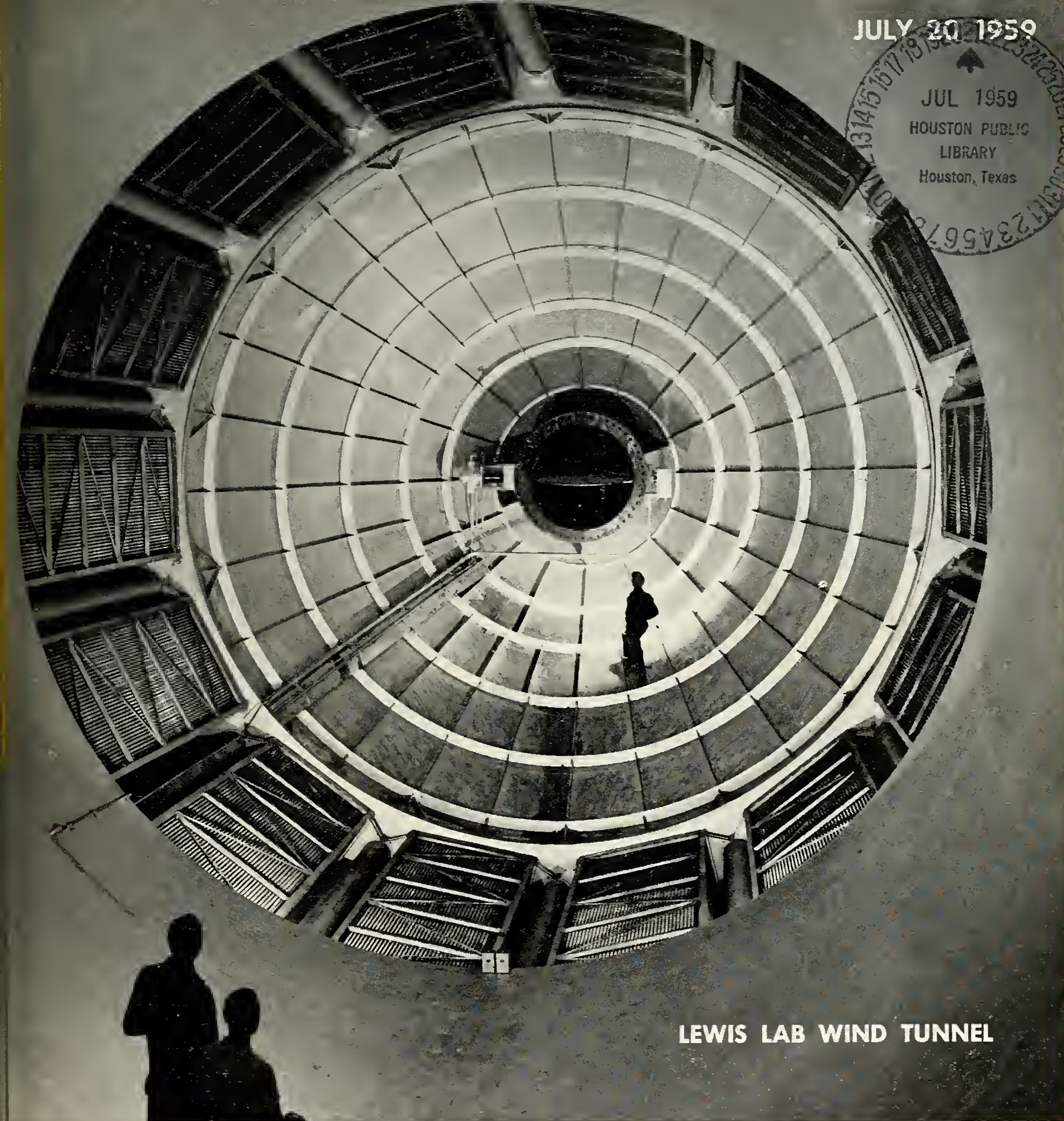
JULY 20, 1959



LEWIS LAB WIND TUNNEL

missiles and rockets

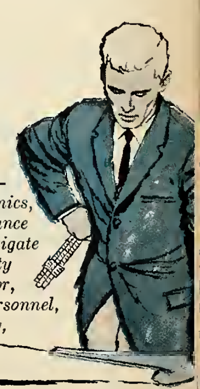
MAGAZINE OF WORLD ASTRONAUTICS

HIRD ANNUAL

Engineering Progress Issue

nd World Guided Missile Encyclopedia

AN AMERICAN AVIATION PUBLICATION



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Missiles and Rockets Volume 5 Number

Published each Monday by American Avia Publications, Inc., 1001 Vermont Ave., N Washington 5, D.C.

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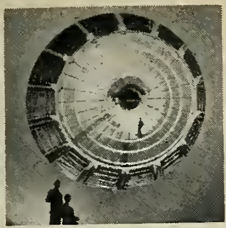
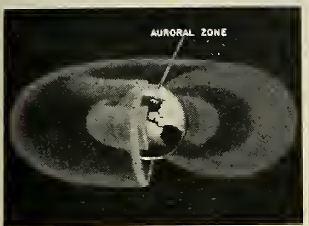
Printed at the Telegraph Press, Harrisburg Second class postage paid at Washington, and at additional mailing offices. Copyr 1959, American Aviation Publications, Inc.

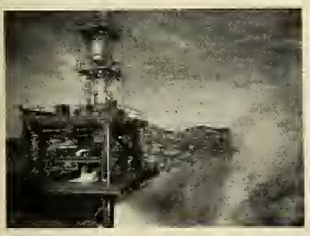
Subscription rates: U.S., Canada and Pos Union Nations—1 year, $8.00; 2 years, $12. 3 years, $14.00. Foreign—1 year, $10.00; years, $18.00; 3 years, $26.00. Single co rate—$.75. Subscriptions are solicited o from persons with identifiable commerc or professional interests in missiles a rockets. Subscription orders and changes address should be referred to Circulat Fulfillment Mgr., M/R, 1001 Vermont A Washington 5, D.C. Please allow 4 we for change to become effective and encl recent address label if possible.



COVER: upstream view of the No. 2 cooler of the Unitary Plan Wind Tunnel at the Lewis Flight Propulsion Laboratory, NASA facility at Cleveland, Ohio.



EARTH'S inner and outer radiation belts, named for Van Allen, are shown in a new artist's conception. (See the Astrophysics report, p. 43.)



TEST firing of individual H-1 engines is carried out at Rocketdyne's Propulsion Field Laboratory in the Santa Susana Mountains. (See the report on liquid engines, p. 53.)

POWERFUL *Titan* ICBM is readied for static testing at one of Martin-Denver's four static test stands. (M/R's annual missile encyclopedia is included in this issue—see p. 137.)

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

ANNUAL ENGINEERING PROGRESS ISSUE

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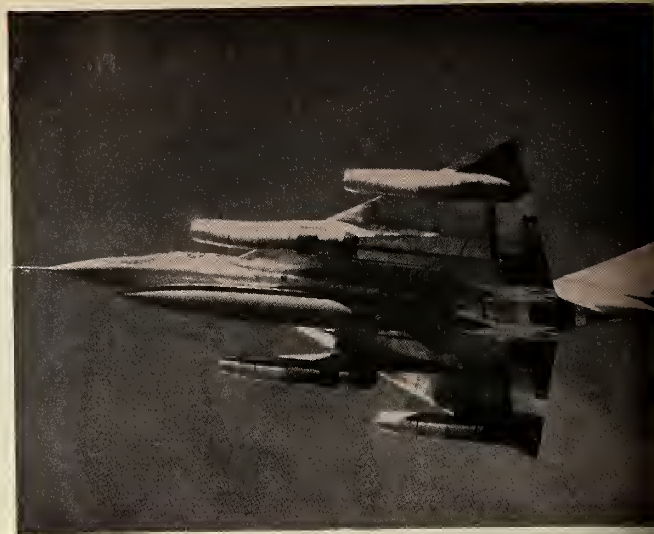
The PLANE

America's newest production bomber, the Convair B58 Hustler. This delta-wing jet employs an area-ruled fuselage for supersonic regime efficiency, and has reportedly been flown in excess of Mach 2 at 50,000 feet. Engines are four J 79's, in pods below the wings.



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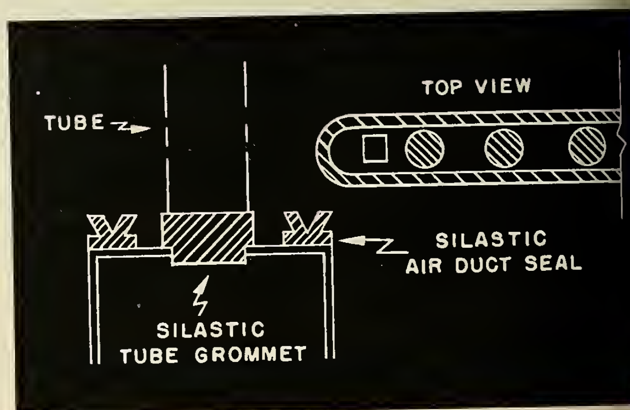

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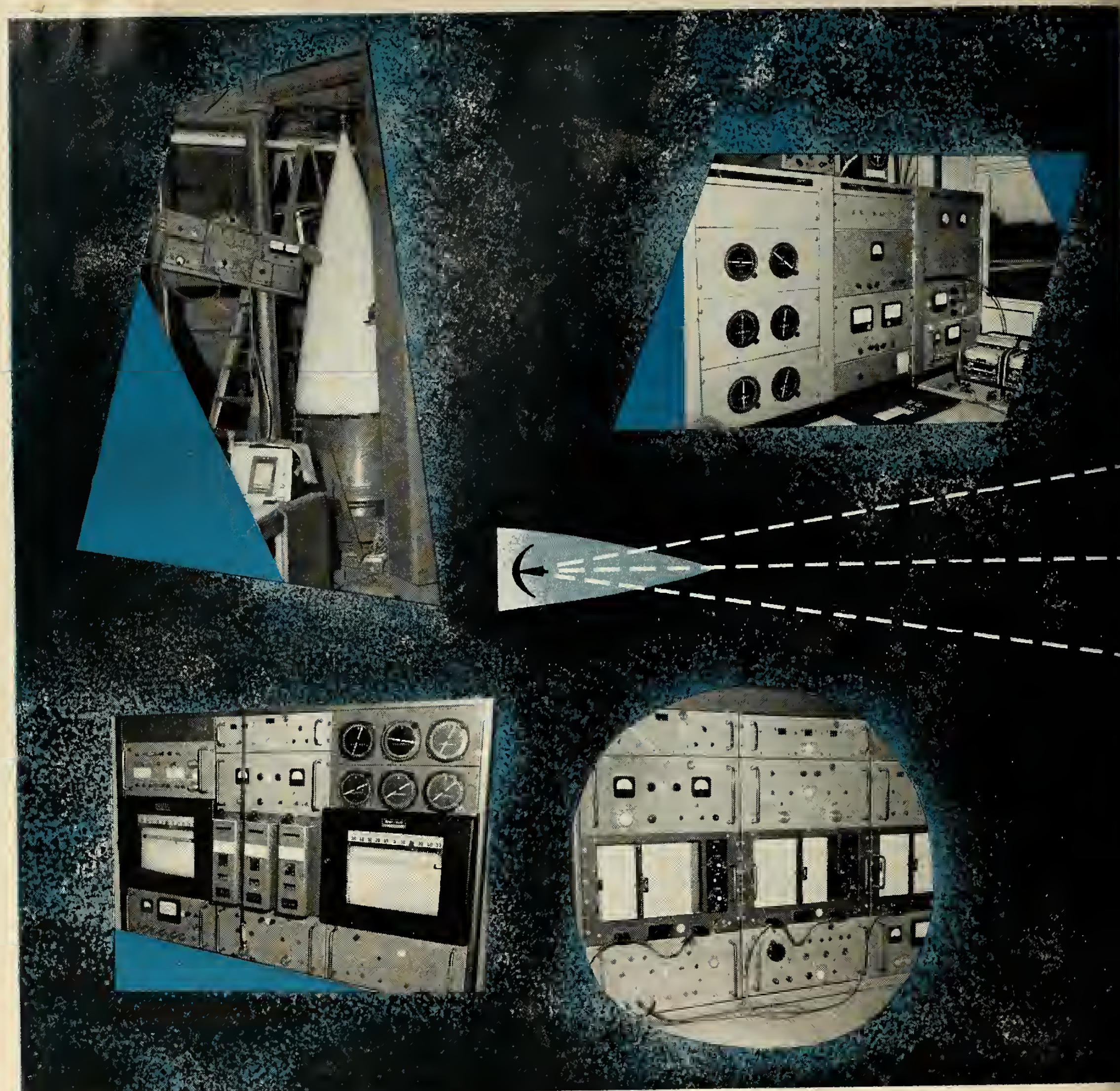

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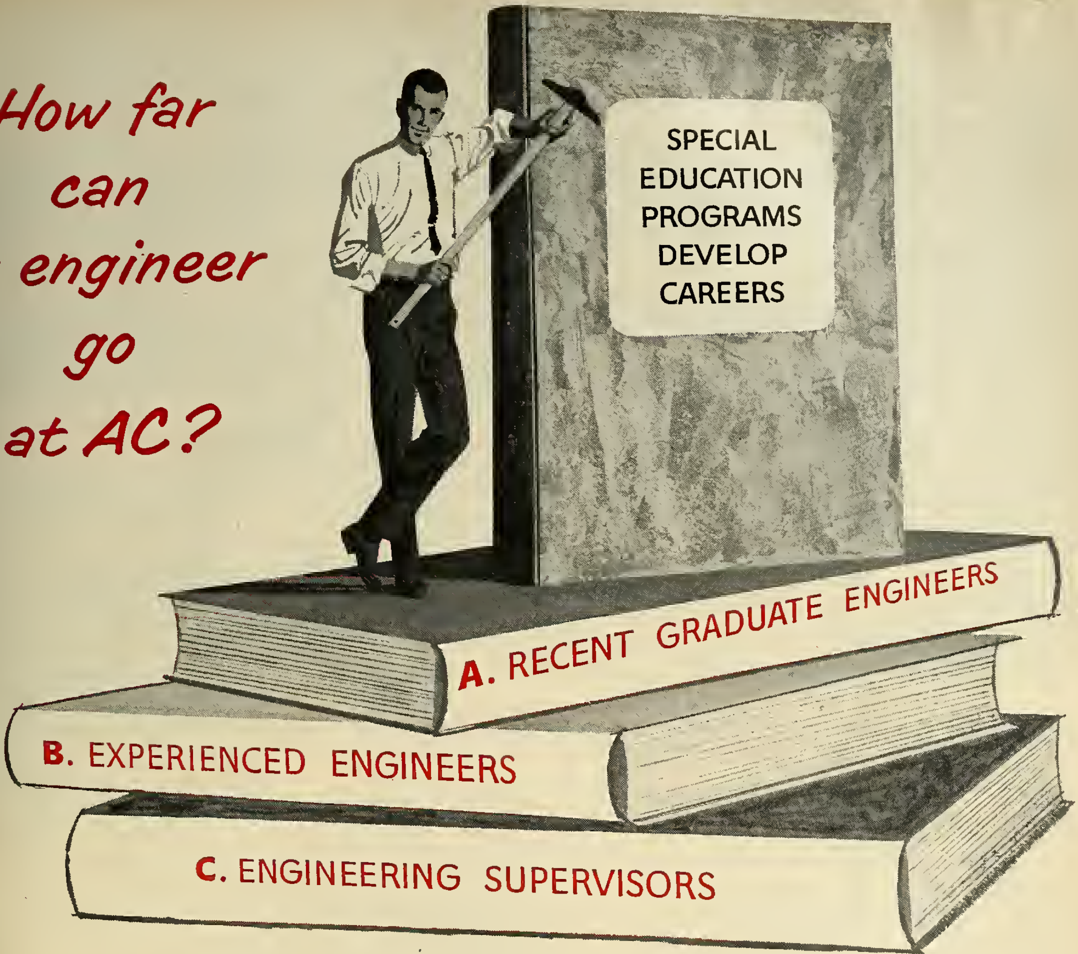

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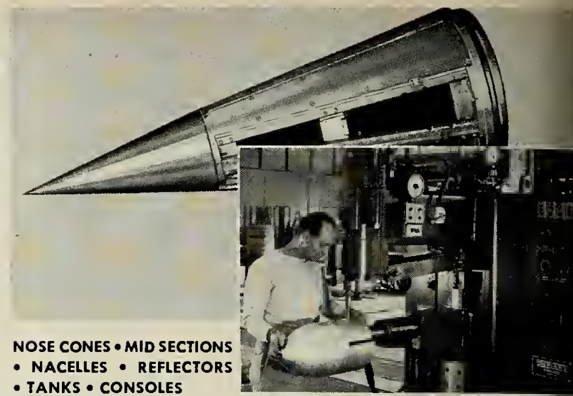

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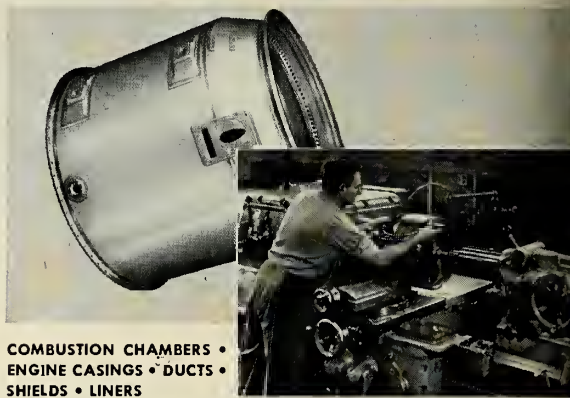

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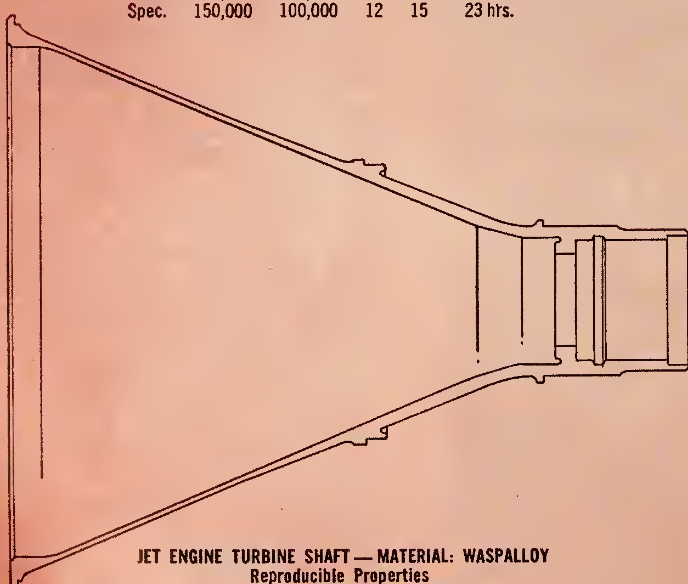
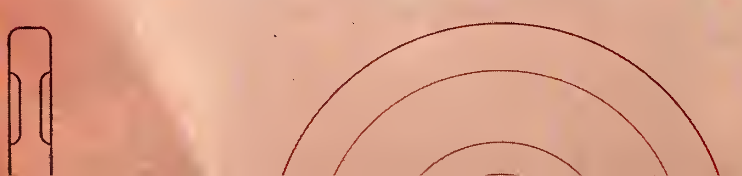
	175,000	128,000	20	23	225 hrs.
Spec.	150,000	100,000	12	15	23 hrs.



