but space battles, and we should be spending a certain fraction of our national resources to ensure that we do not lag in obtaining space supremacy. Besides the direct military importance of space, our prestige as world leaders might well dictate that we undertake lunar expeditions and even interplanetary flight when the appropriate technological advances have been made and the time is ripe. Thus, it is indeed fortunate that the technology advances required



BALLISTIC MISSILE TRAJECTORY Missile is powered only during the initial portion of its flight, from the launch point to the thrust-cutoff point. Guidance and control must be accomplished during this phase because after thrust ceases, the missile's motion cannot be influenced. Launched vertically, ICBM or IRBM takes a programmed turn toward the target, then rises further in free flight outside the atmosphere to a high point, the apogee, and finally falls in an arc back to the atmosphere reentry point. From there it continues to its predetermined target.

in support of military objectives can, in large part, directly support these more speculative space ventures. . . .

Where does all this lead? My thought is that the evolution of space vehicles will be a gradual step-by-step process, with the first step beyond ballistic missiles being the unmanned, artificial Earth satellite and then perhaps unmanned exploratory flights to the moon or Mars. These first flights would no doubt be research vehicles to gather scientific data and to accumulate information on space environmental conditions for future design use. The information gathered from these flights will supplement the information gathered from ballistic missile test flights. Many of the things that we can learn from satellites will lead not only to a better understanding of conditions to be encountered in space, but will lead to a better understanding of our own planet. Weather reconnaissance can be accomplished in a more effective manner. This will lead to a better understanding of the movements of polar air masses and the courses of jet streams and will permit improved long-range weather forecasts and improved aircraft and missile operations. A better understanding of the Earth's magnetic field will lead to better radio communications, more reliable navigation instruments, and perhaps new ideas for propulsive devices. Refined data on the Earth's gravitational effects will lead to improved guidance. Much remains to be known about cosmic rays. Unmanned satellites will be the means for obtaining this information.

I have described some of the benefits to be derived from our early ventures into space, and the contributions the ICBM program is making in this direction.

Payload capability of a future satellite could be in the order of hundreds or even a thousand pounds. Such payload would permit more instrumentation and many varied types of space experiments.

Vehicles with additional complications could be made to have the ability to return intact from space. However, without fundamental extension the environment during spaceflight would not be suitable for a human passenger. Therefore, manned spaceflight cannot be attempted with such apparatus, but many of the associated physiological questions can be answered by experiments with animals. We may, in fact, be able to fill nearly all the gaps in our knowledge which are now holding back the design of manned spacecraft,

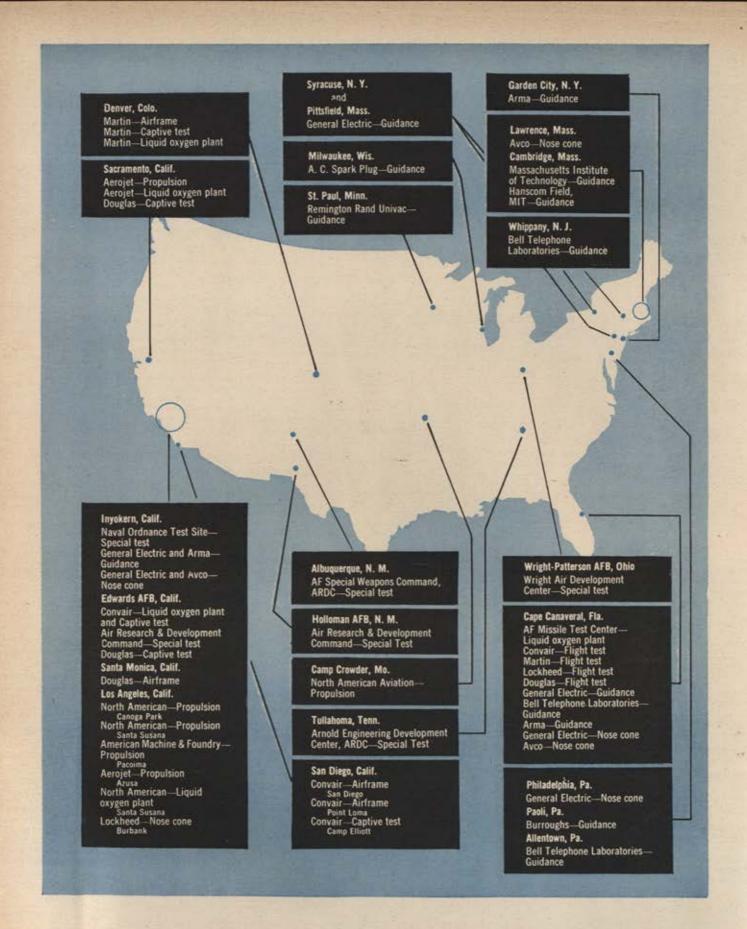
Given vehicles with these capabilities, still another avenue for a scientific achievement is immediately opened—for with additional rocket thrust a lunar research vehicle is highly possible. In view of the small additional cost of such an experiment, it seems certain that in the not too distant future it will be tried.

The ICBM program, through the technology it is fostering, the facilities that have been established, the industrial teams being developed, and the vehicles themselves, is providing the key to the further development of spaceflight. Many fascinating new horizons are sure to open within the next decade as a direct result.

There is ample precedent in history for the utilization of military capability to explore unknown regions. Over the centuries the great explorations of this planet have been conducted by military men, usually with no precise idea of what the ultimate value of their discoveries might be—either in a military or an economic sense. But the exploring was done, and the value usually followed.

Columbus discovered America as an admiral in the service of Spain, Magellan and Sir Francis Drake were military men. The Lewis and Clark expedition, which opened the West, was a military enterprise. Likewise Admiral Byrd's exploits at both Poles.

So it is quite fitting that the Air Force should be interested in furthering the knowledge of its new medium, just as did the Army and Navy in theirs in the past. It has been estimated that during the next five to seven years, American exploration in space must be based on ICBM technology. Hence this section will be devoted to the ICBM program, with charts beginning on page 76, a chronology of ICBM milestones on page 80, and a text beginning on page 84.—The Editors



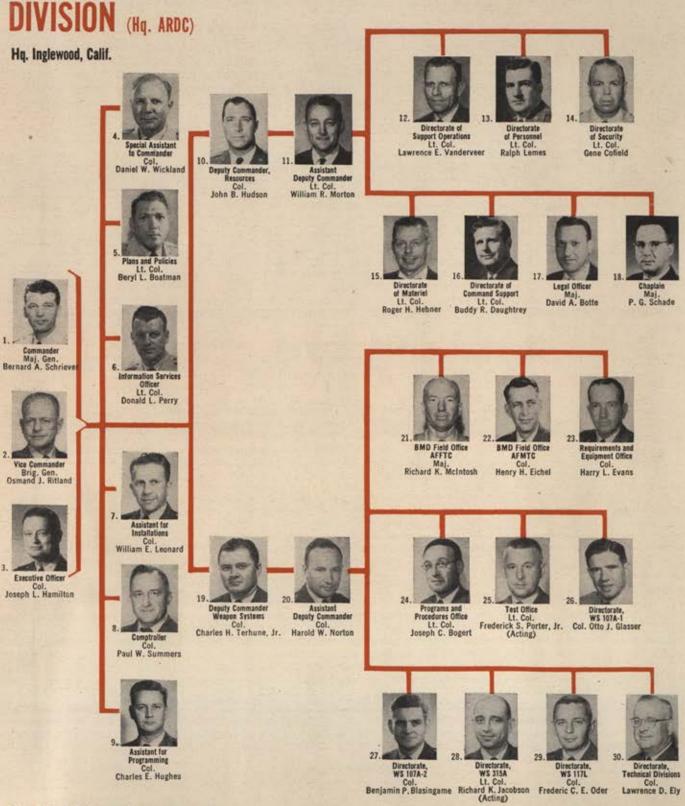
USAF'S MISSILE DEVELOPMENT COMPLEX across the nation is illustrated in this chart, which shows the widespread military-industrial cooperating network that is working on all phases of missilry. Ranging from California in the west to Massachusetts in the east, Minnesota in the north to New Mexico in the southwest, and covering all the complicated area of missile development from guidance to fuels, the skills of thousands of specialists are today preparing the way for the array of space-age weapons that will assure increased US deterrent power in the new age. A basic feature of USAF's approach is concurrent weapon development and production and training of personnel.

#### AIR FORCE House BALLISTIC **National Security Council MISSILE** Defense Secretary, Neil H. McElroy **ORGANIZATION** Office. Secretary of Defense **Ballistic Missiles Committee** Air Force Secretary, James H. Douglas **Ballistic Missiles Committee** Secretary of the Air Force Hq. USAF USAF Chief of Staff, Gen. Thomas D. White AMC ARDC Commander, CINCSAC Commander, Hq. ARDC Gen. Thomas S. Power Lt. Gen. Samuel E. Anderson Edwin W. Rawlings AFBMD Assistant for Asst. CINCSAC (SAC-Mike) Commander, **Ballistic Missiles** Brig. Gen. Maj. Gen. Col. William R. Large, Jr. Ben I. Funk Bernard A. Schriever Air Force Ballistic SAC-Mike Staff Ballistic Missiles Office (AMC) Missiles Division (Hq. ARDC) at AFBMD at AFBMD Space Technology Laboratories (Ramo-Wooldridge) First Missile **Associate Contractors** Division (SAC) and Subcontractors

Atlas

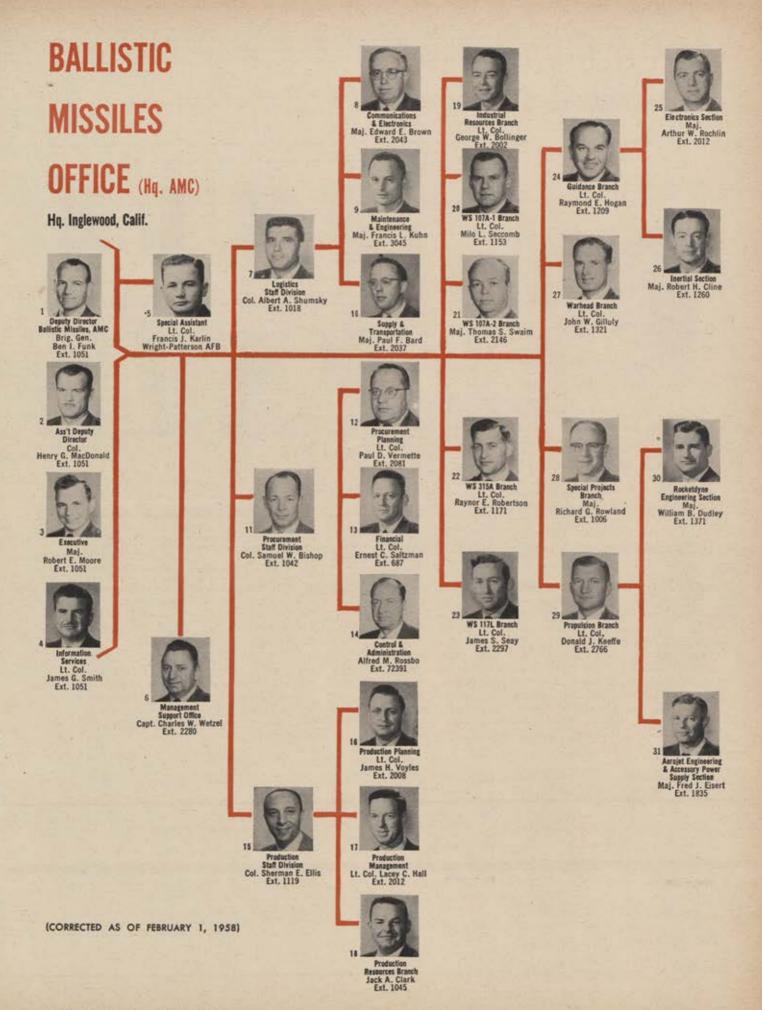
Cooke AFB, Calif.

### AIR FORCE **BALLISTIC MISSILE**



#### **AIR FORCE Magazine Photocharts**

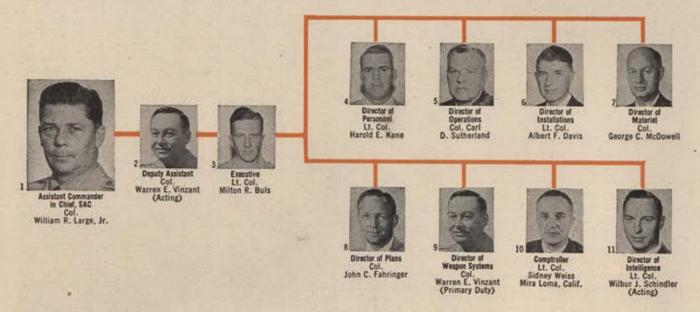
(CORRECTED AS OF FEBRUARY 1, 1958)



#### STRATEGIC AIR COMMAND

Office of the Assistant Commander in Chief (SAC-Mike)

Hq. Inglewood, Calif.



(CORRECTED AS OF FEBRUARY 1, 1958)

#### USAF BALLISTIC MISSILE MILESTONES

1946 Twenty-eight missile projects undertaken in AAF after completion of assessment of German V-1s and V-2s.

Industrial development programs inaugurated for development of large-thrust liquid-rocket motors, notably North American work departing from V-2 designs and producing larger, higher-thrust and lighter-weight motors, to be used later in Redstone, Navaho, Atlas, Thor, and Jupiter missiles.

In April, Project MX-774 started to study rocket missile capabilities with objective of ICBM development. Contract was with Consolidated Vultee, later to become Convair. Project later became Atlas. Same year AAF began studies of Earth satellite feasibility.

MX-774 project canceled in June, due to problems including reentry temperatures, plus view that glide-type missiles showed better range and payload potential and seemed closer to achievement. Convair kept project alive with own funds.

Same month, long-range surface-to-surface missiles were given fourth priority in R&D. Priorities were (1) bomber-launched air-to-surface and air-to-air missile; (2) surface-to-surface missiles, 150-nautical-mile range; (3) surface-to-air missiles and fighter-launched air-to-air missiles; (4) long-range surface-to-surface missiles.

In September, AF study reported feasibility of Earth satellites.

AF continued Earth satellite program studies.

During September-December, three MX-774
test vehicles were fired, verifying design, gim-

baling of engines, guidance, airframe, lightweight rocket structures.

1949-50 AF reports confirmed feasibility of a longrange rocket weapon system.

In January 1950, Air Research and Development Command was established and given responsibility for all AF R&D.

1951 In January, Project MX-1593 inaugurated to study comparative merits of rockets vs. glide missiles.

Same month, ARDC ordered to study long-range (5,500-nautical-mile) rocket development, comparing glide and rocket missiles. Study contract issued to Convair, which had performed work on MX-774.

In September, ballistic approach chosen for concentration in Convair contract. Code name Atlas assigned.

Atlas component development program started.
Military characteristics included 5,500-nauticalmile range, special weapon (thermonuclear)

payload.

In December, Atlas project reviewed by AF Scientific Advisory Board ad hoc committee under Dr. C. B. Millikan. Board recommended AF retain in its program a project leading to ICBM carrying an atomic warhead, with attention to guidance, propulsion, and reentry problems.

1953 In June, AF Strategic Missiles Evaluation Committee, known as "Teapot Committee," was formed with Dr. John von Neumann as chairman.

Next month, Convair submitted proposed "crash" program on Atlas at the request of Trevor Gardner, then Spe-

cial Assistant to the Secretary of the Air Force for R&D. In October, Dr. von Neumann and AF Scientific Advisory Board reported to AF Chief of Staff that thermonuclear weapons of small size and weight, ideal for missile warheads, were feasible.

In November, review of AF missile program by newly formed Strategic Missiles Evaluation Committee began.

1954 Gardner recommended to AF Chief of Staff that AF ballistic missiles program be restudied by scientific-technical group with view to centrali-

zation of authority for an accelerated program.

In February, Strategic Missiles Evaluation Committee recommended new and comprehensive weapon system study, covering all alternate approaches, with a new ICBM development-management agency to perform study and manage ICBM program, and called for high priority and necessary funds.

In March, General Twining submitted memo to AF Secretary Talbott approving ICBM acceleration and steps

recommended by SMEC.

Same month, AF study reemphasized feasibility and utility of Earth satellite for reconnaissance, intelligence, and weather observation.

During March-May, tests at Pacific Proving Ground, Operation Castle, confirmed feasibility of development of small, lightweight, high-yield thermonuclear weapons.

In April, AF Office of Assistant Chief of Staff for Guided

Missiles was established at Hq. USAF.

In July, Western Development Division of ARDC was established, with basic mission of (1) management of development program for WS 107A (Atlas) including ground support; (2) development of operations, logistical, and personnel concepts; (3) authority over all aspects of above. Then Brig. Gen. B. A. Schriever named to head WDD.

In August-December, WDD established missile study program, decided to use multiple procurement sources and

selective industrial competitions.

General Schriever assumed WDD command in August

at Inglewood, Calif.

Same month, AMC issued letter establishing Special Aircraft Project Office to perform procurement and contracting functions for Atlas project.

In December, basic configuration on the reoriented Atlas was decided. Missile size decreased. Number of engines

decreased.

1955 Intercontinental Ballistic Missile Scientific Advisory Committee to the AF Secretary chartered in January.

Same month, Ramo-Wooldridge Corp. contract arranged for ICBM technical direction and systems engineering.

In March, general operational requirements for satellite outlined.

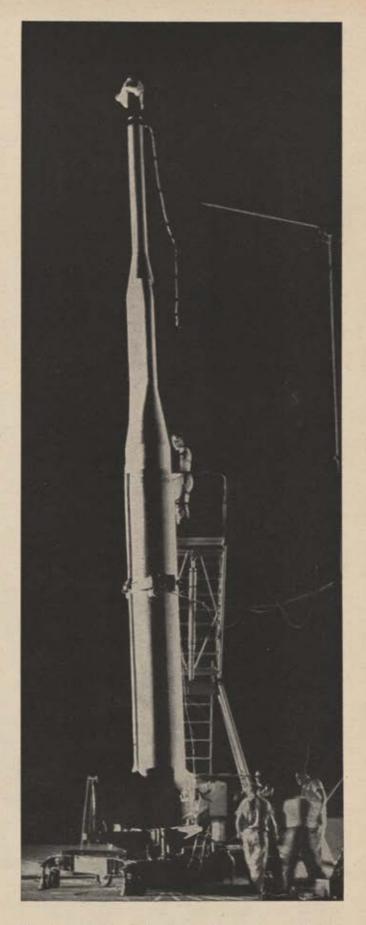
In May, WDD authorized to proceed with development of alternate ICBM airframe configuration (Titan project). Same month, WDD assigned to evaluate industry proposals for a tactical ballistic missile of 1,000 nautical-mile-range. (IRBM).

In September, President Eisenhower and the National Security Council stated that Atlas had highest R&D priority, and this would be subject to change only by Presidential action. Secretary of Defense directed to proceed with WS 107A program with maximum urgency.

In October, Gen. Thomas S. Power announced management responsibility for advanced reconnaissance satellite

would be transferred to WDD.

In November, memo from Secretary of Defense assigned highest priority to ICBM, added IRBM #1 (Thor) to AF ballistic missile program-programs to be carried out at maximum rate permitted by technology.



The vital problem of reentry, a key to successful missilry, has been intensively studied with launchings of the Lockheed X-17, shown here. Standing four-stories high, the X-17 is a three-stage missile, powered by solid propellants, and is used by the Air Force to test nose cones.

WDD mission amended in December to include responsibility for earliest possible ICBM operational capability and development of IRBM with second priority.

Basic agreements reached in January with Army and Navy concerning coordination of IRBMs #1 and #2. AF agreed to allocate its North American-developed engines to power IRBM #2 (Jupiter). Later that month, WDD directed to give coequal priority to ICBM and IRBM programs, with higher headquarters to be notified in case of interference between programs.

In March, AMC established post of Deputy Director for Ballistic Missiles; Brig. Gen. Ben I. Funk assigned. AMC activities directed to provide maximum support to ICBM,

IRBM programs.

In May, SAC and ARDC agreed on responsibilities for IRBMs. WDD would be responsible for developing, manning, training, equipping operational units in accordance with SAC-ARDC planning. SAC would be responsible for overseas deployment of WDD-trained wings for further training to combat readiness. As units showed combat readiness, SAC would assume command jurisdiction.

In November, General Funk was given additional assignment as weapon systems manager for ballistic missiles, responsible for AMC functions in ballistic missile programs.

Same month, Secretary of Defense directed that a part of Camp Cooke, Calif., be transferred from Army to AF.

In January, first Thor launch attempt unsuccessful when contaminated fuel caused a valve failure. Attempt was made only thirteen months after Thor contract was signed with Douglas Aircraft. In April, second Thor erroneously destroyed due to malfunction of range safety instrumentation.

function of range safety instrumentation.

Next month, third Thor launch attempt unsuccessful

because of failure of pressure valve.

In June, first Atlas' engine failed at 10,000 feet; missile destroyed.

In August, National Security Council approved Department of Defense recommendation to reorient ballistic missile programs. Recommendations included: (1) combination of Thor-Jupiter programs and joint AF-Army-OSD committee to evaluate both programs; (2) suspension or cancellation of Thor and Jupiter production to test requirements; (3) curtailment of contractor overtime except for flight test; (4) continuation of Atlas at highest priority; (5) reduction of Titan priority; (6) recognition of slight delay in IRBM programs as result of above.

Same month, fourth Thor exploded after ninety-six seconds of flight due to fire resulting in loss of autopilot.

In September, fifth Thor launched successfully. Engine operated to automatic shutdown. Range 1,300 nautical miles.

A few days later, second Atlas' engine shut down prematurely; missile destroyed.

In October, sixth Thor's engine thrust deteriorated after liftoff; missile destroyed on stand.

October 11, seventh Thor launched successfully in excess of 1,000 nautical miles to impact point.

On October 24, eighth Thor launched successfully to an impact point in excess of 2,300 nautical miles.

In November, BMD directed to establish production capability in the Thor program. A few days later, weapon system management responsibility for ballistic missile defense assigned to Ballistic Missile Division.

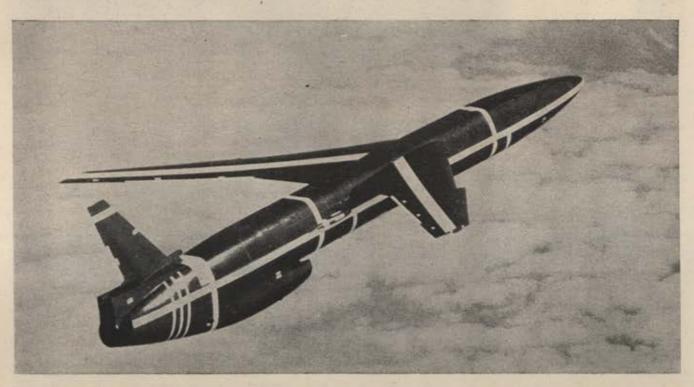
On November 27, AF directed to proceed with operational deployment of both Thor and Jupiter. First units to

be ready for deployment by December 1958.

At end of November, AF Chief of Staff Gen. Thomas D. White announced actions designed to provide earlier operational capability in missiles. These included transfer of 1st Missile Division at Cooke AFB from ARDC to SAC, transfer of IOC (Initial Operational Capability) for the ICBM and IRBM to SAC, and assignment of ballistic missile support to the San Bernardino AF Depot.

On December 7, ninth Thor successfully launched with burning time as planned, although momentary interruption of inverter power caused loss of guidance reference points. Missile proceeded on higher angle trajectory than planned.

On December 17, third Atlas successfully launched.



The power-packed Northrop Snark, America's first guided missile with 5,000-mile range. A subsonic airbreather, and all-weather performer, the Snark can seek out an enemy target anywhere in the world and blast it with a nuclear warhead.



This is a spectacular night view of the USAF Thor in its containing gantry at the Missile Test Center, Patrick AFB, Fla. An indication of the huge size of the Air Force intermediate-range missile and the surrounding works may be obtained by looking closely at the left of the photograph, where a large fuel truck stands with "4" on its side. This giant IRBM, being manufactured by Douglas, is a leading member of the Air Force family of missiles that form its developing armory for the space age. Maj. Gen. Bernard A. Schriever, Commander, USAF Ballistic Missile Division, has said that the Thor—adjusted—could be used to launch an inspection vehicle around the moon.



Thor IRBM test at Cape Canaveral, Fla. USAF approach in missile development is the concurrent and carefully planned creation of production capabilities as the weapons are developed, with personnel being trained to handle missiles, leading to earlier operational units.

# The USAF BALLISTIC MISSILE PROGRAM

N any discussion, a definition of terms is always desirable. And there has been much confusion about guided missiles in general and ballistic missiles in particular. Our own glossary, on page 157, defines a ballistic missile thus:

"Unmanned vehicle, the major portion of whose flight path to its target is a ballistic trajectory which is determined by gravitational and drag forces alone."

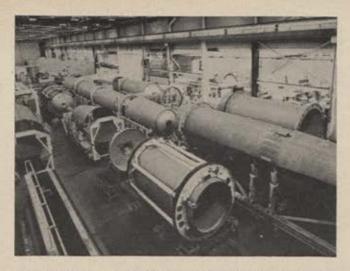
A ballistic missile has often been compared with a rock thrown by hand or a cannon shell shot through the air. In a broad sense, these analogies are correct, for a ballistic missile is primarily a method of throwing a bomb 5,000 or more miles.

But there is another analogy that describes the ballistic missile in terms more familiar to persons whose background has been in aviation. The Air Force has a technique called toss-bombing, in which a pilot goes into a high-speed climb pointed in the proper direction. At just the right moment he releases a bomb. Inertia carries the bomb upward and forward until it reaches the apogee, or highest point of its trajectory. Then it curves toward Earth, gathering speed as it is accelerated by gravity. You could say that the bomb is "guided" up to the point where it is released from the airplane, From then on the laws of physics take over.

Essentially the same principles are employed with the ballistic missile. It has an airframe and an engine like the airplane, which carries the pilot up to bombing altitude. It has a guidance and control system which take the place of the human pilot and his fire-control system. The nose cone with its warhead is the bomb.

Thus a ballistic missile is not catapulted through the air like a stone from a sling. Rather it is propelled by its rocket engine to hundreds of miles above the Earth, where the thin atmosphere offers almost no resistance. The initial launch is vertical, to get the missile through the thickest part of the atmosphere in a hurry. Then the missile is tipped over by the guidance system so that it is in the proper trajectory when the engine burns out. At the proper time and place the nose cone is released, continues its climb to the apogee, and descends on its trajectory, like the tossed bomb, at a rapidly increasing velocity.

Since the major portion of the ballistic missile's flight is outside the atmosphere—in space—there are important differences between it and the toss-bombing airplane, however. The missile uses a rocket engine (not requiring air for



View of Thor production line at Douglas' Santa Monica, Calif., plant. This is the airframe assembly station. The Thor, product of industry-military cooperative development, will contribute to deterrent strength at projected launch sites to be built in NATO countries.

oxidizing fuel), and its guidance system works by making changes in the direction of the rocket thrust, since there is no air for airfoil controls to work against.

Another problem not encountered by the toss-bomber is that of reentry. When the missile nose cone with its warhead reenters the atmosphere, friction occurs. This generates heat, like the Boy Scout rubbing his sticks together. But at the tremendous speeds at which an ICBM nose cone travels the heat is enormous, estimated at 14,000 degrees Fahrenheit. This is the temperature of the air flowing over the nose cone. The nose-cone material itself must be kept much cooler or it would burn up like a meteorite. The use of various heat-transfer methods to accomplish this has been, of course, one of the great achievements of the ballistic missile program, and the details have not been made public.

How did the Air Force get into the ballistic missile business in the first place? Its interest dates back to World War II and the first reports that the Germans had successfully fired a ballistic missile—the V-2. The Germans produced about 6,000 V-2s in 1944 and 1945 and launched more than 3,600 of them against the Allies.

The V-2 had a range of from 200 to 300 miles. It was highly inaccurate, and its TNT warhead weighed only a ton. It was highly inefficient as a strategic weapon compared to its cost in skilled technical manpower and critical materials. Yet it was effective to a degree that Gen. Dwight D. Eisenhower commented on it in his book, Crusade in Europe, as follows:

"It seemed likely that if the German had succeeded in perfecting and using these new weapons six months earlier than he did, our invasion of Europe would have proved exceedingly difficult, perhaps impossible. I feel sure that if he had succeeded in using these weapons over a six-month period . . . OVERLORD (the main cross-channel assault) might well have been written off."

Following defeat of Germany, technical intelligence teams of the then Army Air Corps examined with keen interest captured test and operational data, as well as hardware. In principle, a liquid-fueled ballistic missile appeared technically sound. But it would take much work to make it practical, effective, and reliable even though the advent of the atomic bomb had reduced the need for the accuracy required to make TNT effective.

At that time, the development of air-breathing missiles, using well-proven methods of propulsion and guidance,

appeared to be a better bet for the short haul. Yet the Air Force mission of strategic deterrence would be enhanced immeasurably if the range of the ballistic missile could be stretched to an intercontinental capability with acceptable accuracy. This would mean a missile at least ten times as accurate and with ten times the range of the V-2. Neither appeared possible without considerable advances in the state of the art.

Therefore, in 1946 the Air Force gave Convair, then Consolidated-Vultee, a systems study contract called Project MX-774, pointed toward development of an intercontinental ballistic missile. This was the forerunner of Atlas, now one of the three ballistic missiles in the Air Force program. MX-774 was a victim of a slim Air Force budget the following year. Even so, it yielded much useful information about powerplant, stabilization, and guidance problems.

Convair was interested enough in the project to keep it alive with company money. In 1951 the Air Force came through with a second contract, the beginning of the Atlas program. But the relatively modest yield of the atomic bomb made accuracy requirements unacceptably high. And the weight and bulk of the first crude hydrogen bombs called for fantastic amounts of power to achieve intercontinental range.

The program might well have died had it not been for the so-called thermonuclear breakthrough of 1952. This made it possible to package a hydrogen bomb in a bundle small enough to fit into a missile nose cone. Thus, both the stringent accuracy requirement and the extremely high propulsion requirement were simultaneously eliminated. The thermonuclear breakthrough brought the development of an intercontinental ballistic missile well within the range of the existing state of the art, which would make the resulting weapon both militarily desirable and technically feasible.

The famous Teapot Committee of eleven top scientists, headed by the late Dr. John von Neumann, made a thorough study of the problem and came up with the recommendation that the ICBM program be speeded up to take advantage of the new warhead. The program got top Air Force priority, and Air Research and Development Command set up a separate division in Los Angeles, with full authority and responsibility for the entire AF ballistic missile program. It was called the Western Development Division of ARDC, now the Ballistic Missile Division. Its first commander, Brig. Gen. (now major general) Bernard A. Schriever, still heads BMD.

From the beginning the Ballistic Missile Division di-

Although it is huge, the Thor is capable of being airlifted to launching sites. Here a Thor is shown being loaded onto an Air Force C-124 Globemaster for air-shipment to the Air Force Missile Test Center for testing at the missile capital of the world—Cape Canaveral, Fla.





Except for the urban surroundings, this represents a typical launching layout for USAF Thor. This aerial view, showing the missile and ground facilities, was photographed during a Douglas display of missile systems, including support equipment, for visiting military officers.

rected its efforts toward obtaining an operational capability in the shortest period of time. This led to a concept of management new in weapon system development—the concept of concurrency.

The old concept, safe, sure, and terribly slow, consisted of a lengthy period of research and development, followed by component testing, the building of as few as one prototype, exhaustive testing of the prototype, and finally, if everything worked, a production order. Tooling alone often took enough time for the gradual phasing in of personnel, bases, support equipment, and logistic backup.