JET ENGINE TURBINE SHAFT — MATERIAL: WASPALLOY
Reproducible Properties

	T.S.	Y.S. .02%	E.L.	R.A.	S.R. 1350° F. 70,000 lb./sq. in.
	196,200	131,700	23	32	71 hrs.
Spec.	160,000	90,000	15	18	23 hrs.



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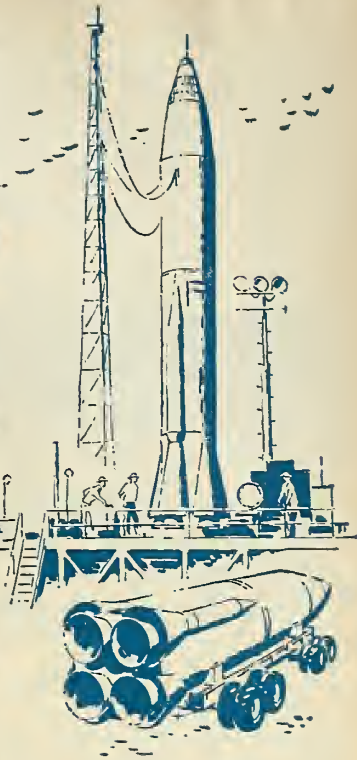

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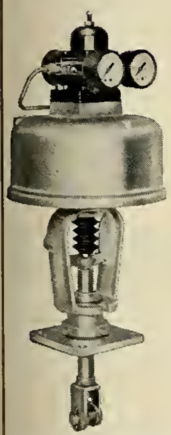

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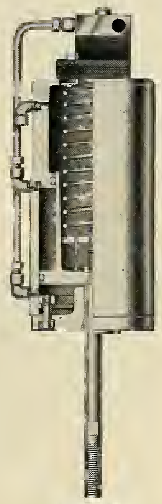

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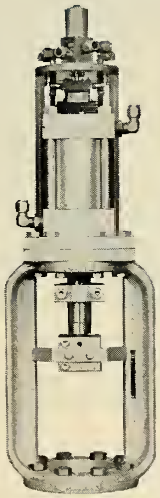

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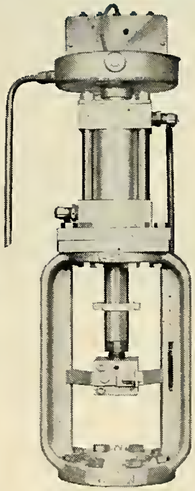

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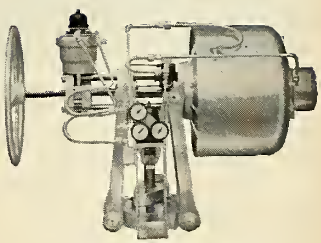

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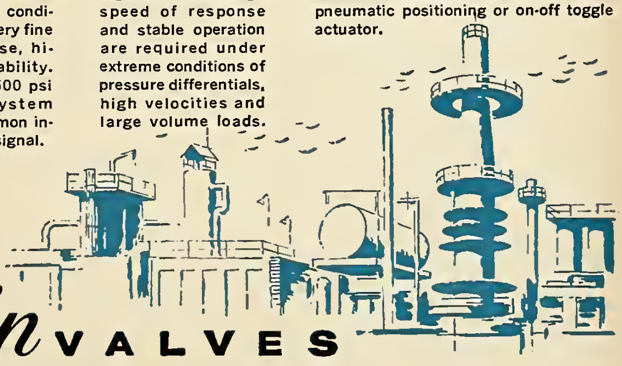

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Washington Countdown

IN THE PENTAGON

Which military service will run . . .

the new satellite detection fence is up for decision at the Pentagon's top levels. The command could encompass all U.S. military tracking facilities around the world. All three services want the job.

• • •

Recent Soviet 'Zooniks' . . .

may have soared some 1000 miles into space before returning to earth. The Russians aren't saying, but this is the educated guess of a number of U.S. experts. The flights obviously are aimed at collecting data on survival in space.

• • •

Pentagon sources complain . . .

that the GAO—Congress' fiscal watchdog—is stepping out of bounds in checking up on military expenditures. They say GAO is not only checking up on fiscal matters but also making judgments on the reliability of weapons.

• • •

No extensive delays . . .

in the *Discoverer* satellite schedule are now expected to result from recent failures. ARPA and the Air Force had planned to launch *Discoverer V* about the end of July. The shot is expected to be a full equipment checkout. No wildlife.

• • •

Behind the scenes an AF fight . . .

is shaping up over handling of weapon systems development. The trend appears to be moving toward greater centralization. A top-level AF committee is studying the question.

ON CAPITOL HILL

The House-cut NASA budget . . .

probably will stay cut—at least in part. But NASA appears to have little to worry about. Whatever dollars are lost in the first round are fairly certain to be regained by slipping them into a FY '60 supplemental appropriations bill later on.

The Hébert Subcommittee investigation . . .

into hiring of ex-military officers by defense contractors is scheduled to get down to specifics in its new round of hearings. Among other things, the subcommittee wants definitions of such activities as "selling," "promoting," and "negotiating."

At NASA

Would an astronaut die . . .

if the **Convair** *Atlas* designed to boost him into space exploded on the launching pad and the *Mercury* escape system failed to blast him free? NASA experts say no. The heat-resistant escape capsule would save him anyway.

• • •

But, incidentally, the strain . . .

of the ride to safety in an escape capsule is nothing to look forward to. If the *Mercury* capsule is blasted free from ground level, the astronaut will have to sustain as much as 20 g's for about one second.

• • •

Testing of Big Joe . . .

the boiler plated capsule mounted on top of an *Atlas,* will begin in late summer. The shots, which will test the capsule's heat shield on re-entry, have been delayed because of the recent defects discovered in the *Atlas* vehicle.

• • •

Chrysler's *Jupiter* may be put back . . .

in the *Mercury* program for budgetary reasons. NASA would like to use *Atlases* for the early *Mercury* tests. But cheaper *Jupiters* may have to be used because of congressional cuts in NASA's budget.

AROUND TOWN

Some of the reports . . .

that are being passed as the "latest" in the nation's capital:

. . . The French will explode their first A-bomb in a matter of months and begin developing nuclear warheads for missiles.

. . . Officials are worrying about a new Red power play in troubled Latin America's Possible Soviet goal: missile bases at America's back door.

. . . Top civilian scientists fear they see a trend back toward starving civilian federal research programs in favor of military research.

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Ability of energy to do work?
A mathematical convenience?
Gibbs' Free Energy?
What does it mean in isothermal electrochemistry?

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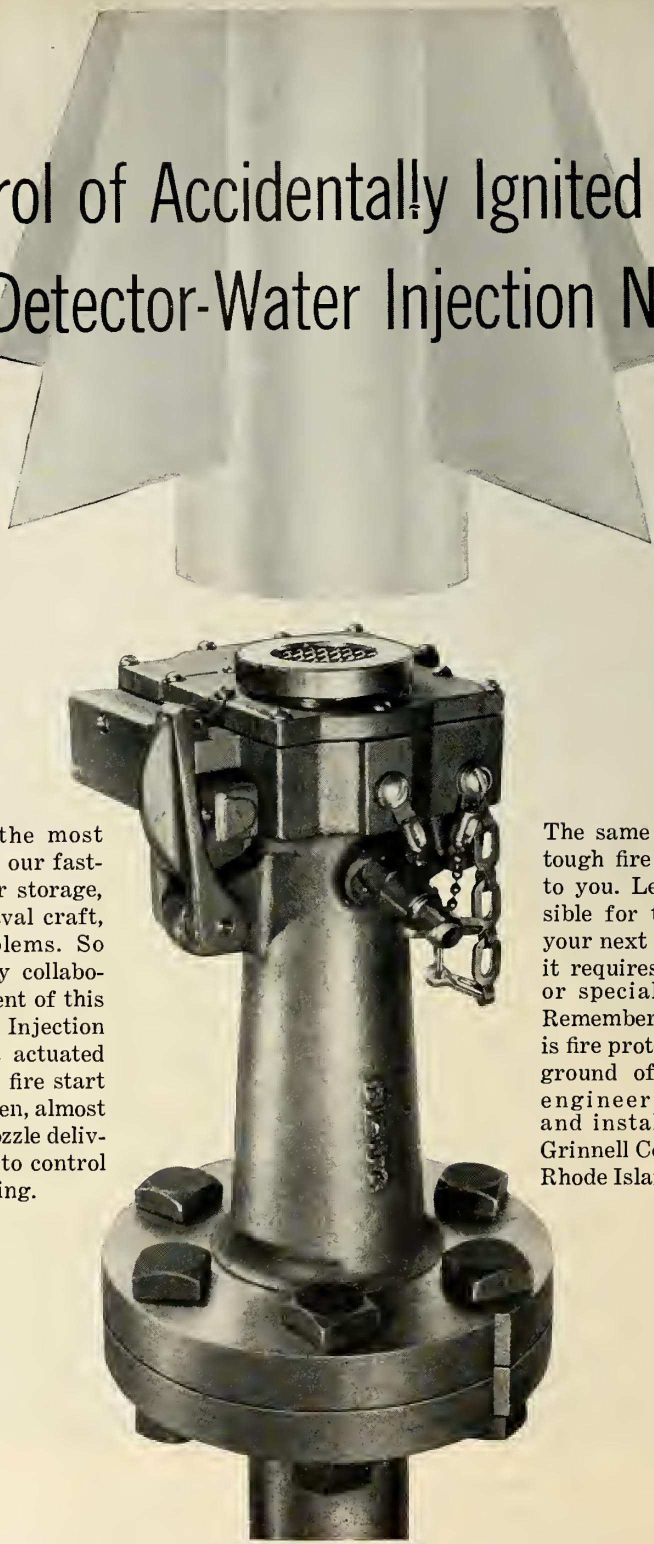

Missiles are among the most destructive weapons in our fast-growing arsenal. Their storage, particularly aboard naval craft, creates critical problems. So Grinnell and the Navy collaborated on the development of this Fire Detector - Water Injection Nozzle. This device is actuated by shock waves should fire start in a missile booster. Then, almost instantaneously, the nozzle delivers a stream of water to control or extinguish the burning.

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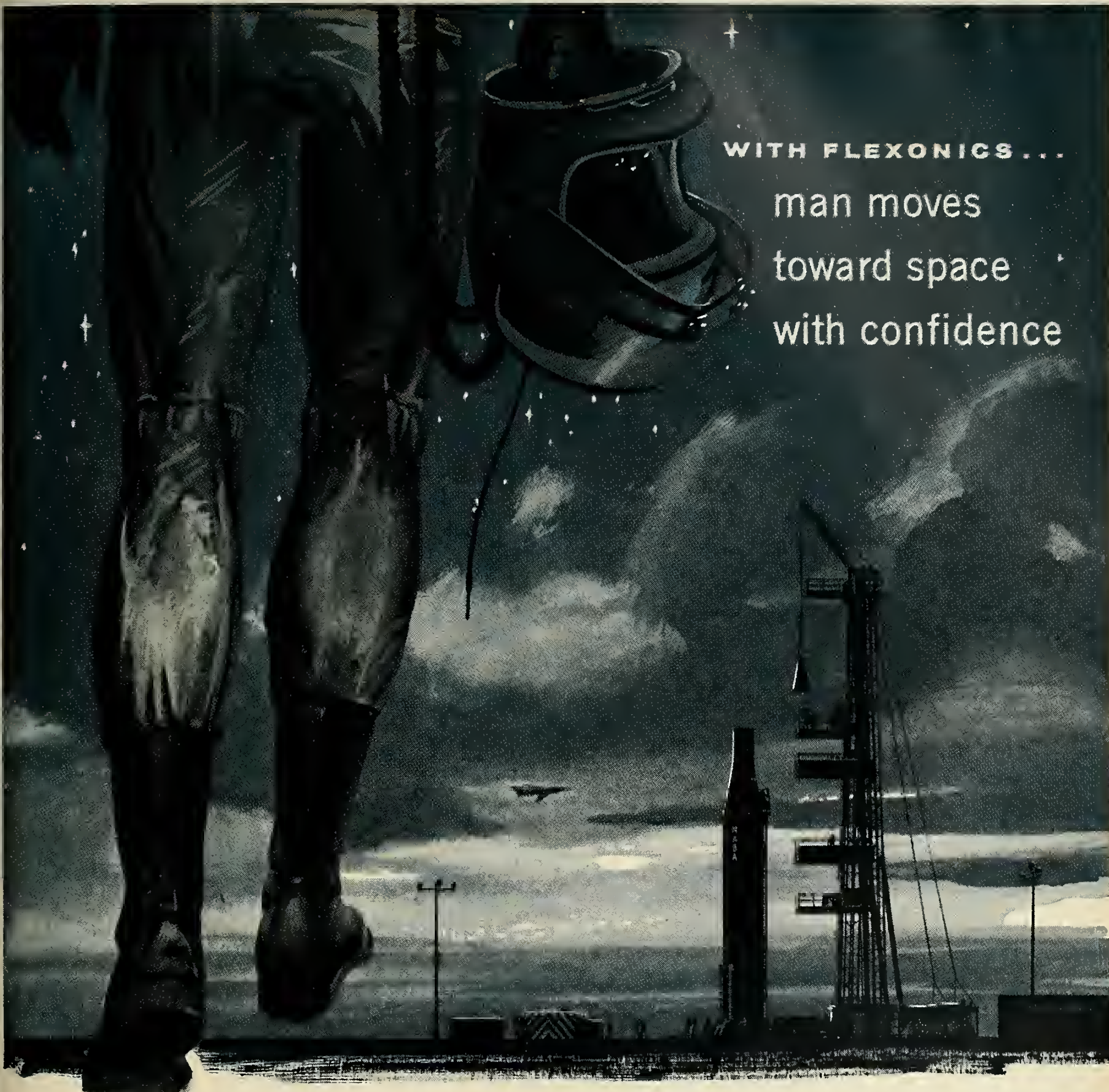

When man first steps into the vehicle that will carry him into outer space, it will be with complete confidence.

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Industry Countdown

STRUCTURES

Satellite rendezvous . . .

system is being researched by **Norair Division** of **Northrop Corp.** Concept is to permit maneuverable manned satellite to couple in space with life support satellite in permanent orbit. Hook-on would be effected through target satellite controlled approach (TSCA)—space version of aircraft ground controlled approach, or through maneuverable satellite landing system. MSLS would utilize search-and-track radar beacon aboard target satellite with pilot performing terminal phase guidance and coupling through visual observation.

• • •

'Super' *Hawk* . . .

is under research and development by the Army. On the operational **Raytheon**-built *Hawk* low-flying anti-aircraft missile, the Army is planning to spend an additional $127 million in FY 1960. Plans call for 15 *Hawk* battalions—13 operational in mid-1961.

• • •

Reports are current in France . . .

that De Gaulle hopes to get help from **Boeing** in producing a solid-fuel IRBM of his own. Advisors have told him that the cost, plus production of an atomic warhead would be a prohibitive 18 billion francs (about $3½ billion) or more. The French almost-ready atomic bomb is presently uncomfortably large for an aircraft, let alone a missile warhead.