But the heat was on the nation's ballistic missile program, heat generated in Moscow. Russian developments in the field did not permit such a leisurely approach. So it was decided to proceed with the development of the weapon system and to develop concurrently a production base in industry and an operational capability to include training, logistics, and operations. In short, the concurrency concept was a calculated risk, designed to telescope the lead-time between beginning work on a weapon system and seeing it ready for operational use.

Thus while test missiles are being fired from Cape Canaveral, their successors are rolling off fully-tooled production lines. Facilities for training and operations are simultaneously under way at Cooke Air Force Base, Calif., and at Cheyenne, Wyo., with another base in the process of selection. Meanwhile, the first training manuals are off the presses, and the first group of missile instructors is being trained, not only in the technique and handling of the missiles but in the human factors involved as well.

How this "all together and all at once" approach pays off is perhaps most dramatically illustrated by the first flight of the Thor intermediate-range ballistic missile. Only eleven months after BMD got the go-ahead from the Department of Defense, the first Thor missile came off the production line. And the Air Force is still shooting for December 1958 as the date for the first Thor operational squadron to be ready for shipment overseas. If it makes this target, it will have been exactly three years since the Thor project began.

These spectacular achievements in shortening lead-time could not have been possible without the closest cooperation between the Air Force and the aviation industry. With a broad industry base, working intimately with the AF in research, development, testing, and production, problems are being solved as they arise, not discovered with dismay months later.

Seventeen prime contractors, supported by a network of more than 200 major subcontractors, are engaged in the ballistic missile program. In addition, there are more than 200,000 suppliers of parts scattered across the country. Key contractors alone employ more than 70,000 people. (A directory of prime and major subcontractors begins on page 135.) Add to these the substantial number of military personnel, university scientists, and personnel of cooperating government agencies involved in the program and the total exceeds that of the gigantic effort that developed the atomic bomb.

Perhaps no element of the ballistic missile program has been subject to more misinformation, misunderstanding, and misapprehension than the missile test program. Newsmen on watch at the beaches near Cape Canaveral keep running box scores, as if in the press box at Yankee Stadium. If a missile goes out of sight, it's a home run. Anything less is a strike-out or, in the most charitable



A US Army Jupiter intermediate-range ballistic missile rising from its launching pad at a recent test. The Jupiter flew its prescribed course and landed in the "preselected target area." Jupiter IRBM, developed by the Army Ballistic Missile Agency, is produced by Chrysler.

interpretation, a foul ball. As a result, a great many Americans judge a given missile solely by the number of "suc-

cessful" flights it has made.

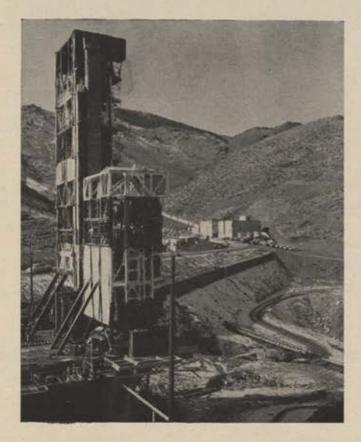
This is wrong, and here's why. Take an airplane. Before it goes into service it undergoes literally hundreds of test flights. But a ballistic missile is a one-shot operation and to duplicate hundreds of test flights you would have to shoot hundreds of missiles. Further, a test aircraft is flown by an experienced engineering test pilot. When he lands he is able to report exactly how the plane handled, what worked, what didn't, and to make concrete suggestions for improvement. As a substitute in the testing of our growing family of missiles, we have developed telemetering devices which report electronically on what was right or wrong with a missile firing. But even the most sophisticated of such devices can never be a complete substitute for human reporting, if only for the reason that there just aren't enough communications channels available to keep an eye on each and every component.

As a result, the ballistic missile program developed a test philosophy of its own. Briefly, this is how that philos-

ophy works:

• No dead-end testing: This is an outgrowth of the concurrency concept and means that no component is tested except in the configuration in which it will appear in the production version of the missile. For example, the very first flight test vehicle of a given system usually consists of only the airframe, the autopilot, and the propulsion system. But these are put together just as they will be in the complete missile so that other components—guidance, auxiliary power, nose cone, etc.—can be added in future tests without compromising the information gained initially.

• Ground test whenever possible: Obviously this is for



Here are two captive test stands at Martin's Denver Division, where work is progressing on Titan, ICBM backup to the USAF's Atlas. In center background is the control building, or blockhouse, from which instrumentation circuitry is carried through tunnels to the two test stands.

USAF Atlas intercontinental ballistic missile rises into the Florida sky at Cape Canaveral during a series of recent firings. The Atlas is under development for the Air Force by the Convair Division of the General Dynamics Corp. and has been tested successfully several times.



reasons of economy. Flight testing is expensive and actually does not yield the same kind or amount of information that a ground test system can provide.

• Test early and often: This means that each part is tested before it goes into a component, each component is tested before it becomes part of a subsystem, and each subsystem is tested before it goes into the missile for captive and later flight tests. The farther down the test totem pole an item is, the more times it is tested. This is both efficient and economical, since it results in the expensive flight tests being numerically only a small part of the entire test program.

A logical question at this point is, after all this testing, why do missiles burn up on the pad, blow up in flight, or

wander off course and have to be destroyed?

One answer is the complexity of the bird itself. Each missile contains thousands of parts, hundreds of tubes, relays, valves, etc. The entire system is supposed to be



This sixty-foot-high web-like structure is a USAF automatic tracking telemetry antenna, used to track ballistic missiles. Designated TLM-18, this is one of five which work together to follow missiles as they fly their prescribed courses. The antenna (note man at base) towers higher than a seven-story building at its Melbourne, Fla., location. The others are being set up at Cape Canaveral and at downrange stations in Antigua, in the British West Indies; Fernando de Noronha, off the eastern coast of Brazil; and on Ascension Island, in the South Atlantic Ocean.

fully automatic from the time of firing and, in most cases, the components function "in line," that is, the failure of one means the failure of the system. A failure of a single relay, a single blown tube, a short circuit, a badly soldered wire, a bit of dirt in a line, may ruin a firing. It is something like the old-fashioned kind of Christmas tree lights, where one bulb burning out would cause the whole set to go out.

The other factor, of course, goes back to the fact that there is no human being aboard to note when something goes wrong and, in many cases, to make the necessary corrective adjustment. Once a ballistic missile is fired, there isn't a lot the crew can do about it except blow it up should it veer off course or go awry for various other reasons.

This explains why not every shoot is a successful one, despite exhaustive testing ahead of time. It also explains why such exhaustive testing, from tiny part to finished missile, is an absolute necessity. Reliability becomes a crucial factor in the development, in the production, and in the operation of a ballistic missile weapon system.

From the beginning of the ballistic program it was apparent that a conventional approach to the logistics problem would be far too cumbersome, either to support the development phase or, and even more important, to provide operational ballistic missile units with logistic support that would make possible the kind of quick reaction time

needed to respond effectively to an enemy attack.

Logistics is defined in the official Air Force dictionary
as "that part of the military activity that provides for the
buildup and transport of a military force by providing for
supplies, equipment, transportation, maintenance, construction and operation of facilities, movement and evacu-

ation of personnel, and other like services, so as to render the military force efficient and effective in both combat

and noncombat operations."

A quick and dirty abbreviation of this formal definition might be "to have the right thing at the right place at the right time in the right quantity." While the Air Force, through its logistics agency, the Air Materiel Command, is currently engaged in a long-range program designed to do just that with a minimum of wasted time, money, and effort, the ballistic missiles program just couldn't wait for the whole Air Force logistics setup to be overhauled. So, in effect, a little AMC was set up within the Ballistic Missile Division (see Photochart, page 78). It is called the Ballistic Missiles Office (see Photochart, page 79). Its commander, Brig. Gen. Ben I. Funk, works directly with General Schriever at BMD headquarters in Inglewood, Calif., but his shop is a separate organizational element of Headquarters AMC and is directly responsible to General Rawlings for the logistics support of the entire AF ballistic missile program.

The establishment of BMO has had many collateral benefits for the Air Force. It has furnished a test bed for the kind of logistic practices which AMC hopes to have in effect, Air-Force-wide, within the next ten years.

Here's how it works, in brief, In the beginning, at least, operational ballistic missile squadrons will be on or near existing Air Force bases. The host base will take care of so-called "housekeeping" items—food, clothing, gasoline, brooms, mops—anything not directly connected with the firing of the missile. All hardware involved in the weapon system itself and needed to keep the squadron in constant readiness is provided directly to the squadron by the weapon system manager, General Funk. Red tape is kept to a minimum. There are no stock-record accounts at base level; the books are kept centrally, by BMO. There are no requisitions to be forwarded to depots in the time-honored tradition. The accent is on urgency, supply of operational items will be automatic, on the basis of periodic reports (see chart, page 91).

Maintenance work will be done at squadron level as much as possible, with mobile maintenance teams moving from base to base to tackle the harder nuts. Any item not repairable on the spot will be shipped either to an AMA

depot or direct to the contractor.

In the beginning, those items not now stock in AMA depots will be furnished by the contractor, but this responsibility will shift to AMC whenever the AMA depot system can handle it more effectively.

Air transport will be used to the maximum, both in the United States and overseas even though budgetary restrictions make it highly unlikely that there will be enough of the right kind of airlift to meet the ballistic missile logistic

requirement.

Probably the most important single key to the kind of streamlined logistic system envisaged is the use of electronic data-processing equipment. A pilot EDPC (Electronic Data-Processing Center) is in existence at the San Bernardino, Calif., Air Materiel Area. San Bernardino AMA currently supports the Ballistic Missiles Office. All logistics information—from the field, from BMO, from the contractors, etc.—will funnel through this center, which is linked through the latest in communications systems with all elements.

The necessity for this kind of logistics operation has existed in the Air Force for years. Until the ballistic missile



Frequently in the news these days is Cape Canaveral, Fla., scene of the Air Force Missile Test Center, shown here in an over-all aerial view. Missiles are launched from the pads along upper right side of the base, and sent out along the 5,000-mile, over-water, ballistic missile test range.

program came along, it was on an "it would be nice if" sort of basis. But to make ballistic missiles effective operationally there was no alternative, And the host of components made it mandatory to cut pipeline time and stockpiles to a minimum. On this basis alone the system should pay for itself. A recent study indicated that the old system of requisitions and stockpiles could eventually add up to as much as \$16 billion in spares alone. Under the new system this money can be invested in operational readiness where the true payoff lies.

We have taken a bird's eye look at the development program for ballistic missiles. Now let's look at the birds themselves, the missiles which are the end item of this

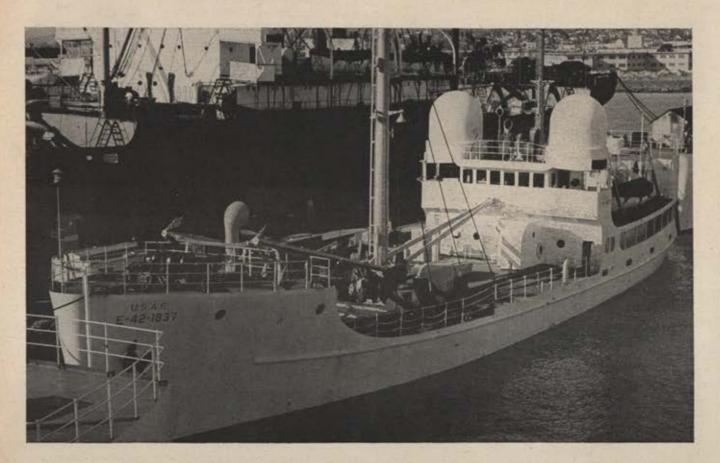
massive effort.

At present the Air Force program includes three ballistic missiles. One is an intermediate-range ballistic missile (IRBM)—the Thor. Two are intercontinental ballistic missiles (ICBM)—the Atlas and the Titan, Here is how they line up:

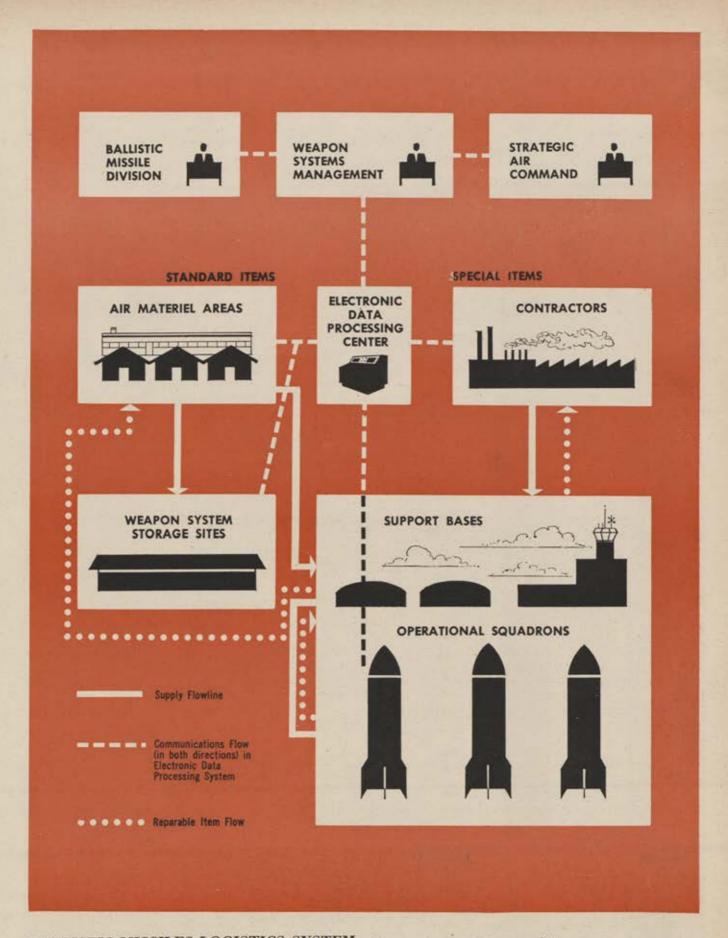
• Atlas: The first missile in the program, designed for a range of 5,500 nautical miles. Its official designation is Weapon System 107A-1. Available information, including estimates made from published photographs, indicate that it is about seventy-five feet long and ten feet in diameter. Convair Division of General Dynamics is the prime contractor for the airframe, called SM-65 (the SM stands for "strategic missile"). Convair is also responsible for systems integration, which means it puts everything together—airframe, engine, guidance system, nose cone, etc. The Rocketdyne Division of North American Aviation is the contractor for the propulsion system. This consists of three liquid-propellant engines—two boosters generating about 150,000 pounds of thrust apiece and a single sus-

tainer engine of about 60,000 pounds. The sustainer is so called because it burns throughout the entire time the missile is in powered flight as opposed to the boosters, which burn out earlier. Takeoff weight of the Atlas is estimated to be something over 200,000 pounds. The guidance system is built by the Heavy Military Electronic Equipment Dept. of the General Electric Co. with the computer portion of the system by the Burroughs Corp. Massachusetts Institute of Technology is also a contractor in guidance system research. The nose-cone contractor is General Electric's Missile and Ordnance Systems Dept. The auxiliary power system is by American Machine and Foundry. Atlas is currently in the test-firing stage, and several have been fired successfully from the AF Missile Test Center.

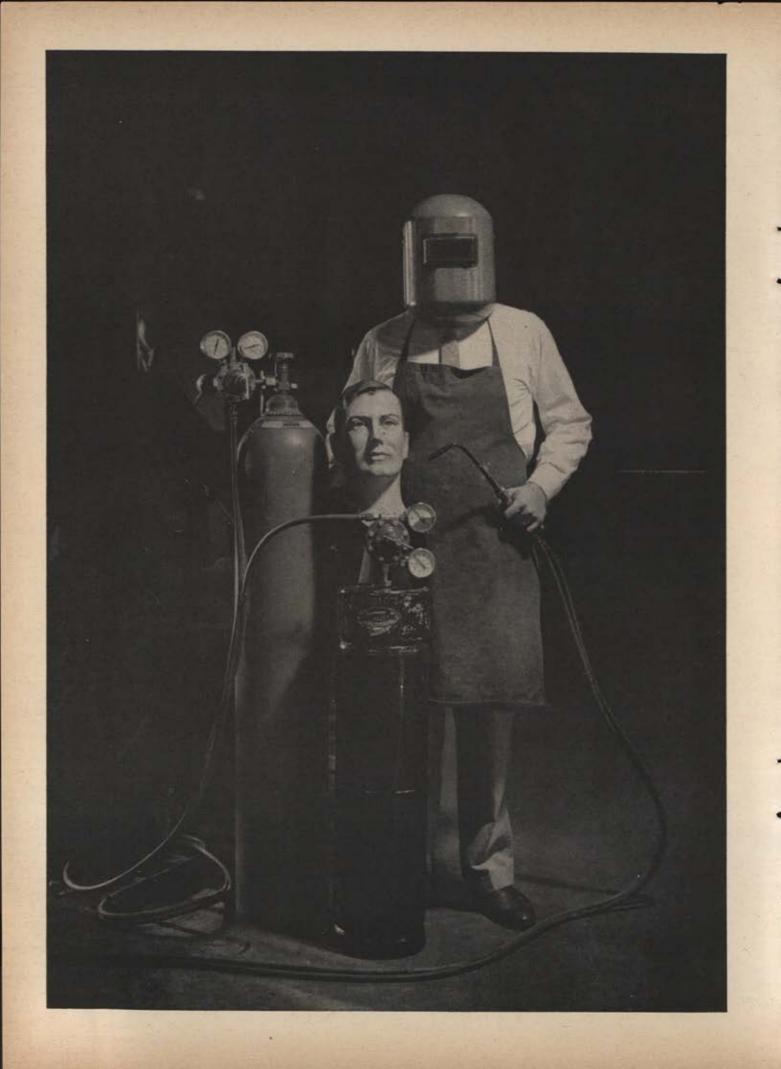
 Titan: Called a more sophisticated missile than Atlas. presumably because its two-stage design calls for the power for the second stage to be started when the first-stage power cuts off. Its designed range is the same as for Atlas -5.500 nautical miles. Its weapon system designation is WS 107A-2. The airframe is designated SM-68 and is being built by the Martin Co. in a new plant at Denver, Colo. It is longer than Atlas, an estimated height of ninety feet, but its diameter of about ten feet is approximately the same. First-stage propulsion system generates about 300,000 pounds of thrust; that of the second stage about 60,000 pounds. Both use liquid propellants. Propulsion system contractor is Aerojet-General, a part of the General Tire and Rubber Co. Titan's launching weight is about 200,000 pounds. The guidance system is handled by three contractors. American Bosch Arma makes the inertial portion of the guidance system, the Remington Rand Univac Div. of the Sperry Rand Corp. makes the computer, and (Continued on page 93)



A ship of the USAF's "navy," sporting huge twin radomes at midships. This is one of the half-dozen, 178-foot-long, thirty-foot-wide "Ocean Range Vessels" of the Air Force, used to gather data on test-firings of missiles from Cape Canaveral, Fla. Pan American World Airways—USAF contractor for missile test range operations—is responsible for the maintenance of the ships. The Radio Corporation of America handles the telemetry equipment on the small fleet. The ships are invaluable in tracking the ballistic missiles as they course over the 5,000-mile over-water range.



BALLISTIC MISSILES LOGISTICS SYSTEM will cut red-tape and keep need for records to a minimum. Squadrons will be supplied automatically, based on periodic reports, with priority items sent by airlift. Under the proposed system, missile units will be linked with the weapon system manager through an electronic data-processing center, as well as by two-way communications that will also encompass the various storage sites and contractors. The operational squadrons will not be required to submit the traditional formal requisitions for supplies.



#### Is it possible to build a MAN?

"Theoretically, yes," said the scientist. "Or a reasonably remarkable imitation—a kind of mechanical analogue. Call it a habit machine, a mechanism operating according to the laws of the conditioned reflex."

You mean that you could actually build a mechanical mind? One that would exhibit emotions —such as love, fear, anger, loyalty?

"We're doing something like that now in advanced missile development," the scientist replied. "In a limited, highly specialized way, of course."

"Take the 'pilot' that is being developed for the big long-range missile. He has a wonderful memory, and can solve many complex navigational problems in a flash. He loves perfection, and actually becomes highly excited when he gets off course. He's a tough-skinned character, impervious to the cold at several hundred miles altitude and the incredible heat at re-entry. And his loyalty is heroic. His life is a single mission, the mission his whole life... and maybe ours, too. He's a pretty important fellow."

What about the complete man-made Man? What would that entail?

"A mechanism the size of the capitol in Washington, and the best scientific resources in the world. But it could be done. You see, it's only a question of how physical matter is organized. As a great biophysicist explained, 'If material is organized in a certain way, it will walk like a man. If it is organized in another way, it will fly like a missile.'"

Still, wouldn't there be something missing in the complete man-made Man – something very important?

"Yes," said the scientist. "A soul."



the third contractor is the Western Electric Co. Avon has the contract for Titan's nose cone.

· Thor: A single-stage missile with a designed range of 1,500 miles. Thor is designated Weapon System 315A. It is an estimated sixty-five feet in length and more than eight feet in diameter. Launching weight is under 100,000 pounds. The airframe, SM-75, is built by the Douglas Aircraft Co. North American Rocketdyne makes the engine, estimated as generating 150,000 pounds of thrust. The inertial guidance system is being built by the AC Spark Plug Div. of the General Motors Corp. The nose cone, like that of Atlas, is by General Electric. Thor is currently in assembly-line production, and the first operational squadron is scheduled to be deployed overseas before the end of the year.

On all three AF ballistic missiles the Space Technology Laboratory of the Ramo-Wooldridge Corp. is a prime contractor for systems engineering and technical direction.

The concept of concurrency, the "all together and all at once" philosophy which has characterized the AF ballistic missile program from the beginning extends into the operational side, as well as development and production. In fact, quite early in the game the bold decision was made to get missiles into operational units while they were still under development. This Initial Operational Capability (IOC) was at first made the responsibility of the developing command, ARDC. But as time went on it appeared that, since Strategic Air Command was to be the ultimate user of the new weapons, it would pay to get SAC into the operational act as soon as possible. So, on January 1 of this year the 1st Missile Division, at Cooke Air Force Base, Calif. was transferred to SAC. Its commander is Maj. Gen. David Wade, whose outfit is responsible for the IOC phase for both ICBMs and IRBMs.

Cooke has been described as twentysix miles of beach, with a few mountains thrown in for good measure. Its selection as the site for the first operational ballistic missile unit was not by chance because it combined many desirable features. Among these were the facts that it was already owned by the Defense Department and that it had some buildings, a road network, utilities, a rail spur, and would not take as long to get in shape as starting from scratch somewhere else. Weather permits construction and training the year round. And the vast Pacific Ocean, stretching to the West, makes a pretty fair firing range. Cooke will be both an operational and a training base.

(Continued on page 95)





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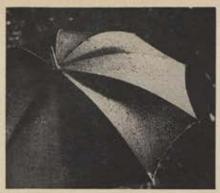
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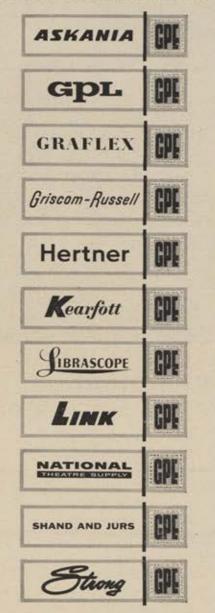
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Address inquiries to: General Precision Equipment Corporation 92 GOLD STREET, NEW YORK 38, N. Y. To ensure a continuing close relationship with the development program, a little SAC headquarters was set up at Inglewood, Calif., to work with Generals Schriever and Funk. It is called "SAC-Mike (see Photochart, page 80), the "Mike" presumably being a phonetic alphabet abbreviation for missile. Its job is to keep the developing agency advised of SAC's latest operational requirements and to relay new technical information back to SAC.

Basic to the integration of ballistic missiles, or any missiles, into SAC's operational inventory is the "mixed force" concept. SAC is firm in its belief that the unmanned weapon cannot take over entirely the SAC mission, that there are certain targets and missions suitable for it but others which are manifestly not. This is why it intends to replace the B-47 with the Convair B-58 Hustler and the B-52 with the hypersonic WS 110A chemical bomber. It is also why SAC sees a role for the Northrop Snark, the non-ballistic, air-breathing missile with an intercontinental range, which has already flown several 5,000-mile tests.

On the credit side of the ballistic missile ledger is its tremendous speed, with the accompanying factor of short warning time, posing tough defense problems for the enemy. Its range is an attractive element for SAC commanders, as is its quick reaction time.

On the debit side are several other factors. A ballistic missile cannot be diverted from one target to another while in flight. Indeed, it cannot be recalled once it has been launched. It has no human reason with which to deal with novel situations. And it cannot return to tell a commander whether or not it hit the target.

So until missiles become considerably more sophisticated than they are at present, SAC sees them as a valuable major adjunct to its manned bomber force, as a means to allow the manned force to accomplish its mission with as few losses as possible. Missile launchings would probably precede manned bombers in order to cause destruction and confusion in the enemy's defenses and would be used on targets where less than pinpoint accuracy would not affect successful accomplishment of the mission.

The phasing-in of missiles will be greatly enhanced by the support structure of SAC which is already in existence. Indeed it can be said that no other military organization in the world has the worldwide system of logistics, communications, and intelligence that are indispensable corollaries to the weapon systems.

The Thor, the Atlas, and the Titan must be considered as only the first steps toward even more sophisticated weapon systems. Now, high-energy exotic fuels can extend the range and/or load-carrying ability of the ballistic missile. Reliability will improve. Guidance systems will become more discriminating. Solid fuels will begin to overcome their present limitations of erratic combustion and a tendency to deteriorate in storage.

Two developments in particular appear to hold much promise for the future. One, which is hardly more than a gleam in a designer's eye at the moment but which seems to be technically feasible, is some method of diverting a ballistic missile from its trajectory. Such a device would be an effective countermeasure against projected defense systems that are predicated on the fact that now ballistic missiles, once launched, must follow a mathematically predictable path.

The second development under study is an air-launched ballistic missile which, in many ways, gets us back to the old toss-bombing analogy with which we started this discussion. With a bomber aircraft serving as a launching platform, the missile would begin its flight well above the thickest part of the atmosphere, and much less power would be required than for the same range-payload combination in an Earth-launched missile.

In closing this discussion of the US ballistic missile program a word of caution would appear to be in order.

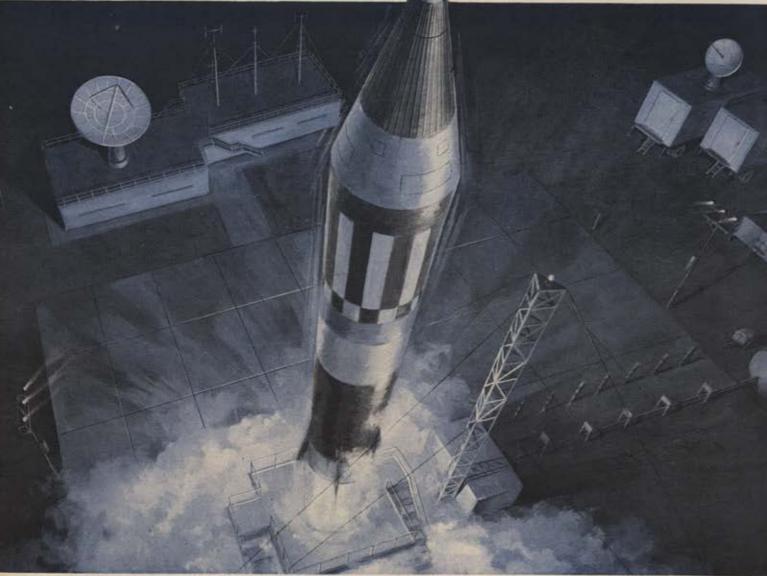
While the *development* program has met all its schedules and has not suffered from a shortage of money, once the program got into high gear, the *production* schedules of finished weapon systems are far short of an all-out effort. The country has the capacity for producing far more ballistic missiles than is contemplated.

Meanwhile, the Soviet competition is not standing still. The integration of operational ballistic missiles into the Strategic Air Command will enhance our deterrent power. But an operational capability in ballistic missiles on the part of the Soviet Union could well cancel out any such advantage. And there is every reason to believe that it is approaching such a capability at least as fast as we,

This is all the more reason to look to our over-all force—in being and to come—and to maintain the kind of deterrent posture that cannot be upset by Soviet achievements in any one field. It means a continued improving force in manned bombers, in defense against Soviet air attack, in ballistic and other missiles and, above all, bold measures to ensure that all of the first steps into space are not taken by Russians.

-John F. Loosbrock

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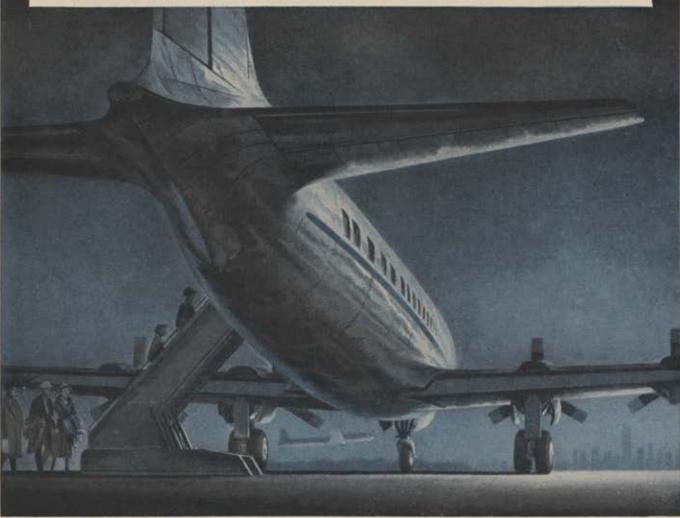
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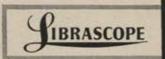
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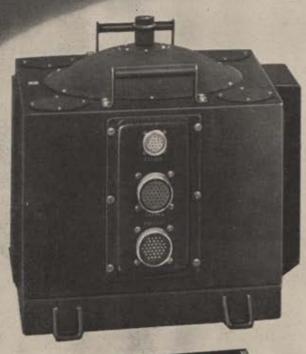
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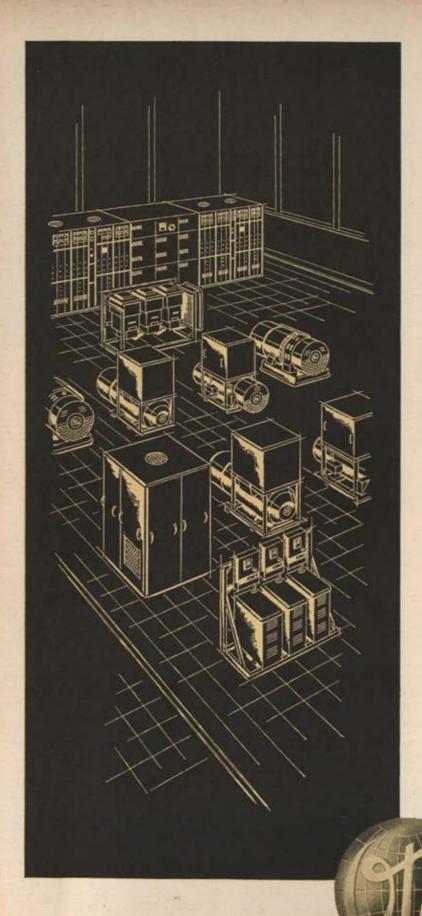
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#### Rascal Joins SAC

The nation's first air-to-surface missile, the Bell GAM-63 Rascal, is now on operational status with the Strategic Air Command of the U. S. Air Force.

This rocket-powered guided missile can extend the penetration ability of SAC crews since it is launched and accurately directed on its mission while the bomber which carries it remains many miles away from the target area.