• • •

Government recognition . . .

of the missile industry won't be possible for at least two years. It takes that long to make the change in the Standard Industrial Classification of the Census Bureau. Argument is under way now whether missiles should be classed as ammo/ordnance, lumped together with aircraft or treated separately in the 1958 census of manufacturers listing dollar value of contracts. This will be published in 1960.

• • •

Total of $384 million . . .

so far has been awarded **The Martin Co. Denver Division** for design, fabrication and test of *Titan* ICBM. Recently, ARPA chose modified first stage of *Titan* as second stage of 200-foot, 1.3 million pound thrust *Saturn* space vehicle.

• • •

Timetable for missile cruiser . . .

Long Beach to be ready for action is early 1961. The *Talos*- and advanced *Terrier*-carrying nuclear-powered warship was launched at the **Bethlehem Steel Co.** shipyard in Quincy, Mass., on July 14. Outfitting will take until late next year.

PROPULSION

Dynasoar propulsion . . .

systems proposals are being reviewed by Source Selection Board composed of AMC, ARDC and SAC officials. **Boeing** concept would use *Atlas* or *Titan* to blast off the boost-glide space vehicle, while **Martin-Bell** proposes using *Titan* only.

• • •

Saturn at lift-off . . .

will weigh about 580 tons—500 of it fuel. Booster for the 1.3 million pound thrust vehicle is cluster of eight H-1 **Rocketdyne** engines.

• • •

In pop-up tests . . .

of full-scale mockup *Polaris* at San Clemente Island, Calif., **Lockheed** is using 186-foot barge-mounted crane to catch the instrumented missile in the air. Operation is called "fish-hook."

ELECTRONICS

Western Electric has won . . .

the $25 million-plus NASA contract to construct the Project *Mercury* world-wide tracking range. On the **Western Electric** team are **Bell Telephone Laboratories, International Business Machines, Bendix Aviation Corp.** and **Burns and Roe, Inc.** Formal contract negotiations will begin this week.

• • •

Improved Azusa Mark II . . .

tracking system is being readied by **Convair Astronautics** for installation soon at Cape Canaveral under $1.7 million contract. Azusa circuits presently are aboard *Thor, Jupiter, Polaris, Atlas* and *Titan.* Mark II, which employs continuous microwave signal showing velocity and position, will be installed in second generation missiles and space vehicles.

ASTROPHYSICS

The Czechs are setting up . . .

an astronautics commission in the country's Academy of Sciences. But reports from the Iron Curtain country say the commission will not participate in any satellite or rocket launchings. Activity will be confined to optical, photographic and radio observation of cosmic activity.

• • •

"Moon garden" of snap beans . . .

carrots and turnips is being grown in pressurized vessels by **Republic Aviation** researchers. Project is aimed at determining the feasibility of growing crops to support a lunar base. Results so far indicate that little germination results in seeds planted in simulated altitude of 46,000 feet.


230,000 P.S.I.

PMR Outlines Plans To Spend $30 Million

by Robert Mount
Special M/R Correspondent

OXNARD, CALIF.—Pacific Missile Range development of downrange and coastal facilities moves into high gear this fiscal year with $30 million in expenditures authorized.

Island facilities at Eniwetok, Wake, Kaneohe Bay, Midway and Kwajalein are under way, and some modification of the tracking station at Ka Lae, South Point, Hawaii, may also be in the cards.

In addition, PMR will develop new instrumentation facilities at Point Montara, near San Francisco; Granite Canyon, on the Monterey Peninsula; Piedras Blancas, west of Paso Robles; Point Pillar, south of Point Montara; and at Laguna Peak, next to Pacific Missile Range Headquarters, Point Mugu.

Expenditures at PMR headquarters itself this year will total about $18 million, with nearly $10 million more earmarked for Point Arguello development. Launching pads for the Air Force project, WS-117L (Project *Sentry*) are under construction at a contract cost of over $5 million at Point Arguello. *Sentry* is the advanced reconnaissance satellite, still listed in Air Force releases under that name. It will utilize **Convair's** *Atlas* for a booster and a **Lockheed**-developed satellite stage.

• **For the islands**—Island development planned this year includes:

• Eniwetok—Communications data link with Wake Island, to handle missile impaction location data, $317,000. SOFAR MILS (Sound Frequency and Ranging/Missile Impact Location System) installation, $435,000. Sounding rocket facility to obtain high-altitude meteorology data, $22,000. Such data are essential for operations involving nose cone re-entry and missile impact data collection.

• Wake Island—Expansion of Federal Aviation Agency transmitter building, $93,000, needed because ICBM target area is near Wake Island and impact data must be transmitted. Wake is one of several PMR stations in what eventually will become Naval Missile Facility Western Pacific. Another $190,000 will be spent here for civilian bachelor quarters this year.

• Midway—SOFAR MILS installation, $435,000.

• Kaneohe Bay—SOFAR MILS installation, $486,000. PMR Hawaiian Islands communications center located at this Marine Corps Air Station will cost another $123,000.

• Ka Lee, South Point, Hawaii—Although no money is explicitly earmarked for this site, recently acquired from the Air Force in a transfer, it has been reported that this deep space tracking station may be modified to increase its ICBM tracking capabilities.

• **On the coast**—Instrumentation along the West Coast budgeted for this year includes:

Instrumentation stations with portable communications and tracking equipment at Point Montara, Granite Canyon and Piedras Blancas, to cost a total of $423,000.

At Point Pillar, the Navy will construct permanent instrumentation facilities costing $545,000, and $63,000 more in photographic and calibration instrumentation for air-to-air and air-to-surface missiles.

A new remote monitoring building atop Laguna Peak, near PMR headquarters at Point Mugu, will extend monitoring coverage to the Los Angeles Basin, presumably to refine current capabilities for frequency screening and interference control.

At Point Mugu, the following major construction is planned:

Roads, $3 million; missile project building, $2.9 million; armament test project building, $2.4 million, which may herald transfer of some armament system studies from Patuxent River, Md., to Mugu; PMR headquarters building, $1.8 million, to house about 600 administrative and operations personnel by 1961; parking facilities and flight aprons, $1.1 million; instrumentation facilities $750,000; frequency control facilities $580,000.

At Point Arguello, planned interservice and inter-agency launch site for PMR, the following are approved:

Roads and facilities, $5 million; security facilities, $955,000; central launch control building and missile assembly building, each costing $873,000; multipurpose Marine detachment quarters $410,000; range users' engineering building, $400,000; second unit of radio receiver station, $238,000; operational computer center, $233,000; ordnance assembly building, $200,000; public works shop, $150,000; launch site support, $65,000.

Beryllium Heat Sink Is Forged for *Mercury*

CLEVELAND—An 80-inch saucer-shaped beryllium disc has been forged for heat-sink service in the Project *Mercury* space capsule.

A 50,000-ton press at the **Alcoa** plant here squeezed a steel-jacketed beryllium billet into the shape desired at a temperature of 2000° F. **Brush Beryllium Co.** hot-pressed the 62-inch billet by a patented process involving simultaneous application of vacuum, heat and pressure.

After preliminary machining by Brush, Alcoa heated the billet in a special furnace. Then a huge manipulator placed it on a pre-heated die and pressed it to 3 inches thick. The forged part goes back to Brush for precision finish machining, after which Alcoa will perform ultrasonic inspection.

The shield will form part of the outside covering of the capsule, for which **McDonnell Aircraft Corp.** is prime contractor. The shield will be the leading face of the chamber on the return to earth. The piece is one of a series of beryllium forgings Brush and Alcoa will produce for *Mercury*. Beryllium was chosen because it is only a fifth the weight of steel and is an excellent heat absorber.

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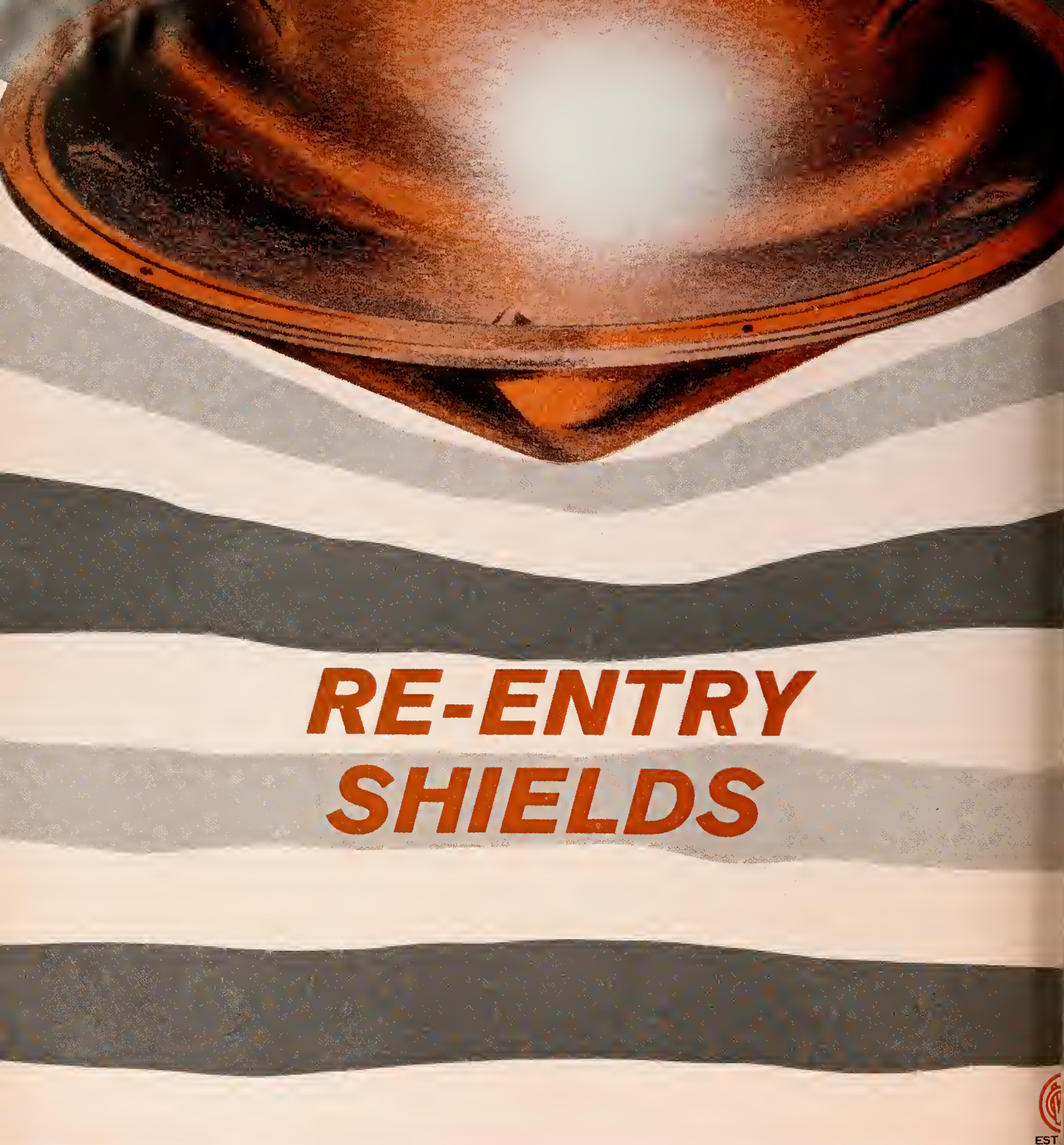
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Ford Motor Company

THE AMERICAN ROAD
DEARBORN, MICHIGAN

We are pleased to announce the establishment of a new division of Ford Motor Company.

On July 1, 1959, Aeronutronic Systems, Inc., a subsidiary, will be merged with the Company, and its operations will be carried on by Aeronutronic, a Division of Ford Motor Company.

Aeronutronic was organized in 1956 with the goal of large-scale participation in the nation's space and missile programs. Over the past three years, the subsidiary has achieved an excellent reputation and record of accomplishment and we are happy to welcome the new operating end-product division of the parent company.

As a division of the company, Aeronutronic will continue to have as its objective the development and manufacture of advanced technical products for both military and commercial purposes in the areas of weapon systems and space systems, missile range systems and instrumentation, advanced electronics, data processing systems and computers.

The merging of Aeronutronic into Ford Motor Company will permit more effective Company support of Aeronutronic programs and thus facilitate the undertaking of more extensive projects than have been feasible in the past.

Chairman of the Board

President

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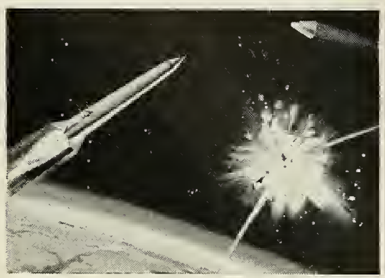

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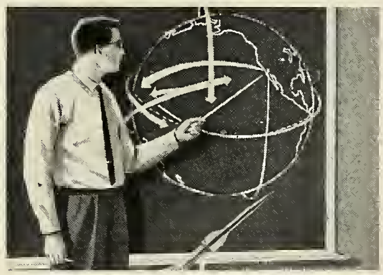

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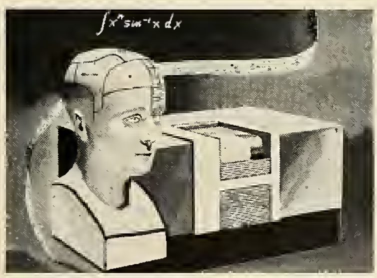

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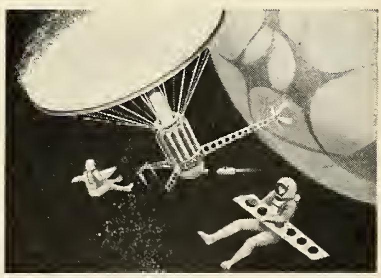

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LITARY AND INDUSTRY IN SCIENCE AND TECHNOLOGY

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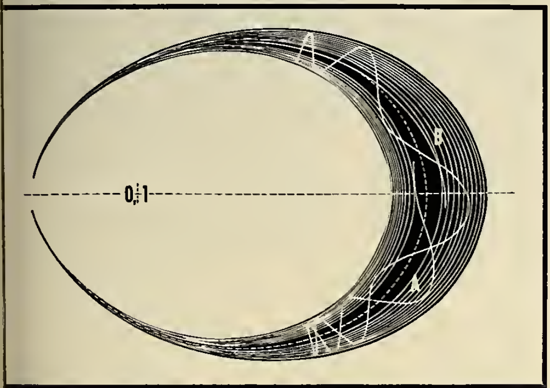
Van Allen Discovery Most Important

U.S. has obtained more fundamental scientific information from its satellites than the USSR from its instruments in heavier payloads



RBITS OF trapped particles, from the paper published by oermer in 1913: Orbit A shows a particle injected into the diation belt at a large angle to direction of the local mag- tic field; Orbit B, particle injected at small angle. (Fig. 1)

INNER AND outer radiation belts in space. Outer belt penetrates into the atmosphere at the latitudes of the auroral zones. Zones are indicated by light bands across the surface of the earth. (Fig. 2)

by Dr. Robert Jastrow

WASHINGTON—The first step toward e exploration of space occurred ap- oximately 22 months ago as a part of e International Geophysical Year. In e short interval since October, 1957, e new tools of research, the satellite d the space rocket, have produced o unexpected results of fundamental ientific importance.

First, instruments placed in the *Ex- prer* satellites by James A. Van Allen ve revealed the existence of layers energetic particles in the outer atmosphere. This discovery constitutes the most significant research achievement of the IGY satellite program. The layers may provide the explanation for the aurora and other geophysical phenomena, and they will also influence the design of vehicles for manned space flight, whose occupants must be shielded against their harmful biological effects.

Second, the shape of the earth has been determined very accurately with the aid of data from the first *Vanguard* satellite. As a result of this investigation, we have found that our planet tends toward the shape of a pear, with its stem at the North Pole. This discovery may produce major changes in our ideas on the interior structure of the earth.

Each of these discoveries was made with the aid of a U.S. satellite having a payload with a weight of approximately 10 pounds. It is a remarkable fact, and to the credit of the scientists responsible for the design of these small satellites, that they could be constructed to yield so much information per pound of instruments. It can be reasonably stated that we have obtained more fundamental scientific information from our satellites than the U.S.S.R. from its instruments, and on a per pound basis our yield of information has been amazing.

Of course, this is not to say that we could not have done even more in this first stage of space exploration, if heavier satellites had been available.

In addition to these two results of greatest fundamental importance, both the U.S. and the U.S.S.R. space research programs have also yielded other interesting data on the properties of the ionosphere and on the density and tem-

About the Author

Robert Jastrow, 33-year-old geophysicist and nuclear theorist, is chief of the Theoretical Division and chairman of the Lunar Explorations Working Group of the National Aeronautics and Space Administration.

Jastrow, who was graduated from Columbia College at the age of 18 and won his Ph. D. at 22, has lectured in physics at Columbia, Cooper Union, Leiden (the Netherlands), California, Yale and Maryland universities. He has been a member of the Institute for Advanced Study at Princeton, N.J., and consultant to the U.S. Naval Research Labo- tory, the Convair Division of General Dynamics, and the Los Alamos Scientific boratory. Jastrow joined NASA in 1958.

perature of the upper atmosphere.

• **Trapped particles**—The discovery of an intense zone of radiation in the outer atmosphere was first reported by Van Allen and his collaborators at the State University of Iowa on May 1, 1958. at a meeting of the National Academy of Sciences in Washington. Van Allen's results were confirmed by *Sputnik* data released by the U.S.S.R. at the Moscow IGY conference early in August, 1958. The zone discovered by Van Allen is commonly called a radiation belt, but the term is a misnomer because it is really a belt of particles rather than radiation.

Wc shall begin with a few remarks on the general features of the Van Allen particles. They are known to be electrically charged (probably a mixture of clectrons and protons), because their intensity follows precisely the shape of the earth's magnetic field. A magnetic field acts on charged particles, but it does not have an effect on neutral particles and radiation.

Also. we know from a great deal of theoretical research, going back to papers published by the Norwegian physicist Stoermer a half century ago, that charged particles can be trapped in the earth's magnetic field in orbits in which they spiral about the lines of magnetic force, traveling back and forth between the north and south magnetic poles. Fig. 1 shows typical orbits of trapped particles, reproduced from the original paper which Stoermer published in *Videnskapsselkapets Skrifter* in 1913. The particles can stay in these trapped orbits for very long times, perhaps as long as several years if they are at altitudes of one thousand miles or more. The trapped particles are injected into the outer atmosphere at an exceedingly slow rate, but because they stay there so long the *total number* of particles in the atmosphere will still build up to very large values. That is the key to the formation of the Van Allen layer.

The *Pioneer III* space rocket showed that the layer actually consists of two separate zones, as shown in Fig. 2. Each zone contains particles with energies varying from approximately 20,000 to several million volts or more. There may be an appreciable number of particles at still lower energies, but these could not have been detected with the instruments flown thus far.

It is found that the particles only appear in appreciable numbers above 200 miles in the northern latitudes and above 600 miles over the equator, and have a maximum density of about 1 per cubic centimeter. However, the Russians have reported *Sputnik III* results which suggest that in or near the auroral zone, the outer belt may reach a density of 100 particles/cm at an energy of 10,000 volts.

• **Protons or electrons?**—The component at the lower energies probably consists of electrons. The more energetic particles are protons or a mixture of protons and electrons. In the inner zone, the penetrating particles have been definitely identified as protons with energies up to one billion volts, according to the results of an emulsion experiment recently conducted by White and Freden of the Livermore laboratory. The concentration of energetic particles is greatest in the inner zone, but is still only 0.1 per cent of the density of soft electrons in that zone.

The inner zone is peaked at an altitude of 2500 miles. The outer zone has a maximum at an altitude of 10,000 miles, and extends into space to a distance of approximately 35,000 miles from the center of the earth.

Until recently, we did not know the mechanism that produced the two zones. This problem of the origin of the zones was the subject of a very lively debate, marked by high atmospheric temperatures, at a recent conference sponsored by the NASA Theoretical Division. However, it is now believed, on the basis of a preliminary report by Van Allen on the *Pioneer IV* results, that the outer layer is produced by particles coming from the sun. The surface of the sun boils and bubbles in a very active manner, occasionally emitting large gusts of plasma or charged particles into the solar system. The *Pioneer IV* flight came immediately after 5 days of continuous and unusually intense solar activity of this sort, *and showed radiation intensities in the outer zone which were many times greater than those measured in the* Pioneer III *space rocket.* The *Pioneer III* flight had occurred in a time of solar quiet. The difference between the radiation levels measured in the *Pioneer III* and *IV* flights definitely establishes that the outer zone is fed by particles from the sun.

It is not yet precisely clear how the outer zone is built up by the solar streams. It may consist of the actual solar particles which have been trapped near the earth by the geomagnetic field, or it is possible that the sola stream produces the trapped particle indirectly by collisions with air atom The NASA schedule of rocket an satellite launchings includes exper ments which will indicate which c these theories is correct.

• **Cosmic ray reflection?**—The caus of the inner zone has not yet been de termined, but the available theoretica evidence indicates that at least som of the particles in this belt are produce by the beta decay of cosmic ray neu trons, as suggested by Christofilos, b Singer, and by the Soviet physici Vernov. The observations by Frede and White also support the hypothes that the inner belt is produced by co mic rays. The Freden-White data in dicate that the number and energ distribution of the energetic proto are in good agreement with what w expect from the beta decay of fa neutrons.

The presence of a gap between th two zones still presents a serious prol lem. On the hypothesis of beta-deca for the inner zone and a solar orig for the outer zone, we would expe the inner zone to rise smoothly in the outer, and it is difficult to expla the finding of a minimum in radiatic intensity between the two. In this co nection an interesting suggestion w made at the NASA conference by D Dessler of the **Lockheed Missile ar Space Division,** who pointed out th there is an irregularity in the geoma netic field which may be described a hole or depression in the magnet contours. He pointed out, further, th the lines of force passing through th irregularity are located at the positic of the gap between the zones. Wh particles are trapped on these lines force in the magnetic field they descei to lower altitudes than would be t case in a perfect dipole field. At t lower altitudes they pass through denser atmosphere and are rapidly moved from the radiation zone.

• **Geophysical effects**—As Fig. 2 i dicates, the particles in the outer zo are funnelled into the Arctic and A arctic by the concentration of the ma netic field near the north and sou poles. The outer zone dips down in the atmosphere in these regions a disturbs the normal conditions whi exist at other latitudes. Two examp will indicate the consequences of t interaction between the trapped p ticles and the atmosphere.

First, we are rather certain that t *aurora borealis* and the *aurora aust lis* result from the excitation of t Arctic and Antarctic atmospheres collisions between air atoms and particles trapped in the outer zone.

Second, the trapped particle zo

xplain the recent surprising discovery hat the air at high altitudes is warmer n the arctic than in the temperate ones. This discovery was made by the nalysis of experiments performed in .S. rockets at the White Sands missile nge in Arizona, and at the Fort hurchill range in the Canadian Arc-c. The rocket measurements indicated hat at altitudes above between 90 and 40 miles the air over Fort Churchill as a temperature of approximately 00°F., as compared with a relatively ol 2000°F. over Arizona.

We can understand these tempera-re differences as a result of heating oduced by collisions between the apped particles in the outer zone and e atoms and molecules of the upper mosphere. The Van Allen data, sup-emented by *Sputnik III* results and rocket measurements performed by e Naval Research Laboratory and the ate University of Iowa, provide opportunity to make a quantitative st of this heating mechanism. With e aid of the rocket and satellite data, Harris of the NASA Theoretical Di-sion and the author have carried out lculations that show that collisions th the Van Allen particles must use an increase of several thousand grees in the temperature at the cen-r of the auroral zone, in qualitative reement with the observations.

Thus we see that the trapped par-le layers provide the explanation for number of geophysical phenomena. is this geophysical significance of the pped particles that makes their dis-very so important to fundamental earch.

• **Radiological hazard**—The trapped rticle layer has an additional signifi-nce for space technology in that it y constitute a serious radiological zard to the personnel of future man-d space flights. In order to determine e biological exposure level produced the layer, we must know the ener-s of the trapped particles, and ether they consist of electrons, pro-ns, or heavier particles. Detailed swers to these questions should be ovided in the future by further ex-iments now in preparation. The a available at present tell us only t the exposure levels appear to be hin the range from 2 to 50 roent-s for personnel in a vehicle passing ough the atmosphere to the moon outer space. These levels are far ow the estimated lethal dosage for mans, and they can be further re-ced by body shielding. This problem y not be a major one in comparison h other uncertainties of the first ce flights.

Of course, the exposure can be ch greater for personnel in a manned orbiting satellite. It may in fact be necessary for the early manned satellites to remain at low latitudes and relatively low altitudes, below 400 miles, where the intensity of the radiation belt is sharply reduced.

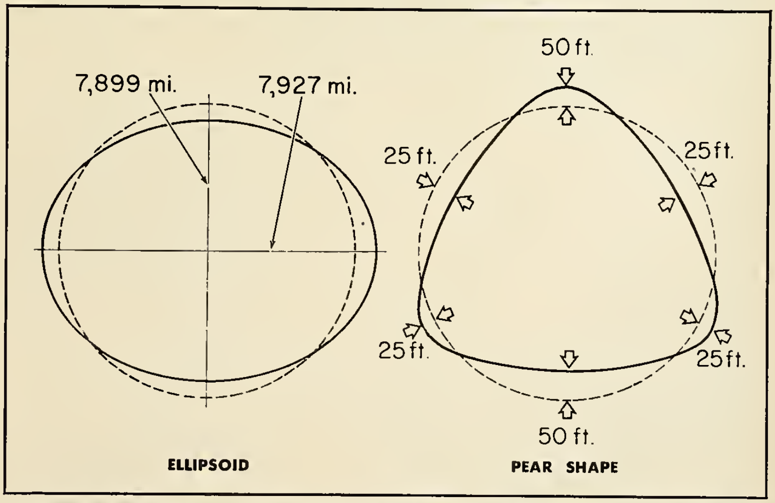
• **Shape of the Earth—1958**—*Beta 2*, the first *Vanguard* satellite, was launched on March 17, 1958. Later in 1958, O'Keefe, Eckels, and Squires, three scientists in the Theoretical Division of the NASA Goddard Space Flight Center, recognized certain changes in the perigee height of the satellite (orbital point closest to the earth) that were contrary to the established theory on the shape of the earth. This theory maintained that the earth had the shape of nearly perfect sphere, flattened somewhat at the poles, and bulging at the equator by about 12 miles as a result of the outward centrifugal force produced by the rotation of the earth. If the "flattened sphere" theory were correct, the force of gravity on the satellite would be the same in the northern and southern hemispheres. Actually, the orbit was found to be different in the northern and southern hemispheres. This indicated that the earth was not symmetrical above and below the equator as previously indicated.

The new findings show that the sea level at the north polar cap is raised by about 50 feet above what has been considered normal. At the solar polar cap there is a depression of 50 feet in the sea level. There are also small changes of the sea level in the temperate zones. The combined effect of these variations is to give the earth a tendency toward the shape of a pear, with the narrow end in the Arctic and the broad base in the Antarctic. A schematic representation of the old and the new shapes is shown below in Fig. 3.

This result is not entirely new. Without indicating his reasons, Columbus stated in the 15th century that the earth must be pear-shaped, as the following quotation proves: ". . . that it is not round in the way they have written, except that it has the shape of a pear that is very round, except where it would have a stem, where it is higher . . . " (Henry Vignaud, *Histoire Critique de la Grande Entreprise de Christophe Colomb*, Paris, H. Welter, 1911.)

A 50-foot variation seems insignificant in comparison with the 4000-mile radius of the earth, or even in comparison with the 12 mile difference between the polar and equatorial radii. However, this change means that there is an excess of matter near the North Pole, or a deficiency at the South Pole, sufficient to draw up the level of the sea by 50 feet *over an area the size of the Atlantic Ocean*. Such variations in the distribution of mass imply very large shearing forces in the interior of the earth.

We may ask what can be the cause of the pear shape. That is not known, but we can make some interesting guesses. For example, we know that the earth is currently growing warmer. It is possible that the Antarctic ice cap has been decreasing in thickness faster



SHAPE OF the earth from *Vanguard* satellite data: The drawing on the left represents the old conception of the spheroidal earth, with a 26 mile difference between the diameters at the pole and the equator. The figure on the left shows, in exaggerated form, the effect of adding a pear-shaped component to the ellipsoid, as required to fit the *Vanguard* data. In both drawings dashed circle represents an equivalent spherical earth with equal volume. (Fig. 3)

shape of geoid established . . .

than the earth beneath can bounce back beneath the reduced load. That would account for the depression at the base of the pear.

The above result indicates that the interior of the earth is not as plastic as originally assumed. NASA scientists have in fact concluded that a mechanical strength at least as great as that of a brick wall is required to support the dome in the north and the variations in the southern hemisphere.

• **Ionosphere properties**—The U.S.S.R. satellites have been the major source of ionospheric information thus far, primarily because these satellites transmit on the relatively low frequencies of 20 and 40 megacycles.

Low frequencies are poor for tracking purposes because the signals are bent by the electrons in the ionosphere during the course of their passage from the satellite to the ground tracking stations, producing an error in the apparent position of the satellite. At 40 megacycles the ionosphere produces an average error of 6 miles in the position of a satellite 600 miles from the observing station.

However, the bending that adversely affects the low-frequency signals for tracking purposes can provide valuable data on the state of the ionosphere, provided the true position of the satellite is known at all times. For example, the difference between the true position and the apparent radio position depends on the number of atmospheric electrons in the path of the signal from the satellite to the observing station. This effect has been used by several scientists to measure the electron density in the ionosphere. The true position can be determined by optical methods if the satellite is sufficiently large. Otherwise it can be done by combining a large number of radio observations for improved accuracy.

The U.S.S.R. satellite, *Sputnik I*, is a particularly intriguing satellite for ionospheric studies because it transmitted signals on both 20 and 40 megacycles for an extended period. Excellent worldwide recordings were obtained on both frequencies during the radio lifetime of this satellite. The ionosphere physicists must know the true position of *Sputnik I* in order to extract scientific information from these records. Thus far the U.S.S.R. has unfortunately not furnished any detailed information on the orbits of *Sputnik I* or the other Russian satellites, although requests for this information were made in 1958 at the IGY conference in Moscow.

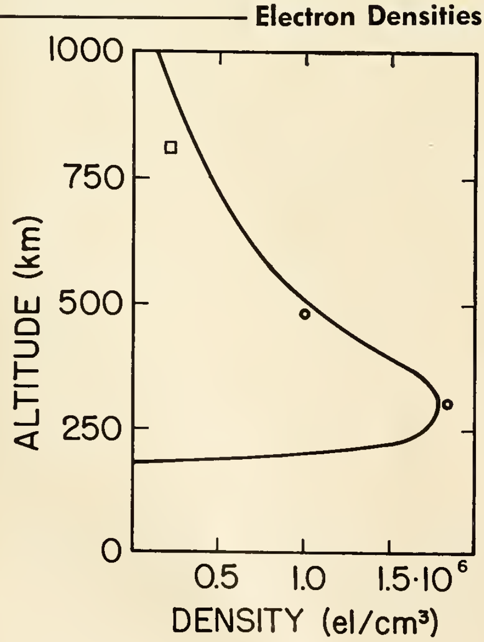
• *Sputnik* **ephemeris**—In the absence of orbit information from the U.S.S.R., the Theoretical Division of NASA has collected all available radio observations and combined them to produce an ephemeris, or table o true positions, for *Sputnik I*. Thi ephemeris has an accuracy of only te kilometers in the position of the satel lite, but it is the best one available t American and European scientists a the present time. The NASA ephemeri for *Sputnik I* is being made available t all scientists in the U.S.A. and in othe countries.

The Moscow IGY conference in cluded a Soviet report on ionospheri investigations, based on undisclose U.S.S.R. orbit data. Prof. Alpert of th University of Moscow gave the result of an analysis of the *Sputnik I* signals which indicated that the upper layer o the ionosphere extends to much highe altitudes than had been anticipated Alpert found the very important resul that the number of electrons above th level of maximum density in the iono sphere is 3.5 times greater than th number below the maximum. The elec tron density profile obtained by Alper is shown in Fig. 4, together wit U.S.S.R. rocket data. The Alpert profil appears to be a reasonable representa tion of ionospheric densities unde average conditions.

The third U.S.S.R. satellite, *Sputni III*, has also yielded interesting iono sphere results obtained from a devic called the "ion trap." The ion trap i a spherical collector approximately 1 inches in diameter, attached to the sur face of the satellite by an extendin rod 30 inches long. A negative voltag is placed on the trap, drawing all near by positive ions to it. The rate at whic the ions are collected is telemetere automatically to the ground, and pro vides a measurement of the number o positive ions in the neighborhood o the satellite.

A few samples of the ion trap dat were presented at the Moscow con ference. They indicated that the io density values are in reasonable agree ment with the electron densities meas ured by Alpert, as shown in Figure 4 As a by-product of the experiment, th ion trap also showed that *Sputnik II* acquired an appreciable negative charg in its passage through the ionosphere corresponding to negative potentials o several volts. An investigation by scien tists in the NASA Theoretical Divisio indicates that a satellite can be charge to still higher potentials, on the orde of thousands of volts, in those parts o its orbit that extend into the region o the great radiation belt. An extensio of the calculations published in 195 by C. A. Pearse and the author show that if the satellite is charged to kilo volt potentials, it will be slowed dow

Electron Densities



VARIATION of electron density with altitude in the upper ionosphere, as determined from U.S.S.R. rocket and satellite data: The solid line represents the electron density profile obtained by Alpert and his collaborators from the analysis of ***Sputnik I*** **signals. The circles are data obtained in U.S.S.R. rocket flights, and the square represents the charge density measurement derived from the ion trap mounted in** ***Sputnik III*****. (Fig. 4).**

y an electrical drag force which is 10 › 100 times greater than the ordinary ›rodynamic drag.