Bell Aircraft designed, developed and now produces the Rascal "Crewsaver" for the Air Force under a complete weapon systems responsibility. This responsibility includes the airframe, guidance, liquid fuel rocket power plant, ground support and launching equipment and techniques and training.



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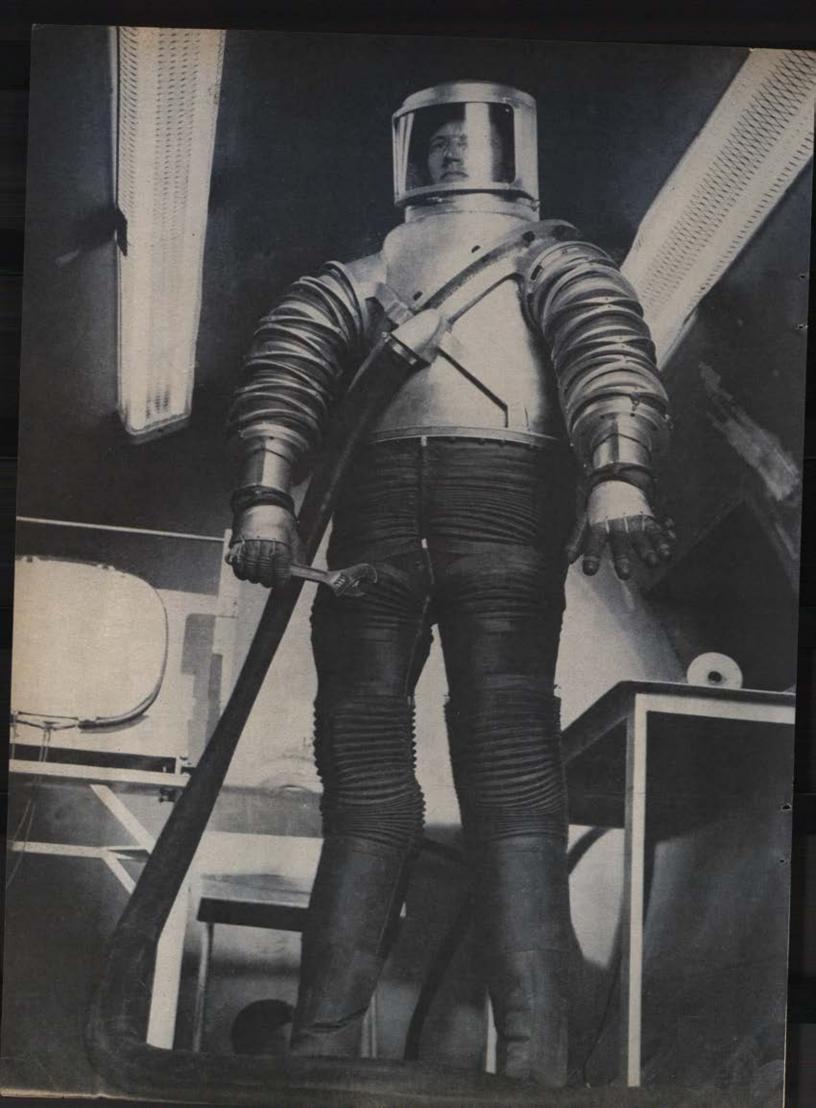
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Star-captains glow."

Where the fleet of stars is anchored and the young

-JAMES ELROY FLECKER

## MAN IN SPACE

AN'S mind has already invaded space-in the form of electronically reporting satellites. But the true conquest of space will come only when man himself flies through the void in vehicles of his own design.

For hundreds of centuries man has hurled things through the air-rocks, arrows, bullets, and rockets. Yet he did not conquer the air until December 17, 1903, when

the Wright brothers flew at Kitty Hawk.

Neither will he truly conquer space until he penetrates it in manned vehicles, whose paths he can plan, and in which he can return at a time and to a place of his own

But can fragile man, with his limited physiological and psychological tolerances, survive travel in this totally new environment? He must endure the strain of violent launch acceleration that for several minutes will multiply his weight nearly ten times-a few moments later he will enter the strange world of weightlessness. He must continue to breathe in a cabin surrounded by a void that could boil his blood in seconds. He must be able to work in a heavily automated environment for extended periods with the company of only a few shipmates under equal stresses. How will he sleep and eat and perform necessary bodily functions? And what effect will the mysterious cosmic rays that streak through the void have on his body?

The answer to the central question of man's ability to endure spaceflight-the key to the true conquest of space -is a qualified yes. Man can survive this supreme adventure, say "space doctors" like Dr. Hubertus Strughold, Adviser to the USAF's Department of Space Medicine at

Randolph AFB, Tex., but only with numerous special adjustments and safeguards designed to approximate his earthly environment or help him adjust to some conditions he has never before encountered. Dr. Strughold is probably the world's leading authority

on the medical aspects of spaceflight. With USAF colleagues like Dr. Siegfried J. Gerathewohl, who specializes on the crucial weightlessness problem at Randolph, ARDC's Col. John P. Stapp, and Maj. David G. Simons at Holloman AFB, N.M., specializing on acceleration stress and super-high-altitude ballooning, he symbolizes the Air Force's pioneering studies of man in space.

Dr. Strughold points out that we have already experienced, within the atmosphere, conditions of "space equivalence." Yet, he adds, our forays, thus far, are in what he calls the "amphibian stage."

That experience in "near space" has included balloon ascensions and rocket-plane flights. Men have passed the 50,000-foot level, where free air cannot contribute to respiration, and the 63,000-foot level where human blood would boil outside a protected environment exactly as it would on the airless surface of the moon.

These two altitudes mark "physiological conditions of space equivalence," Dr. Strughold says. At 80,000 feet, he adds, air compression for cockpits is impractical, since the machinery required is too heavy, generates too much heat, and the sparse air contains poisonous ozone, injurious to equipment and man alike. It is at that altitude, says Dr. Strughold, that the sealed cabin, with a built-in atmosphere, becomes mandatory. Man, from that point on, must take his environment with him as he ventures out into

The sealed cabin will be his container in spaceflight, and currently provides the best clues to his reactions to

extended travel in space.

And at this writing, man's first "flight into space" right here on Earth was nearing a successful conclusion at the USAF Department of Space Medicine under Dr.

Spacesuit prelude. USAFOSR-Litton research has produced the suit at left for experimentation in the Litton Inhabited High Vacuum Laboratory. Wearer of the suit is provided with breathable atmosphere and warmth and can work with tools in the simulated ninety-five-mile-high altitude.







Brutal crushing G force of rapid acceleration on the human form has been dramatically tested at Hollman AFB, N. M., in ultra-high-speed rides by ARDC's Col. John Stapp on the Northrop-built rocket sled. Colonel Stapp's rides have earned him nickname of "fastest man on earth." In first picture Colonel Stapp has just been strapped into the sled seat and his face is relaxed. Second photo shows sharp facial contortion, increased G pressures, as sled builds up speed. Third picture shows Stapp at the end of his ride. At speeds of 600-plus mph, he has survived more than forty Gs.

Strughold's guidance, as a result of a seven-day sojourn in a furnace-shaped "space cabin" by a twenty-three-year-old airman volunteer, Donald G. Farrell.

During his week-long stay in the USAF "space cabin" Airman Farrell breathed oxygen supplied from the outside, lived off a replenishable prepacked "pantry," and was subjected to a battery of psychological testings at a "control panel" where, from his cramped sitting position, he performed operations to test fatigue patterns and psychological responses. His living space, 100 cubic feet, barely let him lie down for sleeping. Wastes were disposed of chemically. He was scheduled through varying work-time patterns to test efficiency. His responsestrackable through electronic devices and visible via closedcircuit television-will provide monumental data. Already, a number of short "flights" in Space Medicine's sealed cabin have been successfully completed, but twentyfour hours has been the longest stay. Equivalent altitude in the cabin during the "space" trip was 18,000 feet. The experiment was supervised by Lt. Col. George Steinkamp, Chief of the Department of Space Medicine.

The psychological problems of a week-long confinement may well outweigh the physiological problems. And heavy attention was paid to the subject's alertness, judgment, and moods.

One painful problem Airman Farrell did not have to worry about is multi-G acceleration and body-weight increase at high-speed blastoff. This is the fantastic pressure and body weight multiplication that will be experienced by the carefully selected crewmen of the first USAF manned spacecraft. But thanks to the death-defying experiments of Colonel Stapp, we know that a normal man can endure—not without temporary discomfort—brief accelerations of up to about forty Gs. Reaching speeds of 632 mph on a rocket sled, forty-seven-year-old Colonel Stapp has experienced the forty-G pressure for a fifth of a second and demonstrated man's surprising tolerance.

The Gs endured by Colonel Stapp far surpass what spacemen would expect at blastoff from Earth. Estimates based on present-day rocket fuels indicate that peaks of eight or nine Gs would mark the first-stage period of perhaps three minutes. From then on, Gs would decrease in minutes down to two or three as the final boosting rocket fell off and the ship headed into space. And the G problem would be much lessened, if as some suggest the first

ship to the moon were launched from a space station, rather than from the Earth.

Of course, Colonel Stapp has built up his endurance to multi-G stress through numerous rocket-sled rides and has been protected as thoroughly as possible by special suiting and helmet. Future USAF spacemen would likewise be pretrained for increased G tolerance in centrifugal machines and would wear pressurized suits as they lay prone during actual blastoff. The prone position has been adjudged best to avoid blackouts, caused by blood draining from the head, or "red-outs," blood pooling in the skull.

Most authorities agree with Brig. Gen. Don D. Flickinger, Director of Human Factors, ARDC, that spacemen will be so busy coping with increased Gs during blastoff that practically all of the ship's operations will have to be automatic. It is expected, however, that he could painfully press a button to operate an escape mechanism, should the blastoff abort,

But, having endured increased Gs, the spaceman's problems will be just beginning. As propulsion ends and the last rocket stage drops off, he will have entered the unfriendly void. And he will be weightless.

This unearthly condition cannot be duplicated, except for brief periods, within the atmosphere. But the brief periods attained through experimentation have already yielded substantial data on what man can expect in the weightless state. Working intensely on the weightlessness problem is Dr. Gerathewohl of the Department of Space Medicine. To attain brief intervals of zero gravity, F-94Cs are flown at high speed at Randolph in parabolic maneuver patterns, much like an aerial roller coaster (see diagram).

The zero-gravity state is reached at the top of the curve for periods up to about forty seconds, time enough for motion picture recording of the phenomenon and for the subject to experience sensations of weightlessness.

Of the people run through zero gravity, reports Dr. Gerathewohl, about thirty percent have suffered ill effects of one kind or another. Some of these, he points out, are prone to sea- or airsickness. He adds that the factors of anticipation and the roller-coaster rise on the curve into zero gravity may have brought on some of the nausea.

But experimentation so far has demonstrated that zero gravity, for long or short intervals, does not bother the majority of the subjects. Dr. Gerathewohl feels that most humans can, with training and orientation, adjust to the weightless state. Fortunately, it appears that the eyes can be trusted for orientation in the spaceship—since the sensitive mechanisms in the ears that ordinarily provide balance are useless in zero gravity.

Dr. Gerathewohl is attacking the visual orientation problem with inflight experiments in which subjects strike targets with dart-like styluses to test eye-hand coordination. These experiments have indicated a tendency to overreach in the beginning but gradual improvement in aiming. This supports the view that repeated experience can "train" the eyes to accept the zero-gravity state.

Presumably, if the potential space flyer shows quick adaptation in the earliest periods of zero gravity, he will do all right during longer periods. But those who do not adjust fairly rapidly at first may never be able to stand the zero-gravity state for extended intervals, Dr. Gerathewohl suggests.

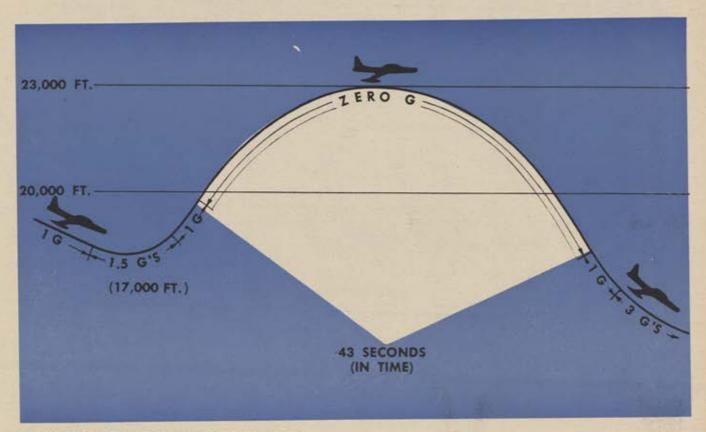
Still mysterious is the actual physical effect weightlessness has on body fluids and tissue, muscle actions, and other organs. Thus far it is apparent that, with special arrangements for drinking, and careful and thorough chewing, feeding would not be a problem. Right here on Earth, many persons have chewed, swallowed, and begun to digest food while upside-down. Drinking is a greater problem, since it is theoretically possible to drown in a glass of water in zero gravity because liquids float freely and could rush into the nose. But squeeze tubes or bottles could be used to force fluids into the mouth, where muscles would take over.

Sleep, too, is a problem, but Dr. Gerathewohl and his colleagues do not consider it insuperable, and they are experimenting with varying work cycles to create enough fatigue to induce proper rest.

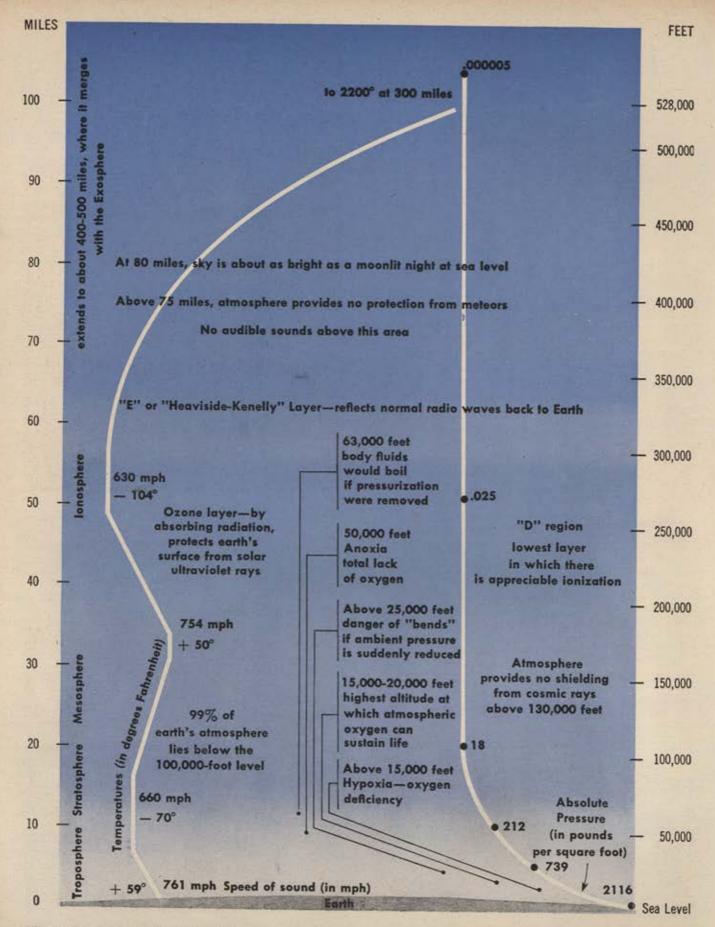


The F-94C zero-gravity lab-in-the-air is flown by USAF Maj. Herbert D. Stallings at Randolph AFB, Tex., shown here (left) charting a flight with Dr. Siegfried J. Gerathewohl, who directs the Department of Space Medicine weightlessness experiments at the base using data gained in flights.

One man whose everyday job involves staying in zero gravity, Maj. Herbert D. Stallings, Jr., pilot throughout all of the Randolph Space Medicine weightlessness flights, probably holds the world's zero-gravity endurance record—more than thirty hours, the total of many momentary stays in weightlessness. Flying with him as subjects at Randolph have been newsmen, airmen volunteers, and several flight surgeons, whose reactions are especially valuable in view of their more precise objectivity.



HOW F-94 REACHES ZERO GRAVITY Chart illustrates the flight pattern used by Major Stallings to attain brief periods of zero gravity in the F-94C. The maneuver begins at an altitude of about 18,000 feet, then reaches about 23,000 feet at the very top of the parabola, at which point it yields about forty seconds of virtual weightlessness, before dropping down again. The reactions of subjects taken at the zero-gravity level are carefully recorded and analyzed on the ground at Randolph. Dr. Gerathewohl feels most humans will be able to adapt to the weightless state.



THE HAZARDS OF SPACE Chart above illustrates the dangers to man as he rises up and out of the Earth's atmosphere. From 15,000-20,000 feet is the highest altitude where atmospheric oxygen will sustain life. At 63,000 feet, blood boils. At 80,000 feet, a sealed cabin with self-contained environment is mandatory. At 130,000 feet, atmospheric shielding of cosmic rays ends. Ninety-nine percent of the atmosphere is located below the 100,000-foot level. Physiological "space equivalence" begins far below that. Above 75 miles, atmospheric shielding against meteors ends.

Another problem of weightlessness for extended periods will be the lack of the sense of atmospheric pressure on the skin surfaces. Dr. Gerathewohl suggests that the spaceman could be seated in something like an infant's highchair, with the underside of the "tray" padded with soft foam rubber. Secured in such a seat, the spaceman would feel gentle but firm pressure on his thighs. This type of seat could be leaned backward and used for a bed during rest periods. To move about the cabin, the spaceman could release himself from his highchair and walk on suction-cupped shoes or use guide rails.

But is this weightlessness necessary? Is there no way

of creating some sort of artificial gravity?

There is—and it has both advantages and disadvantages. A gentle spinning movement could be generated to rotate the spaceship, providing an artificial gravity. But this approach would take additional power and create the problem of determining exactly how much spin and gravity were needed. A further problem might be that of changing the rate of rotation to adjust the crew to the new levels of gravity to be experienced when the ship landed on other planets.

Dr. Gerathewohl feels that the complications of providing artificial gravity on extended flights might be more trouble than they were worth and that providing crew comfort in zero gravity actually would be much easier. He cites the possibility of failure or unexpected change in the spinning method which could make the "floor" suddenly the ceiling and disrupt a crew which had become used to the security of their artificial gravity.

As USAF Space Medicine studies the human factors, the Air Force is proceeding to the actuality of spaceflight

that will test the medical data.

The planned flights of what will be the USAF's first step toward a manned satellite—the North American X-15 which will fly at 100-mile-plus altitudes—are expected to subject test pilots to periods of up to six minutes of zero gravity. Such extended times will provide additional invaluable data to the studies conducted by the Department of Space Medicine and the work of the ARDC's Aero Medical Laboratory, where veteran researchers like E. R. Ballinger and others have also made intense studies.

Weightless or not, man will have to breathe in his sealed environment, be it a satellite, a ship to the moon, or beyond. The simplest solution is to take along the necessary oxygen. This could probably suffice for a trip to the moon, taking about a week, but the problem becomes complicated for extended voyages, such as on a permanent space station or on longer trips to the inner

planets of our solar system.



Hypoxia. Severe oxygen shortage occurs at levels above 20,000 feet, numbing judgment and bringing on drunken-like reactions. Center cadet, undergoing dexterity tests under hypoxia conditions, fumbles with the pegs which must be properly placed in holes, as his buddies watch.



At super-high altitudes, explosive decompression would be fatal to unprotected airmen. Drastic reduction of atmospheric pressure releases gases in liquids, causing "boiling" as illustrated here in simulated high-altitude chamber, with beaker of exploding fluid held by experimenter.



Human blood boils at a level of 63,000 feet, making protective pressurized clothing mandatory. Pictured is an experimental demonstration—using simulated human blood—of this space-travel hazard. This experiment was carried out by personnel at the School of Aviation Medicine.



The very nature of our earthly oxygen-carbon-dioxide cycle may come to the rescue here. Dr. A. E. Slater of the British Interplanetary Society suggests the key to the problem with his remark that the Earth itself, "which is the only manned spaceship known to exist, does not need to take in stores (apart from the energy of solar radiation) to keep its inhabitants alive. Living matter merely circulates among the various forms of life, forming a closed system. . . . Green plants use solar energy to build up carbohydrates (which form most of their substance) from the carbon dioxide in the air and the hydrogen in water,

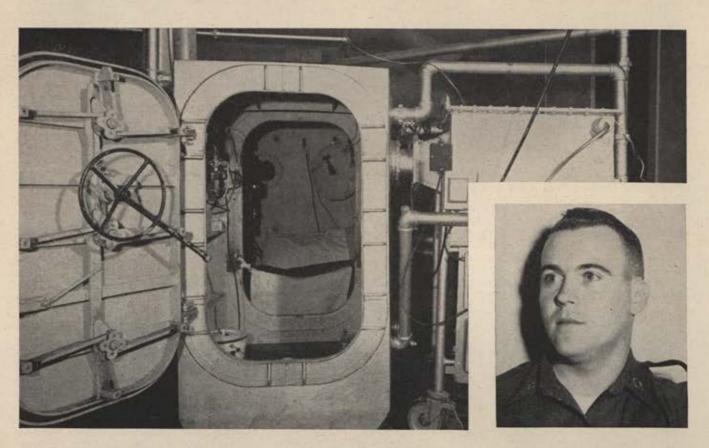
The individual's reaction to isolation is a major potential problem in projected extended spaceflight. Wright Aero Medical Lab subject, left, scated alone and surrounded by darkness for long hours during psychological tests, helps provide scientists with clues to human reactions.

liberating the oxygen from the water; animals breathe this oxygen and use it for 'burning' the food they have eaten, which consists of plants, or of other animals which have eaten plants. This 'burning' process produces carbon dioxide and water which the plants again build up into carbohydrates."

This process of photosynthesis may provide the answer to the ticklish problem of sufficient oxygen in the sealed cabin of spaceships on long trips, if carrying prepacked oxygen seems unfeasible. USAF space medics are busy checking its possibilities. At Randolph AFB, mice have already lived for periods of up to seventy-two hours on oxygen supplied by nourished algae, minute vegetable life kept in specially built tanks through which run fluorescent light tubes to provide the equivalent of sunlight (see photo, page 117).

These experiments, at the University of Texas and in the microbiology lab at Randolph, reenact the very cycle of life on our planet. And they demonstrate the theoretical possibility of using such equipment aboard spaceships. Such a method is not without problems. Providing artificial light for the algae presents a power problem as does supplying nutrient for the plants. But it is believed that human waste could be processed for food for the algae and that, in turn, part of the algae could actually be processed as human food.

So it might be possible to operate a closed system



A/IC Donald G. Farrell has spent seven days and nights in "space" right here on Earth by living in USAF space Medicine's sealed cabin at Randolph AFB in experiment designed to duplicate the conditions spaceman would experience in flight. Farrell breathed piped-in oxygen, was subjected to varying work cycles, lived in simulated 18,000-foot altitude, operated "control" boards, was observed continuously. He was not able to see outside, nor could he smoke. This was the longest such stay in AF's Space Medicine cabin. Earlier record was twenty-four hours.

which would absorb the crew's exhaled carbon dioxide and wastes, be nourished by those, and in turn produce the vital oxygen and food. Today's equipment is of course purely experimental, but it works. Capt. Robert D. Gafford, in charge of the Randolph experiment, points out that such a system would require great attitudes of objectivity on the part of the crew.

And what of cosmic rays? Scientists have long known that the Earth's atmosphere shields us from the major effects of these powerful radiations from outer space which are capable of destroying human tissue cells. As man rises through and out of the atmosphere, he will have to face the naked power of these bombardments, and suffer the risk of damage to brain, eyes, reproductive glands, and other vitals.

The cosmic ray problem is multifold. It involves immediate damage and tolerance, long-range genetic damage which cannot be charted at the time of the bombardment, and the problem of shielding in terms of additional weight.

Opinion is divided on man's tolerance to cosmic rays. Some scientists believe that the risk of unseen genetic damage is great. Others suggest that cosmic-ray exposure on the initially brief spaceflights will not be a prohibiting factor. They believe that much longer periods of exposure than mere weeks or days would be necessary to create high levels of danger. They add that by the time really extended spaceflight is accomplished, so much more will be known about cosmic rays that the problems will be lessened.

We already have some hints concerning the amount of cosmic-ray bombardment in near space. America's first satellite, Explorer, has revealed that at its 219-1,587-mile orbital heights, cosmic radiation is no more than twelve times that on the Earth's surface, Scientists do not consider this a large increase.

Again, the psychological problems of space flight may far outweigh the physical. In his report, Major Simons, who rode into the heavier cosmic-ray area, laid greater stress on his feelings of detachment than on his physical reactions during his sojourn at 102,000 feet.

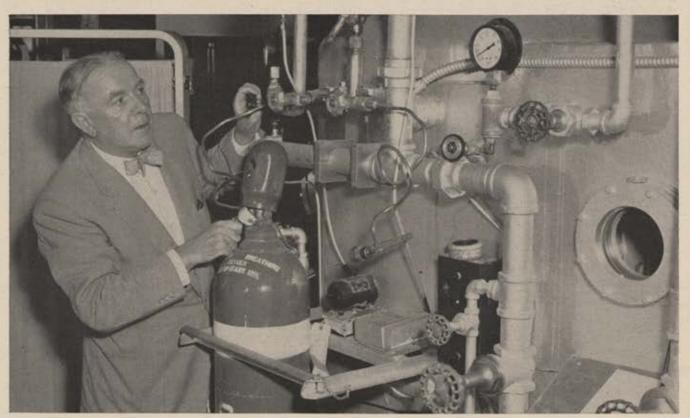
There are other tangible space bullets crewmen will have to face. Showering continually through the cosmos are fast-moving meteoritic particles, ranging from the nearly invisible to the sizable. Moving at tremendous speeds through unresisting space, they could do heavy damage to spaceship hulls. Large meteors could smash holes in the ship, and minute meteoritic dust could wear away hulls as sandblasting would. Happily, most experts agree that the chances of large meteors striking a ship in the vastness of space are infinitesimal. Actually, smaller, powder-like meteoritic dust is a greater problem. Some engineers have suggested that ships could be equipped with "meteor bumpers" designed to take the brunt of both crash impact and the sandblasting effect of the smaller particles. Explorer has thus far been unbothered by meteoritic dust.

But impatient man cannot wait for one hundred percent assurance from the researchers—even if that were eventually possible. Certainly the Air Force cannot delay its progress into manned spaceflight. And it is not,

The first step in that progression is the flight of USAF's North American X-15, scheduled to be tested in 1959 as a joint USAF-North American venture with the National Advisory Committee for Aeronautics, and with the Navy providing some fiscal support.

Prelude to the USAF's first manned satellite, the X-15 is expected to reach 100-mile-plus altitudes, with some experts suggesting that peak altitude may even reach the 200-300-mile range (see chart, page 121).

The X-15 will explore the vital question of human and



USAF's Dr. Hubertus Strughold, "father of space medicine," checks the Randolph space cabin during final preparations for Airman Farrell's seven-day experiment. Now Adviser to USAF Space Medicine, Dr. Strughold's theoretical studies and practical experiments in the medical problems of space travel go back to the twenties, when he began his studies in the field. Honored throughout Europe for his contributions, Dr. Strughold came to the USAF in 1949, is now a citizen of the United States. In 1954 he received the International Astronomical Federation Oberth award.



This Philippine macaque monkey soared to an altitude of about thirty-six miles in USAF Acrobee rocket launchings and was parachuted to Earth unharmed inside the rocket's nose. The animal's container is just visible at top portion of rocket drawing on the wall in background. The effects of such high-altitude flight on the subject, particularly cosmic rays, are carefully followed periodically by USAF scientists. The animal has thus far not demonstrated any ill effects. At left is Brig. Gen. Wayne O. Kester, former AF Veterinary Service chief. The monkey is now at the National Zoo, Washington.

vehicular reentry through the atmospheric friction barrier. Approximately fifty feet long, the X-15 is a short-winged cigar in appearance, and will be powered by liquid-fuel engines. Pitch and yaw control rockets will be located in the nose and at top and bottom of the fuselage. The primary navigation system will be inertial, giving the pilot his position in all three dimensions, since high altitudes preclude the usefulness of ordinary flight instrumentation like altimeter and airspeed indicator.

The X-15 will probably be launched from a modified B-52 at altitudes of 30,000-40,000 feet, high over Wendover AFB, Utah, landing at Edwards AFB, Calif. Early flight tests will be by North American's Scott Crossfield. Later maximum performance tests will be flown by Capt. Iven C. Kincheloe, Jr. NACA's Joseph A. Walker will fly

the plane for the research agency.

Hoped-for accomplishment of the X-15 will be the successful trial of the skip maneuver, in which the plane is flown down into denser air for a brief time, then back up briefly, then coasting down again, gradually decelerating preparatory to reentry through the dense atmosphere. The flight of the X-15 will provide tremendous data on man's suitability to space. Its pilots will face longer periods of zero gravity, decision-making in the near-void, exposure to speeds of from Mach 5 to Mach 7. Its range is expected to be nearly five times that of the Bell X-1 and X-2, that is, a total of about 450 miles.

Follow-on vehicle to the X-15 will be the orbital bomber, a true manned satellite. North American reportedly has in mind an advanced version of the X-15, souped-up with boosters. Dr. Walter Dornberger, who ran the V-2 operation at Peenemünde and now works for Bell Aircraft, con-

ceives a boost-glide vehicle, thrown into orbic with existing propulsion hardware, that could circle the Earth seven times at an altitude of seven miles, gliding in and out of the atmosphere for braking effect, and return its two-man crew to base after dropping a 5,000-pound payload of nuclear armament anywhere in the world.

After the orbital bomber and small manned satellite will come the really giant accomplishment—the large manned space station, the true, operating man-made moon,

The manned station will be the first real permanent test of space medicine. Orbiting around the Earth, it will be a self-contained world out of this world, with regularly assigned crew, living quarters designed for maximum comfort, its own gravitational system provided by spinning, its own oxygen-provision system (probably the algae cycle now being studied).

Hurtling around the world, it will provide superb reconnaissance and observation facilities and a continuing flow of data on such mysteries as cosmic rays and meteors.

Further, it may provide a much easier launching position for the inevitable trip to the moon, since the atmosphereless surroundings would not present the launching difficulties encountered on Earth, with its escape velocity of 25,000 mph and consequently enormous thrust needs.

What would life on a manned space station be like? This is certain. It would be the most different experience ever faced by man. Only the very best, the most stable, the most dedicated personnel could be assigned to such an otherworldly task. Tours of duty would undoubtedly be short, certainly at first, geared to the arrival of supply ships and replacements. But, the USAF is sure, there would be no shortage of volunteers.

How would the space station be constructed? The most commonly suggested method is to put the pieces together in the preselected position. Of course, the most rigorous celestial mathematics would be necessary to get the components in the right place at the right time. Convair's Krafft Ehricke has suggested one method. He believes that the ships could be launched in a series to the orbital position, then hooked together to form what would look like a bicycle tire. With this beginning, later supply ships could bring up components to add sophistication and needed additional equipment.

From the space station, whether it is used as a launching point for lunar trips or only for observation, the next step is mankind's dream of the ages, the trip to the moon. In fact, this step could possibly antedate the space station. The USAF has already suggested that the Thor IRBM, modified, could possibly be used for launching an inspec-

tion vehicle around the moon.

Earth's nearest natural neighbor, the moon is, so far as astronomers know, a nearly atmosphereless, crater-pocked rock with, at best, small residual pockets of gases that might be employed for small-scale manufacture of artificial atmosphere. But most authorities believe that man will have to bring atmospheric ingredients along with him in his lunar spaceship.