• **Density and temperature**—Direct easurements of the density of the atosphere have been made by installg ionization gauges in rockets. These easurements extend to an altitude of 50 miles. For altitudes above 150 iles the density has been measured inrectly, by analysis of satellite orbits. he indirect measurements depend on e fact that the atmospheric drag rces acting on the satellite are proortional to air density. The drag forces use a decrease in the energy and erefore in the period of revolution of e satellite, which can be easily meased and analyzed to give the average r density in the orbit.

The striking feature of the latest cket measurements of density is their eat variability with time of day, seain and latitude. The data show that an altitude of several hundred kiloeters the upper atmosphere is two nes heavier in the day than at night, d two times heavier in the summer an in winter. During a summer day arctic latitudes, where the "day" lasts arly 24 hours, the density is four to ght times greater than the density at e same time in the temperate zones.

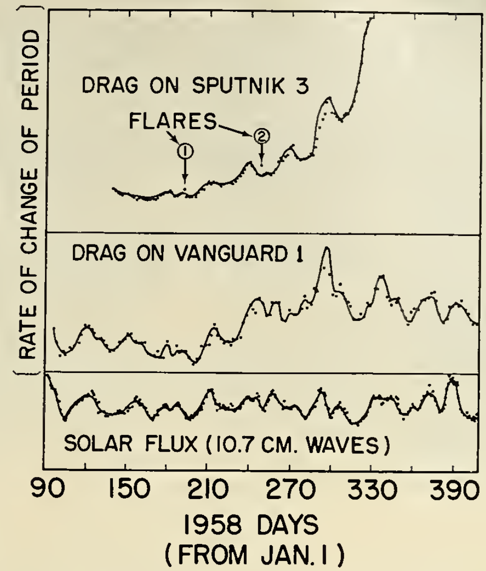
There appears to be a simple exnation for all of these effects, mely, that prolonged exposure to the n heats the atmosphere and causes upward expansion, producing very ge relative increases in the thin air high altitudes.

• **Satellite drag variations**—The satite density data also show large fluctions in addition to the systematic riations described above. These fluctions are probably the result of atspheric heating produced by streams energetic particles and radiation m the Sun. Dr. Jacchia of the rvard Observatory has in fact discovered that the apparently random fluctuations are actually proportional to the changes in the intensity of the 10-centimeter radiation from the sun, which constitutes an excellent measure of solar surface activity. The correlation between the satellite drag and solar flux is shown in Fig. 5.

Jacchia has been able to eliminate electromagnetic radiation as the source of the drag variations, and has succeeded in identifying the heating effect with the arrival of corpuscular streams in the vicinity of the earth, following major solar flares. The proof of this result is shown in a report recently published by Jacchia in *Nature*. Fig. 6 shows that the drag increases observed after two solar flares did not occur at the time of the flares, but began approximately 1 day later at the same time that the magnetic K index spurted upward. A rise in the K index signifies the onset of a magnetic storm, and therefore the arrival of the relatively slow-moving solar corpuscular stream which accompanies the flare.

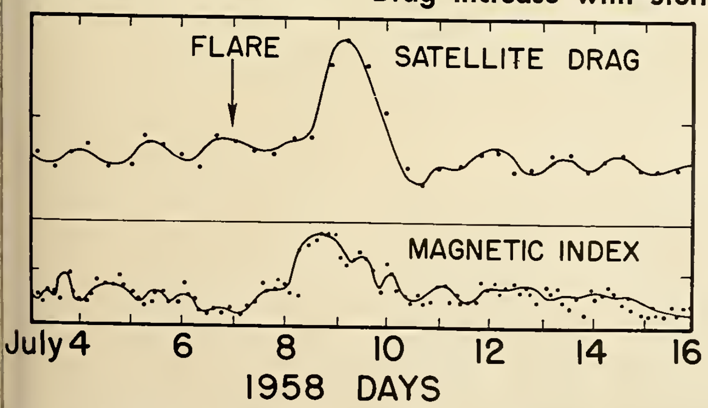
This beautiful demonstration of the relation between upper atmosphere properties and solar corpuscular streams promises to open a new chapter in the study of solar-terrestrial relationships. I believe that in retrospect it will turn out to be one of the most significant results to come from the IGY satellite program.

Solar Effect on Satellite Drag

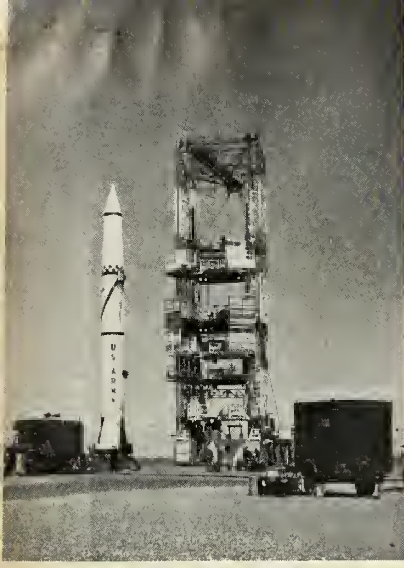


CORRELATION between solar activity and satellite drag. In the graph satellite drag is plotted on the same base with the observed flux of solar radiation in the 10 centimeter region of the spectrum. The 10 centimeter radiation is an accurate measure of solar activity. The figure demonstrates a perfect correlation of maxima and minima in the two curves. (Fig. 5).

Drag Increase with Storms



CORRELATION of drag increases with magnetic storms, following a major solar flare: The time of occurrence of the flare is indicated by an arrow. The onset of the magnetic storm, which signifies the arrival of corpuscular streams from the sun, is marked by the increase in the magnetic index plotted from the lower graph. (Fig. 6).



SERVICE tower for *Redstone* at White Sands.

Missile Support Progress . . .

Bigger Vehicles Will Pose More Baffling Engineering

Solution to missile support problems largely rests with Army's Corp of Engineers which has lion's share of responsibility

WASHINGTON—The art of launching a rocket has reached such refinement that the supporting mechanisms and structures required to get our exotic birds off the ground present the most baffling of engineering problems.

The solution of some of these support problems is a responsibility of the U.S. Army Corps of Engineers, headed by Maj. Gen. E. C. Itschner. As the Chief of Engineers explains it, the Engineers' role in the Government's missile and space program is a multiple one—performing a variety of missions for the Army Missile System; constructing missile bases for the Air Force; and carrying on construction projects for the Advanced Research Projects Agency and the National Aeronautics and Space Administration.

Working closely with the Army Ordnance Missile Command, the Corps of Engineers' support of guided missile and rocket operations includes the provision of Engineer troops; construction of missile sites, test laboratories, training centers and other facilities needed to train men and develop weapons; supply and maintenance of engineer equipment and material; provision of maps and geodetic data; and development by research; often in cooperation with industry, of new engineer equipment for the Army's family of missiles.

• **Keeping abreast**—All of these areas of support are equally important to the Army missile program, Gen. Itschner said, but to those whose interests lie primarily in keeping abreast of new developments in the constantly changing requirements of the program, a review of the research efforts of the Corps is in order. These efforts affect all Army missiles, from the operational *Lacrosse* to the still-to-be tested *Pershing,* successor to the *Redstone* family.

"Nuclear warfare will impose a requirement for great mobility on our ground forces, which must have the capability of hitting the enemy, then dispersing and regrouping again for another strike where it is least expected," Gen. Itschner explained. "We must be able to move our rockets and missiles into the battle area and out again on short notice. Supporting equipment, such as power generators, fuel tanks, fire control vans and radar equipment must also be easily and quickly moved. To attain this mobility, the Corps is developing smaller and lighter equipment which will do the job for which a particular missile has been designed.

"For example, the presently avai able conventional engine generat capable of providing power r quired for guidance of the *Lacros* missile weighs 900 pounds with a cessories. Since it is necessary th this generator be manpacked to t forward observers' position, we a developing a generator of 3 KW ou put, 400 cycle with precise pow regulation capable of being carri by one man, or with a full fu tank, by two men. The **Curtiss-Wrig Corporation, Santa Barbara Divisio** developed and demonstrated enginee ing models in sixteen months. One the unusual engineering characteristi of this generator is the silencing fe ture. Operational noise from this equi ment will not be heard further than few hundred feet.

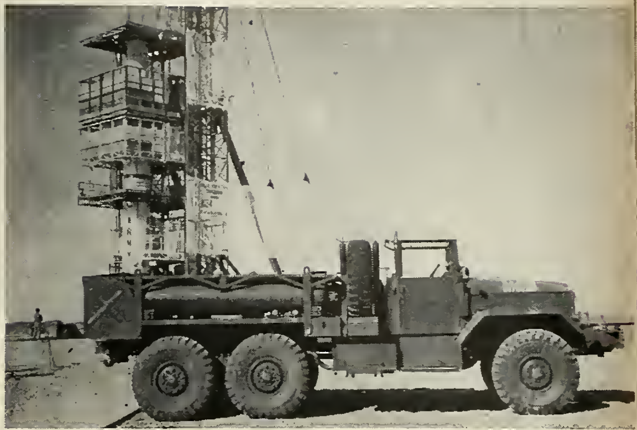
"Also under development is t power pack for the *Pershing* miss system. This pack is a combination utilities ordinarily furnished by t Corps of Engineers as separate piec of equipment. The various units a packaged on one base plate, with lit greater total weight than is norma found in any one of the componen Electric power of three different outp characteristics, high pressure air (30 psi), and conditioned air all generat from one gas turbine drive, are cluded for a total weight of abc 2600 pounds. This unit will be tra ported on a vehicle weighing 95 pounds which also mounts a fire cc trol hut. The standard air compress of the size needed, three generato and an air-conditioning plant heati unit, with four vehicles previously quired to transport them, would wei upwards of 28,000 pounds."

• **Interservice cooperation**—Of vi

About the Army Engineer Chief

Maj. Gen. Itschner has charge of the booming missile construction program for both the Army and Air Force. In addition, he is responsible for the Corps' nationwide civil functions. A graduate of West Point (1924) and Cornell, the General has served in Army construction projects all over the world—Europe in WWII, the Philippines, and Korea. Known as a "man in a hurry," his major responsibility now is directing construction of the new Air Force ICBM bases along with a whole range of missile research and development, testing, and launching facilities, including the Army's Nike bases.

IYDROGEN peroxide service truck is part of support equip-
ıent for *Redstone*.



BIG TASKS are performed by vehicles in missile support. Representative is this 5000-lb compressed air storage tank.

enefit to the Army in speeding the evelopment of the *Pershing* system is ıe precedent established by having one echnical service participating directly ı the program of another, the Chief f Engineers said. Specifically, the ower pack is being developed by the **Martin Company,** contractor for de- elopment of the missile system for the)rdnance Corps, Army Ballistic Mis- le Agency, and the Engineer Research nd Development Laboratories (ERDL) who serve as technical supervisor of the ack development for the ABMA, op- rating within the framework of the rime contract.

"Again, in the high power acqui- tion radar (HIPAR) building for the nproved *Nike-Hercules,* as in the *ershing* power pack, we have an in- egrated Engineer-Ordnance working elationship," Gen. Itschner pointed ut. "ERDL is the technical super- isor for the Army Rocket and Guided Missile Agency for the development f a pre-fabricated building to house new radar. It is evident that the rmy will gain from this joint opera- on in both the development and logis- cs stages. Experience gained by the orps of Engineers from participation development will enhance our capa- lity for providing spare parts and aintenance support of the resulting roduction item."

In the HIPAR building, where mo- lity and weight are of prime im- ortance, the unique engineering prob- m is in retaining the necessary air- ght panel seal despite repeated as- mbly and disassembly of the build- g, a problem not heretofore involved prefabricated building. Inflated seals e being used at all joints, and it ppears possible that a technical break-through in this particular problem area may result, the General disclosed.

Another development item with a requirement for high performance and low weight is the air-conditioner—heater plant for an Army field missile. This plant, a unit weighing 350 pounds, provides 38,000 BTU of air-conditioning and approximately 35,000 BTU heating per hour. It will be used in a van or a shelter of a field battery control center. Two difficult engineering problems—vibration and noise level—were encountered due to the high rotating speeds of the motors and compressors. Both are being solved through unique packaging and insulating methods. Because of an immediate requirement for this unit, a six month development time was imposed. Production models are scheduled with an initial delivery time of nine months.

• **Skyscraper on wheels**—Recently, the design was completed for a 305-foot missile service tower to be built at Cape Canaveral for the Advanced Research Projects Agency space vehicle, the *Saturn*. (MISSILES AND ROCKETS, June 8, 1959.) The tower, as tall as a 28-story building, will be on wheels.

Another ARPA project at Redstone Arsenal, is a static test tower being modified for use with the *Saturn*. This is the Army Ballistic Missile Agency's 140-foot tower previously used to test missiles up to the size of the *Jupiter*. Upon completion of the work, the tower will be capable of statically testing missiles having up to 1,500,000 pounds of thrust.

The work consists of driving approximately 6000 lineal feet of steel piling, constructing two reinforced concrete underground anchors 61 feet below bedrock and erecting approximately 470 tons of structural steel to be used for mounting the hold-down devices for the missile test. A cantilevered 100-ton bridge crane and hoist will be erected atop the modified structure for lifting the missiles and equipment into test positions.

Another missile service tower, fabricated by the **Noble Co.,** Oakland, Calif., is under contract with ERDL and scheduled for erection at Cape Canaveral in July. It is a mobile structure 150.25 feet tall, composed of twin towers mounted on a rubber tired trailer 42½ feet long. The tower has a traveling crane on top and is designed to handle *Jupiter* and *Redstone* type missiles. When servicing of the missile is completed, the tower moves away on its own trailer.

As missiles become more sophisticated, the demand for purer fuel becomes more urgent, Gen. Itschner said. The Ordnance Corps has determined the maximum allowable hydrocarbon count as .03 parts per million in the liquid oxygen as it is pumped into a missile such as the *Redstone,* largest field operational weapon of the Army. There must, therefore, be frequent purity checks by the soldier missilemen of the Engineer unit charged with supplying the fuel. To meet this requirement, ERDL is pursuing a project for developing a test instrument that can be easily used by the engineer soldier for checking the purity of LOX with a maximum of accuracy and a minimum of danger. Another field instrument under development by ERDL is for checking the dew point moisture content of compressed air at temperatures as low as –85 Fahrenheit.

• **Storage problems**—Loss of liquid

oxygen through evaporation during storage and transfer to the missile is another problem which plagues the Engineers. This loss, which now varies from 50 to 75 percent, is being reduced by improved equipment, especially fittings. ERDL is also developing a new type of storage container with unusual types of insulation. Inasmuch as LOX must be hauled from our mobile field generating plants to the launching sites in nine-ton tank trucks, the handling problem is a major one. Even though the Engineers have developed LOX plants with capacities of up to twenty tons per day, fantastic amounts are required to fuel a 70-foot missile. Heavy losses, particularly in the event of an actual combat situation, might cripple operations.

The Corps of Engineers' research and development work for the Army missile systems presently constitutes at least 25% of the research and development effort at ERDL. This work is being carried on both by ERDL personnel and by contract. It includes dozens of projects not heretofore mentioned, such as special air-transportable and mobile cranes, safety shower bath units to decontaminate personnel and clothing worn around toxic fuels, night vision equipment and special tools such as a welding machine for use on thin gauge materials. ERDL is even developing an unusually effective vacuum cleaner for cleaning the electronic and other delicate equipment used in the control vans.

Recently, the Corps completed an engineering analysis of the power requirements for the *Nike-Zeus*, including consideration of the remote stations where commercial power is not available. Transportation of fuel is a costly and often hazardous logistical effort. It has been determined that nuclear power plants can be designed to meet the stringent specifications required in operation of *Nike-Zeus* radar and electronic equipment. **Alco Products, Inc.,** which built the first Army power reactor plant at Fort Belvoir, Virginia, has completed a preliminary design and has been selected by the Army to complete the final plans of the proposed plant.

Missiles, regardless of whether they are Army surface-to-surface weapons or the Air Force's intercontinental ballistic missile, must be aimed at the target before they can be fired, Gen. Itschner noted. To attain the degree of accuracy needed to make missile warfare pay off in victory, the man aiming the weapon must know two things. First, he must know precisely where the missile is located at the time of launching, and second, he must know precisely where the target is in relation to the missile.

The task of locating targets and the guiding of the missiles to them is a complicated one requiring close coordination of the efforts of many men. Basically, it is a mapping job. The Engineers are responsible for providing the interconnected grids and earth measuring information necessary to direct longer range strategic missiles.

Said Gen. Itschner, "With the Air Force, we are working on the use of high altitude electronically controlled aerial photography to speed the compilation of maps, and we are using helicopters and geodimeters to accelerate field surveys. By using electronic digital computers, the time required for geodetic control adjustment has been reduced by years.

• **Where we are**—"Engineer teams on Pacific islands, using tracking devices, are obtaining valuable data from the *Vanguard* satellite as to precise island locations, which heretofore have been mistakenly located on maps from hundreds of meters to miles from their actual positions. This activity is helping us to get the answer to the question, 'Where in the world are we?'

"To help perfect methods of rapidly and accurately locating targets within a tactical area, which might be 200 miles deep on an atomic age battlefield, the Corps of Engineers is evaluating various target location systems. These involve the use of day and night aerial photography, radarscope photography to map the ground through clouds and darkness, and electronic systems to locate the photographic aircraft with respect to known ground stations."

A large part of the Engineers' efforts in construction are being directed toward the Army and Air Force missile programs. Construction of missile support facilities involves types and methods of building undreamed of a few years ago. Specifications now require construction tolerances which were possible before only as laboratory experiments.

"The *Zeus*, third generation of the *Nike* family, will create greater problems," Gen. Itschner predicted. This weapon is the Army's anti-missile missile designed to intercept enemy ICBM's in flight. The *Nike-Zeus* is a highly complicated system that brings the scientist, manufacturer and construction man together. Missile, test, and launching facilities are designed, developed, and built simultaneously. Flexibility will be the watchword at all times for those connected with the development of this missile. Constructors, designers and manufacturers will have to adapt themselves to the demands imposed by the rapidly widening knowledge being acquired by missile experts, for whom there seemingly are no limits except the horizons of their imaginations.

"Where these scientists and missile experts will take us in the space age is difficult to foresee at this point. The Army's Corps of Engineers, however, is preparing for whatever problems present themselves, whether they be on the moon or some fantastic reconnaissance space station on the route to Mars. Our Engineer research and development experts are conducting studies on space construction problems in sanitation, water supply, thermodynamics, electric power and advanced methods of prefabricated shelter construction. One of the programs considered important to the future involves a look into new sources of energy such as thermoelectric and thermionic generators and solar energy.

"The by-products of the research which our space program has brought about are leading us to portals of knowledge which are only now beginning to open for the benefit of mankind."

TWO IMPORTANT items for *Jupiter:* 100 KW power generator and vertical check-out shelter.

Fertile Field for New Applications

Microminiaturization, solid-state physics and communications technology are promising areas

by Robert J. Jeffries

DANBURY, CONN.—Whenever a new ientific fact is discovered, or when a w technology gains momentum, there a great tendency for authors and blishers to rush into print with a ultitude of predictions and projecns as to what the future will bring. areas already established there are e traditional articles on the "state the art" which appear periodically.

Both categories of exposition—e projections and implications of new chniques, and the periodic review established technologies—fill import functions. In general, they serve e needs of the "lay" public, as a basic ucational tool, and the practitioner the field, possibly as a stimulant, and rtainly, in the minimum, as a conient tabulation of the art, by means which he can mentally check his n progress and understanding.

Progress in Space Instrumentation ses a particularly difficult subject on ich to write an article for the reade of MISSILES AND ROCKETS Magazine. be correct, the author must define at he means by "Instrumentation"; must also define what he means by pace"; the meaning of "Progress" may take as self-evident. Also it obvious that the audience is not a y" audience in the sense of being technically unsophisticated in the subject, and lastly, for reasons of security, it is impossible to present an up-to-date review of the state-of-the-art in any detail.

What objective and means is there left then which justifies an article at all? The answer lies in perspective. If an article can present a situation in perspective in such a manner as to aid the reader in a better comprehension of his own role and problems, if it can stimulate the reader to a more creative synthesis of solutions to his problems, if it can direct attention to critical areas in need of attention and potentialities as yet unexploited, then it serves a useful purpose. In a modest way these shall be the objectives of this article.

• **What is instrumentation?**—Literally hundreds of efforts have been made over several years to define instrumentation. A synthesis of these several efforts, which in the least serves to define the scope of interests of this article is as follows:

"Equipment and techniques associated with and essential to the detection, measurement, transmission, translation and display of information, and including possible associated computation and utilization of the information for control purposes."

• **What is space?**—For purposes of this discussion, space may be defined as the volume around us excluding the earth, the oceans, and the atmosphere. Unfortunately, this definition tells us little, really, in that it assumes a precise definition of "atmosphere." One can define "atmosphere" as one chooses. For immediate purposes, let us assume as a purely arbitrary decision, that the atmosphere extends from the surface of the earth and its oceans to a height of 100 miles. Space then becomes the volume around the planet Earth, but external to a spherical shell 100 miles thick, surrounding the Earth. Obviously this definition is unique to the understanding and use of an earth-oriented creature.

• **What is space instrumentation?**—From the definitions above, it is apparent that Space Instrumentation embraces all the instruments that guide and control space vehicles, measure characteristics and performance of space vehicles and operate on and digest, display, and automatically react to the resultant information. It also includes the hardware and techniques of measurement of space and its contents. This is to say that Space Instrumentation embraces virtually every technique and piece of hardware designed to gather data in space or related to the gathering of that data. Space instrumentation is not generally understood to include considerations of propellants, propulsion or structures. But what of a nose cone? In some instances, a nose cone becomes, in itself, an instrument—detecting, and measuring directly and indirectly, meteoric dust, temperature, etc. All the above considerations demonstrate the necessity for an arbitrary agreement as to what shall be embraced by the term space instrumentation. For purposes of this discussion, space instrumentation is defined to include the following:

About the Author

Robert J. Jeffries is president of Data-Control Systems Inc., Danbury, Conn. A former assistant to the president of Daystrom Inc., Dr. Jeffries was president of the Instrument Society of America in 1957-58.

He has taught engineering at various universities and has been a consultant to all three military services, the National Bureau of Standards and numerous commercial firms. Jeffries is a founder and trustee of the Foundation for Instrumentation Education and Research.

small business to benefit . . .

• Instrumentation for measuring characteristics of space vehicles,

• Instrumentation for measuring characteristics of space and its contents,

• Instrumentation for communicating and displaying space data.

Measurements of temperature, acceleration, position, flow, stress, vibration, noise, etc. are commonly made today by means of a host of different transducers. These measurements will continue to be made in the years to come. This past year has seen a continuation of the long-term trend, in which transducers are becoming smaller, lighter, of higher frequency response and greater output. There is evidence of a renewed interest in variable-reluctance phenomena in transducers. Most transducers in use today yield analog output signals. There are coming to the fore an ever-increasing number of techniques, combined with conventional transducer principles, which yield digital output signals. The number of measurements which can be made with sufficient accuracy to justify the resolution of digital representation is still small. The advantages of reduced susceptibility to degradation of data in subsequent handling is currently the most important influence in the stimulation of digital techniques.

• **Terse messages**—Space engineers are employing techniques of predigestion of data in flight, with subsequent transmission of derived and statistical characterizations of phenomena. Probably the greatest incentive and utility of such techniques lie not in the inherent data analysis that occurs but in a reduction of the total information to be relayed to a remote point or points.

Solutions to several of today's problems will undoubtedly become operational in the next few years. For example, with the advent of transistor circuitry we can anticipate that transducer outputs will ultimately be adapted to current-input circuits, rather than voltage-inputs. In the near future, however, and before the above can come to pass, the present 0-5 volt input levels will begin to lose popularity. Signal-conditioners, that is amplifiers, and signal translators for modifying available transducer signals to adapt them to conventional standardized telemetry equipments will increase in number and complexity. Finally, the technology is forced to an entirely new approach based on the characteristics of solid-state circuitry. Low-level, solid-state computers will replace electromechanical devices and multi-channel amplifiers. Some prototypes of this type already exist.

A prime objective will continue to be the reduction in size of all equipment. Many components, such as voltage-controlled oscillators, are already approaching a situation wherein the connectors and junction boxes are as large as the components themselves. Further reduction in actual size of individual components does not appear to offer as much margin for improvement as do several other avenues. In the near future, one can expect high-speed, low-level commutation to reduce the space requirements of multi-channel systems. New multiplexing concepts will permit more efficient utilization of available power, thus reducing space requirements for RF components and space and weight in the energy source. For sustained flights, power "captured" in flight is already being used to reduce overall weight requirements. The present enthusiasm for digitized data, while justified in many instances, must be tempered with the sobering fact that in most applications digitization of data increases the space and weight requirements of the instrumentation equipment required for a given information capability.

The most important and exciting promise of the future for all types of flight instrumentation lies in the evolving techniques of microminiaturization. There can be no doubt that these techniques have the potential to reduce the size and weight of all flight instrumentation circuitry. Some equipment of this type is now in use. However, several fundamental facts stand out at this time: (1) Microminiaturization techniques, being relatively new, have not yet progressed to a stage, at which it is possible to achieve accuracies and stabilities comparable to conventional circuit techniques in reproducible units. (2) Microminiaturized circuits are essentially custom-made, with a high rate of failures, with complicated fabrication problems and large capital equipment requirements.

The manufacturers of space instrumentation hardware are, in the main, small businesses. This is so because of the rate of technological advance, the relatively small production runs involved, and the high premium on individual initiative and adaptability. As small businesses they are not able to undertake the basic research inherent to microminiaturized circuit development. For these reasons it is not to b anticipated that conventional *miniatur ized* standard flight instrumentation wil be replaced in the near future, for th bulk of space vehicle instrumentation with *microminiaturized circuitry.*

• **Measuring characteristics of spac**—The obvious questions asked first b any explorer of a new world are "What is present?", and "How much i there?" As we initiate our manned ex plorations of space we begin with thes elementary questions. It is almost cor rect to say we are in the Stone Age o space knowledge; we must first find ou whether the environment of this nev "space world" is hostile to our being We must first detect and measure, an later evaluate, the effects of such thing as radiation, meteorites, weightlessness etc. The fundamental problem is to de cide what we should be looking for Once the variables to be detected an measured are defined, then the appro priate hardware can be developed.

While we progress toward manne exploration of space, we learn muc from unmanned observation stations Missiles in trajectory, satellites in or bit and balloon-borne stations affor us effective vantage points for view ing space from a new angle an without the distractions and interfer ences associated with an earth-boun observatory. Obviously, most of th measurements made on far-space fro any vehicle located in near-space mus be based on electromagnetic phenom ena—received, reflected, refracted, o absorbed. The sciences and techno ogies of astronomy, optics, chemic analysis and photometry, working wit the instrument technologists are no evolving the transducer hardware adapted to the near-space environmen Balloon-borne telescopes, spectometer star trackers, etc. are now familia items for work in near-space.

• **Instrumentation for communica ing**—Telemetry is the all-inclusive wor used to embrace the concepts and hard wares involved in remote measure ments. In practice, one usually diffe entiates among transducer, telemetr and display equipment. Telemetr equipment provides the communicatio links between the measuring tran ducers and the display equipment.

The prime objectives of curre telemetry development are improve accuracy, reliability, space and weig reduction. Improved resolution is po sible through pulse code technique (However, improved resolution do not necessarily mean improved accu acy.) Pulse-coded data can be relaye from point-to-point either by radio wire with no theoretical degradatio of quality. This represents a distin advantage over transmission of data i

ıalog form. If however, in a pulse-
ɔde system, the transmission bit rate
high, there is the possibility of lost
ts, ambiguities, and loss of synchroni-
ıtion. These must be accounted for in
ny evaluation of ultimate accuracy.

Size and weight reduction in the
verall telemetry system can probably
e best effected by employing new
stem concepts. Pulse-coded systems
ill almost certainly increase size and
eight requirements. The power and
ace requirements of pulse-code equip-
ent capable of transmitting several
annels of high-frequency intelligence
ta today are much greater than the
rresponding analog system. Employ-
ent of RF links in the microwave
nds poses additional problems. The
ficiencies of transmitters in these
nds is relatively low. Compromises
ill be necessary to balance increased
formation-handling capability against
duced electrical efficiency. A recently
nounced heterodyne technique, which
rmits the superposition of several
andard analog multiplexes and the
multaneous transmission of very high-
equency intelligence over a single RF
ık, appears to hold considerable
omise for reduction of overall system
ze and weight.

The display of telemetry data poses
veral problems that are not solely
chnical. During flight, ground per-
nnel are aided by real-time informa-
on displays. During subsequent data
alysis much time and effort can fre-
ently be saved, if, instead of reduc-
g all available data, a quick search
n be made for "interesting" phe-
mena, and that portion of the data
spected minutely. Inasmuch as every
ght represents a large investment, it
desirable to process all available data
every conceivable way, usually prior
the next flight. In general, then the
splay problem is really three prob-
ms; (1) real-time quick-look, (2)
ta-reduction search and quick-look,
d, (3) detailed comprehensive data
duction. All three appear to be essen-
l to full and effective utilization of
e flight data. As intelligence frequen-
es go higher, as the number of chan-
ls of information increases and as
mmutation rates increase, new and
sically different techniques of real-
ne and quick-look display will be
quired.

In summary, Space Instrumentation
n be said to be a fertile field for the
plication of new ideas. These ideas
w encompass the most sophisticated
ncepts of solid-state physics, com-
unication theory, and astronautics.
t the most successful hardwares are,
d will continue to be, those that are
e simplest, most reliable, most ac-
rate, and available on short procure-
ent-lead times.

Liquid Engine Progress . . .

Power, Simplification, Reliability Still Criteria

Cheaper oxygen-jet fuels will be dominant for some time because of tremendous propellant consumption of rockets still under design

by Roy Healy

Los Angeles—Major current trends in the design and development of liquid propellant rocket engines for space vehicles and ballistic missile booster applications are (1) simplification for increased reliability, (2) higher thrust chamber pressures for improved performance, (3) optimized packaging for ease of installation and better accessibility and (4) clustering of individual engines to attain very high thrust levels.

The **Rocketdyne** Model H-1 engine, eight of which are to be assembled as the 1,500,000 pound thrust powerplant of the ARPA/Army *Saturn* space vehicle booster, exemplifies the current trends in large liquid propellant engines. Other new Rocketdyne engines under development, such as the 1,500,000 pound thrust single-chamber Model F-1, four of which will form the NASA *Nova* vehicle booster, will emphasize the same trends.

In mid-1958, Dr. Wernher von Braun, Director of Development Operations for Army Ballistic Missiles Agency asked Rocketdyne management to submit a proposal on clustering eight Advanced *Jupiter* engines for a huge space vehicle, then designated as the *Juno V*. He established design goals of simplification, improved performance, optimized packaging and clustering.

Available rocket engines were considered. Rocketdyne decided to propose a repackaged, uprated, much simplified version of the 150,000 pound IRBM engine being used in both the *Jupiter* and *Thor* ballistic missile program. We took advantage of the accumulated three years of developmental experience, including flight testing, on those programs as well as technical data from the *Navaho*, *Atlas* and *Redstone* engines. These enabled us to select and arrange components and the operational sequence.

• **Experimental testing**—Entirely separate from its production programs, Rocketdyne maintains an Experimental Engine group that constantly studies and tests new concepts and advanced designs for possible future use. A number of devices and techniques selected for incorporation into the H-1 engine had been proved promising by that group.

The Advanced Research Projects Agency accepted the Army Ballistic Missile Agency *Juno V* (now *Saturn*) proposal in September 1958. In that same month, Rocketdyne received the go-ahead to initiate engine design and development.

Rocketdyne adopted the philosophy of developing and delivering the H-1 as a single, basic, "any-position, plug-in" engine. This approach permitted the use of existing test facilities and

About the Author

Roy Healy is manager of the Saturn rocket engine program for Rocketdyne, a division of North American Aviation, Inc. Healy has more than a quarter of a century of experience in aircraft and rocketry. He first became interested in rockets in the mid-20's, and by 1935 had joined the ARS. He was president of ARS in 1942, and again in 1947.

His earlier work at Rocketdyne was on the Redstone system, and by 1954 he was supervisor of the unit. He participated in adapting the Redstone for use of Hydyne. In 1958 he was appointed as program manager for Jupiter engines.

INDIVIDUAL firing of Rocketdyne's H-1 engines for Project *Saturn* is accomplished in Santa Susana mountains.

reduced the propellant requirements for testing to a modest proportion. Utilization of basic components from the latest models of *Jupiter* and *Thor* engines allowed the use of existing tooling and manufacturing techniques and minimized the long-lead time for procurement of components. The approach is expected to make possible the goal of flight testing in late 1960.

The initial prototype engine was assembled to R&D type drawings. Firings were initiated at the Propulsion Field Laboratory in the Santa Susana mountains in December, 1958. The initial engine was delivered to ABMA after acceptance testing in April 1959, eight months after the design effort commenced.

• **Eliminated components**—To arrive at the H-1 engine, we modified existing *Jupiter* and *Thor* engines by eliminating many minor components, simplifying operation, and further improving and repackaging of major components. As an example of the former, the initial IRBM engines delivered in 1956 were built with five pneumatic pressure regulators and seventeen solenoid valves for proper start and shutdown operation. Gradual improvement of the engines reduced these requirements to a single pressure regulator and three solenoid valves. The more advanced H-1 design eliminates pressure regulators and solenoid valves entirely. A greatly simplified start sequence, using a pyrophoric fluid to ignite the main thrust chamber, has sharply reduced the electrical circuitry required. By mounting the turbopump assembly, valves, and other accessories directly on the sides of the thrust chamber, we achieved a lighter, more compact engine of smaller envelope dimensions.

Each of the eight engines powering the *Saturn* booster will be mounted into the missile by attaching the upper portion of the gimbal block assembly to structural members. The missile can then be controlled directionally by gimballing or swiveling the four outer engines. The missile guidance equipment exercises control through the medium of movable struts that adjust the positions of the outer engines.

The first cluster assembly and the firing of the eight-engine power-plant will be accomplished at ABMA on a mammoth test stand now being modified from its original *Jupiter* configuration. Initial launchings are planned from Cape Canaveral. Studies are in progress on parachute recovery of the *Saturn* first-stage booster.