Although the time (five to seven days) required for a "coasting" flight to the moon is relatively short, landing

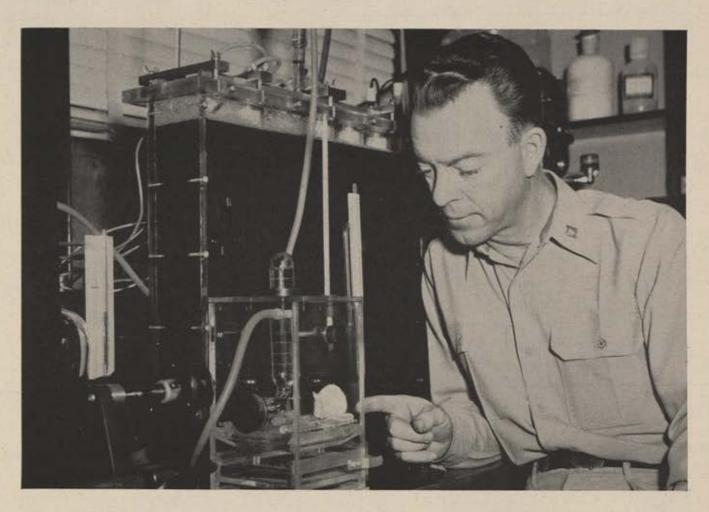
problems might be quite formidable, because of the need for the most careful selection of a landing point on the rugged surface and the careful timing absolutely necessary for proper braking through the airless "atmosphere." The finest skill in reverse jetting would be needed to touchdown without mishap. Of course, prior to any landings, circumlunar robot and manned flights will have taken place to chart and photograph the moon's surface for selection of landing and base areas.

Beyond the pure scientific excitement of conquest, the military value of the moon is great. High-powered telescopes could be used for clear reconnaissance; retaliatory missile launchings could probably be effected in the event of nuclear war. (see "The Space Frontier," page 42).

The aftermath of successful landings would be establishment of lunar bases, and here repeated would be the test of man's ability to create and thrive in an artificial environment. The moon's temperatures range from terrific heat to extreme cold, ranging from 250 degrees above to 200 degrees below zero Fahrenheit, as the moon faces or turns away from the sun.

To move about on the silent high-vacuum surface of the moon, crewmen will have to wear spacesuits providing oxygen and pressure, yet allowing enough mobility to work with tools. Already research toward development of such suiting is being pushed forward in projects like the USAF-

(Continued on page 120)



Photosynthesis—the giving off of oxygen by plants—may be the solution to the manufacture of the life-sustaining gas in spaceship scaled cabins. In Randolph microbiology lab, Space Medicine's Capt. Robert D. Gafford checks reactions of white mouse in plastic case, living on oxygen supplied by algae in the tank in background. The carbon dioxide exhaled by the mouse is converted to oxygen by the plant life, which, in turn, receives energy from fluorescent lighting and is fed by special nutrients. Experimental mice have lived up to three days on oxygen supplied by the algae.





# Westinghouse metal miracles boost jet engine performance 15%

Turbojet "hot end" parts, made from clad molybdenum, are increasing jet engine efficiency up to 15% by permitting higher turbojet operating temperatures. Developed by Westinghouse research scientists, this new method of coating molybdenum to prevent high-temperature oxidation has proved successful during extended engine testing of "clad-moly" parts at temperatures above 2000°F.

Development of this protective coating—which remains intact and effective after molybdenum alloy sheets or shapes are formed into parts of complex shapes—is part of the advanced metals research program at Westinghouse. The Aviation Gas Turbine Division is helping to keep America strong by applying this coating and other new research developments to create better and better jet engines for the defense of America.

Take advantage of Westinghouse's ability to engineer, develop and produce equipment for America's defense. Contact your Westinghouse Defense Products sales engineer, or write: Westinghouse Electric Corporation, Aviation Gas Turbine Division, P. O. Box 288, Kansas City, Missouri.



The first stage turbine nozzle vanes (outlined in red) were chosen for initial testing as they are subjected to the highest temperatures and are most susceptible to thermal shock.

Westinghouse Westinghouse



At left, balloonist's-eye view of the curve of the Earth. This remarkable photo was taken by USAF Maj. David G. Simons during his record-breaking ascension to an altitude of 102,000 feet for a solitary thirty-two-hour period. Note how dark the sky appears at top of the photo.

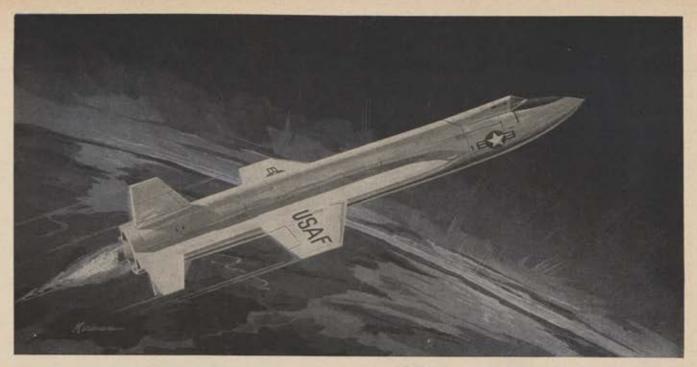
OSR-Litton Industries Inhabited High Vacuum Laboratory, where space-like vacuum conditions have been created in a cylindrical container. A space-suited "inhabitant" has performed mechanical tasks in the vacuum chamber (see cut, page 108), and the results of such research will eventually lead to adequate suiting for wear outside spaceships and on such airless environments as the moon's,

The first needs of the lunar pioneers would be basic—shelter, air, and food stores. Shelter would probably be set up in the form of pressurized domes, deflatable and easily packed in the spaceship. The layer of dust which covers the moon could be used as an excellent insulator. Personal communication would be by radio. An odd feature of longerrange radio communication problems would be the expected ease of communication with Earth, as opposed to the short-range difficulties of distance communication on the lunar surface because of the smaller diameter of the moon and the nearer horizon.

Once established; the next problem would be energy to

Below, self-portrait of Man-High. Major Simons photographed himself nineteen miles above the Earth by timing a flash of strobe light set in the balloon gondola to light up the interior for periodic photo-recording. He survived the experiment without suffering ill effects.





### 100-200 MILE HEIGHT HITS PEAK 3,600 MPH, FUEL EXHAUSTED 100,000 feet PLUNGES EARTHWARD THROUGH HEAT, STRESS ZONE ENTERS LOWER ATMOSPHERE 40,000 feet CONTROLS WORK DROPPED FROM B-52, X-15 ROCKETS SKYWARD AGAIN GLIDING IN, PILOT MAKES DEAD STICK LANDING Wendover AFB . Sait Lake City . Edwards AFB Sea Level

ON THE EDGE OF SPACE
An artist's conception of North American's X-15, soon to reach super-altitudes in joint USAF-NACA test flights.
Skip-glide maneuver is hoped-for accomplishment of revolutionary craft, which is considered prelude to USAF launch and flight of manned satellite.



FLIGHT OF THE X-15 Launched from a B-52 high over Wendover AFB, Utah, the X-15 will hurtle upward with its giant fuel load to peak speeds near 3,600 mph and 100 miles or more altitude, then start downward through the atmosphere, buffeted by shock waves and extreme heat, until it reaches the 40,000-foot level, then gliding to deadstick landing at Edwards AFB, Calif.

FULL PRESSURE SUIT The MC-2, developed for extreme-altitude flight, is modeled by North American test pilot Scott Crossfield, who will wear it during the X-15's first flight.

Life on Mars? In jars at Space

Medicine laboratory are bacteria being subjected to conditions approximating those on Mars. And
some of them are hardy enough
to survive. Working on this revealing experiment is

USAF Lt. John A. Kooistra, Jr.



operate machinery. Solar energy could be received by mirror devices, with heat relayed to fluids, such as water or mercury, then turned into steam to operate turbines and generators. There would be the disadvantage of non-operation during the lunar night, but a heat-storing method might be devised to overcome that. The only need would be to crank the machinery periodically to follow the movement of the sun, and this could probably be made automatic eventually.

As the first moonmen worked to set up their rudimentary base, supply ships would have to be sent periodically with additional provisions for more permanent materials for the eventual large lunar base. Meanwhile, the moonmen would continue to live in their pressurized domes.

As supplies accumulated, construction of the permanent base would begin. By then considerable knowledge of the minerals and of construction possibilities of lunar stones would have been obtained. The first permanent dome could be a kind of giant igloo of heavy stone, sprayed from the inside to make it airtight. Should temperature changes be too violent for this method, however, it might be necessary to construct the bases underground or in caves, where temperatures would be more constant.

With establishment of a sizable base with numerous personnel, the need for a permanent oxygen supply would become vital, and at this point, large-scale use of the algae method described earlier might be arranged. This would be a self-contained system and, once established, automatic.

Although sizable military and scientific crews may be established on the moon and perform highly important work there, the moon is really only a beginning in the journey to the planets. Of course, there is the eventual possibility—far in the future—of providing an artificial atmosphere on large areas of the moon.

After the moon, where? Mars?

Our mysterious neighbor, at its closest, thirty-five million

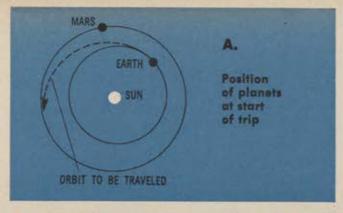
miles from Earth, is the logical next destination. But after the knowledge gained on the moon, human landings on Mars would seem much easier. Probably the initial method of firing robot survey and tracking flights used prior to lunar landings would be duplicated before any human flights were attempted.

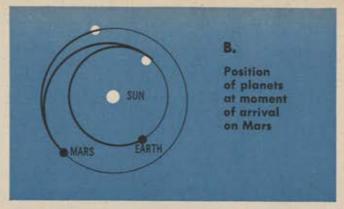
Oddly, the long way to Mars would have to be taken because of the prohibitive fuel requirements for the more direct route. The most economic approach is a giant sweeping curve—nearly 300 million miles long—around the sun and into the Martian orbit. The probing rockets would take some eight months for the trip, coasting freely after the initial launch from Earth (see chart, next page).

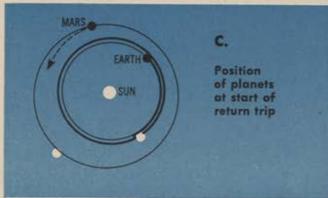
What will the astronaut find when he lands on the Redand-Green Planet? Mars is much like Earth, but the differences are great, too. Day length is about the same, and
the sky, blue on Earth, is probably a whitish blue on Mars.
But as on the moon, space medicine would have to plan for
intense conditions. The much less dense atmosphere of
Mars is mostly (about ninety-eight percent) nitrogen, and
the "sea-level" pressure (there are no seas on Mars) is
equivalent to a terrestrial level of 55,000 feet, which is just
about the edge of workability for pressurized breathing of
oxygen. Initial explorations in pressure suits would, according to Dr. Strughold, have to be limited to an hour or a
little more, after which time the crewmen would have to
return to the environment of the sealed cabin of their
spaceship.

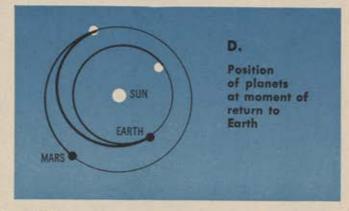
Gravity, as on the moon, is much lower than that of Earth, and this would facilitate mobility. Cosmic rays are not expected to be too great a problem, thanks to the existence of atmosphere. Earthmen, says Dr. Strughold, would find Mars a strange "second Earth." But, just as the moon might be transformed by technological miracles, so might Mars.

The explorers of Mars will provide the answer to such









To Mars and back, around the sun, would take 2% years by orbital route. One-way trip would require 258 days, but spacemen would have to wait on or near Mars for 455 days before starting the 258-day voyage by orbit back to Earth.

questions as the mysterious "canali" which some astronomers once thought indicated the existence of intelligent Martian life. Data on the observed green areas on Mars which appear in the equatorial areas seasonally will be obtained. The temperature ranges on Mars, as on the moon, are extreme, but they might allow for the hardiest forms of plant life.

An interesting preview of these Martian conditions has been studied right here on Earth. USAF's Space Medicine scientists have grown bacteria strains under conditions approximating those of Mars (see photo, previous page), and some of the bacteria have survived. This is but one indication of the enormous adaptability of life.

We have traveled, in words, as men will in reality, to Mars. Men will want to know their other near neighbor, Venus, utterly mysterious, shrouded always in hovering clouds. We will learn if it is, as some suggest, a steaming primordial swamp, or a windswept desert. We know it will not be hospitable and that it, too, will present formidable challenges to space medicine.

Part of man's exploration of space will be devoted to learning if we are alone—an accident of life—in the universe. Will we find what is now more probable, in the light of the vastness of the universe, that environments conducive to intelligent life exist elsewhere?

Of our own solar system, on the plus or minus scale of hospitality to life as we know it, only Mars or Venus offers any possibility. And they are both deficient in oxygen.

Traveling out from the sun, what possibilities for life? Mercury, the nearest to the sun, seems too close to the fiery orb and is on the minus side in the necessities: atmosphere, hydrosphere, bearable temperatures, carbon dioxide, oxygen. Venus, Earth, and Mars seem to form the only belt where all the prerequisites are available in some quantity and form. Beyond Mars, the outer planets—Jupiter, Saturn, Uranus, Neptune—have proto-atmospheres dominated by

hydrogen, ammonia, and methane-frozen atmospheres which may forever bar human exploration. Outermost Pluto is, in most respects, a mystery.

It is, in fact, a possibility that because of physiological reasons we may never see the outer planets of our own system, and our flight *outside* the solar system may be the step beyond Venus.

Such exploration is doubtless far in the future and dependent on—aside from the propulsion problem—the very nature of the universe. The nearest galaxy to our Milky Way is approximately one million light years away. Even with the most exotic, today-unknown propulsion methods, it would take untold time, traveling at nearly the speed of light, to reach such a destination. But there may be an answer to that problem, too, in Einstein's Theory of Relativity.

Even if we never get to the far reaches of the universe, the exploration we do accomplish may well provide the answers to the secret of life, the origin of our own solar system, the formation of the universe.

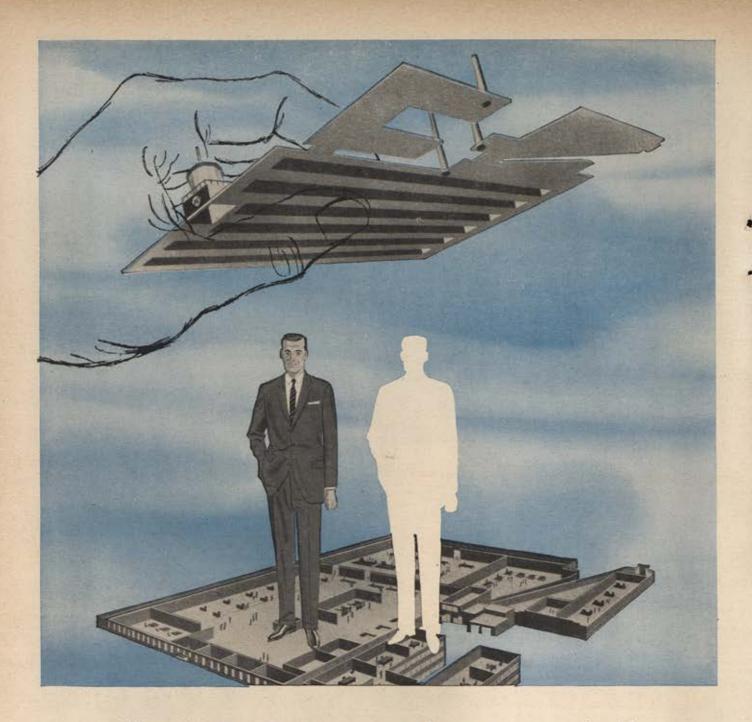
Astronomers used to believe that solar systems such as ours were rather rare. Now this trend of belief is reversing in the face of theories that all the stuff of the universe was created by a series of "explosions," or a single incredibly large explosion at the "beginning." If this is true, then there is not too much reason to doubt that many stars are suns with solar systems, and that many solar systems could contain the prerequisites of life.

This question may some day, in the cons of the future, become tremendously important to mankind.

For many experts believe our sun is a dying star, that possibly only a few billion years remain before it begins to cool in a cosmic way, snuffing out with it the life that depends on it. Man will need a new home then.

The work of today's space doctors is part of the beginning of that search into the universe.

-WILLIAM LEAVITT



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### It tracks down an enemy at 300 miles

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## AROUND THE WORLD WITH SIKORSKY HELICOPTERS



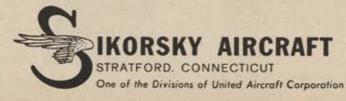
45 TONS PER HOUR—In northern Norway, pilots of the U. S. Army's 8th Helicopter Battalion carried loads of building materials, steel, electronic equipment, and even dynamite to mountain-top sites of micro-wave relay stations. The H-34As (Sikorsky S-58s) delivered their cargo at the rate of 1½ tons every 2 minutes.

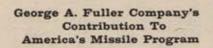


LIFTING THE LANTERN—An HR2S-1 (Sikorsky S-56) from the Second Marine Aircraft Wing places a 1740-lb. lantern atop a new 142-foot lighthouse at Cape Fear, N. C., with only 6 inches of clearance on the sides. Hovering stability for this difficult job was provided by Sikorsky's Automatic Stabilization Equipment in the HR2S-1.



**52 RESCUED**—The crew of the grounded French freighter *Pei-Ho* were flown ashore near Casablanca, Morocco, by an H-19 (Sikorsky S-55) of the Air Force's Air Rescue Service, which is on duty around the world. All 52 of the crew were rescued. The H-19 came from the U. S. base at Port Lyautey.





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> ROCKET TEST TRACK U. S. Government Edwards, California

ROCKET TEST STANDS Douglas Aircraft Company Nimbus, California

> Air Products, Inc. Edwards, California

INSTRUMENTATION SYSTEM
Convair
Edwards, California

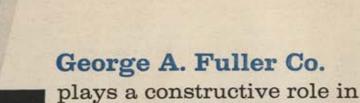
"BRAVO" TEST STANDS North American Aviation, Inc. Santa Susana, California

"COCA" TEST STANDS North American Aviation, Inc. Santa Susana, California

> U. S. Government Edwards, California

North American Aviation, Inc. Chatsworth, California

North American Aviation, Inc. Palmdale, California



Since 1882 the George A. Fuller Company has taken the lead in all types of building construction. From the famous Fuller (Flatiron) Building—one of the earliest steel skyscrapers—through thousands of projects all over America for commerce, industry, education and defense, Fuller continues to build its reputation for superior performance.

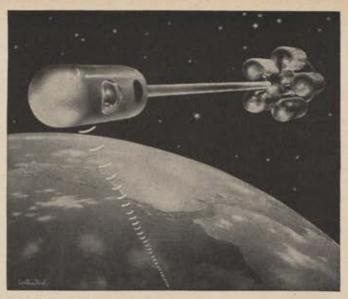
America's missile program

GEORGE A. FULLER COMPANY 3100 West 8th Street • Los Angeles 5, California





TEST INSTRUMENTS Bulova's rugged Tachometer Tester for all jet and reciprocating systems meets MIL-T-945A requirements—is accurate to 0.1% with engines on or off. Simple to operate and maintain, this field unit also serves in maintenance depots. Precise Bulova testers include the dual purpose Torqmeter—a dynamometer or calibrated torque source



RECONNAISSANCE SYSTEMS Bulova-developed miniaturized sensor packages, geared to specific tactical missions, feed combat surveillance data to Bulova analysis and display systems. Camera, Infra-red, TV and radar techniques, combined and integrated, aid decision-making on land and in space. Satellite applications? Unlimited!

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To conceive, develop and manufacture a broad range of advanced electronic and electro-mechanical devices...this is the Bulova capability.

Meeting the needs of defense and industry is an unusually creative group of scientists, engineers and technicians, backed by 80 years' experience in precision production. Bulova

With dynamic imability has invaded technological are modern-day mirac tems and component tems and component full information, we compare the company of the company

With dynamic imagination, Bulova's capability has invaded the often uncharted technological areas to originate many modern-day miracles in miniaturized systems and components.

Here is a proven capability ready to assist you from concept to mass production. For full information, write Department G.I.S.-2.

BULOVA RESEARCH AND DEVELOPMENT LABORATORIES, INC.

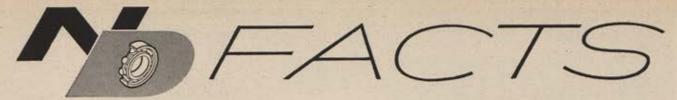
BULOVA PARK - JACKSON HEIGHTS - NEW YORK

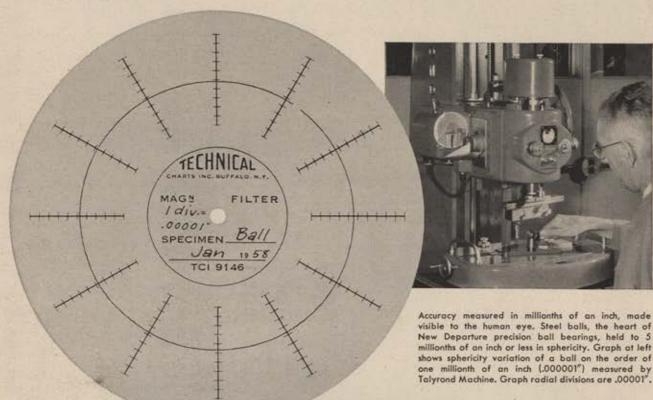


INFRA-RED COMPONENTS Bulova's advanced IR projects include mosaic cells that will automatically filter out unwanted wave lengths and picture targets clearly against any background. Bulova infra-red R&D covers lead selenide and lead sulfide cells, missile seeker cells, reticles, filters and thermistor bolometers...for defense and industry.



INFRA-RED SYSTEMS Bulova's IR Illuminators put unseen spotlights on night objectives. Bulova's development capability extends to fire control systems that detect, track and automatically lock on target. Designed for accuracy and simplicity, these high resolution units will serve our nation's land, sea and air forces.







The extreme accuracy of New Departure ball bearing component parts is now playing a vital role in successful missiles for the Army, Navy and Air Force. Above —typical bearing parts, less separator —unretouched photograph.

## PORTRAIT of PRECISION!

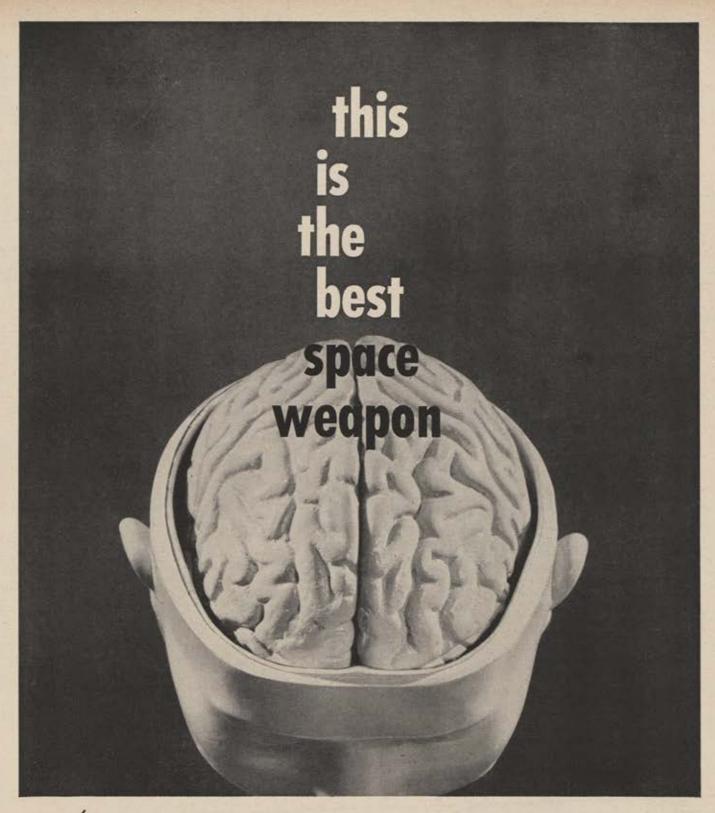
A mechanism is only as accurate and reliable as the bearings supporting its moving parts. For the designer the problem is how to achieve the essential rigidity or accuracy of location, yet be assured of extreme freedom of rotation.

A "tip-off" to the solution lies in the chart above—super-precise steel balls, the heart of New Departure precision ball bearings. For, with balls held to 5 millionths of an inch or less out-of-roundness and other bearing parts finished with comparable care, such bearings can be mounted and *preloaded* to provide the hairsplitting exactness of location and *ease of rotation* required of the finest precision instruments.

The AChiever guidance system proved in tests of the Air Force's Thor ballistic missile demands tolerances often measured in millionths of an inch, as is the case with the New Departure ball bearings on which the AChiever's precision gyros turn.



DIVISION OF GENERAL MOTORS, BRISTOL, CONN.





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SAC's new "Rascal" air-to-ground guided missile gets swift, sure handling on the ground, thanks to this  $\mathbf{QCf}$ -built transporter. It's an important part of making the 13,000-pound missile truly operational, for fast ground handling when the chips are down.

As prime contractor or sub-contractor, American Car and Foundry Division of  $\mathbf{QCf}$  is well equipped to handle such important jobs. Four major plants include extensive facilities for casting, welding, hot and cold forging, heat treating, cutting, forming, drawing and light and heavy assembly. The division is fully prepared to produce ordnance material from any stage of develop-

ment—including such varied items as ground tanks, artillery shells, rocket sleds, armor plate, rocket engine cases, support equipment, depth charges, and many others.

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Sales Offices: New York, Chicago, St. Louis, Cleveland, Washington, D. C., Philadelphia, San Francisco. Plants: Berwick, Pa., Huntington, W. Va., St. Louis, Mo.



PRODUCTS FOR DEFENSE

## the s-cope

#### OF WHAT'S HERE AND WHAT'S COMING

from Electronics Division, Stromberg-Carlson, A Division of General Dynamics Corporation, 1466 N. Goodman Street, Rochester 3, N. Y.



#### THE SHAPE THAT MAKES MACH 5

By way of preamble, let us describe briefly the Arnold Engineering Development Center, a key Air Force installation at Tullahoma, Tennessee. This installation is being built by U. S. Army Corps of Engineers for the U. S. Air Force. (Design architects—Sverdrup & Parcel.) Its facilities will consist of wind tunnels for testing models and propulsion systems of aircraft and missiles under conditions simulating an incredibly wide range of altitude, airspeed and temperatures.

The propulsion facilities will comprise two large "closed circuit" type wind tunnels, of the same chamber size; plus compressors driven by a single set of motors developing 216,000 HP—a lot of muscle. The transonic circuit tests engines and airframes, or models, at air velocities reaching a modest Mach 1.5. The supersonic circuit can take such units to what was once the never-never land of Mach 5.

#### THE NOZZLE'S THE NUB

Just upstream of the supersonic test chamber is a variable shape nozzle, the contour of which determines what air velocity is whipped up at the test section. The nozzle walls are two flexible steel plates, each 100' long, 16' high, and 1½-3" thick. The walls, with 29 pairs of screw jacks on each, which are moved as desired, can mold the tunnel walls into any one of 300 different contours. Obviously, this is not the same as sinking a two-inch putt.

What's needed is the capacity to control these movements automatically or manually, keeping the tunnel operator visually apprized at all times of the wall positions.

So . . . where, you may ask, does Stromberg-Carlson come in?

We designed the electronic control system that positions the jacks and coordinates their motion with the required accuracy of  $\pm 0.008$ " over a seven and one-half foot travel.



Here's the nuts-and-bolts story. The control system consists essentially of 29 "station units"—one each for the set of four jacks at each tunnel station. A memory and programmer feeds the positional commands to the various station units. An input section and control console permit the selection of the various modes of operation and actuation of the necessary safeguards.

#### PULSEBEAT AND HEART

The memory is a magnetic tape on which are recorded, in block form, 29 trains of pulses, each about 40,000 pulse intervals long and corresponding to one of the 29 station units.

The heart of the station unit is a digital subtractor which compares the position of the steel plate (supplied by the position sensing system) with the commanded position obtained from the memory pulse train for that station. The difference, if any, is converted to an analog voltage which is fed to the jack motors in a direction that reduces the error.

All in all, the control system consists of 26 sevenfoot racks with functional elements packaged as plug-in printed card modules; all circuits are transistorized.

#### 200 PERCENTER

In the plant of a certain worldfamous photographic firm, shutter assemblies for roll film cameras are automatically as-

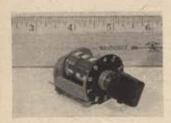
sembled and 200 per cent tested at the rate of 13,000 per day.

This feat of high-speed production and mathematically improbable testing is accomplished by combining the camera maker's production machinery with Stromberg-Carlson test gear. Assembled shutters are automatically loaded on an endless conveyor in pallets which are positioned in successive assembly and test stations. After a shutter is tested at one station, it goes through a second identical station. Thus 200%.

Stromberg-Carlson made the two identical sets of high-speed electronic measuring equipment which are integrated with the assembly facilities. During each cycle the measuring circuits are successively activated, read out and reset by programming switches synchronized with the conveyor drive—at the rate of 30 test cycles per minute per station.

At the end of the test cycle the reject circuits are read out. Reject conditions are registered on tallying counters and stored in a memory drum synchronized with the conveyor drive. Rejected assemblies are automatically sorted in bins according to certain combinations of reject conditions. They can then be adjusted and retested.

The net result of all this: a significant reduction in the number of cameras returned from the field.



#### **OUTGROWTH**

As one phase of a data link development program, ever-alert Stromberg-Carlson engineers have evolved a series

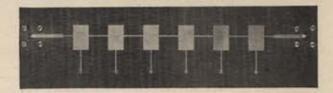
of light, small, reliable rotary binary encoding switches.

They have 10 or 26 detented positions and use 6 brush pickoffs providing standard teletype code. One brush input is common and makes continuous contact with a metallic coded area on the insulated drum surface. The other pickoff brushes make or break contact with the common brush through the coded area, depending on switch position.

We've been particularly careful in the selection of "base materials" and in the fabrication techniques we use in making these switches. The brush connectors are pins which can be dip soldered into printed boards.

While the switches are basically equivalent to rotary tap switches having 5 decks, 5 poles, nonshorting 10 and 26 positions and hence should find many applications in all types of switching, their primary application is to digital encoding where small size and high performance are what you want.

#### **OUTGROWTH AGAIN**



From a microwave development program we have evolved a series of microwave circuit elements which combine light weight, small size and (as the advertising fraternity says) best of all, low cost—with extremely low insertion loss and good termination. Through the good offices of precision printed wiring techniques, these units have been designed and operated successfully over a wide frequency range.

Illustrated here is one example, a band-pass filter. Others include antenna radiating elements, variable tuning sections and detector mounts. In certain applications these can be used singly; in others they can be combined so that they constitute, in effect, the entire r.f. section of a microwave receiver.

We've worked out designs which show very low insertion loss and exceptional impedance over wide ranges of frequency. Components have been designed for impedance levels ranging from 20 to 80 ohms.

While they have myriad applications in microwave receiving equipment, their primary destiny is to be used where low cost and small size must be combined with high performance.

You may find yourself thirsting for more data on all these matters, just for your own information. Or you may have a problem we can help solve. We offer our engineering talents and techniques. Write to Military Marketing Department at the address on the masthead.

This is the first in a series of communications outlining unique developments, processes and techniques in electronics.



#### STROMBERG-CARLSON

1466 N. Goodman St., Rochester 3, N. Y.



## A BALLISTIC MISSILE DIRECTORY

The following directory of prime contractors and major subcontractors in the nation's ballistic missile program is, to our knowledge, the most comprehensive listing of its kind ever published. At the same time, it admittedly is not complete. For example, the program is so vast in scope (much larger than the celebrated Manhattan Project for atomic-bomb development) that an abbreviated style had to be adopted. Further, specific identification of products, services, and missile systems was not always possible for security reasons. And, of course, there are thousands of suppliers to the program who are not included in this directory. The information presented is based on questionnaires sent to a list of companies provided by the services. However, since the program is dynamic and still relatively new, no list currently available can be considered complete. With these reservations, we present the directory as a pioneer effort in documenting the industry "team" engaged in developing and producing the nation's first family of space weapons.—The Editors.