The ARPA/ABMA *Saturn* booster is a natural outgrowth of Rocketdyne's experience in multi-engined projects. The original *Navaho* powerplant consisted of a pair of 120,000-pound thrust oxygen-alcohol engines. The advanced *Navaho* (G-38) consisted of three 135,000-pound thrust oxygen-jet fuel engines. Although the *Navaho* program was terminated prior to flight of the latter assembly, the engine development was progressing in a most satisfactory manner. In test firings, thrust levels of the clustered engines had reached more than 400,000 pounds, the highest level attained this side of the Iron Curtain at the time.

The original *Atlas* engine concept under development at Rocketdyne required a takeoff thrust of 660,000 pounds, a cluster arrangement consisting of four 135,000 pound booster engines, a sustainer of 120,000 pound output, and two 1000-pound thrust vernier engines for roll control and terminal velocity trim. During 1953, a breakthrough in thermonuclear warhead design permitted the sharp reduction in power requirements. This permitted the current *Atlas* concept of two boosters of 150,000 pounds each, plus a sustainer of 60,000 pounds thrust—with the vernier engine requirements remaining unchanged.

Extensive developmental and flight experience had been obtained on these cluster arrangements by the fall of 1958, when the Saturn program was initiated.

•**Parallel development**—The ARPA *Saturn* program, based on a cluster of existing engines, and the NASA program for development by Rocketdyne of a single engine of 1.5-million pounds thrust complement each other. When the more powerful NASA engine is available it too, in all probability, will be clustered to give the U.S. greater-tonnage-in-space capabilities. As more powerful engines are developed they will be used in groups of four, six, eight or more to make possible larger and larger spacecraft with increasing payload carrying capabilities.

One of the most effective factors utilized in the improvement of current production engines, and in the design of advanced models, has been Rocketdyne's extensive system of reporting troubles, inspection squawks and operational malfunctions. This embraces not only difficulties encountered in firing tests and missile launch operation, but also pre- and post-firing checkouts of the engine systems. The accumulated data are fed into automatic calculating and data storage machines, permitting rapid analysis and review of those items requiring design improvement. Constant scrutiny of reliability of the various components, operating sequences, etc., is invaluable in product improvement and the formulation of new engine concepts.

This continuous survey will sometimes reveal that the engine system has a component with an unacceptable record of malfunctions. In such a case we review possible design and quality control improvements in that component. We also decide whether the component might not be eliminated and its function served by dual-function use of other components in the system.

Rocketdyne conducted over 4000 large rocket engine tests during 1958 at the Santa Susana facility, using over 24 million gallons of liquid oxygen. In addition to the engine tests, close to 18,000 component tests were performed with propellants at the same facility.

The energy released in a 150,000-pound IRBM engine is equivalent to exploding some 1500 half-pound sticks of dynamite per second in the engine's thin-walled thrust chamber. To harness and control this tremendous energy, components and operational sequences must not only be reliable functionally but extremely precise in reproducibility of operation. It is not sufficient that a valve open or close upon receipt of a signal to do so—it must act in a predetermined number of milliseconds and in proper time relationship (again in milliseconds) to the operation of other system components. It is because of this rigid requirement that components developed for industrial use, and even the more rigorous requirements of aircraft use, are not suitable for rocket engine application.

• **Severe specifications**—In addition to the criticalness of operation as outlined above, the extreme temperature and vibration environments of rocket operation make more severe the specifications for rocket engine parts. The fact that America's missile program is progressing in a satisfactory manner is a tribute to the ingenuity and capabilities of this country's rocket designers.

Some clearly defined trends are becoming apparent in the liquid propellant field. For future ballistic missiles the desirabilility for instant readiness has promoted interest in the storable propellant combinations. Because of good performance and non-corrosive nature, nitrogen tetroxide is tending to replace the red and white fuming nitric acids as an oxidizer. To maintain performance at the oxygen-jet fuel levels, unsymmetrical dimethylhydrazine and hydrazine are the most commonly used fuels, both being hypergolic with the nitrogen tetroxide.

All of Rocketdyne's current production engines, designed for operation with oxygen-jet fuel, have been fired with storable propellants after relatively minor modifications. A number of our experimental engines have also been operated with the storable combinations.

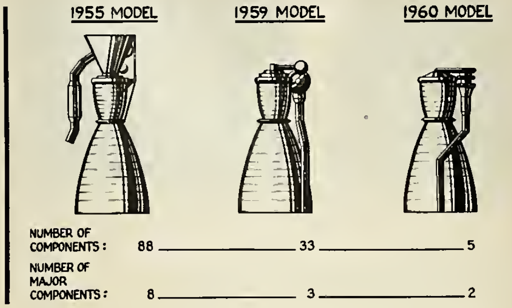
Increasingly more powerful space vehicle booster rockets are inevitable. Power levels in the tens of millions of pounds of thrust are now being considered. The tremendous propellant consumptions of these powerplants, and the fact that instant readiness is not a requirement, make it probable that the plentiful, inexpensive (2¢ a pound) and easily handled oxygen-jet fuel combination will be dominant for some time to come. Sea-level specific impulse values in the 245-275 second range can be expected from these booster engines.

For first-stage engines the trend toward higher chamber pressures continues with newer designs featuring thrust chambers operating in the 1000 psia range. Conversely, for upper-stage and in-space engines the trend is toward thrust chambers operating in the 200 to 300 psia range, and there are advocates of much lower pressures. These lower pressures, coupled with recent advances in the fabrication of lightweight, high-strength pressure vessels, makes attractive simple, pressure-fed rocket systems using helium as the pressurant. In such simple systems the tanks, lines and thrust chamber can be integrated into a compact power package.

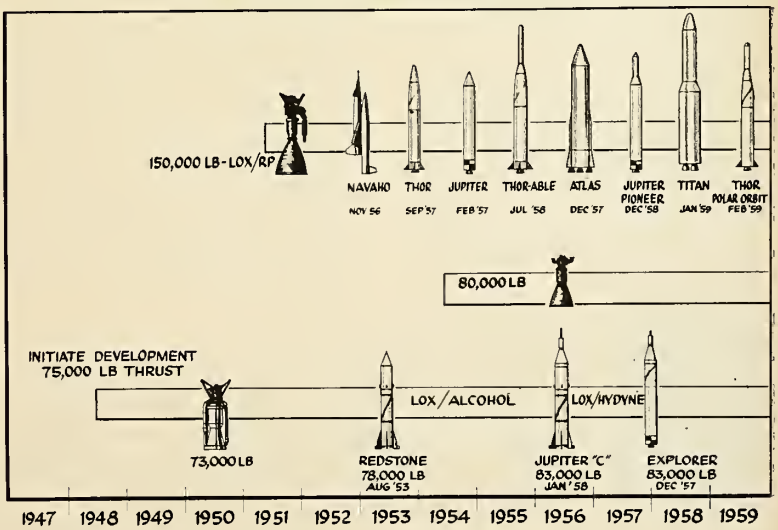
The increased importance of specific impulse, and the relatively small size of upper stages as compared to the huge booster stage, makes the high energy propellant combinations, such as fluorine-hydrazine and oxygen-hydrogen, attractive for upper stage use. Vacuum specific impulses in the 350- to 475-second ranges may be attained.

The advances achieved in the past decade by the high-thrust liquid propellant rocket engine have been outstanding. Continuation of current trends in seeking ever more powerful, more simplified, higher performance engines will make the accomplishments of the next decade even more fantastic. That time-span may see the fulfillment of a goal that I knew 25 years ago only as an amateur rocketeer's dream—the landing of a man on the moon.

SIMPLIFICATION and reliability have been major efforts in liquid propellants.



Large Rocket Engine Development






SERIES OF PHOTOGRAPHS of dog-carrying *Sputnik II* made it possible to deduct that the total length of rocket body and

Astrometry Progress . . .

Little Support for Vital Program

Additional equipment and new methods for using it are needed if U.S. is to have continuous location capability for spacecraft

by Dr. Douglas Duke

MELBOURNE, FLA.—For defense reasons, it is mandatory that the U.S. be continuously aware of the space location of all earth satellites and space vehicles. This is so, due to the possible future necessity of distinguishing approaching ballistic missiles from other vehicles which present no threat. There exist, in addition, other reasons that make this capability very desirable. Principal among these are performance analysis of our own space vehicles, geophysical and geodetic applications, testing of instrumentation capabilities and obtaining further information on the structural and operating features of foreign satellites.

A beginning toward developing space-location ability was made, shortly after the first *Sputnik* made its appearance, with the establishment of Project *Spacetrack* within A. R. D. C. The purpose of this project was to gather the maximum possible amount of tracking and configuration data on foreign satellites. The writer had the good fortune to be intimately involved with these efforts at the Atlantic Missile Range for the first 15 months of the project's existence, during which time the A. M. R. furnished the majority of the information received by the *Spacetrack* Filter Center at A. F. Cambridge Research Center, where prediction computations were carried out. During this period, there were many successes and failures. These have indicated the direction in which the development of new instrumentation systems and data-reduction techniques should move and also the most efficient organization of existing facilities.

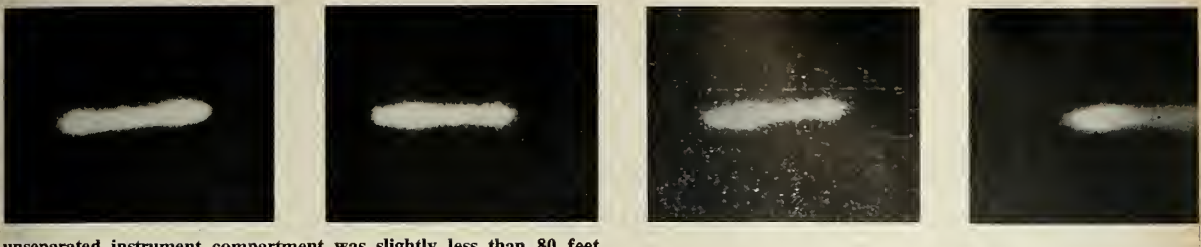
One obvious method of knowing the position of a space vehicle at any arbitrary moment is simply by maintaining continuous track of it. However, this would require world-wide instrumentation, which would be extremely costly, especially in the case of satellites that revolve only a few hundred miles above the earth's surface. Since it is reasonably expected that there will be a considerable number of orbiting satellites in the space about the earth in the near future, there would be an increasing requirement for simultaneous tracking of more than one body at individual stations. This would further increase the scope and cost of a continuous real-time tracking operation on all space vehicles.

Such an operation is, however, quite unnecessary. The laws of celestial mechanics show that the relative orbit of one mass point about another will be an ellipse. In the absence of any external perturbing influences the geometrical features of the ellipse will remain forever the same, as will the period of revolution about the orbit. Once we determine these quantities accurately, we can use them in a machine computer to predict where the object would be considerably later in the future. We could also improve the accuracy of the quantities continuously, merely by obtaining occasional later observations and combining these with those obtained earlier. Thus the need for real-time tracking could be reduced drastically and the capacity of a space surveillance system would be very large.

Unfortunately there do exist disturbing influences which impair the above prediction method considerably. The fact that the earth is not a perfect sphere, but flattened and otherwise deformed at the poles, and the presence of a tenuous but definitely existing trace of the atmosphere out to several hundred miles—both cause large departures from the invariant elliptical orbit, especially for close satellites. The earth's

About the Author

Dr. Douglas Duke is technical adviser for space technology at Radiation Inc., Melbourne, Fla. From November, 1957, to January, 1959, he was project engineer for the Spacetrack Project at the Atlantic Missile Range. Duke obtained his Ph. D. in astronomy and astrophysics from the Yerkes Observatory at the University of Chicago in 1950. He taught astronomy at several universities and has worked in the fields of missile and satellite tracking instrumentation since 1955.



unseparated instrument compartment was slightly less than 80 feet.

oblateness affects the space orientation of the orbit but not its size, shape, or period of revolution. The drag caused by the thin layers of the atmosphere has just the converse effect, not affecting the former ones, but causing changes in the latter quantities. For vehicles quite far from the earth, the above effects become small, but in this case, we must then consider the perturbing gravitational effects of the moon and the sun.

• **Complex calculations**—Practically all of the early work done at A. M. R. involved close satellites, so that earth's oblateness and atmosphere drag were of great importantce. The oblateness provided only minor difficulties since there existed theoretical formulas and enough observational material to take these effects into account reasonably accurately. The difficulties encountered with atmospheric drag have, however, been quite severe. Although the loss of energy due to drag is small during a single revolution, the effect is a cumulative one. During each revolution, the size of the orbit is reduced slightly by drag. Therefore, on the next revolution, the satellite spends more of its time in the lower atmospheric region where drag occurs, and the drag itself is greater than on the previous orbit. The net result is a decay type of behavior of the period of revolution and the size of the orbit. Both values decrease at an ever-increasing rate, until the satellite passes so low into the atmosphere that the remaining orbital energy is completely dissipated by a final meteor-like plunge to earth.

Supposedly a knowledge of the atmospheric density as a function of altitude and of the drag coefficient of the satellite should allow fairly accurate calculation of the future course of the decay of the orbit. But our knowledge of atmospheric densities at high altitudes is quite meager. We also have little idea how the densities may vary as the hour of the day, the season of the year, or the latitude are changed. Moreover, in the case of foreign satellites, our knowledge of configuration details is scant so that the drag coefficient is not well known. Since these bodies also have had considerable tumbling motion, the effective cross-sectional area of the drag-producing surface has been subject to unpredictable changes.

• *Sputnik* **deviations**—The result of all this is that position predictions of low altitude foreign satellites have been far from satisfactory. The drag rate has varied in essentially an unpredictable manner. An example is shown in Fig. 1, where the rate of change of the period of revolution is graphed with revolution number since launch for the last-stage rocket of *Sputnik III (1958 Delta 1)*. The oscillations present seem small, but over several hundred revolutions, they produced errors of the order of twenty minutes in the time of appearance of the rocket. For this reason, the distant past history of orbit behavior was of little value in making predictions. At the *Spacetrack* Filter Center, it was necessary to restrict the computer analysis to perhaps the last one or two weeks of observational data, predict future positions for perhaps ten days, and then hope for the best. Usually departures of several minutes appeared in three or four days, and often it was necessary to repeat the prediction calculations several times a week. Otherwise the calculated passage times would soon have been in error by a considerable fraction of an hour.

Even the position in the sky is affected seriously by errors in the time of appearance. At the latitude of the U.S., the earth rotates about 15 miles every minute. An error in appearance time of ten minutes means that the satellite will pass over a point 150 miles distant from the calculated point. At low passes (height 150 or 200 miles), this means either a large departure in the place in the sky where it will be seen, or that it will pass too low on the horizon to be seen at all.

It is evident that the neat theoretical scheme, which called only for "occasional" observations to verify the calculations, was completely imposible. In the case of the *Sputniks*, there were two periods every six weeks, each approximately one week in duration, during which they could he tracked optically from the Atlantic Missile Range. At other times, the objects passed overhead either during broad daylight or in the middle part of the night, when the earth's shadow allowed no optical target from reflection of sunlight.

• **Triangulating** *Sputniks*—The tests involved principally the use of Askania cine-theodolites and Mark 51 optical trackers. Every attempt was made to obtain angular positions from at least two stations on the range, so that the actual space position could be triangulated. Since there is a fair amount of cloudy weather along the range, this meant usually four observing stations per pass to have a high probability of at least two successful sets of angles. The Askanias provided an accuracy that was an order of magnitude better than the optical trackers (.01 degree vs. 0.1 degree), but since all the Askanias at A. M. R. are in a small area around Cape Canaveral, it was necessary to use the optical trackers whenever downrange data was desired. It is expected that theodolite coverage soon will be available downrange.

The highest accuracies obtainable optically are those of the ballistic camera. But such high accuracy is only needed for geodetic studies with satellites. For merely keeping track of the period of revolution, the ability of the Askania to track fainter objects and the greater speed and ease of theodolite data readout made its use most practical. Of course, there is a delay for processing and reading the film. This delay could be eliminated by digital readout equipment. It is expected that such equipment will shortly be procured for A. M. R. theodolites. When this is so, real-time satellite angle position can he fed directly to the *Spacetrack* calculation center at Cambridge for instantaneous checking and correction of calculated satellite position.

Even after these improvements have heen made, there still will remain some difficulties. One is that of observing faint satellites. In the case of the *Sputnik* rockets, their relative brilliance eliminated such a problem. But with the smaller American *Explorer* and *Vanguard* satellites, and for the *Sputnik III* nose cone, considerable observation difficulty has been encountered. These objects are usually just barely visible or entirely invisihle to the unaided eye. Therefore, the theodolite observer cannot take advantage of the wide field of view of the unaided eye but must point his tracking telescope in the predicted position and wait for the satellite to

need for better instruments . . .

enter the field of view. This field is only about four degrees in diameter. Usually, the object either does not enter the field, or passes near the edge so quickly that observation is impossible. This difficulty is greatly enhanced in the case of non-spherical objects that are tumbling. The intensity of their light varies widely. Thus the object may be much fainter than maximum light during the short time it is in the field of view.

• **Telescopes needed**—The addition of very wide field, low-power, high-brightness acquisition telescopes is a prime necessity, if full success with theodolites is to be realized. The field of view should be about 20 degrees in diameter. Thus the area of the sky in the field of view will be 25 times the present case, and the probability of acquisition correspondingly larger.