## **Prime Contractors**

#### ATLAS ICBM

Development Agency: US Air Force

#### AIRFRAME AND SYSTEMS INTEGRATION

CONVAIR DIVISION OF GENERAL DYNAMICS CORP., 3165 Pacific Highway, San Diego 12, Calif.; Pres.: J. T. McNarney

Astronautics Div., 5001 Kearney Villa Rd., San Diego, Calif.; Mgr.: J. R. Dempsey

Mgr. of Operations: W. L. Young, P. O. Box 1128, San Diego, Calif.

Dir. of Scientific Research: C. L. Critchfield, 3165 Pacific Highway, San Diego, Calif.

#### PROPULSION

NORTH AMERICAN AVIATION, INC., International Airport, Los Angeles 45, Calif.; Chmn. of the Board: J. H. Kindelberger

Rocketdyne Div., 6633 Canoga Ave., Canoga Park, Calif.; V-Pres. & Gen. Mgr.: Samuel K. Hoffman

Production Mgr.: Ross Clark Chief Engineer: T. F. Dixon

#### GUIDANCE AND CONTROL

GENERAL ELECTRIC CO., 570 Lexington Ave., New York, N. Y.; Pres.: R. J. Cordiner

Missile and Guidance Section, Heavy Military Electronic Equipment Dept., Court St., Syracuse, N. Y.; Mgr.: R. L. Shetler

Mgr., Manufacturing: D. L. Johnson

Mgr., Engineering Operations: J. K. Records

BURROUGHS CORP., 6071 Second Ave., Detroit 32,

Mich.; Pres.: John S. Coleman

Defense Contracts Organization; Gen. Mgr.: Paul S. Mirabito

V-Pres., Manufacturing: Edward Kertscher, 67 35th St., Brooklyn, N. Y.

V-Pres., Research & Engineering: Dr. Irven Travis, 6071 Second Ave., Detroit 32, Mich.

#### NOSE CONE

GENERAL ELECTRIC CO., 570 Lexington Ave., N. Y., N. Y., Pres.: R. J. Cordiner

Missile and Ordnance Systems Dept., 3198 Chestnut St., Philadelphia 4, Pa.; Gen. Mgr.: G. F. Metcalf

Scientist: H. Paige

#### SYSTEMS ENGINEERING AND TECHNICAL DIRECTION

RAMO-WOOLDRIDGE CORP., 5730 Arbor Vitae St., Los Angeles 45, Calif.; Pres.: Dr. Dean E. Wooldridge Space Technology Laboratories; Pres.: Dr. Simon Ramo

Program Dir.: D. E. B. Doll Sr. Scientist: Dr. M. U. Clauser

#### AUXILIARY POWER

AMERICAN MACHINE & FOUNDRY CO., 261 Madison Ave., New York 16, N. Y.; Chmn. of the Board: Morehead Patterson

Defense Products Group, 1101 N. Royal St., Alexandria,

Va.; Exec.: S. J. Childs
Divisional V-Pres.: C. W. Adams, Broadway &
Kennedy Rd., Buffalo, N. Y.

Scientific Dir.: R. A. Kimes, 11 Bruce Pl., Greenwich, Conn.

(Continued on following page)

#### TITAN ICBM

Development Agency: US Air Force

#### AIRFRAME AND SYSTEMS INTEGRATION

THE MARTIN CO., Baltimore 3, Md.; Pres.: George M. Bunker

Denver Div., Denver 1, Colo.; V-Pres. & Gen. Mgr.: H. W. Merrill

Dir., Manufacturing: R. M. Blakey Dir., Engineering Research: A. C. Hall

#### PROPULSION

AEROJET-GENERAL CORP., 6352 N. Irwindale Ave., Azusa, Calif.; Pres.: Dan H. Kimball

Liquid Rocket Plant, Sacramento, Calif.; V-Pres.: R. B. Young

Production Mgr.: R. J. Mill

Scientist: Dr. Theodore von Kármán

#### GUIDANCE AND CONTROL

AMERICAN BOSCH ARMA CORP., 320 Fulton Ave., Hempstead, N. Y.; Pres.: C. W. Perelle

Arma Div., Roosevelt Field, Garden City, N. Y.; V-Pres. & Div. Mgr.: E. D. Gittens

Production Mgr.: W. W. Alexander

SPERRY RAND CORP., 30 Rockefeller Plaza, New York, N. Y.; Pres.: H. F. Vicker

Remington Rand Univac Div., Univac Park, St. Paul 16, Minn.; V-Pres. & Gen. Mgr.: C. W. Norris Mgr., Manufacturing Operation: J. H. Vye Chief Engineer: George S. Hanson

WESTERN ELECTRIC CO., INC., 120 B'way, N. Y. C. Radio Div., V-Pres.: F. R. Lack
Bell Telephone Laboratories, Whippany, N. J.

#### NOSE CONE

AVCO MANUFACTURING CORP., 420 Lexington Ave., New York, N. Y.; Chmn. of the Board: Victor Emanuel Avco Research Laboratory, 2385 Revere Beach Pkwy., Everett 49, Mass.; Dir.: Dr. Arthur R. Kantrowitz Lab. Mgr.: James P. Kennedy Research and Advanced Development Div., 20 S. Union St. Lawrence, Mass.: Pres.: Dr. L. P. Smith Mgr., Tech. Serv.: A. J. Maki

SYSTEMS ENGINEERING AND TECHNICAL DIRECTION RAMO-WOOLDRIDGE CORP. (see Atlas)

#### AUXILIARY POWER

AEROJET-GENERAL CORP. (see Propulsion above)

#### THOR IRBM

Development Agency: US Air Force

#### AIRFRAME AND SYSTEMS INTEGRATION

DOUGLAS AIRCRAFT CO., INC., 3000 Ocean Park Blvd., Santa Monica, Calif.; Chmn. of the Board: Donald W. Douglas, Sr.

Santa Monica Div., V-Pres. & Gen. Mgr.: L. A. Carter Chief Missiles Engineer: Elmer P. Wheaton

#### PROPULSION

NORTH AMERICAN AVIATION, INC. (see Atlas)

#### GUIDANCE AND CONTROL

GENERAL MOTORS CORP., 3044 W. Grand Blvd., De-

troit 2, Mich.; Pres.: Harlow H. Curtice

AC Spark Plug Div., 1925 E. Kenilworth Pl., Milwaukee

 Wis.; Operations Mgr.: Martin J. Caserio Works Mgr.: Roy E. McCullough Chief Engineer: Bruce H. Schwarze

#### NOSE CONE

GENERAL ELECTRIC CO. (see Atlas: Nose Cone)

SYSTEMS ENGINEERING AND TECHNICAL DIRECTION RAMO-WOOLDRIDGE CORP. (see Atlas)

#### JUPITER IRBM

Development Agency: US Army

#### AIRFRAME AND SYSTEMS INTEGRATION

CHRYSLER CORP., 341 Massachusetts Ave., Highland Park, Mich.; Pres.: L. L. Colbert

Missile Div., 6230 John R St., Detroit 31, Mich.; Group Exec.—Defense: Irving J. Minett

Dir. of Operations: H. D. Lowrey, 3811 Van Dyke Ave., Sterling Township, Mich.

Exec. Engineer: J. P. Butterfield, Sterling Township,

#### PROPULSION

NORTH AMERICAN AVIATION, INC. (see Atlas) Rocketdyne Div.

#### GUIDANCE AND CONTROL

SPERRY RAND CORP., 30 Rockefeller Plaza, New York, N. Y., Pres.: H. F. Vicker

Ford Instrument Co. Div., 31-10 Thomson Ave., Long Island City 1, N. Y., Pres. & Gen. Mgr.: Charles S. Rockwell

V-Pres., Manufacturing: Albert E. Edwards Mgr., Missile Development Div.: Lawrence S. Brown Sperry Farragut Co. Div., Bristol, Tenn.; Pres. & Gen. Mgr.: Charles S. Rockwell

#### NOSE CONE

GOODYEAR TIRE & RUBBER CO., 1144 E. Market St., Akron 16, Ohio; Pres.: E. J. Thomas

Goodyear Aircraft Corp., 1210 Massillon Rd., Akron 15, Ohio; Pres.: Thomas A. Knowles V-Pres., Production: V. L. Follo

Chief Engineer: E. A. Brittenham

#### POLARIS IRBM

Development Agency: US Navy

#### WEAPONS SYSTEM MANAGER, AIRFRAME, NOSE CONE

LOCKHEED AIRCRAFT CORP., 2555 N. Hollywood Way, Burbank, Calif.; Chmn. of the Board & Chief Exec.: Robert E. Gross

Missiles Systems Div., Sunnyvale, Calif.; Gen. Mgr.: L. E. Root

Scientist: Dr. L. N. Ridenour

#### GUIDANCE AND CONTROL

GENERAL ELECTRIC CO.

Missile and Ordnance Systems Dept. (See Atlas: Nose Cone.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, Mass.

PROPULSION

AEROJET-GENERAL CORP. (see Titan)

Solid Rocket Plant, Sacramento, Calif.; Mgr.: R. D. Geckler

Production Mgr.: F. Miller

Scientist: Dr. Theodore von Kármán

LAUNCHING & HANDLING EQUIPMENT

WESTINGHOUSE ELECTRIC CORP., 3 Gateway Center, P. O. Box 2278, Pittsburgh 30, Pa.; Pres.: Mark W. Cresap, Jr.

Sunnyvale Manufacturing Div., Hendy Ave., Sunnyvale,

Calif.; Mgr.: J. S. Hagan

Production Mgr.: R. N. Parkin

Scientist: Dr. George F. Mechlin, Jr.

TEST RANGE INSTRUMENTATION

INTERSTATE ELECTRONICS CORP., 707 E. Vermont

Ave., Anaheim, Calif.

Pres.: Paul H. Reedy

Development Dept.; Mgr. and Dir. of Development:

Dr. James F. Jenkins

## Major Subcontractors

A

ACF INDUSTRIES, INC., 30 Church St., New York 7, N. Y.

Pres.: James F. Clark

Advanced Products Div.; Pres.: R. Furrer

Rocket thrust chambers (Polaris); special pressure vessel heads, airborne storage bottles (Titan); rocket engine thrust mounts (Thor); special assembly equipment (Jupiter), airframe and missile components.

American Car and Foundry Div.; Pres.: H. H. Rogge Ground-handling equipment (Jupiter).

Avion Div., 11 Park Pl., Paramus, N. J.; Pres.: R. F. Wehrlin

Magnetic components, radar beacons (Atlas, Titan); engineering services (Jupiter).

Nuclear Products-Erco Div., P. O. Box 5, Riverdale, Md.; Pres.: Dr. Marshall G. Holloway

Maintenance training equipment (Atlas); subassembly development (Titan); substructure (Jupiter).

ADVANCE GEAR & MACHINE CORP., 5851 Holmes Ave., Los Angeles 1, Calif.

Pres.: Charles M. Piglia

Turbo pump and rocket motor gears (Atlas, Titan, Thor, Jupiter).

AERONCA MANUFACTURING CORP., Rte. 4, Middletown, Ohio.

Pres.: John A. Lawler

Tracking system, electronic cannisters, ground-support equipment, beacon encoders (Atlas).

AIR REDUCTION COMPANY, INC., 150 E. 42d St., New York 17, N. Y.

Pres.: John A. Hill

Automatic welding tooling, welding engineering service (Titan, Jupiter); industrial gases, gas-handling engineering, fuels, and oxidants, R&D.

AIRBORNE INSTRUMENTS LABORATORY, INC., 160 Old Country Rd., Mineola, N. Y.

Pres.: Hector R. Skifter

Microwave equipment components (Atlas); R&D.

AIRCRAFT ARMAMENTS, INC., Cockeysville, Md.

V-Pres. & Gen. Mgr.: Joel M. Jacobson

Flight simulators, telemetering checkout equipment

(Titan); special test equipment (Atlas).

ALLIED RESEARCH ASSOCIATES, INC., 43 Leon St., Boston 15, Mass.

Pres.: Lawrence Levy

Design studies, aerodynamics and structures, rocket and jet propulsion, nuclear weapons effects, instrumentation and systems engineering, vibration analysis, design and testing, physics and physical chemistry, vibration isolators, nuclear radiation monitoring system, solid plastic scintillators.

AMELCO, INC., 2040 Colorado Ave., Santa Monica, Calif.

Pres.: Remy L. Hudson

R&D for telemetery checkout monitors, data subcommutation equipment, instrumentation patch panels; IOC for checkout trailer, RIM building test equipment (Thor).

AMERICAN BOSCH ARMA CORP., 320 Fulton Ave., Hempstead, N. Y.

Pres.: C. W. Perelle

Chicago Div., 5851 W. 95th St., Oak Lawn, Ill.; Mgr.: A. V. Sommer

Production test ground-support equipment (Titan); equipment and field-evaluation equipment for inertial guidance systems.

AMERICAN ELECTRONIC LABORATORIES, INC., 121 N. 7th St., Philadelphia 6, Pa.

Pres.: Dr. Leon Riebman

Spectrum analyzer, low-level amplifier, ground-control boxes, ground-terminal boxes, environmental testing components and chassis (Atlas); miscellaneous test equipment (Atlas, Jupiter, Thor); telemetering antennas, crystal holders, low-pass filters.

AMERICAN MACHINE & FOUNDRY CO., 261 Madison Ave., New York 16, N. Y.

Pres.: Carter L. Burgess

Missile-handling systems (Titan).

AMPEX CORP., 934 Charter St., Redwood City, Calif.

Pres.: George I. Long, Jr.

Airborne and missile-borne laboratory, instrumentation recorders for research, test, and operations, mag-(Continued on following page) netic systems and special products research services.

AMPHENOL ELECTRONICS CORP., 1830 S. 54th Ave., Chicago 50. Ill.

Pres.: Arthur J. Schmitt

West Coast Div., 5356 W. Pico Blvd., Los Angeles, Calif., Mgr.: J. H. Schaefer

Umbilical, interstage, computer package, internal and RF connectors (Atlas, Titan); disconnect and programming connectors (Titan); umbilical and internal connectors (Thor); cable assemblies (Titan).

FRED F. ANTELLINE, 1852 Moore St., San Diego 1, Calif.

Pres.: Fred F. Antelline

Ground-handling cooling system (Atlas).

APPLIED SCIENCE CORPORATION OF PRINCETON, P. O. Box 44, Princeton, N. J.

Pres.: Thomas C. Roberts

Instrumentation Div.; Mgr.: Robert E. Navin.

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ARDE ASSOCIATES, 75 Austin St., Newark 2, N. J. Pres.: C. G. Sage

R&D, engineering and design services.

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Dir.: Dr. H. A. Leedy

Research services in special materials, ceramics, alloy, developments, propellant chemistry, combustion-chamber design.

ATLANTIC RESEARCH CORP., 901 N. Columbus St., Alexandria, Va.,

Pres.: Arch C. Scurlock

Materials evaluation (Polaris); sounding rockets, nosecone instrumentation, and instrument racks for upperair research.

ATLAS POWDER CO., Concord Pike and New Murphy Rd., Wilmington 99, Del.

Pres.: R. K. Gottshall

Explosives Div.; Gen. Mgr.: Max E. Colson

Initiators, detonators, switches, relays, boosters, primes, destructors, power cartridges; R&D for explosives and devices.

AUDIO PRODUCTIONS, INC., 630 Ninth Ave., New York, N. Y.

Pres.: Frank K. Speidell

Production of sound and color motion pictures (Titan).

AUTOMATION INSTRUMENTS, INC., 401 E. Green St., Pasadena, Calif.

Pres.: J. Randolph Richards

Aircraft Inspection Div., 7750 Monroe St., Paramount, Calif.; Mgr.: Floyd Clark

Nondestructive testing (Titan).

AVCO MANUFACTURING CORP., 420 Lexington Ave., New York, N. Y.

Board Chmn.: Victor Emanuel

Avco Research Laboratory, 2385 Revere Beach Pkway., Everett 49, Mass.; Dir.: Dr. Arthur R. Kantrowitz Research in high-temperature gas dynamics, reentry physics, shock tube, chemical physics, reentry heat transfer, are wind tunnel, magneto-hydrodynamics.

Crosley Div., 1329 Arlington St., Cincinnati 25, Ohio.

Pres.: F. C. Reith

Structures, ground-support, ground-handling equipment, guidance and control systems, acquisition and track radar system.

B

BAIRD-ATOMIC, INC., 33 University Rd., Cambridge 38, Mass.

Pres.: Davis R. Dewey, II.

R&D-electronics, infrared studies, infrared tracking system.

BABCOCK RADIO ENGINEERING, INC., 1640 Monrovia Ave., Costa Mesa, Calif.

Pres.: Ferris M. Smith

Range-safety equipment (Titan); test equipment (Atlas).

BALDWIN-LIMA-HAMILTON CORP., Philadelphia National Bank Bldg., Philadelphia 7, Pa.

Pres.: McClure Kelley

Eddystone Div., Eddystone, Pa.; Gen. Mgr.: P. A. White Support-stand mechanisms, heat-stress analysis, loading cranes, test equipment, nozzles, rings, flanges.

Electronics and Instrumentation Div., 42 Fourth Ave., Waltham 54, Mass.; V-Pres.: Robert G. Tabors

Missile launcher and measurement systems (Atlas, Titan); missile-weighing systems (Thor); thrust-measurement systems, fuel and oxidizer weight recording and engine-thrust recording systems.

Hamilton Div., 545 N. 3d St., Hamilton, Ohio; Gen.

Mgr.: Walter A. Rentschler

Machine tools, missile components (Titan).

Standard Steel Works, Burnham, Pa.; Gen. Mgr.: John D. Tyson

Aft domes and dome rings, nozzles, sustainer parts.

THE BALDWIN PIANO CO., 1801 Gilbert Ave., Cincinnati 2, Ohio

Pres.: Lucien Wulsin

Electronics Div.; Mgr.: J. H. Bruning

Analog to digital converter for instrumentation (Atlas).

THE BARDEN CORP., 33 E. Franklin St., Danbury, Conn. Pres.: J. Robert Tomlinson

Precision ball bearings.

BARRY CONTROLS INC., 813 Pleasant St., Watertown, Mass.

Pres.: Ervin Pietz

Vibration isolation systems.

BASIC TOOL INDUSTRIES, INC., 14439 S. Avalon Blvd., Gardena, Calif.

Pres.: L. C. Wiemken

Launcher and ground-supporting equipment, handling trailers and accessories, component parts and assemblies, ground systems checkout benches and supporting equipment (Atlas, Thor).

BATTELLE MEMORIAL INSTITUTE, 505 King Ave., Columbus 1, Ohio.

Pres.: B. D. Thomas

Research in nozzle and nose-cone materials, nuclear

problems, reliability of electronics components, semiconductor devices, high-temperature seals for hydraulic systems, internal and external aerodynamics, thermodynamics, stress analysis for components, highand low-temperature alloys for components, economics of materials, methods, and processes, and operations analysis.

BELL AIRCRAFT CORP., P. O. Box 1, Buffalo 5, N. Y. Pres.: Leston P. Faneuf

Special Weapons Div.; Gen. Mgr.: Glenn L. Lord. Various components.

BELOCK INSTRUMENT CORP., 112-03 14th Ave., College Point 56, N. Y.

Pres.: Harry D. Belock

Programming and switching devices (Atlas); test equipment (Jupiter); timing devices and ship-motion simulator computer (Polaris).

BENDIX AVIATION CORP., Fisher Bldg., Detroit 2, Mich.

Pres.: M. P. Ferguson

Bendix Systems Div., 327 S. 4th Ave., Ann Arbor, Mich.; Gen. Mgr.: Dr. R. D. O'Neal

Preliminary design of penetration aid.

Cincinnati Div., 3130 Wasson Rd., Cincinnati 8, Ohio;

Plant Mgr.: L. E. Rasmussen

Electronic and electro-mechanical assemblies and subassemblies, complex cable assemblies (Atlas, Titan, Thor, Jupiter, Polaris).

Computer Div., 5630 Arbor Vitae St., Los Angeles 45, Calif.; Gen. Mgr.: M. W. Horrell

Single- and three-axis flight simulators.

Eclipse-Pioneer Div., Teterboro, N. J.; Factory Mgr.: A. Drenkard

Flight-control and guidance systems, three-gyro stable platforms; two-gyro all-attitude control, programming, and stabilization devices, hydraulic, electric servo and actuating packages, low-inertia servo motors, rate and motor generators, analog-digital converters and related components for servomechanism and computing equipment, ground-support equipment (Atlas, Titan, Thor, Jupiter, Polaris).

Friez Instrument Div., 1400 Taylor Ave., Towson 4,

Md.; Gen. Mgr.: L. D. Kiley

Barometric pressure switches, acceleration switches, regulated power supplies, liquid oxygen temperature probes, timers, launching site test equipment, launching site meteorological equipment, telemetering equipment.

Pacific Div., 11600 Sherman Way, North Hollywood,

Calif.; Gen. Mgr.: R. C. Fuller

Main body telemetering, assorted hydraulic components (Atlas); nose-cone telemetering and assorted hydraulic components (Titan, Thor, Atlas); telemetering components (Jupiter); assorted hydraulic components (Polaris).

Products Div.-Missiles, 400 S. Beiger St., Mishawaka,

Ind.; Gen. Mgr.: Arthur C. Omberg

Research.

Red Bank Div., N. J. State Highway #35, Eatontown, N. J.; Gen. Mgr.: E. F. Kolar

Amplifier-type tubes (Atlas, Thor, Titan, Jupiter,

Polaris); semiconductor devices.

Scintilla Div., Sidney, N. Y.; Gen. Mgr.: G. E. Steiner Electrical connectors (Atlas, Thor, Titan, Jupiter); engine-control harnessing (Atlas, Thor, Titan, Jupiter); protected wiring assemblies (Atlas, Thor, Titan). Skinner Div., P. O. Box 135, Royal Oak, Mich.; Gen. Mgr.: Fred C. Weyburne

Filters (Jupiter, Thor).

Utica Div., 211 Seward Ave., Utica, N. Y.; Gen. Mgr.: W. Michel

High-pressure containers (Jupiter).

York Div., York, Pa.; Gen. Mgr.: H. Walker Electronic packages (Atlas).

BONE ENGINEERING CORP., 701 W. Broadway, Glendale 4. Calif.

Pres.: Wm. L. Worthen

Electroforming (Titan); ground-power support equipment (Atlas).

BORG-WARNER CORP., 310 S. Michigan Ave., Chicago 4, Ill.

Chmn. of the Board: R. C. Ingersoll

BJ Electronics, 3300 Newport Blvd., Santa Ana, Calif.; Gen. Mgr.: John R. Harkness

Vibratron transducer systems, accelerometer systems: RF test instrumentation, test equipment, environmental testing services.

York Corp., Roosevelt Ave., York, Pa.; Pres.: H. M.

Haase

Compressors, heat exchangers, precision machining and assembly, metal fabrications, refrigeration valves and fittings, refrigeration and air-conditioning applications, field installation and service.

BROADVIEW RESEARCH CORP., 1127 Chula Vista Ave., Burlingame, Calif.

Pres.: Richard De Lancie

Applied Physics Div.; Dir.: Dr. Boris Ragent

Research for fuel explosive hazards, heat, and mass transfer, fluid dynamics (Atlas).

BROOKS & PERKINS, INC., 1950 W. Fort St., Detroit 16, Mich.

Pres.: E. Howard Perkins

Various components (Atlas); nose cones, missile, and airplane airframe assemblies.

THE BRUSH BERYLLIUM CO., 43401 Perkins Ave., Cleveland 3, Ohio

Pres.: Bengt R. F. Kjellgren

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C

CADILLAC GAGE CO., P. O. Box 3806, Detroit 5, Mich. Pres.: R. E. Bauer

Hydraulic control systems (Atlas, Thor, Titan, Jupiter).

CALCOR CORP., 1620 N. Spring St., Los Angeles 53, Calif.

Pres.: Andy F. Brown

Electronic consoles and cabinets, motor mounts, ducts, hose assemblies (Atlas, Thor, Jupiter).

CALIFORNIA AIRCRAFT PRODUCTS, 790 Greenfield Dr., El Cajon, Calif.

Pres.: John Straza

Chemical Milling Div., 4102 E. Main St., Grand Prairie, Tex.; Gen. Mgr.: Nelson Sherman

Hi-temperature (Atlas); sheet-metal assemblies (Thor); chemical-milled skins (Atlas, Thor).

(Continued on page 142)

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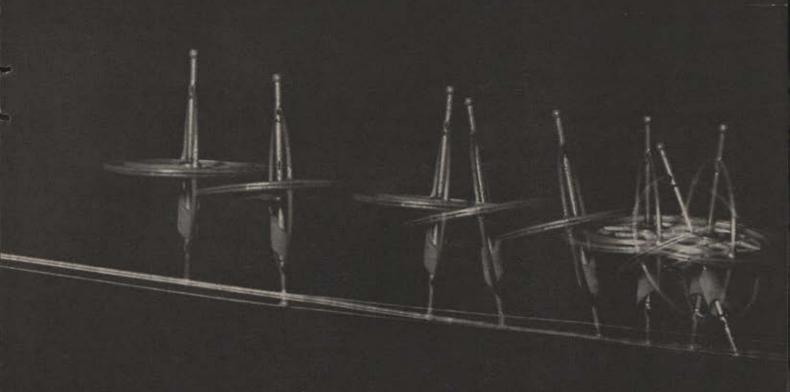
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- 3. Grand Bahama AAFB
- 4. Eleuthera AAFB
- 5. San Salvador AAFB
- 6. Mayaguana AAFB
- 7. Grand Turk AAFB 8. Dominican Rep. AAFB
- 9. Mayaguez AAFB
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Land-Air, Inc., 7444 W. Wilson Ave., Chicago 31, Ill. Pres.: Martin T. Dyke

Range instrumentation and operations services, ground-support services, ground-support equipment, R&D for range-instrumentation and ground-support equipment.

CAMBRIDGE CORP., 2 Industrial Park, Lowell, Mass. Pres.: John W. Logan

Lox pumping and fuel-pumping systems (Atlas), lox tanks (Thor); lox trailers (Jupiter).

CHALCO ENGINEERING CORP., 15126 S. Broadway, Gardena, Calif.

Pres.: C. R. Heimbuch

Ground-handling equipment, production-test equipment, instrumentation-recording systems, engineering research and development (Atlas).

THE CHAMPION CO., 400 Harrison St., Springfield, Ohio. Pres.: M. E. Baker

Special Products Div.; Mgr.: Joe C. Mills

Metal shipping containers (Thor, Jupiter, Atlas); pressure vessels (Titan).

CHICAGO MIDWAY LABORATORIES, The University of Chicago, 6220 S. Drexel Ave., Chicago 37, Ill. Dir.: T. R. Hogness

R&D on reentry problems (Atlas, Titan); guidancesystem analysis (Atlas).

CHRISTIE MACHINE WORKS, 201 Harrison St., San Francisco 5, Calif.

Pres.: A. Edwin Christie

Rotor turbine wheels (Atlas, Titan); connecting levers, pistons, valves, racks, shafts, actuators, flange combustion chambers, ring flanges, pump seals, lox swivel assemblies, gearbox seals, gimbal ring supports, nozzle assemblies, flange oxide pump, manifold axial combustion chamber ring (Titan).

CLARY CORP., 408 Junipero St., San Gabriel, Calif. Pres.: Hugh L. Clary

Clary Dynamics Div.; Pres.: Paul J. Meeks Gyros, servo actuators (Atlas).

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Pres.: R. T. Silberman

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Components for test instrumentation and data-processing.

CONSOLIDATED AVIONICS CORP., 800 Shames Dr., Westbury, L. I., N. Y.

Pres.: H. R. Glixon

Automatic checkout equipment (Titan); data-reduction systems, telemetry systems, instrumentation recorder.

CONSOLIDATED ELECTRODYNAMICS, 300 N. Sierra Madre Villa, Pasadena, Calif.

Pres.: Hugh F. Colvin

Automatic data-processing systems (Titan, Atlas, Jupiter); magnetic-tape systems (Polaris); recording oscillographs (Titan, Jupiter, Thor); shock tester (Polaris, Titan, Atlas); propellant checkout system (Atlas); transducers (Atlas, Titan, Thor).

CONTROL DATA CORP., 501 Park Ave., Minneapolis 4, Minn.

Pres.: William C. Norris

Control systems, digital and analog computers, ground-checkout equipment, gyroscopes, accelerometers, inertial-navigation devices, servo motors, autopilots.

COOK ELECTRIC CO., 2700 N. Southport Ave., Chicago 14, Ill.

Pres.: Walter C. Hasselhorn

Evaluation instrumentation and telemetry systems, evaluation data-reduction service (Atlas).

Cook Research Laboratories, 6401 Oakton Ave., Morton Grove, Ill.; Dir.: Dr. J. Robert Downing

Nose-cone recovery systems (Atlas, Thor, Jupiter); perforated tape reader (Atlas).

Cinefonics, Inc., 2700 N. Southport Ave., Chicago 14, Ill.; Pres.: Charles O. Probst

Film production services (Jupiter); reentry nose-cone recovery system, product films, progress reports, briefing films.

Electronic Systems Div., 8100 Monticello Ave., Skokie, Ill.; Mgr.: Earl Washburn

Missile range instrumentation, automatic drive theodolite acquisition equipment applicable for all systems.

CUMMINS ENGINE CO., INC., 1000 Fifth St., Columbus, Ind.

Pres.: R. E. Huthsteiner

Ground power equipment (Thor).

CUSHING & NEVELL, 101 Park Ave., New York 17, N. Y.

Partner: George Cushing

Technical data, training material (Atlas, Titan); various systems of the missile program.

D

DAVIDSON MANUFACTURING CO., 2223 Ramona Blvd., West Covina, Calif.

Pres.: Don E. Davidson

Azimuth alignment theodolite (Thor, Atlas, Jupiter, Polaris); optical assemblies (Thor, Atlas); automatic autocollinator (Atlas); optical test instruments.

DENVER RESEARCH INSTITUTE, University of Denver, University Park Campus, Denver 10, Colo.

Dir.: Shirley A. Johnson, Ir.

Research—nose cone materials (Atlas, Thor); inertial-guidance platform (Thor); explosives, stage detachment system, airframe and structures, high-temperature lubricants, cable impedance, aluminum weldments (Titan); auxiliary power supply (Atlas).

DESIGN SERVICE CO., INC., 76 Ninth Ave., New York 11, N. Y.

Pres.: A. A. Signorelli

Item descriptions (Atlas); technical manuals, design and drafting, illustrated parts breakdowns, provisioning parts breakdowns, animated visual displays, technical services (Thor).

ALLEN B. DUMONT LABORATORIES, INC., 750

Bloomfield Ave., Clifton, N. J.

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System test equipment, gyro test equipment, amplifiers, displays, militarized closed circuit TV equipment, radio inertial missile equipment monitor.

DUNLAP AND ASSOCIATES, INC., 429 Atlantic St., Stamford, Conn.

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Human engineering (Thor, Polaris); performance evaluation, training requirements studies (Thor); training program evaluation, maintenance programming (Polaris).

DYNAC, INC., 395 Page Mill Rd., Palo Alto, Calif.

Pres.: R. E. Rawlins

Radar simulators, custom instrumentation systems, aircraft and missile checkout systems, ground-support instrumentation systems.

THE EAGLE-PICHER CO., American Bldg., Parkway & Walnut, Cincinnati 2, Ohio.

V-Pres.: Miles M. Zoller

Couples Div., C & Porter Sts., Joplin, Mo.

Gen. Mgr.: Miles M. Zoller

Primary and secondary batteries, silver zinc, nickelcadmium and thermal cells.

EASTMAN KODAK CO., 343 State St., Rochester 4, N. Y. Pres.: Dr. A. K. Chapman

Apparatus and Optical Div., 400 Plymouth Ave., North Rochester 4, N. Y.; Vice-Pres. and Gen. Mgr.: N. B. Green

Power supplies, instrumentation, telemetering, beacon, computers, miss-distance indicators, closed loop television, safety and arming systems, precision, mechanical and optical devices.

ELECTROMAGNETIC RESEARCH CORP., 711 14th St., N.W., Washington 5, D. C.

Pres.: Martin Katzin

Nose-cone antenna design (Atlas).

ELECTRO-MECHANICAL RESEARCH, INC., P. O. Box 3041, Sarasota, Fla.

Pres.: J. C. Legrand

Airborne telemeter and ground-station acquisition and data (Atlas, Titan); reduction equipment (Thor, Jupiter, Polaris).

ELECTRONIC ENGINEERING CO., 1601 E. Chestnut St., Santa Ana, Calif.

Pres.: Burgess Dempster

Data-processing systems (Thor, Atlas); timing and launching systems for test (Atlas, Thor, Jupiter, Po-

ELLIOTT ENGINEERING CO., INC., 2800 E. Century Blvd., Lynwood, Calif.

Pres.: J. O. George

Metallic ducting, liquid oxygen lines, bellows, precision machine work (Atlas, Titan); metallic ducting, precision machine work (Thor); lox lines, bellows, welded assemblies (Jupiter).

EL-TRONICS, INC., 1360 Suburban Station Building, Philadelphia 3, Pa.

Pres.: Thomas P. Tanis

Warren Components Div., S. Irvine St., Warren, Pa.;

V-Pres.: David Cropp

Integrating accelerometer switch for nose cones, lox fill and drain sensor switch, humidity-sensing system, seals for altitude controls.

EMERSON RADIO & PHONOGRAPH CORP., 14th & Cole Sts., Jersey City, N. J.

Pres.: Benjamin Abrams

Government Electronics Div., 14th & Cole Sts., Jersey City, N. J.; Gen. Mgr.: Dorman D. Israel Cable harness, programmers (Atlas).

EPSCO, INC., 588 Commonwealth Ave., Boston 15, Mass. Pres.: Bernard M. Gordon

Automatic telemetry reduction systems (Atlas); datastorage components (Titan).

FEDERAL MANUFACTURING & ENGINEERING CORP., 1055 Stewart Ave., Garden City, N. Y.

Pres.: James K. Malone

Vibration isolators (Atlas).

FOOD MACHINERY AND CHEMICAL CORP., 1105

Coleman Ave., San Jose 3, Calif. Chmn. of the Board: Paul L. Davies

Ordnance Div.; Mgr.: James M. Hait

Florida Div., Fairway Ave., Lakeland, Fla.; Mgr.: Howard L. Shannon

Becco Chemical Div., P. O. Station B, Buffalo, N. Y.; Pres.: Frederick A. Gilbert

Transporter, launcher, and power-control trailer (Thor).

THE FRANKLIN INSTITUTE OF STATE OF PENN-SYLVANIA, 20th & Benjamin Franklin Pkwy., Philadelphia 3, Pa.

Exec. V-Pres.: J. S. Burlew

Laboratories for Research and Development; Dir.: Nicol H. Smith

Electro-hydraulic servo systems, test stand vibration analysis, special hydraulic studies, inertial load simulators and linear accelerators for testing, ship motion simulator studies (Jupiter); measurements of thermal properties at extreme temperatures (Thor, Atlas); shipboard missile installations (Polaris, Jupiter); highspeed friction studies for nose-cone reentry (Atlas); supporting research and development on fuzing, safety, and arming systems.

FRUEHAUF TRAILER CO., 10940 Harper St., Detroit 32, Mich.

Pres.: Roy Fruehauf

Missile Products Div.; Mgr.: E. R. Neumann

Ground-handling equipment (Thor, Atlas, Titan, Polaris, Jupiter).

GEORGE A. FULLER CO., 597 Madison Ave., New York 22, N. Y.

Pres.: Ray C. Daly

Los Angeles Div., 3100 W. 8th St., Los Angeles 5, Calif.; V-Pres.: William V. Lawson

Production center, test stands, calibration and test building, sodium reactor, test facility, cold flow laboratory, engineering and production fixtures.

(Continued on following page)

FUTURECRAFT CORP., 1717 N. Chico Ave., El Monte, Calif.

Pres.: Meyer Piet

Propellant valves, explosive valves (Titan, Atlas).

G

G. W. GALLOWAY CO., 220 S. First Ave., Arcadia, Calif. Pres.: G. W. Galloway

Construction Div., Arcadia, Calif.; Construction Mgr.: R. H. Dibley

Tanks (Polaris); high-pressure piping systems, fuel transfer and storage facilities, pneumatic instrumentation lines (Atlas); turbo-pump and high-flow test facilities.

GENERAL BRONZE CORP., 711 Stewart Ave., Garden City, N. Y.

Dir. of Electronics: Ira Kamen

Missile-tracking antenna systems, conical scanners, wave guide systems, antenna research, telemetry antennas, microwave systems.

GENERAL DYNAMICS CORP., 445 Park Ave., New York 22, N. Y.

Pres.: Frank Pace, Jr.

Stromberg-Carlson Co., 100 Carlson Rd., Rochester, N. Y.; Pres.: R. C. Tait

Special test equipment (Atlas).

GENERAL METALS CORP., 220 Bush St., San Francisco, Calif.

Pres.: W. E. Butts

Adel Precision Products Div., 10777 Van Owen St., Burbank, Calif.; Gen. Mgr.: C. W. Eliason Valves (Atlas).

GENERAL MILLS, INC., 400 Second Ave. S., Minneapolis, Minn.

Pres.: Charles H. Bell

Mechanical Div., 1620 Central Ave., Minneapolis, Minn. R&D.

GENERAL PLANT PROTECTION CORP., 2515 W. 7th St., Los Angeles, Calif.

Pres.: Ralph E. Davis

Plant protection and industrial security services.

GENERAL MOTORS CORP., 3044 W. Grand Blvd., Detroit 2, Mich.

Pres.: Harlow H. Curtice

New Departure Div., 269 N. Main St., Bristol, Conn.; Gen. Mgr.: Seth H. Stover

High precision instrument and miniature ball bearings.

GENERAL PRECISION EQUIPMENT CORP., 92 Gold St., New York, N. Y.

Pres.: Herman G. Place

Librascope, Inc., 808 Western Ave., Glendale, Calif.; Pres.: Lewis W. Imm

Visual display ground equipment (Atlas).

GOODYEAR TIRE & RUBBER CO., 1144 E. Market St., Akron 16, Ohio

Pres.: E. J. Thomas

Goodyear Aircraft Corp., 1210 Massillon Rd., Akron 15, Ohio; Pres.: Thomas A. Knowles Ground-support (Atlas).

GOULD-NATIONAL BATTERIES, Pleasant St., East-hampton, Mass.

Pres.: G. B. Ellis

Nickel Cadmium Div.; Pres.: G. B. Ellis

Nickel cadmium storage batteries, aircraft-starting batteries.

THE GRISCOM-RUSSELL CO., Massillon, Ohio

Pres.: Kenneth B. Ris

Heat-exchanger equipment.

GRUEN INDUSTRIES, INC., Time Hill, Cincinnati 6, Ohio

Pres.: Edward H. Weitzen

Gruen Precision Laboratories, Cincinnati, Ohio; Dir. of Eng. & Mfg.: Philip H. Borden

Inertial test equipment (Atlas); safety and arming devices (Jupiter); inertial guidance components.

Gruen Applied Science Div., 60 Hempstead Ave., Hempstead, L. I., N. Y.; Exec. V-Pres.: Dr. Antonio Ferri

R&D, aerodynamics and propulsion, dynamics and electronics (Atlas).

H

B. H. HADLEY, INC., 1427 S. Garey Ave., Pomona, Calif.

Pres.: B. H. Hadley

Liquid oxygen and fuel regulators, assorted valves, coupling assemblies (Atlas); gates, retainers, assemblies, rings.

PAUL HARDEMAN, INC., 10955 W. Pico Blvd., Los Angeles 64, Calif.

Pres.: Paul Hardeman

Electronic, pneumatic, hydraulic instrumentation design, fabrication and installation, fuel-handling, design and fabrication, environmental design and installation, general construction, engineering (Atlas, Titan, Thor, Jupiter).

HENNEY MOTOR CO., Inc., P. O. Box 1157, Stamford, Conn.

Pres.: C. Russell Feldmann

Oneida Products Div., Canastota, N. Y.; V-Pres.; C. W. Trout

Vans for electronics equipment (Atlas).

HERLO ENGINEERING CORP., 549 N. Prairie Ave., Hawthorne, Calif.

Pres.: Robert E. Cole

Machined parts and component assemblies; fuel and relief valves (Atlas, Thor, Jupiter).

THE HICKS CORP., 1671 Hyde Park Ave., Hyde Park, Mass.

Pres.: Thomas Wheeler

Booster and JATO cases (Polaris).

HITEMP WIRES, INC., 1200 Shames Dr., Westbury, N. Y.

Pres.: George F. Rolfe

Cables (Titan, Atlas); wire, engineering assistance, (Atlas, Jupiter).

(Continued on page 148)

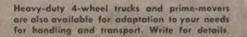
### Mild exercise for "Bertha"

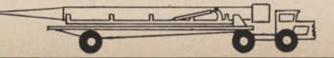
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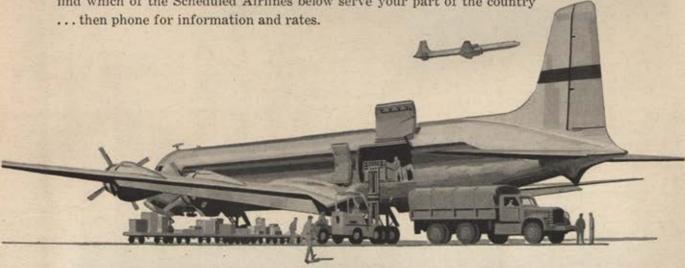
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Los Angeles, Calif.

Pres.: R. C. Wilcox

Photographic and film-processing equipment, remotecontrol parabolas for radar tracking, reflectors.

THE HUFFORD CORPORATION, 1700 E. Grand Ave.,

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Pres.: M. L. Bengston

Launching platforms, missile check stands, launching parts, hydraulic packages for launchers (Titan, Po-

HUNTER-BRISTOL CORP., Emilie Rd., Bristol, Pa.

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Test sleds (Titan); support equipment (Atlas).

INTER-CONTINENT ENGINEERING CO., 1520 N.

Highland Ave., Los Angeles 28, Calif.

Pres.: James T. Jury

Engineering services, test stands, guidance systems (Jupiter, Polaris).

INTER-CONTINENT ENGINEERING CO. OF SAN FRANCISCO, 301 Market St., San Francisco 5, Calif.

Pres.: James T. Jury

Engineering services, test stands, guidance systems (Jupiter, Polaris).

INTERSTATE ENGINEERING CORP., 707 E. Vermont St., Anaheim, Calif.

Pres.: F. E. Booth

Undercarriage for support equipment (Thor).

Interstate Electronics Corp.; Pres.: Paul H. Reedy Study and master planning for test instrumentation, complete electronics system for test instrumentation (Polaris); scaler amplifiers for telemetered data handling (Atlas).

Interstate Precision Products Corp.; V-Pres.: M. G.

Electric shut-off values, vernier drive sector, gear valve tank vent assembly, cylinders, valves, actuators, compensator (Atlas); valves (Titan).

K

KAISER INDUSTRIES CORP., 1924 Broadway, Oakland 12, Calif.

Pres.: Edgar F. Kaiser

Kaiser Aircraft & Electronics; V-Pres. & Gen. Mgr.: Clay P. Bedford

Fabrication and assembly of unit components, manufacture of aluminum test capsules (Polaris); machining of missile propulsion unit components (Titan).

KAISER STEEL CORP., 1924 Broadway, Oakland, Calif.

V-Pres. & Gen. Mgr.: Jack L. Ashby

Test towers, flame deflectors (Atlas); erector towers, umbilical towers, flame deflectors (Titan).

KEARFOTT CO., INC., 1150 McBride Ave., Little Falls, N. J.

Pres.: D. W. Smith

Gyros (Atlas, Titan, Polaris, Jupiter); components (Atlas, Titan, Polaris, Jupiter, Thor); inertial guidance.

KIRK ENGINEERING CO., 1776 S. Robertson St., Los Angeles, Calif.

Pres.: Thomas L. Kirk

Eastern Div., 910 Bankers Securities Bldg., Philadelphia 7, Pa.; Mgr.: Theodore A. Raymond

Contract and consulting engineering, engineering services (Atlas, Jupiter, Titan, Polaris, Thor).

LADISH CO., 5481 S. Packard Ave., Cudahy, Wis.

Pres.: V. F. Braun

Pacific Div., 3321 E. Slauson Ave., Los Angeles 58. Calif.; Mgr.: H. C. Ende

Drop forgings, press forgings, rolled rings.

LEACH CORP., 18435 Susana Rd., Compton, Calif.

Pres.: K. F. Julin

Inet Div.; Gen. Mgr.: K. F. Julin

Ground power units (Atlas); synchronous motor generators (Jupiter); variable frequency motor generator (Thor); MG sets (Titan).

Relay Div., 5915 S. Avalon Blvd., Los Angeles 3, Calif.

Gen. Mgr.: K. F. Julin

Electrical relays and contractors, ground-support equipment (Atlas, Thor, Jupiter, Titan, Polaris).

ARTHUR D. LITTLE, INC., 30 Memorial Dr., Cambridge 42. Mass.

Pres.: Raymond P. Stevens

Engineering Div., 20 Acorn Park, Cambridge 40, Mass.; V-Pres.: Allen Latham, Jr.

Cryogenic consultants (Atlas, Titan, Thor).

LITTON INDUSTRIES, INC., 336 N. Foothill Rd., Beverly Hills, Calif.

Pres.: Charles B. Thornton

Litton Industries of Maryland, Inc., 4910 Calvert Rd., College Park, Md.; Gen. Mgr.: Russell W. McFall

Telemetering system (Jupiter); precision components, study of warhead control systems.

Electron Tube Div., 960 Industrial Rd., San Carlos, Calif.; Mng. Dir.: Dr. Norman H. Moore

Magnetrons (Atlas, Thor); traveling wave tubes, gas tubes, and noise sources (Atlas).

M

MACHINE ENGINEERING CO., INC., 5110 E. 15th St., Tulsa 12, Okla.

Pres.: I. W. Carter

Tooling, design and production parts (Titan).

THE W. L. MAXSON CORP., 475 Tenth Ave., New York 18, N. Y.

Pres.: H. A. Leander

Safety and arming device (Thor); guidance systems, flowmeters (Atlas).

McGRAW-HILL BOOK CO., INC., 330 W. 42d St. New York 36, N. Y.

Pres.: Curtis G. Benjamin Texts and reference books.

MELPAR, INC., 3000 Arlington Blvd., Falls Church, Va. Pres.: Thomas Meloy

Ordnance devices (Jupiter); radar beacons (Atlas, Titan, Thor); antennas, antenna-test equipment (Atlas).

MILGO ELECTRONIC CORP., 7601 N. W. 37th Ave., Miami 47, Fla.

Pres.: Monroe A. Miller

Sequence programmers (Atlas, Titan, Thor, Polaris); analog coordinate conversion equipment (Atlas, Thor, Titan); data-transmission equipment, timing equipment (Atlas, Thor).

MILLER METAL PRODUCTS, INC., 2215 Russell St., Baltimore 30, Md.

Pres.: M. M. Miller

Research Laboratories Div., 2832 Maisel St., Baltimore 30, Md.; Exec. V-Pres.: H. C. Filbert

Automatic checkout test systems, dynamic balancing equipment, moment of inertia, weight and CG measuring equipment (Atlas, Thor, Titan); missile-tracking and location systems, automation of production equipment (Atlas, Thor).

MINNEAPOLIS-HONEYWELL REGULATOR CO., 2753 Fourth Ave. S., Minneapolis 8, Minn.

Pres.: Paul B. Wishart

Military Products Group, 2600 Ridgway Rd., Minneapolis 13, Minn.; V-Pres. in Charge: Stephen F. Keating Guidance, warhead and fuzing ground-handling (Atlas); reference guidance system (Titan); guidance, warheads, fuzing, and ground-support components (Atlas, Polaris, Titan, Thor).

MODERN DIE & TOOL CORP., 5901 S. Avalon Blvd., Los Angeles 3, Calif.

Pres.: John G. Buyser

Gimbal assemblies, machined components.

#### N

NARMCO MANUFACTURING CO., 5159 Baltimore Dr., Las Mesa, Calif.

Pres.: N. F. Trost

Exterior sandwich pods, bulkheads (Atlas).

NATIONAL CO., INC., 61 Sherman St., Malden, Mass. Chmn. of the Board: Herbert C. Guterman

Test and checkout equipment (Atlas); telemetering equipment (Polaris); communication systems, radio engineering.

NELSON TECHNICAL ENTERPRISES, INC., 116% W. Main St., St. Charles, Ill.

Pres.: Donald A. Nelson

Reliability test program, maintenance handbooks (Atlas).

NORDEN-KETAY CORP., 58 Commerce Rd., Stamford, Conn.

Pres.: P. R. Roehm

Instrument and Systems Div., Wiley St., Milford, Conn. Gen. Mgr.: Ernest J. Greenwood

Pendulum test set (Atlas); stable platform (Titan).

Norden Laboratories Div., 121 Westmoreland Ave.,
White Plains, N. Y.; Tech. Dir.: C. F. Schaefer
Guidance and control (Titan); stabilization-measuring
instruments (Polaris); digital techniques, simulation

NORTH ELECTRIC CO., 553 South Market St., Galion, Ohio

Pres.: Hans Kraepelien

facilities (Atlas).

Telephone-type relays, telephone communications, and tone-signaling equipment, various ground-support equipment.

#### 0

OAKLAND MACHINE WORKS, 561 4th St., Oakland, Calif.

Owner: Walter N. Fanning

Parts and tooling for solid and liquid engines.

#### P

PACIFIC AUTOMATION PRODUCTS, INC., 1000 Air Way, Glendale, Calif.

Pres.: Frank Gard Jameson Cable system (Atlas).

PACKARD-BELL ELECTRONICS CORP., 12383 W. Olympic Blvd., Los Angeles 64, Calif.

Pres.: Robert S. Bell.

Ground-support equipment (Thor).

J. C. PEACOCK, INC., 1673 E. 82d Pl., Los Angeles 1, Calif.

Pres.: J. C. Peacock

Lox, quick disconnects, accumulators, hydraulic actuators (Atlas); valves, regulators.

PELTON STEEL CASTING CO., 148 W. Dewey Pl., Milwaukee 7, Wis.

Pres.: Allen M. Slichter

Pacific Alloy Engineering Corp., 400 Raleigh Ave., El Cajon, Calif.; Gen. Mgr.: Walter H. Dunn Castings (Titan, Polaris).

THE PERKIN-ELMER CORP., Main Ave., Norwalk, Conn. Pres.: Richard S. Perkin

Engineering and Optical Div.; Mgr.: Roderick M. Scott Azimuth-alignment theodolite (Thor, Jupiter); precision optics, R&D.

PHILCO CORP., C & Tioga Sts., Philadelphia, Pa. Pres.: James M. Skinner, Jr.

Philco TechRep Div.; V-Pres.: Robert F. Herr Service (Jupiter).

PHILLIPS-CARTER-OSBORN, INC., 831 14th St., Denver 2, Colo.

Pres.: Orley O. Phillips

Engineering service for test facilities (Titan).

PLANNING RESEARCH CORP., 10966 Le Conte Ave., Los Angeles 24, Calif.

Pres.: Robert W. Krueger

Unit-proficiency training for ground-guidance systems, AICBM studies (Atlas).

(Continued on following page)

POTTER INSTRUMENT CO., Sunnyside Blvd., Plainview, N. Y.

Pres.: John T. Potter

Digital magnetic tape handling systems, high-speed electronic printing systems, tape handler, counting equipment.

PRECISION SHEET METAL, INC., 5235 W. 104th St., Los Angeles 45, Calif.

Pres.: O. E. Podeyn

Fabricators of precision components (Atlas, Titan,

THE PYLE-NATIONAL CO., 1334 N. Kostner Ave., Chicago 51, Ill.

Pres.: William C. Croft

Electrical connectors, cable systems, and electrical equipment used in conjunction with support facilities (Thor, Jupiter).

RADIAPHONE CO., INC., 600 E. Evergreen Ave., Monrovia, Calif.

Pres.: Marshall Setnan

Data-acquisition and recording system, patch panel custom consoles, calibrating test carts (Atlas).

RADIO CORPORATION OF AMERICA, 30 Rockefeller Plaza, New York, N. Y.

Pres.: J. J. Burns

Defense Electronic Products Div., Front & Cooper Sts., Camden 2, N. J.; Exec. V-Pres.: A. L. Malcarney Electrical control assembly (Thor); ground checkout equipment (Atlas); instrumentation (Jupiter).

REACTION MOTORS, INC., Ford Rd., Denville, N. J. Pres.: R. W. Young

Propulsion system components (Atlas, Jupiter).

REEVES INSTRUMENT CORP., Roosevelt Field, Garden City, N. Y.

Pres.: D. T. Bonner

Star tracker, stable platforms, high-precision gyros (Polaris); resolvers (Atlas); gyros reference and programmer (Titan); instrumentation radars.

RELIANT INDUSTRIES, 4935 Firestone Blvd., South Gate, Calif.

Secy.-Treas.: R. W. Stevenson

Liquid oxygen tanks (Atlas); motor mounts, line assemblies (Atlas, Thor, Jupiter).

RESEARCH WELDING & ENGINEERING CO., INC., 18201 S. Santa Fe Ave., Compton, Calif.

Pres.: John A. Toland

Pressure vessels (Atlas, Thor).

RHEEM MANUFACTURING CO., 400 Park Ave., New York 22, N. Y. Pres.: A. L. Walker

Aircraft Div., 11711 Woodruff Ave., Downey, Calif.; Gen. Mgr.: L. M. Limbach

Titanium pressure vessel (Atlas).

RIVERSIDE PLASTICS CORP., Miller Rd., Hicksville,

Pres.: H. C. Tomford

Reinforced plastic parts, radomes, honeycomb laminates, high-temperature phenolic molding.

#### S

SANCOR CORP., 1700 E. Grand Ave., El Segundo, Calif. Pres.: M. L. Bengston

Hydraulic carriers and conveyors for ground handling (Titan, Polaris).

SERVOMECHANISMS, INC., 12500 Aviation Blvd., Hawthorne, Calif.

Pres.: William W. Shannon

Subsystems Div.; Gen. Mgr.: Gerard Q. Decker

Transducers, pitot and static pressure, angle of pitch and yaw, high range altimeter.

Magnetics Div., 1000 W. El Segundo Blvd., Hawthorne, Calif.; Mgr.: William T. Smither

Transformers, reactors, chokes, coils (Thor).

Mechatrol Div., 625 Main St., Westbury, L. I., N. Y.; Mgr.: John J. Dempsey

Synchronous motors (Atlas, Jupiter, Polaris, Titan).

THE SIEGLER CORP., 8352 Brookhurst Ave., Anaheim, Calif.

Pres.: John G. Brooks

Hallamore Electronic Co.; Pres: Lloyd G. Hallamore Telemetering systems, missile checkout equipment, ground-support equipment (Atlas); instrumentation (Titan, Polaris, Jupiter).

SNAP-TITE, INC., 201 Titusville Rd., Union City, Pa. Pres.: Malcolm S. Clark Quick-disconnect (Titan).

SOLAR AIRCRAFT CO., 2200 Pacific Highway, San Diego 12, Calif.

Pres.: Herbert Kunzel

Components (Atlas); combustion chambers and bellows (Titan); tank parts (Polaris); ducting (Jupiter).

SOLON FOUNDRY, INC., 6370 Som Center Rd., Solon, Ohio.

Pres.: A. M. Hubman

Som Precision Industries, Inc.; V-Pres.: D. S. Smith Aluminum and magnesium sand castings.

SONOTONE CORP., Box 200, Elmsford, N. Y. Pres.: I. I. Schachtel

Rechargeable storage battery (Titan, Thor, Polaris); electronic tubes (Atlas, Jupiter).

SOROBAN ENGINEERING, INC., Kissimmee Highway, Melbourne, Fla.

Pres.: Charles F. West

Digital-computer equipment, test-equipment sequencers, controllers, perforated tape recorders, readers and tabulators.

SPACE CORP., P. O. Box 5175, Garland, Tex.

Pres.: M. G. Hughett

Weight- and thrust-measurement system (Atlas, Titan); erector actuation (Titan).

STANDARD-THOMSON CORP., 152 Grove St., Waltham 54, Mass.

Pres.: John E. Woods

(Continued on page 154)



### ENGINEERING BEYOND THE EXPECTED

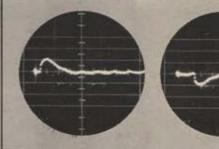
DESIGN—When time dictates, available equipment can be adapted to your specifications. But you receive custom design, beyond the expected, when you need it. For example, the transistorized MAGAMP power supply (right). This unit provides a faster response time... a lower overshoot and undershoot... and remote regulation at longer distances than has ever been achieved before with this type of power supply.

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time-consuming delays. A reliable source, any way you look at it. And a reliable way to rid yourself of a major

The MAGAMP has a surge capacity of 400% overload for 2 seconds. Regulation at the load is 1% or better. Recovery time is less than 50 milliseconds. Overshoot and undershoot are less than 25%, with a 30% change in load. (Scale in above photos: 5V/CM and .10MS/CM.)



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Bulletin TC-108 A . . . Describes properties, etc. of Arnold Bobbin Cores.

Bulletin PC-109... Essential data on Arnold Iron Powder Cores.

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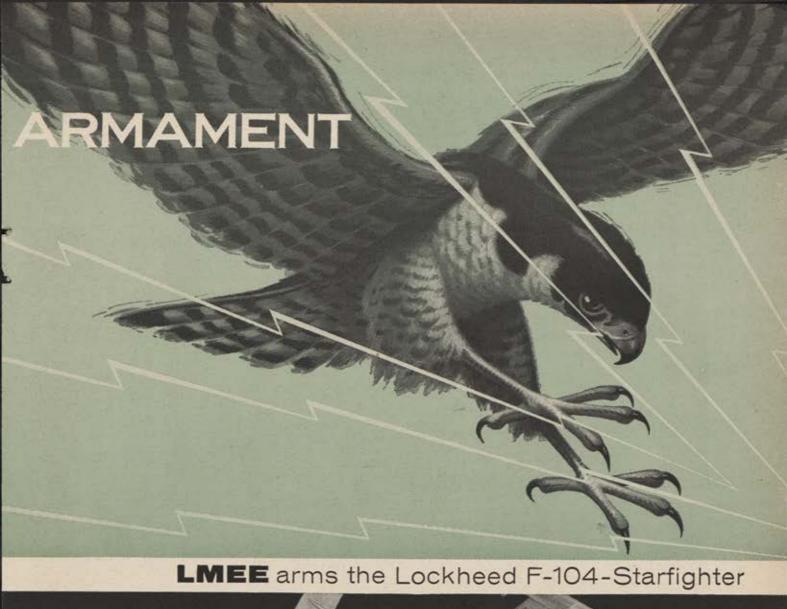
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STEWART & STEVENSON SERVICES, INC., 4516 Harrisburg Blvd., Houston 1, Tex.

Chmn.: Ross Stewart

Ground powerplant (Atlas).

SUN ELECTRIC CORP., 6323 Avondale Ave., Chicago 31, Ill.

Pres.: R. R. Malik

Hydraulic test and support equipment (Titan).

T

THE TALCO ENGINEERING CO., 2685 State St., Hamden, Conn.

Pres.: F. G. Talley

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TELE-DYNAMICS, INC., 5000 Parkside Ave., Philadelphia 31, Pa.

Pres.: E. E. Lewis

Telemetering systems (Titan); telemetering components (Thor); command-actuate receivers (Titan, Polaris).

A. S. THOMAS, INC., 161 Devonshire St., Boston 10, Mass

Pres.: Abdelnour S. Thomas

Consultants on research, design and development of antennas (Atlas, Titan).

THOMPSON PRODUCTS, INC., 28555 Euclid Ave., Cleveland 17, Ohio

Pres.: J. D. Wright

Jet Div.; Mgr.: S. C. Pace

Rocket engine ejector nozzles, nose and frame structures, high- and low-pressure tanks.

Accessories Div.; Mgr.: P. T. Angell

Accessory power systems, ground-handling systems, fuel systems, precision-machined parts.

Electronics Div., 2196 Clarkwood Rd., Cleveland 3, Ohio; Mgr.: W. M. Jones

Electronic control systems and components.

TITANIUM FABRICATORS, INC., 3906 Cohasset St., Burbank, Calif.

Pres.: O. M. Bell

Missile components, titanium alloy pressure vessels, new materials (Atlas).

TRANSCO PRODUCTS, INC., 12210 Nebraska Ave., Los Angeles 25. Calif.

Pres.: M. W. Sawyer Antenna (Thor). TRANS-SONICS, INC., P. O. Box 328, Lexington 73, Mass. Pres.: Vernon C. Westcott

Pressure and temperature transducers (Atlas, Titan, Thor); liquid-level transducers (Thor).

V

VARO MANUFACTURING CO., INC., 2201 Walnut St., Garland, Tex.

Pres.: Austin N. Stanton

Precision power supplies, frequency meters (Atlas, Titan, Thor).

VICKERS, INC. (Division of Sperry Rand), Administrative and Engineering Center, Detroit 32, Mich.

Pres.: J. F. Forster

Head Hydraulics Div.; Gen. Mgr.: B. W. Badenoch Hydraulic pumps (Atlas, Titan, Thor, Polaris); valves (Thor).

Machinery Hydraulics Div., Aurora St., Waterbury 20. Conn.; Operations Mgr.: G. M. Darsch

Hydraulic equipment for ground-handling, testing and launching (Atlas, Titan, Thor).

VITRO CORPORATION OF AMERICA, 261 Madison Ave., New York, N. Y.

Pres.: J. Carlton Ward, Jr.

Vitro Laboratories, 14000 Georgia Ave., Silver Spring Md.; Pres.: Dr. G. Russell Tatum Systems engineering, navigation analysis (Polaris).

W

WALDRIP ENGINEERING CO., 11810 Center St., Hollydale, Calif.

Pres.: R. N. Simpson

Ground-support equipment (Polaris); flame deflector: (Atlas); launching equipment.

WALLACE PROCESS PIPING CO., INC., P. O. Box 9658, Wright Station, Norfolk, Va.

Pres.: Sam Wallace

Denver Div., P. O. Box 4027, Denver, Colo.; V-Pres.: Arthur C. Parker

Outfitting of static test stands (Titan).

WARNER, INC., 522 Fifth Ave., New York 36, N. Y. Pres.: Leon P. Rynar

Military handbooks, engineering reports (Atlas).

WASTE KING CORP., 3300 E. 50th St., Los Angeles 58 Calif.

Pres.: Bertram Given

Technical Products Div., 4600 Pacific Blvd., Los Angeles 58, Calif.; Exec. V-Pres.: Howard Given

Heat exchangers, valves, turbo pumps, combustion chambers, control components (Atlas, Thor, Jupiter); gyros (Jupiter).

WESTERN GEAR CORP., 2600 E. Imperial Highway, Lynwood, Calif.

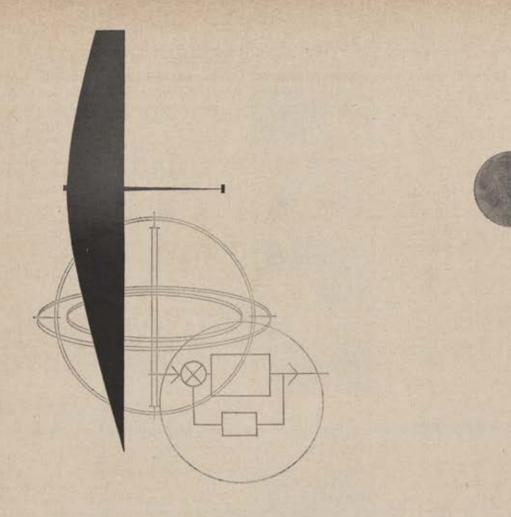
Pres.: T. J. Bannan

Turbo pump drives.

WHEELER LABORATORIES, INC., 122 Cutter Mill Rd., Great Neck, N. Y.

Pres.: Harold A. Wheeler

Microwave antennas (Titan).



### GUIDANCE and CONTROL in SPACE TECHNOLOGY

It is becoming increasingly apparent that many of the techniques and analyses, and much of the equipment, developed for the present Air Force ICBM-IRBM programs will have a wide future application in space technology. For instance, many of the guidance and control techniques for ICBM's are applicable to the space vehicles of the near future.

An important element of these applications is precision. The precision required of the guidance and control system for vehicles aimed at the moon or one of the planets is not substantially greater than that required for the Air Force ICBM-IRBM programs. And, the precision needed to guide a vehicle into a near-circular orbit of Earth is even less than that required for ICBM's.

The problem of communication with lunar and planetary vehicles is, of course, made more difficult by the much greater distances involved. This, however, is not an insurmountable difficulty if today's trends continue in the use of higher transmitted power, narrower communication bandwidths and amplifiers with very low noise-figures.

The problems of operating electronic equipment in the space beyond our atmosphere are already encountered on present ballistic missile trajectories. The principal difference in the case of space vehicle applications is the requirement for longer equipment lifetimes. Electronic equipment and power supplies will have to last for several hours or days or weeks, instead of a few minutes, under conditions of vacuum pressure, zero "g" fields, and bombardment by micrometeorites, high-energy particles, and radiation.

The preceding examples serve to illustrate some of the ways in which the ICBM-IRBM programs are advancing the basic techniques of space technology.

Since 1954, Space Technology Laboratories has been providing over-all technical direction and systems engineering for these programs. Both in support of this responsibility and in anticipation of future system requirements, the Laboratories are presently engaged in a wide variety of advanced research and experimental development projects (as distinct from development for manufacturing, in which STL is not engaged). These activities are directed toward the exploration of new approaches in space vehicle electronics, aerodynamics, propulsion, and structures.

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### A Military Astronautics Glossary

Absolute zero. Theoretical point at which all molecular motion stops; the lowest possible temperature, equivalent to -469.6 Fahrenheit or -273.15 Centigrade.

Air breakup. Destruction of a high-altitude or reentry research vehicle by aerodynamic forces on its reentry into the atmosphere; done to reduce the impact velocity and to aid in the recovery of records and instruments.

Airframe. Assembled structural and aerodynamic components of an aircraft or guided missile.

Airglow. Radiation arising in the upper atmosphere from recombination of dissociated molecules and ionized molecules and atoms after they have been affected by solar radiation. In the daytime it keeps the sky light even at heights of fifty miles, while at night it limits photographic exposures at astronomical observatories.

Alpha 57-1. Code system established for identifying Earth-satellites and components. Alpha 57-1 is the Russian Sputnik I rocket vehicle, Alpha 57-2 the Sputnik satellite body, and Alpha 57-3 the protective nose cone designation.

Alpha 58-1. Official code identification for Explorer, the first

Earth satellite to be successfully launched in 1958.

Anoxia. Absence of oxygen in the blood, cells, or tissue, as would be the case if a person were at 50,000 feet or above without oxygen equipment.

Antigravity. Effect upon masses such as rocket vehicles and human bodies by which some still-to-be-discovered energy field would cancel or reduce gravitational attraction of Earth,

Antimissile missile. Defensive weapon system including detection, tracking, and calculation of the extended trajectory of incoming missiles, and launch a guided missile that will destroy an attacking missile.

Antipodal bomber. Special type of boost-glide bomber that lands at the antipode of its launching point, the place on the globe diametrically opposite, after dropping the bombs from a point on its out-of-the-atmosphere trajectory.

Aphelion. Point on an elliptical orbit around the sun which is farthest from the sun.

Apogee. Point on an elliptical orbit (of the moon or artificial satellite) around the Earth which is farthest from the Earth.

Asteroid, or minor planet. The many thousands of small worlds, revolving around the sun, mainly between the orbits of Mars and Jupiter.

Astrogation. Navigating in space.

Astronautics. Word coined by R. Esnault-Pelterie, a French pioneer in this field, to mean the science of space travel; now encompasses propulsion systems and vehicles.

Astronomical unit. Mean distance of the Earth from the sun, equal to 92,907,000 miles.

Astronomy. The oldest of the sciences; treats of the celestial bodies, their magnitudes, motions, constitution, location.

Astrophysics. Application of the laws and principles of physics to all aspects of stellar astronomy.

Atlas. USAF ICBM. Length (figures estimated) seventy-five feet, diameter ten feet, stage-and-a-half airframe with liquid propellant sustainer, thrust about 60,000 pounds; two boosters in flared-base skirt of 150,000 pounds each; launching weight over 200,000 pounds; design range 5,500 miles; in flight test, WS 107A-1, airframe, Convair SM-65; propulsion, North American Rocketdyne; guidance, GE and Burroughs; nose cone, GE

MOSD; warhead, Sandia Corp.

Atmosphere. Gaseous envelope surrounding a star, planet, or satellite; weight of the Earth's atmosphere at sea level is about 14.7 pounds psi, principally nitrogen and oxygen; divided into reference zones: troposphere, sea level to ten miles; stratosphere, ten-sixteen miles; mesophere, sixteen-fifty miles; ionosphere or thermosphere, fifty-200 miles; exosphere, 200-1,000 miles.

Atmospheric braking. Deliberate maneuver of applying atmospheric drag to decelerate a satellite or space vehicle for landing upon a planet that has a usable atmosphere; can be accomplished by entering at a nearly flat gradual trajectory or by making a series of passes through the atmosphere.

Attitude. Orientation of an air vehicle as determined by the inclination of its axis to some frame of reference, usually the

Attitude jets. Sometimes called steering jets, attitude-control jets, or roll, pitch, and yaw jets; fixed or movable gas nozzles on a rocket, missile, or satellite operated continuously or intermittently to change the attitude or position either in the atmos-

phere or in space.

Aurora. Commonly known as the northern and southern lights; a high-altitude airglow caused by solar particles, predominantly protons, moving as charged particles in the Earth's magnetic field and interacting with the Earth's atmosphere.

Backout. Reversing the countdown sequence because of the failure of a component in the missile or a hold of unacceptable duration. Most serious task during backout is removal of the propellants from missile tanks.

Ballistic missile. Unmanned vehicle, the major portion of whose flight path to its target is a ballistic trajectory which is

determined by gravitational and drag forces alone.

Ballistic trajectory. Also known as coasting and free flight; this is the portion of the ballistic missile trajectory (misnamed the flight) where no propulsive or steering force is applied to the vehicle.

Beta 57-1. According to the code system used for identifying Earth satellites, this is the Sputnik II satellite and attached rocket launching vehicle, which did not separate from the rocket. See Alpha 57-1.

Blowoff. Separation of an instrument section or "package" from the remainder of the rocket vehicle by application of explosive force, to retrieve the instruments after they have collected the required information.

BMD. Ballistic Missile Division, ARDC, Inglewood, Calif. BMO. Ballistic Missiles Office, AMC, Inglewood, Calif.

Boiloff. Vaporization of a cold propellant such as liquid oxygen as the propellant mass rises to higher temperatures because of exposure to local conditions through the walls of the missile tank or other uninsulated containers.

Boost. Descriptive term that defines the use of rocket propulsion, either solid- or liquid-propellant types, during the initial climb, the liftoff, and the first phase of propelled flight.

Boost-glide bomber. Vehicle, with wings or similar aerodynamic surfaces, propelled upward by rocket engines in the manner of a satellite or ICBM into the outer fringes of the atmosphere to glide or skip-glide on the atmosphere (as a stone (Continued on following page)

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skipping over water) long distances while completing its mission.

Burnout velocity (Brennschuss). The velocity along the ballistic trajectory when the propellant is exhausted.

Captive firing. Test-firing of a complete missile where all or any part of the propulsion system is operated at full or partial thrust while the missile is restrained in the test stand.

Celestial mechanics, Branch of astronomy concerned with the laws governing the motions of heavenly bodies.

Celestial sphere. Imaginary sphere of infinite radius, assumed for navigational purposes, the center of which coincides with the center of the Earth.

Characteristic velocity. Sum of all the velocities that have to be attained or overcome for purposes of braking, by a rocket intended for a particular journey.

Chromosphere. One of the atmospheric shells of the sun. It lies above the photosphere and is best visible at time of total eclipse; can be observed spectroscopically at other times.

Circular velocity. Critical velocity at which a satellite will move in a circular orbit around its primary. Circular velocity is a special case of orbital velocity, and one which is not likely to be obtained in practice due to accuracy of control needed.

Circumlunar rocket. Rocket-propelled vehicle designed and operated to take off from Earth, travel to the moon's orbit, circle the moon, and return to Earth.

Cislunar space. Space around the Earth beyond the outermost reaches of the terrestrial atmosphere and within the orbit of the moon.

Comet. Nebulous body that revolves about the sun in elongated ellipse.

Component. Term loosely given to a part, subassembly, or system, when considered as part of a larger assembly or system.

Console. Master instrument panel from which rocket and missile launchings are controlled.

Constellation, stellar. Arbitrary groups into which stars are divided for reference and identification; in most constellations there is no relation between members, they seem close together merely as a result of perspective.

Contraorbit missile, Missile sent backward along the calculated orbit of an approaching spaceship, satellite, or space weapon for the purpose of destroying it in a head-on collision with an explosive warhead or by missiles. Contraorbit attacks are considered much easier to accomplish than orbital attack; the antisatellite missile is one of these weapons.

Controller. Device which receives a measured value of a variable from a sensor, compares that value with some reference value, and supplies a control signal to a control element to maintain the value of the variable within a certain range about the reference value.

Coriolis force. Deflection of a projectile during its flight across the surface of the Earth, caused by the rotation of the Earth.

Cosmic rays. Extremely fast particles continually entering the upper atmosphere from interstellar space; atomic nuclei which have very great energies because of their enormous velocities; potentially dangerous to humans experiencing extended exposure.

Cosmonautics. Word coined in recent years to describe the science, as yet merely academic, of travel beyond the solar system by using radically new forms of propulsion.

Countdown. Series of events that take place from the start of rocket-launching operations until the rocket lifts off the launch stand. Countdown starts with a missile in the ready condition, progresses through loading of propellants and pressurization gas, activating the circuits, last-minute checkout of components, starting the rocket engines, and building up the thrust to the required force for liftoff.

Crossing the trough. Process in an Earth-moon voyage of passing from the influence of terrestrial gravity to the region of space where lunar gravity predominates.

Cruise missile. Guided missile, the major portion of whose flight path to its target is conducted at approximately constant velocity; depends on the dynamic reaction of the air for lift, and upon propulsion forces to balance drag forces.

Cutoff. Shutting off of a working fluid or a combustion process. In a liquid-propellant rocket engine, the time when either

one or both of the main propellant valves is completely shut off.

Doppler effect. Apparent change of wavelength of light (or any other form of wave motion) when the source and the observer are in motion relative to one another.

Down the slot. Vernacular expression for a successful flight of a missile down the test range and within the left and right range limits (parallel lines previously plotted on the range-plotting board) established by range safety personnel.

Ecliptic. Plane of the Earth's orbit around the sun. It is used as a reference plane for other interplanetary orbits. Also the name for the apparent path of the sun through the constellations as projected on the celestial sphere.

EDP center. Electronic data-processing center; automatically operated equipment engineered to simplify the use and interpretation of the mass of data gathered by modern instrument installations. Can automatically handle information fed to it from thousands of widely scattered points.

Electrojet. Current sheet or stream moving in an ionized layer in the upper atmosphere of a planet. On Earth, electrojets move around the equator following the subsolar point and also in polar regions where they give rise to auroral phenomena; generally caused by solar activity.

Escape velocity. Minimum velocity which will enable an object to escape from the surface of a planet or other body without further propulsion. The escape velocity of the Earth is just over seven miles per second, or 25,000 mph.

Exosphere. Outermost region of the Earth's atmosphere, where atoms and molecules move in dynamic orbits under the action of the gravitational field.

Exotic fuel. New fuel combinations under study and development for aircraft and rocket use with the purpose of attaining far greater thrusts than now possible.

Expendable construction. Proposed method of construction for propellant tanks of high-performance rocket vehicles. The tanks are sectioned and each section is jettisoned as soon as it is emptied. This improves the over-all mass ratio and gives a greater burnout velocity.

Explorer. First US satellite to be successfully placed in an Earth-circling orbit. On January 31, at 10:48 p.m. EST, a US Army Jupiter-C launching vehicle left Cape Canaveral, Fla., in a trajectory that placed a satellite developed by the Jet Propulsion Laboratory of the California Institute of Technology in an elliptic orbit. The Explorer satellite is the eighty-inch, solid-propellant last stage of the vehicle. The six-inch-diameter body weighed 30.8 pounds, after burnout, including approximately eleven pounds of instruments in its nose section.

FBM. Fleet ballistic missile, for example Polaris,

FBMS. Fleet ballistic missile system; US Navy program of developing missiles to be launched from nuclear-powered submarines.

Flight-control system. On ballistic missiles and unmanned spaceships, the automatic system that keeps the rocket-propelled vehicle on a prescribed course during liftoff and propelled flight up to the position where the guidance system (if any) becomes operational.

Flight path. Moving position of the center of gravity of an air vehicle or projectile with reference to a coordinate frame fixed either relative to the Earth or its launching platform.

Flight-readiness firing. Complete firing operation of the liquid-propellant rocket engines of the restrained missile in its launch stand to verify its readiness for a flight test or operational mission.

Free fall. Condition of unrestricted motion in a gravitational field. In a rocket coasting without power, the rocket and all its contents are equally under the influence of gravity, irrespective of the distance from Earth, and the entire rocket is in a state of free fall. See Weightlessness.

G force. Force exerted upon an object by gravity or by reaction to acceleration or deceleration, as in a change of direction; one G is the measure of the gravitational pull required to move a body at the rate of about 32.16 feet per second per second.

Galaxy, Spiral system of stars; our galaxy, a disc-shaped

aggregation of stars called the Milky Way, includes our solar system, far out on one of its spiral arms.

Gantry. Crane-type structure, with platforms on different levels, used to erect, assemble, and service large rockets or missiles; may be placed directly over the launching site and rolled away just before firing.

Gegenschein. Faint light area of the sky always opposite the position of the sun on the celestial sphere. Believed to be the reflection of sunlight from particles moving beyond the Earth's

orbit.

Gimbal, Mechanical frame containing two mutually perpendicular intersecting axes of rotation (bearings and/or shafts).

Gravitation. Force of attraction that exists between all particles of matter everywhere in the universe, Between any pair of bodies it is proportional to the mass of each and inversely proportional to the square of the distance between them.

Gravity simulation. Use of centripetal force to simulate weight reaction, in a condition of free fall; possibly achieved by spinning the vehicle to use the centripetal force of the outer periphery on bodies within the vehicle to replace the normal weight reaction experienced at the Earth's surface.

Gravity well. Analogy in which the gravitational field is considered as a deep pit out of which a space vehicle has to climb

to escape from a planetary body.

Ground start. Use of liquid fuel or liquid oxidizer or both from a pressurized ground supply, instead of missile tanks, during the countdown, ignition phase, thrust buildup, and liftoff. This system permits the missile to take off with full tanks, at correct weights; plumbing connections come apart at break-away couplings.

Ground-support equipment. Category which includes all those items required by AF activities to inspect, test, adjust, calibrate, appraise, gauge, measure, repair, overhaul, assemble, disassemble, transport, safeguard, record, process, store, actuate, or otherwise maintain the original functional operating status

of a specific air weapon system.

Guidance system. Obtains and develops target information for the determination of the desired flight path of a missile and communicates this intelligence in the form of commands to a missile flight-control system. A guidance system may be inertial, self-contained within the missile, or the guidance function may be performed by various combinations of ground and airborne components.

Guided missile. An unmanned vehicle moving above the Earth's surface whose trajectory or flight path is capable of be-

ing altered subsequent to its launch.

Gyroscope. Device consisting of a wheel so mounted that its spinning axis is free to rotate about either of two other axes perpendicular to itself and to each other; once set in rotation, its axle will maintain a constant direction, even when the Earth is turning under it; when its axle is pointed due north, it may be used as a gyrocompass.

Hard base. Launching base that is protected against a nuclear bomb by a structure or terrestrial cover (natural or man-made tunnel); the structures are designed for a specified amount of overpressure. See Soft base.

Harvest Moon. Said to be a proposed manned satellite with a first stage based on the Navaho booster design consisting of several rocket engines of many thousands of pounds thrust.

Heaviside-Kenelly layer. Region of the ionosphere that reflects certain radio waves back to Earth; the E layer.

Hohmann orbit. See Tangential ellipse.

Hold. Unscheduled delay or pause in the launching sequence or countdown of a missile or space vehicle.

Hydrosphere. The aqueous envelope of a planet.

Hypersonic. Velocities of five or more times the speed of sound.

Hypoxia. Oxygen deficiency in the blood, cells, or tissue; occurs at about 20,000 feet,

IAD. International Astrophysical Decade, proposed by Krafft Ehricke for world program of scientific investigation.

ICBM. Intercontinental ballistic missile.

Inertial guidance. An onboard guidance system for missiles and satellite vehicles where gyros, accelerometers, and possibly a gyro-stabilized platform satisfy guidance requirements without use of any ground-located components. This system is jamproof and entirely automatic, following a predetermined trajectory.

Inertial space. An assumed stationary frame of reference—a nonrotating set of coordinates in space—relative to which the trajectory of a space vehicle or long-range missile is calculated.

Interstellar flight. Flight between stars, strictly between orbits around stars. The shortest interstellar flight from the solar system is to Proxima Centauri, a distance of 24 x 10<sup>12</sup> miles. Traveling at the speed of light, an interstellar space vehicle would take 4½ years for such a journey, and a similar time for the return.

IOC. Initial operational capability of a ballistic missile weapon system; the IOC includes the launch complexes, maintenance areas, ground-support equipment, the missiles, personnel, and other elements of a weapon system. See UOC.

Ionization. Formation of electrically charged particles; can be produced by high-energy radiation such as light or ultraviolet rays, or by collisions of particles in thermal agitation.

Ionized layers. Layers of increased ionization within the ionosphere. Believed to be caused by solar radiation, and labeled the D, E, and F layers. Responsible for absorption and reflection of radio waves and important in connection with communication and the tracking of satellites and other space vehicles.

Ionosphere. Region of the Earth's atmosphere extending fifty to 500 miles above the Earth, merging into the exosphere above.

Ion rocket. Spaceship powerplant, still to be developed, that produces thrust by the reaction obtained from ejecting a highvelocity stream of ions.

IRBM. Intermediate-range ballistic missile.

Jet steering. The use of fixed or movable gas jets on a space weapon, ballistic missile, or sounding rocket to steer it along a desired trajectory, during both propelled flight (main engines) and after thrust cutoff. The jets may be supplied cold pressurized gas or hot gas obtained by burning propellants in a gas generator.

Jupiter. Army IRBM, single-stage, length fifty-eight feet, diameter eight feet, nine inches, thrust 160,000 pounds, designed range, 1,500 miles; product of Army Ballistic Missile Agency, at Redstone Arsenal, Huntsville, Ala.; airframe, Chrysler; guidance, Sperry-Rand; propulsion, North American Rocketdyne; nose cone, Goodyear Aircraft; developed from earlier Redstone and Jupiters A and B; a modified Jupiter C launched the American satellite, Explorer.

Landing rocket. A manned space vehicle operated to transfer passengers and cargo from a satellite or larger orbiting space-ship to the surface of a planet. A landing rocket must be provided with a means of reducing its velocity for a safe entry into the planet's atmosphere and the touchdown.

Launch. Send forth a rocket or missile from its launcher under

its own power.

Launch complex. Launch stand upon which the missile will stand when ready for liftoff, plus the service tower that can be moved out of the way on tracks, the flame bucket, the ground-support equipment located nearby to control the countdown sequence, and the protective building or trailer housing the equipment.

Liftoff. Initial motion along the trajectory of a space weapon or ballistic missile as it rises from the stand under rocket pro-

pulsion; the takeoff.

Light year. Distance traveled in one year by light, which covers 186,284 miles in one second; equal to 5,880,000,000,000 miles.

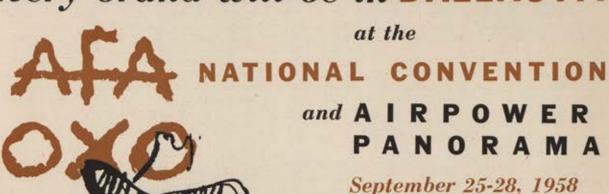
Liquid propellant. Liquid fuel which combines with an oxidizer.

Low-energy primary. Biologically dangerous cosmic ray particle which may be prevented from reaching the Earth by the heliocentric field. A possible hazard to spaceflight.

LOX. Liquid oxygen used as an oxidizer.

Loxing. Vernacular term for the task of loading liquid oxy-(Continued on page 161)

### Every brand will be in DALLAS...



That's right! Every brand of aviation will be represented at the Air Force Association's 1958 Convention and Airpower Panorama in Big "D" in September—pilots and bombardiers, mechanics and mess sergeants, manufacturers and suppliers, generals and privates, mayors and governors, and just plain AFA'ers will be on hand for the big airpower roundup. There will be serious defense discussions, as well as some serious elbow-bending, and some ridin', ropin', and shootin' (the bull, of course). Better plan to be on hand.

#### PROGRAM HIGHLIGHTS

- Thursday September 25

  AFA Business Sessions

  Reserve Forces Seminar

  Panorama Preview

  Reception
- FRIDAY SEPTEMBER 26 Space-Age Symposium Airpower Panorama Airpower Luncheon Western Wing Ding
- SATURDAY SEPTEMBER 27

  AFA Business Sessions
  Industry Briefings
  Airpower Panorama
  Awards Banquet
- SUNDAY SEPTEMBER 28 Trail's-End Brunch

NOTE: There will be an AFA Leaders Workshop Wednesday afternoon, and an AFA Directors meeting Wednesday night, Sept. 24.

SEE PAGE 167 FOR DETAILS ON HOTEL RESERVATIONS

gen into the fuel tanks of a missile from a ground supply. Luminous bands. Faint bands of luminosity appearing in the night airglow. May be caused by the impact of micrometeorites

with the upper atmosphere. Height and origin of the phenomenon are in doubt, due to the difficulty of making observations,

Lunar gravity. The attraction of particles and masses toward

the gravitational center of the moon.

Lunar probe. Unmanned guided missile sent into space with the required velocity and heading to circumnavigate or land on the moon.

M storm. Magnetic storm, produced by disturbances on the sun, identified by an indefinite beginning and ending and a fairly long duration.

Mach cone probe. Device for measuring the temperature of the upper atmosphere; uses sensing elements to determine the position of the shock wave from a slender cone mounted at the

Mach number. Ratio of the velocity of a body to that of sound in the medium being considered; 762 mph at sea level.

Magneto-hydrodynamics. New science dealing with ultrahigh-altitude, high-speed flight; examines whether an electrically charged wing or aerodynamic body passing through a sea of ions can attract these charged particles on the one side and repel them on the other to produce lift,

Magnitude. Brightness of a star; first magnitude is the brightness of a candle flame at a distance of 1,300 feet. Order of magnitude decreases from first to twentieth at a ratio of intensity of 2.5; the first magnitude is 100 times brighter than the sixth; stars of the first six magnitudes are visible to the

Main stage. Phase in the thrust buildup of a single rocket engine or a multiengine rocket powerplant when full thrust (at or above ninety percent of rated thrust) is obtained; with certain multistage designs, main stage defines the operation of rocket engines remaining on the vehicle after booster rockets have been expended and jettisoned.

Mass ratio. Initial mass of the vehicle at the instant of liftoff divided by the final mass at some point of the powered ascent

or at burnout and thrust cutoff.

Meteor bumper. Thin shield, comparable in thickness with the diameter of the meteor to be intercepted, around a space vehicle and designed to thermally dissipate the energy of meteoritic particles; high impact velocity of the meteor leads to vaporization of the meteor and a part of the shield without penetration of any particles to the wall of the space vehicle.

Micrometeorites. Small dust particles moving around the sun; may be debris from the formation of the solar system or interstellar dust coming into the solar system; may cause erosion and destruction of optical and other surfaces on vehicles moving

at interplanetary speeds.

Minitrack. System for tracking artificial satellite by means of radio waves transmitted from the vehicle itself; several ground stations are required.

Mixed force. Concept of retaining strategic air force as the major deterrent to enemy aggression while building up opera-

tional missiles.

Nebulae. Galactic nebulae are clouds of interstellar matter whose presence is revealed either because they are illuminated by a bright star or because they noticeably weaken the light from stars in a particular region of the sky; unborn stars.

Noctilucent cloud. High-altitude terrestrial cloud lying at an altitude of fifty miles in the temperature minimum layer. Appears only after sunset or before sunrise when contrasted against a dark sky; may consist of volcanic dust or interplanetary matter trapped by the temperature inversion.

Nose cone. Assembly at the upper end of a ballistic missile from which it is separated after the end of propelled flight. The nose cone may contain an atomic bomb with an arming and fuzing system and a means of decelerating the body as it

speeds down into the atmosphere. Nova. Star which undergoes a sudden and enormous increase in brightness; about twenty-five appear every year in our galaxy. Supernova is a star which explodes with a liberation of most of its energy into space.

Nuclear rocket. Theoretical rocket device using the energy of nuclear fission or fusion to heat a working fluid or to generate high-energy particles for use as a propulsive jet; expected to yield high specific impulses and thus decrease propellant needed for spaceflight.

Null circle. Theoretical point in space where the gravitational attraction of one planet balances that of another planet; there can be no real null point, circle, or region because the solar system is dynamic, parts of it are always moving in re-

lation to other parts.

Onboard guidance system. Also known as the airborne guidance system and the inflight guidance system. The automatic system on ballistic missiles and unmanned spaceships that sends steering signals through the flight-control system during the terminal phase of propelled flight.

Orbit. Path in which a celestial body moves about the center of gravity of the system to which it belongs; every orbit is basically in the shape of a conic section with the center of

gravity at one focus.

Orbital bomber. See Boost-glide.

Orbital refueling. Suborbital technique analagous to inflight refueling of aircraft. Designed to make possible high characteristic velocities without the penalty of impossibly high individual vehicle takeoff weight. In practice, might consist of sending a manned space vehicle into an orbit just outside the Earth's atmosphere and then replenishing its propellant supply from the payload of tanker rockets sent into the same orbit. These propellants would supply sufficient energy for the manned space vehicle to journey to the moon and later to return to the terrestrial suborbit. More tanker rockets would carry propellants to the returning space vehicle for it to land back on the surface of the Earth.

Orbital velocity. Velocity needed to keep a body moving in a closed orbit around a sun, planet, or satellite. May be circular velocity or elliptical velocity and can vary over wide limits depending on the distance from the attracting force center and upon the magnitude of the attracting force; orbital velocity of

the Earth is 18,000 mph.

Orbit nodes. Points in an orbit where the orbit crosses a reference plane, such as the ecliptic or the equatorial plane.

Ozone layer. Layer in the atmosphere about twenty miles above sea level which strongly absorbs solar ultraviolet radiation; absorption of energy not only converts molecular atmospheric oxygen into ozone but heats the atmosphere and produces a high-temperature layer, a little above the ozone layer.

Pad. Permanent or semipermanent load-bearing surface, constructed or laid on the ground, upon which a permanent or

mobile catapult or launcher can be placed.

Parabola of escape. Critical orbit in a central force field. Orbits of bodies moving in a gravitational field were shown by Newton to be conic sections. Ellipses and hyperbolas are common orbits. Circles and parabolas are limiting orbits. The parabolic orbit is such that a body has escape velocity at every point along it.

Parsec. Astronomical unit of distance equal to 19,150,000,-

Payload. Weight of everything in a rocket or missile that can be described as "useful cargo," such as scientific instruments. passengers, supplies, or, in the case of weapons, the warhead; usually less than a tenth of the total weight of the missile with full propellant tanks. In a step-rocket, the payload of each step but the last consists of the succeeding steps.

Perigee. Point in an elliptical orbit around the Earth which

is closest to the Earth.

Perihelion. Point closest to the sun in the orbit of any member of the solar system.

Perturbations. Effect of gravitational pull of one body upon the orbit of another; a satellite moving around the Earth is disturbed by the gravitational fields of the sun and the moon and by the Earth's bulge.

Photon rocket. Hypothetical reaction-type powerplant based on directional emission of photons, a continuous quantum of radiant energy moving with the velocity of light. The photon

(Continued on following page)

rocket is considered a possible power source for interstellar spaceflight.

Photosphere. Layer of the sun's surface that we normally see; turbulent region on which most of the visible solar fea-

tures appear, such as sunspots and solar flares.

Pied Piper. AF code name for an unmanned satellite, also called ARS (Advanced Reconnaissance Satellite), by Lockheed Aircraft; designated Weapon System 117L. Said to be unmanned, at first, and designed for carrying TV, photographic cameras, infrared spotter, and radar-scanner systems. Orbits for unmanned Pied Pipers would lie between 300 and 1,000 miles, according to unofficial reports.

Plasma jet, High-temperature jet of electrons and positive ions that has been heated and ionized by the magneto-hydrodynamic effect of a strong electrical discharge.

POC. Productional operational capability. See IOC.

Polaris. Navy IRBM. Solid-propellant rocket, estimated to be thirty feet long, diameter four feet; airframe and nose cone, Lockheed; propulsion, Aerojet-General; guidance, GE and MIT; designed to be launched from nuclear-powered submarines.

Pre-stage. Sequential phase in the starting of a large liquidpropellant rocket engine where the initial partial flow of propellants into the thrust chamber is ignited, and this combustion is satisfactorily established before main stage is initiated.

Programmed turn. Automatically controlled turn of a ballistic missile from the vertical direction, maintained after liftoff, into the curved path that will lead to the correct velocity vector at thrust cutoff for the final portion of the trajectory, the coasting flight, that will impact on the target.

Projectile. Body which is accelerated to a velocity by the application of mechanical forces and which continues its motion along a ballistic trajectory. The mechanical forces may be generated by propellant gases in a rocket-propulsion system as well

as in a tube or gun barrel.

Propellant. Liquid or solid substance or substances which either separately or mixed can be changed into a large volume of hot gases at a rate which is suitable for propelling projectiles or air vehicles.

Propulsion system. Portion of an air vehicle whose function is to provide thrust, which is normally used to propel the vehicle through all phases of powered flight, but may be used for attitude control purposes; includes the engines and all necessary associated systems to insure satisfactory operation of the engine either on the ground or in flight.

PU system. Short form for propellant utilization system, the automatic electromechanical system that is installed on very large ballistic missiles, to precisely control the mixture ratio of the liquid propellants (oxidizer to fuel), as they are consumed

during a firing.

Radial velocity. Speed of approach or recession of a body from the point of observation with respect to the Earth; can be determined by measuring the Doppler shift between lines of the same elements in the spectra of the star and of a laboratory on the Earth.

Radio-inertial guidance. Missile or space weapon guidance system that is divided into two major groups: the onboard guidance system and the flight-control system, and the groundlocated guidance station.

Recovery. Maneuver or actions that result in return of an instrumentation section or a "package" of instruments from a sounding rocket or a scientific satellite; recovery can be effected by jettisoning the remaining rocket body from the instrumentation section, then dropping the recoverable unit by parachute or permitting it to fall freely.

Reentry. Entry of a ballistic missile, nose cone, space weapon, or bomb from a satellite bomber into the atmosphere. The reentry point is the portion of the terminal trajectory where

thermal heating becomes critical.

SAC-Mike. Strategic Air Command ballistic missile staff, at BMD, Inglewood, Calif.

Scrub. Vernacular for the act of canceling or backing out of a countdown or launching sequence because of an unacceptable hold or the breakdown of an essential component of the missile.

Separation. Moment when a full stage, half stage, a warhead, or a nose cone is separated from the remainder of the rocket vehicle; the moment when staging is accomplished.

Separation rocket. Relatively small rocket, usually solidpropellant type, that is installed in groups of two or more on a second or higher stage to be operated when its stage needs additional thrust to accelerate away, at separation, from the preceding stage.

Shutdown. Process by which the thrust of a rocket engine is brought from its main stage, steady-state value to a negligible

value.

Skip-glide bomber. Winged vehicle that is boosted above the atmosphere by large rocket-powered stages and turned into a somewhat circular orbit before thrust is cut off. From this point, the extraterrestrial bomber follows an undulating trajectory, glancing or skipping off the upper regions of the atmosphere as it travels tremendous distances around the Earth to complete its mission. See Boost-glide bomber.

Soft base. Launching base that is not protected against atomic

attack. See Hard base.

Solar constant. Amount of energy arriving per unit area exposed to unobstructed solar rays at the mean radius of the Earth's orbit around the sun. Important when calculating the energy input to a space vehicle for cooling purposes or from the standpoint of using a solar engine.

Solar corona. Outer atmospheric shell of the sun, divided into

the F corona and the K corona.

Solar corpuscles. Particles, usually protons, sprayed out into the solar system by disturbances on the sun. If the Earth intercepts one of these sprays, the particles tangle with the Earth's magnetic field and produce ionospheric disturbances.

Solar flare. Catastrophic solar phenomenon which gives rise to intense ultraviolet and corpuscular emission from the associated region of the sun. It affects the structure of the ionosphere and interferes with communications and the control of space vehicles.

Solar noise. Electromagnetic radiation which radiates from the atmosphere of the sun at radio frequencies.

Solid propellant. Chemical or mixture of chemicals in solid form which when properly stimulated, burns itself.

Space gun. Early proposal to fire a vehicle at escape velocity from a monster gun; not technically possible from the surface of the Earth, but may be used one day from the moon for orbital refueling.

Space medicine. Study of the human factors involved in spaceflight; links medicine with extraterrestrial sciences.

Space platform. Large satellite, with both scientific and military applications, conceived as a habitable and safe base in space. The proposed space platforms would contain housing facilities, power supplies, gravity simulation, provisions for transferring personnel and cargo to and from other space vehicles, scientific instruments, weapon systems, controlled atmosphere, and communication systems. Usually conceived as a giant wheel, assembled in space.

Spacesuit. Hermetically sealed enclosure for an individual. supplying him with a respirable atmosphere, suitable tempera-

ture, and permitting him mobility.

Spatiography. System proposed by Dr. Hubertus Strughold for charting a "geography" of space.

Specific impulse, Parameter for rating the performance of a rocket powerplant; shows how many pounds of thrust are obtained by consumption of a pound per second of the propellant.

Specific thrust. Thrust of a rocket engine divided by the propellant consumption rate.

Spin stabilized. Directional stability of a projectile obtained by the action of gyroscopic forces which result from spinning of the body about its axis of symmetry.

Splash. Proving ground vernacular for the intentional destruction or impact of a missile that is deviating from the preselected safe range limits or is malfunctioning because of a fire or premature loss of propulsion.

Stabilized platform. Major part of an all-inertial guidance system, composed of an assembly of gimbal frames that hold

(Continued on page 164)

From Kitty Hawk to the Space Frontier

### A HISTORY OF THE UNITED STATES AIR FORCE, 1907-1957





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three accelerometers in a fixed position in relation to inertial space. The accelerometers are mounted perpendicular to each other to measure accelerations along the three reference axes. These accelerations can be fed to a computer that will determine instantaneous velocity and position in space.

Stage. Portions of powered flight of an air vehicle in which both the thrust and the mass of the vehicle are either essentially constant or are varying slowly and smoothly. A discontinuity of either thrust or mass could signal the end of a stage. Also, elements of a rocket, as the threestage Vanguard.

Staging. Operation whereby a full stage or a half stage is automatically disengaged or unlocked from the adjacent upper stage and permitted to decelerate

away to follow its own return trajectory to the surface.

Stationary orbit. Also, in reference to Earth, known as a twenty-four-hour orbit; a circular orbit around a planet in the equatorial plane and having a rotation period equal to that of the planet. For Earth, the stationary orbit is about 26,000 miles in radius. A body moving in a stable stationary orbit appears fixed in the sky relative to an observer of the surface of the planet in the hemisphere facing the body.

Sunseeker. Two-axis device actuated by servos and controlled by photocells to keep instruments pointed toward the sun despite rolling and tumbling of a rocket vehicle in which the instruments are carried. Used in upper-atmosphere research and may be developed for navigation in space, especially when made sensitive enough to become a star- or planetseeker.

Sweat cooling. Method of controlling the excessive heating of a reentering body or a plane flying at hypersonic velocities. With this method, the surfaces that will be subjected to excessive heating are made of a porous material through which a liquid of high heat capacity is forced. The evaporation of this coolant completes the sweat-cooling process.

T-time. Elapsed time of the flight of a missile or space weapon starting from the moment the vehicle leaves its stand.

Tangential ellipse. Most economical spaceflight transfer ellipse from the energy standpoint; grazes the orbits of arrival and departure. Also known as a Hohmann orbit. The transfer ellipse from Earth to Mars carries a rocket vehicle halfway around the sun and takes about eight months to traverse.

Targeting. In missile warfare, the art of plotting the correct trajectory for a designated target. With an ICBM, the range could be 5,000 nautical miles.

Telemetering system. System for measurement with the aid of intermediate means permitting the measurement to be observed or recorded at a distance from the primary detector.

Terminal velocity. Hypothetical maximum speed a body could attain along a

specified straight flight path under given conditions of weight and thrust if diving through an unlimited distance in air of specified uniform density.

Thermal heating. Aerodynamic heating produced by supersonic and hypersonic travel through the atmosphere; transfer of heat from a laminar or turbulent flow around the nose of a reentry body as it loses kinetic energy.

Thor. USAF IRBM. Length (figures estimated) sixty-five feet, diameter over eight feet, single-stage airframe, launching weight under 100,000 pounds, liquid propellant, design range 1,500 miles; 150,000 pounds thrust; WS 315A, airframe, SM-75 Douglas; nose cone, GE MOSD; warhead, Sandia Corp.; guidance, AC Spark Plug; propulsion, North American Rocketdyne; in assembly-line production.

Thrust buildup. Sequence of events on the start of a large liquid-propellant rocket powerplant that begins with the ignition phase, progresses through prestage, and is completed when full thrust is obtained at main stage.

Thrust, effective vehicle. The resultant force in the direction of motion of an air vehicle, owing to the components of the pressure forces in excess of ambient atmospheric pressure, acting on all inner surfaces of the vehicle parallel to the direction of motion.

Time dilation, Relativity effect experienced within bodies moving at very high speeds in which time measured by a clock traveling within the body seems slower than time measured by a clock at rest in the initial frame of reference (such as Earth). In nature, time dilation seems to slow the decay of mesons passing through the atmosphere. In interstellar flight, it is suggested that time dilation might make it possible for interstellar voyagers to make their trip in a few years of their "time" while many more years pass back on Earth.

Titan. USAF ICBM backup for Atlas; two-stage, liquid-propellant, LOX and kerosene, length (figures estimated) ninety feet, diameter ten feet, launching weight 200,000 pounds; design range 5,500 miles, first-stage engine 300,000 pounds thrust, second-stage 60,000 pounds; WS 107A-2, airframe, SM-68 Martin; propulsion, Aerojet-General; guidance, American Bosch Arma, Western Electric, and Sperry-Rand; nose cone, Avco.

Topping the tank. Ground propellant supply system adjacent to the launch stand that replaces the boiloff or vapor loss of propellant as it is consumed during the thrust buildup before liftoff.

Touchdown. Landing of a manned or unmanned space vehicle on the surface of a planet by any method except gliding. Reverse jets would be the probable method of touchdown.

Transfer ellipse. Path followed by a body moving from one elliptical orbit to another. Transfer ellipses which intersect departure and arrival orbits at large angles are most expensive in energy requirements. See Tangential ellipse.

Translunar space. Interplanetary space beyond the orbit of the moon.

(Continued on following page)

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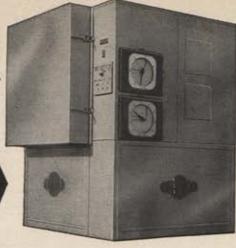
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GLOSSARY\_\_\_\_\_CONTINUED

Ultrasonic. Speeds between sonic and hypersonic.

Umbilical. Electrical cable providing connecting circuits to missile components. Stands in the launcher with control equipment located at a safe distance. Umbilical is ejected at liftoff.

UOC. Ultimate operational capability. See IOC and POC.

Vanguard. Experimental satellite project by US Naval Research Lab as part of the International Geophysical Year.

Vector steering. Vernacular for a steering method where one or more thrust chambers are gimbal-mounted so that the direction of the thrust force (thrust vector) may be tilted in relation to the center of gravity of the missile to produce a turning moment. Two servo actuators, one on the pitch axis and one on the yaw axis, tilt the thrust direction according to signals from the flight-control system.

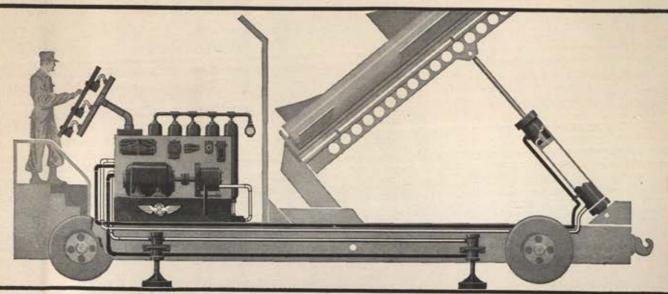
Velocity vector. Combination of two ballistic missile trajectory values; the speed of the missile's center of gravity at a designated point on the trajectory and the angle between the local vertical and the direction of the speed.

Vernier. Small rocket engines or gas nozzles mounted on the outside of a missile or propulsion vehicle for a space weapon which can be tilted by commands from the flight-control system to control the roll, pitch, and yaw attitudes during

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propelled flight. The second important function of verniers is to make the final adjustment of the missile velocity as it approaches the thrust-cutoff point.

Warhead. Portion of the armament system of a guided missile or projectile which consists of the explosive, chemical incendiary, or other contents that inflict the intended damage on the target; includes the charge or filler and its container or casing, but not the fuze.

WDD. Western Development Division, forerunner of BMD. Weapon system. Entity consisting of an instrument of combat, such as a bomber or guided missile, together with all related equipment, support facilities, and services required to bring the instrument upon its target or to the place where it carries out the function for which built.

Weight. Force exerted by a mass under local gravitational acceleration conditions.

Weightlessness. Condition in free fall. May be physiologically unimportant but psychologically dangerous in space flight. Can be avoided by spinning the space vehicle and simulating the effects of gravity by providing a weight feeling with centripetal force.

X-time. Time remaining before the launching of a missile, according to a schedule established by launch control personnel. See T-time.

Zero gravity. See Weightlessness.

Zodiacal band. Faintly luminous band of light appearing on the celestial sphere, connecting the zodiacal light with the Gegenschein. Caused by an extension of the solar corona out and beyond the Earth. Could indicate presence of interplanetary matter in space which might be a hazard to space vehicles moving in the plane of the ecliptic.

ing in the plane of the ecliptic.

Zodiacal light. "Wings" of hazy light extending on either side of the sun approximately in the plane of the ecliptic. Only visible after sunset or before sunrise. Believed to be part of the

outer atmosphere of the sun.-END

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### A Bibliography of Space Literature

The conquest of space is off to a running literary start. Seldom has a nation been so well provided with the fundamentals to understand the beginnings of a new era.

History will, no doubt, mark the space age as beginning in 1957 with the Sputniks, and, thanks to them, the imaginations of writers and publishers are being stirred up. On one aspect of space conquest alone—satellites—Project Vanguard officials report knowledge of seventeen books now in the works. We know of at least a half dozen ballistic missile and space technology volumes scheduled for publication in the months ahead. More are planned and, counting what the British will contribute, this year should be a banner one.

Here is a countdown of books on missiles, rockets, satellites, astronautics, space, spaceflight, and closely related fields already published. They are listed

by subject area and by the year published.

Though not comprehensive, this bibliography affords both layman and specialist a fix on current and past professional and popular books that deal with the great adventure ahead.

### I-ROCKETS AND MISSILES

Rockets Through Space, by Phil E. Cleator (Simon and Schuster, 1936)—An early account of rocketry by the founder of the British Interplanetary Society.

World Power and Atomic Energy: The Impact, by Harry E. Wimperis (London, Constable, 1946)—Discussion of German V-1 and V-2 development and use.

Rockets, by Robert H. Goddard (American Rocket Society, 1946)— Two Smithsonian reports on highaltitude rocket flight and liquid-propellant rocket development.

The Coming Age of Rocket Power, by G. Edward Pendray (Harper, 1947)—History of rockets and examination of their future application.

Rocketry, Jets and Rockets: The Science of the Reaction Motor and Its Practical Application for Aircraft and Space Travel, by Constantin P. Lent (Pen-Ink Publishing Co., 1947)—An illustrated history for beginners.

Mathematical Theory of Rocket Flight, by J. Barkley Rosser, Robert R. Newton, and George L. Gross (Mc-Graw-Hill, 1947)—A technical work on all phases of rocket flight characteristics.

Rocket Development: Liquid-Fuel Rocket Research, 1929-1941, by Dr. Robert H. Goddard, edited by Esther C. Goddard and G. Edward Pendray (Prentice-Hall, 1948)—Based on condensations from notes of the experimentation with rockets kept by America's pioneer rocket developer.

Rockets, Guns and Targets, edited

by John E. Burchard (Little, Brown, 1948)—World War II science series book discussing American rocket ordnance and ballistic missile problems.

Ballistics of the Future, by J. M. J. Kooy, and J. W. H. Uytenbogaart (McGraw-Hill, 1948)—A comprehensive study of exterior ballistics by two Dutch scientists. Chapters on V-1 and V-2 contain detailed designs.

Guided Missiles, by Alfred R. Weyl (London, Temple, 1949)—The origins, development, types, operations, and future possibilities of missiles and rockets.

Internal Ballistics of Solid-Fuel Rockets, by R. N. Wimpress (Mc-Graw-Hill, 1950)—Deals with artillery rockets, based on research at Cal Tech during World War II.

High-Altitude Rocket Research, by Homer E. Newell, Jr. (Academic Press, 1953)—Discusses testing and results of upper air rocket research.

V-2, by Walter Dornberger (Viking, 1954)—Former Peenemünde chief describes German liquid-fuel rocket and missile development between 1930 and 1945.

Rocket Propulsion, with an Introduction to the Idea of Interplanetary Travel, by Eric Burgess (Macmillan, 1954, second revised edition)—Technical presentation based on author's scientific public lectures. Basic theories, problems, and developments of longrange rockets and missiles and their application to space travel.

The Viking Rocket Story, by Milton W. Rosen (Harper, 1955)—Authoritative story of Viking by one of the project officials.

Rockets and Guided Missiles, by John Humphries (Macmillan, 1956)— A survey of achievements in propellants, motors, components, and application of powerplants to missiles.

Principles of Guided Missiles Design, a series edited by Capt. Grayson Merrill, USN (D. Van Nostrand): Vol. I, Guidance, by Arthur S. Locke (1955); Vol. II, Aerodynamics, Propulsion, Structures, by E. A. Bonney, M. J. Zucrow, and C. W. Besserer (1956); Vol. III, Operations Research, Armament, Launching, by Grayson Merrill, Harold Goldberg, and Robert H. Helmholz (1956). Coming in the same series: Vol. IV, Systems Engineering, Range Testing, by J. J. Jerger and R. F. Freitag; Vol. V, Space Flight, by Grayson Merrill, Milton W. Rosen, and Krafft A. Ehricke; and Vol. VI, Guided Missile Designer's Handbook, by C. W. Besserer.

Satellite, by Erik Bergaust and William Beller (Hanover House, 1956; Bantam, 1957)—The research in rocketry and astronautics leading to the launching of earth satellites, and space exploration.

Guided Missiles in War and Peace, by Maj. Nels A. Parson, Jr. (Harvard Univ. Press, 1956)—History of the missile as a military weapon.

Rocket Propulsion Elements, by George P. Sutton (Wiley, 1956)—An introduction to the engineering of rockets, for the specialist.

Frontier to Space, by Eric Burgess (Macmillan, 1956)—How rocket and missile experimentation and flight are adding to man's knowledge.

Guided Weapons, by Eric Burgess (Macmillan, 1957) – Characteristics, operations, and military usefulness of guided and ballistic missiles. For the informed layman and the specialist.

Rockets, Missiles and Space Travel, by Willy Ley (Viking, 1957)—Revised edition of a detailed account of rocket and missile research and test and applications to future space travel.

Rockets and Missiles, by Erik Bergaust (Putnam's, 1957)—Picture story of the rockets and missiles of all services.

Rocket Power and Space Flight, by G. Harry Stine (Holt, 1957)—A simplified explanation of the fundamentals of research and test of rocket and missiles and the future of space travel.

Rocket, by Air Chief Marshal Sir Philip Bennet Joubert de la Ferte

(Philosophical Library, 1957)-A history of rocketry and the story of the German V-2 development and operations against the Allies and allied countermeasures.

The Handbook of Rockets and Guided Missiles, by Norman J. Bowman (Perastadion Press, 1957)-Tabulation of rockets and missiles and their characteristics with 170 diagrams.

Development of the Guided Missile, by Kenneth W. Gatland (Philosophical Library, 1958)-Traces evolution of guided missiles and projects their possible future development for both military and peaceful uses. Contains maps, charts, and data on 140 powered rockets of eight countries. A thorough work for the specialist and layman.

### II-ASTRONAUTICS AND SPACEFLIGHT

Rockets: The Future of Travel Beyond the Stratosphere, by Willy Ley (Viking, 1944)-History of early rocket development and use, theorizing on spaceship construction and flight.

The Conquest of Space, by Willy Ley (Viking, 1949)-Popular introduction to interplanetary flight combining narrative and illustration.

Interplanetary Flight: An Introduction to Astronautics, by Arthur C. Clarke (Harper, 1951)-Surveys interplanetary flight as visualized in 1950, based on known astronautical and scientific fact.

A Handbook of Space Flight, by Wayne Proell and Norman J. Bowman (Perastadion Press, 1950)-A collection of astronautical, gravitational, and conversion tables and available data on rockets and rocket experimentation.

The Exploration of Space, by Arthur C. Clarke (Harper, 1952; Pocket Books edition, 1954)-Thorough and witty analysis and discussion of space travel for the layman.

Across the Space Frontier, edited by Cornelius Ryan (Viking, 1952)-Examination of the feasibility of space travel by a group of eminent scientists including Fred Whipple, Heinz Haber, Joseph Kapran, Oscar Schachter, and Willy Ley. Highly illustrated.

Our Neighbour Worlds, by V. A. Firsoff (London, Hutchinson, 1952)-A combination of astronomy-made-

simple and space travel.

The Atmosphere of the Earth and Planets, edited by Gerard P. Kuiper (Univ. of Chicago Press, 1952, revised edition)-Papers given at Fiftieth Anniversary Symposium of the Yerkes Observatory in 1947 deal with atmospheres of Mars, the Earth, and other planets, and rocket research.

(Continued on following page)

### Designers and Manufacturers of Special Portable Air Conditioning and Refrigeration Equipment

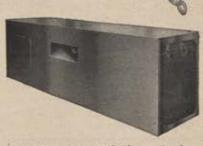
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Conquest of the Moon, edited by Cornelius Ryan (Viking, 1953)—Describes the pioneer expedition to the moon, based on informed speculation and known scientific fact. Contributors include Fred Whipple, Wernher von Braun, and Willy Ley. Highly illustrated.

Flight into Space: The Facts, Fancies and Philosophy, by Jonathan N. Leonard (Random House, 1953)—Nontechnical.

Man in Space, by Heinz Haber (Bobbs-Merrill, 1953)—Discussion of problems of space travel in nontechnical terms with emphasis on human survival and existence.

Space Travel, by Kenneth W. Gatland and Anthony M. Kunesch (Philosophical Library, 1953)—Traces development of rocket from earliest use to 1953, showing how research in related fields brings interplanetary flight nearer.

Into Space, by Phil E. Cleator (Crowell, 1953)—A study of the feasibility of spaceflight, by a British authority.

Rockets Beyond the Earth, by Martin Caidin (McBride, 1952)—The story of rocket development and discussion of spaceship construction and space travel.

Worlds in Space, by Martin Caidin (Holt, 1954)—A popular accounting of outer space. Illustrated.

The Science Book of Space Travel, by Harold L. Goodwin (Watts, 1954; Pocket Books edition, 1955)—Highly readable description of techniques of space travel and the problems that can be anticipated. Contains glossary.

Exploration of the Moon, by Arthur C. Clarke (Harper, 1955)—A fanciful description of what man may find on the moon.

Experiments in the Principles of Space Travel, by Franklyn M. Branley (Crowell, 1955)—Discusses rocket design streamlining, rocket ship engines and temperature control, power, and pressure in space.

Exploring Mars, by Robert S. Richardson (McGraw-Hill, 1954)—Speculation about Mars, the moon, other planets, and asteroids. Describes feasible rocket flight to Mars and moon and the work being done in our major observatories.

The Adventure of Space Travel, by G. V. E. Thompson (London, Dennis Dobson, 1955)—Imaginative popular account of manned exploration of space.

The Exploration of Mars, by Willy
Ley and Wernher von Braun (Viking,
1956)—A blueprint for man's first
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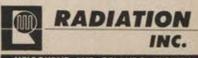
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astronomical and engineering data. A Space Traveler's Guide to Mars, by Dr. I. M. Levitt (Holt, 1956)-Director of the Fels Planetarium bases his speculation on scientific fact.

Man Among the Stars, by Wolfgang D. Müller (Criterion, 1957)-German science writer probes the beginnings, progress, and prospects of spaceflight and its impact on modern civilization.

Man into Space, by Hermann Oberth (Harper, 1957)-Updated views by the famed author of the 1929 Way to Space Travel, which became the bible

of modern astronauts.

The Complete Book of Space Travel (Maco, second edition, 1957, paperback)-A collection of articles on space stations, space travel, space medicine by eminent American missile and astronautic scientists. Well illustrated.

#### III-THE MEN

The Lonely Sky, by William Bridgeman and Jacqueline Hazard (Holt, 1955)-Story of test-flying the Douglas Skyrocket research airplane.

Across the High Frontier: The Story of Test Pilot Major Charles E. Yeager, USAF, by William R. Lundgren (Morrow, 1955)—The biography of the first man to break the sound barrier and an account of his test flights in the Bell X-1.

The Rocket Pioneers, by Beryl Williams and Samuel Epstein (Messner, 1955)-Interesting, simply written, biographies of rocket pioneers from William Congreve to the present.

The Men Behind the Space Rockets, by Heinz Gartmann (McKay, 1956)-The lives and works of the German rocket and missile scientists.

The Fastest Man Alive, by Lt. Col. Frank K. Everest, Jr., USAF, as told to John Guenther (Dutton, 1958)-The story of one of the USAF's top test pilots with emphasis on his flights in the Bell X-2 at extreme altitudes and at speeds above 1,900 mph.

#### IV—EARTH SATELLITES

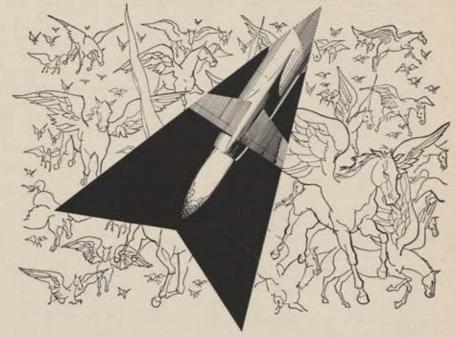
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meeting of the Upper Atmosphere Rocket Research Panel, January 1956 at University of Michigan.

Vanguard: The Story of the First Man-Made Satellite, by Martin Caidin (Dutton, 1957) - Dramatically written account of research and test in preparation for launching first US satellite.

The Making of the Moon: The Story of the Earth Satellite Program, by Arthur C. Clarke (Harper, 1957)-Highly readable account of Project Vanguard, its history and development, and problems of satellite and space experimentation.

(Continued on following page)





Man-Made Moons: The Earth Satellites and What They Will Tell Us, by Irving Adler (John Day, 1957)-Examines our knowledge of the upper atmosphere and what we shall learn from satellites about space.

Around the World in 90 Minutes, by David O. Woodbury (Harcourt, Brace, 1958)-An account of the American Earth satellite program with last minute post-Sputnik revision.

Earth Satellites and the Race for Space Superiority, by G. Harry Stine (Ace Books, 1957)-Layman's glimpse

at what we are doing in rocket and missile research and what we should do to win the race for space.

Satellites and Spaceflight, by Eric Burgess (Macmillan, 1958) - Scientific analysis of earth satellite development including construction, instrumentation, launching, transmission data, and flight orbit. Covers physiological and psychological problems of manned spaceflight, scope of spaceflight program, manned space stations, and expeditions to moon and planets.

### V-REFERENCE AND RESEARCH

German Research in World War II by Col. Leslie E. Simon (Wiley, 1947) -How the Germans organized their R&D.

The Nature of the Universe, by Fred Hoyle (Harper, 1951)-Astrophysicist discusses the universe, future of Earth, and possibility of life on other planets.

Space Medicine, the Human Factor in Flights Beyond the Earth, by John F. Marberger (Univ. of Illinois Press, 1951)-Based on space-medicine symposium at University of Illinois in March 1950, Dr. Hubertus Strughold, Dr. Heinz Haber, Wernher von Braun. and others contributing.

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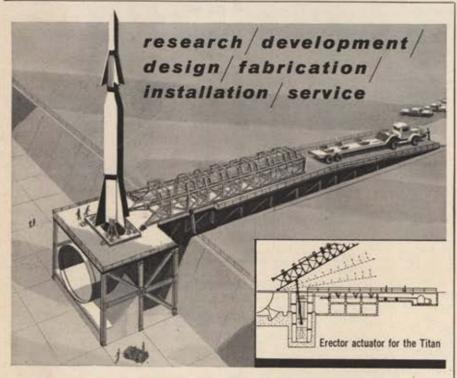
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Rocket Exploration of the Upper Atmosphere, edited by R. L. F. Boyd and J. M. Seaton (Interscience Pub., 1954)-A collection of the papers given by the Gassiot Committee of the Royal Society of London to the Upper Atmosphere Rocket Research Panel of the US.

The Physics of the Stratosphere, by R. M. Goody (Cambridge Univ. Press, England, 1954)-A scientific analysis.



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Jet, by Sir Frank Whittle (Philosophical Library, 1955)—Story of jet engine pioneer and the costs of developing a new science.

200 Miles Up—The Conquest of the Upper Air, by J. Gordon Vaeth (Ronald Press, second edition, 1955)—An account of upper-air research with unmanned stratosphere balloons and rocket flights.

Men, Rockets, and Space Rats, by Lloyd Mallan (Messner, 1956)—A layman's account of the Air Force's achievements toward the exploration of outer space.

The Secrets of Space Flight, by Lloyd Mallan (Fawcett, 1956, paperback)—Picture narrative on the men, the aircraft, the missiles, and rockets probing the edges of space.

Skyrocketing into the Unknown, by Charles Coombs (Morrow, 1954)— The story of high-speed, high-altitude research, experiment, and test flight.

The Ionosphere, by Karl Rawer (Ungar, 1957)—A scientific analysis of the ionosphere and discussion of the methods of scientific observation. For the professional.

The Space Encyclopaedia: A Guide to Astronomy and Space Research, by a group of top US and British scientists (Dutton, 1957)—A comprehensive, authoritative, illustrated encyclopedia of astronomy, astronautics, missiles, and space travel. Emphasis on terminology and definitions relative to our solar system.

Soviet Education for Science and Technology, by Alexander G. Korol (Wiley, 1957)—Thorough, authoritative study of Soviet education in general and scientific education in particular by an MIT senior researcher.

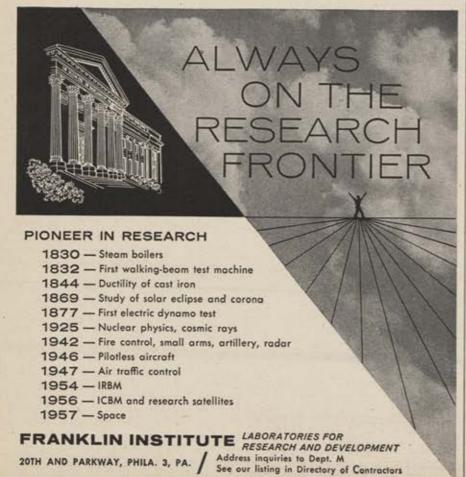
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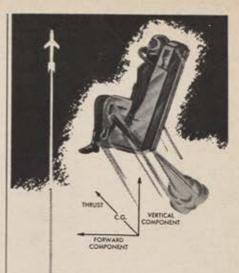
High Speed Flight, by E. Ower and J. Nayler (Philosophical Library, 1958)

—Analyzes problems of high-speed and supersonic flight, as applied both to manned and unmanned vehicles. Traces aerodynamic research and assesses future possibilities for rocketry and aeronautics.

#### VI-FOR THE YOUNGER SET

Guided Missiles: Rockets and Torpedoes, by Frank Ross, Jr., (Lothrop, (Continued on following page)





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Rockets, Jets, Guided Missiles and Space Ships, by Fletcher Pratt and Jack Coggins (Random House, 1951)— Picture book, ages ten to fifteen.

You and Space Travel, by John Lewellen (Childrens Press, 1951)-Illustrated, ages six to eight.

Model Jets and Rockets for Boys, by Raymond F. Yates (Harper, 1952) -Ages twelve to sixteen.

By Space Ship to the Moon, by Fletcher Pratt and Jack Coggins (Random House, 1952)—Ages ten to sixteen.

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The Mystery of Other Worlds Revealed, edited by Lloyd Mallan (Fawcett, 1952)-Ages ten to sixteen.

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Your Trip Into Space, by Lynn Poole (Whittlesey House, 1953)— Illustrated.

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Man, Rockets and Space, by Burr W. Leyson (Dutton, 1954)-Ages ten up.

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An Introduction to Rockets and Spaceflight, by Eric Burgess (London, Hodder and Stoughton, 1956)— Illustrated, for ages ten to fourteen.

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Space Satellite: The Story of Man-Made Moons, Lee Beeland and Robert Wells (Prentice-Hall, 1957)—Illustrated story of satellites, inside and out, and the laws governing their orbiting. Explains atmospheric layers of air blanketing world. Ages eleven to twelve.

The Next Fifty Billion Years, by Kenneth Heuer (Viking, 1957)—An astronomer explains the universe and what our future may be in space.

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