There are other places where significant improvement is possible, subject to development of suitable equipment. Image-tube or television techniques should make it possible to detect the brighter objects in broad daylight. This would mean possibility of optical track at least once each clear day and give much greater continuity to the data. There would be no 4-week "holes" when daytime track was impossible. Also, a method of determining the tracking errors of the theodolite operators in real-time would improve the accuracy. Corrections for these errors could be applied automatically to the digital readout of theodolite axis angles. Without such a tracking correction, one is dependent on the pointing ability of the operator. Although performance appears to have been excellent in the past, such correction capability seems quite desirable.

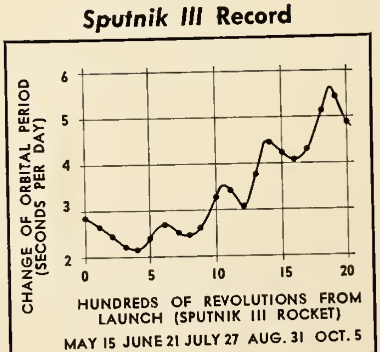
Radar tracking of satellites at A. M. R. has been extremely limited. This is completely due to lack of electronic acquisition equipment to furnish pointing angles for the precision radars. Without pointing information, it has proven to be useless to attempt to pick up satellites with very narrow-beam high-gain systems. Successful track has only been obtained when the target was optically visible so that optical trackers could be used to direct the radar antennas. Results of these cases indicate clearly that addition of electronic acquisition equipment would increase coverage tremendously.

Continuous radio interferometric data has been obtained on the nose cone of *Sputnik III (1958 Delta II)* since its launch on May 15, 1958. A 20 megacycle North-South oriented baseline has made it possible to determine latitude crossing times each day. This unbroken series of observations has yielded interesting information on perturbations of the period of revolution. Considerable efforts have been made to increase the sensitivity of the system, and several other improvements are planned.

• **80-foot rocket**—One of the most interesting results obtained at A. M. R. is the configuration photographs of the *Sputnik* rockets. We were fortunate in possessing a good amount of high-performance long-focal-length tracking optics, due to long-range missile tracking requirements. With such equipment, it was possible to obtain recognizable images to distances of three or four hundred miles. A series of photographs made of the dog-carrying *Sputnik II* on Dec. 21, 1957, at a slant range of about 190 statute miles is shown on thc preceding pages. From such photographs, it was possible to deduce that the total length of the rocket body and unseparated instrument compartment was slightly less than 80 feet. At the time this length measurement met with considerable disbelief. However, the reduction method was exceedingly simple and left no possibility for gross errors. That the injection of such a configuration into satellite orbit was possible was demonstrated last December when the U.S. orbited an entire *Atlas* missile.

Gradations in brightness along the length are apparent, and occasional frames show "hot spots" due to specular reflection of the sun's light from certain surface areas. Tumbling of the object is quite evident. However, details other than the gross length of the object are too blurred for identification. It is reasonably certain that this is not due to tracking error, since, on the best film records, the positions of successive images with respect to the frame edges are nearly constant. It is likely that the limitation is related to atmospheric turbulence.

Sputnik III Record



The difficulties that had to be overcome to obtain these images can only be appreciated by the people at A. M. R. who were involved in the effort. Acquisition by tracking personnel was hampered greatly by the presence of a dome with only an opening for the telescope. The absence of wide-field finder telescopes, such as those discussed above on theodolites, and the lack of any external optical tracker located in the open, which could provide coarse pointing information, greatly reduced the amount of coverage. All the telescopes have conventional two-axis azimuth and elevation mountings. This meant that on high elevation angle passes the satellite could not be tracked as it passed nearly overhead at the very times when the slant range and optical path through the atmosphere were at a minimum.

• **Missile tracking easier**—Of course the instrumentation described above was never intended to be used for satellite tracking, but rather for the launching of missiles from Cape Canaveral. The problems described above are a consequence of this. Compared with satellite observation, the acquisition of a gradually accelerating missile perhaps 20 miles away is a relatively simple matter. Indeed none of the equipment used at A. M. R. for tracking satellites was designed for that purpose. Changes in the equipment, methods of using equipment and the organizational effort will all have to be effected if optimal gathering of information is to take place. Personnel involved in the *Spacetrack* program and other tracking programs have acquired much practical experience and capability. Yet the efforts made up to now have, speaking generally, been too small. They have been made for the most part by individuals or small groups of individuals working almost alone. Relatively little interest and support has been evident up to the near present. We must accelerate the effort if the mission of continuous location capability for all satellites is to be attained within a reasonable time. A high level of cooperation between responsible agencies and between experienced technical and administrative personnel is mandatory. It is hoped that recent plans for an overall study of this problem will lead to its successful solution.

The author wishes to express his gratitude to Walter H. Manning, Jr., Spacetrack task scientist at the Atlantic Missile Range, who assisted in the preparation of the article and the accompanying photographs.

WASP

THESE MEN DO ALMOST NOTHING BUT THINK

Unique new group helps Westinghouse anticipate and plan for future military needs

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So things were completely reorganized in February, 1958. A new Defense Products Group was established, centralizing control of all defense-oriented activities within the company.

But a most interesting—and promising—part of this new organization, the new Westinghouse Advanced Systems Planning Group (now commonly called WASP), wasn't announced publicly until August.

This was a significant development. Since technology is moving faster than ever before, there's a real need to effectively anticipate what will be needed in 5 or 10 years. If this can be done, longer-lived defense systems can be developed more quickly and substantial sums can be saved. WASP should be able to provide the advance thinking needed by Westinghouse to meet this need.

Staffed with hand-picked engineers and scientists—specialists in electronics, outer space, atomic power, ASW, operations research, etc.—and headed by Allan Chilton (top center photo above), WASP operates on a unique charter: to concern itself primarily with

CONTINUED

MATCHING NAVAL REQUIREMENTS with Westinghouse capabilities, Leonard Daw, a professional career specialist in naval strategy, tactics, and weapons systems, is associating advanced technology to future naval systems.

"The idea is sound, but how can we kee from burning up? Present insulations w work. How about ablative heat sinks? N they won't work either in this case."

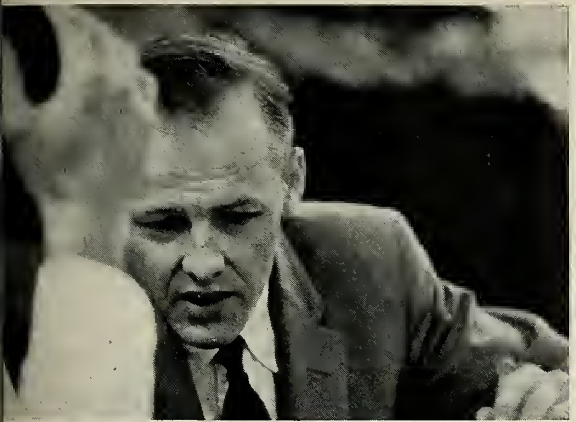
complete advanced weapons systems, to dea the "whole" instead of "parts".

This is not just a "blue-sky thinking" assign Westinghouse believes future defense needs v so complex that only a full-time team of specia like WASP—will be capable of the kind of conc planning and guidance needed.

There's another reason why defense planne be interested in WASP. This new group gives t single point of contact within one of Am largest and most versatile industrial firms to they can take immediate and long-range d problems. No longer will it be necessary for so

". . . son, it circles the earth at 18,000 miles an hour." Space consultant, K. Satyendra, a Ph.D. from India, keeps WASP and other company scientists abreast of space needs. He is an authority in mission, trajectory, and communication concepts.

TOP ENGINEER AT WA Rein Kroon joined Westingho in 1931. Among other acc plishments, he headed the gineering group responsible the design of the first Ameri turbojet engine for aircraft.



"What's the best way to destroy an enemy reconnaissance satellite? Attack it from earth? Or from another satellite? How would we go about either method?"

MAN ON THE MOVE, Bill Robinson has his sights on tomorrow's systems and provides guidance for WASP in planning for future Department of Defense needs.

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Control, Guidance and Navigation Progress . . .

Propulsion Available Will Set Designs

Biggest problem areas are in components hardware and in this area inventiveness and imagination will make greatest inroads

by S. S. Edwards, W. C. Griffith, & J. I. Osborne

Speed is, of course, the key to space flight. The fact that the possibilities of space flight are presently being discussed arises from the recent development of large rocket motors capable of accelerating sizeable masses to speeds approaching escape velocities. Speed is required to overcome the inexorable pull of gravitational fields and to negotiate the tremendous distances involved in a feasible time. Command of thrusting power, therefore, makes possible the contemplation of space travel. However, the present state of propulsion technology does not allow unlimited power. It seems quite reasonable to assume that consideration of power available will impose difficult design requirements on space vehicle weight as also on design of guidance and navigation systems.

In principle, Newton's laws of motion and universal gravitation provide a basis for complete solution of space flight problems in the sense that initial conditions at launch may be adjusted to arrive at any desired place at the correct time without the necessity of providing navigation and terminal guidance systems. However, it is at present inconceivable that a space vehicle could be accelerated in a few minutes to the magnitude and orientation of its velocity vector with sufficient precision for a trip to be measured in weeks or months. Such a direct extrapolation of present technology is obviated by uncertainties in the original velocity and acceleration vectors and in the physical constants.

The gravitational constant is known from laboratory measurements with sufficient accuracy to yield satisfactory figures for the masses of all bodies having observable satellites. In the case of the Moon, Venus, and Mercury, however, the masses have been determined only indirectly and with considerably less accuracy. This does not create any real difficulty, for better data will certainly become available from exploratory probes before actual landings are attempted. The 0.02 percent uncertainty in the astronomical unit, on the other hand, presents a significant problem. Thus, the range of Venus at closest approach is unknown to about 5000 miles, a sizable figure in terms of navigational requirements. Further work with radar returns from the planets, however, will certainly help science to resolve this question.

• **Trajectory uncertainties**—By far the largest present uncertainties originate during missile launch and early powered flight. These result from misalignment in guidance reference; time of launch, thrust direction and magnitude variations; and atmospheric winds. Improved technology may be expected to reduce all of these contributions somewhat but cannot be expected to eliminate them entirely. Thus wide course and terminal navigation and guidance systems will be necessary.

We must assume that by the time a spacecraft reaches a point where its motion is dominated by the gravitational attraction of the target body, the vehicle is on a hyperbola that does not intersect the surface of the target. In general, the energy required to shift trajectories is smaller the farther away the vehicle is from the target. The desirability of making changes as early as possible must be weighed against the penalty of carrying sufficiently precise navigation and guidance equipment to determine what the required changes actually are.

For an initial heading error, simple geometrical analysis indicates that the fuel required to correct the heading

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favors mid-course equipment . . .

halfway to the destination would be three times that required at one-quarter of the way to the destination. If the correction were made at the three-quarter range point, the fuel used would be as much as at nine times one-quarter of the way. Therefore, the trade-off between fuel weight to correct heading and additional weight for precise navigational equipment to determine heading would appear to favor the mid-course navigational equipment. The above computation assumes that the velocity along the course and the fuel weight required to correct a given angle is constant. Fuel weight of approximately 1.4% of vehicle weight is required to correct an error of 1 milliradian for specific impulse of 240 seconds. Improvements in specific impulse will, of course, improve this number.

If the launch guidance requirements are relaxed because of the availability of excess power, a mid-course navigation system is required. Path correction by power application requires that vehicle orientation with respect to its velocity vector is known. The inertial reference system used during the launch maneuvers probably could not be depended upon to maintain orientation to the order of accuracy required for mid-course maneuvers, at least without resetting. However, electronic gyros, presently under development, might perform this function.

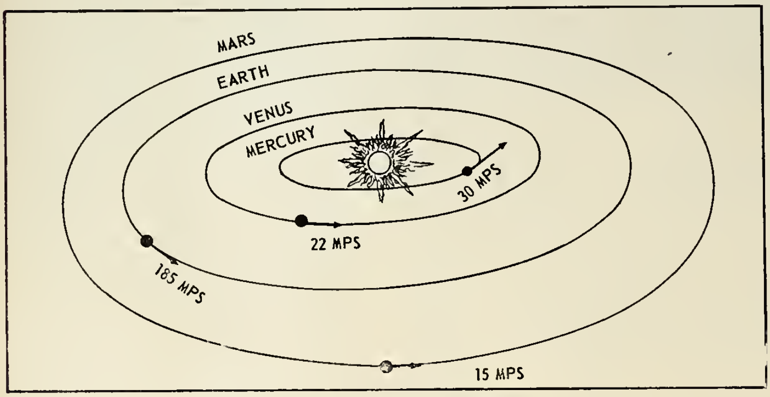

FIG. 1—Solar System Configuration.

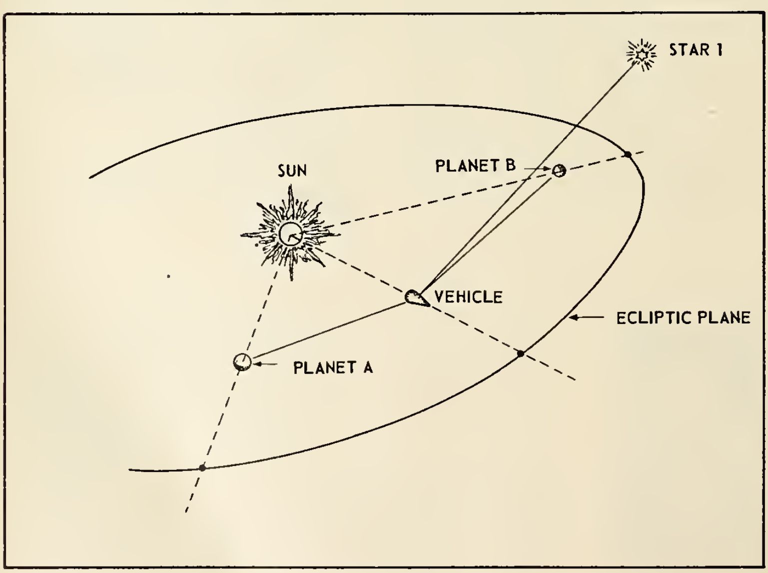

FIG. 2—Position Determination.

• **Celestial astrogation**—Star position readings taken with a sextant may be used to correct a gyro, which can then be used for continuous reference. The accuracy of celestial observation is greatly enhanced if the missile axis system is stabilized in space. This would rule out the use of spin stabilization. Also, changes in vehicle orientation are awkward in a spin-stabilized system. Accordingly, it makes better design sense to spin small gyro elements in an inertially stabilized reference system and measure and control vehicle attitude with respect to these axes. Maintaining constant attitude control by referencing spinning gyros has the disadvantage of cumulative expenditure of power.

Another method might be to omit the gyros and use the stars as a reference system. The vehicle would then be stabilized with reference to the stars probably only during the interval required to fix position.

We assume that the flight is in the ecliptic plane and that the configuration of the solar system is known at all times (Fig. 1). Position in the solar system may be determined in a number of ways, each of which offers certain advantages of accuracy or convenience. The direction of the sun offers the most obvious line for vehicle reference (Fig. 2) and two planets (one of them the target) or a star and planet along with a clock completes the required information. The alternative use of radar ranging on the target has the advantage of giving better range and velocity data but suffers from the extra payload for power and antenna, and gives less angular resolution.

Velocity is obtained by successive position readings and the time interval between them. In the process of evaluating these data, it should be remembered that the inertial guidance used during the launch phase has a digital computer as a major component. The position and velocity measurements discussed are then inputs to the digital computer for orbit computation and error determination. Knowing the orbit errors and the vehicle orientation, it is possible to make mid-course corrections to the trajectory.

Problem areas exist in the realization of the component hardware designed to perform as a system. Here is where inventiveness and imagination will make the greatest inroads in the future.

• **Landing problems**—Having successfully traversed the vast distances separating the earth and planet destination, the successful space flight yet must negotiate the tricky maneuver that

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will allow descent to the surface. Presuming that the incremental velocity given the vehicle in powered maneuvers has not exceeded appreciably the escape velocity from the earth, the speed at which the trajectory has been traversed is approximately the orbital velocity of the earth or about 18.5 miles per second. If the terminal phase of the flight were to result in a tail chase maneuver, the only planets which could be overtaken would be those located at a greater distance from the sun than the earth, in which case, the vehicle would have excess velocity over that of the planet (Fig. 2). Another possibility is that the vehicle could be guided into a relationship such that it could be overtaken by the planet (which then has the greater speed advantage). There are certain advantages in considering such maneuvers in that presumably very little reference to the vehicle-objective relationship would be required. This could result in advantages particularly if rapid computational methods are not available. The interception in which approach is made at large angles between the vehicle and target orbits involves an increasingly more precise monitoring and correction of the closing condition.

To negotiate a landing upon the surface of the planet, the relative differences in the kinetic energy per unit mass between vehicle and target must be considered. Eventually, of course, soft landings will be made in which this difference is adjusted essentially to zero either through atmospheric braking or controlled impulse. Several maneuvers that could be considered are:

1. Ballistic descent with powered braking.
2. Capture in the gravitational field of the target planet and ballistic descent from satellite orbit.
3. Lifting entry from orbit about the planet.

The band of approach paths (figure 3) for which impact can occur is, of course, larger than the band of paths for which appreciable curvature of the hyperbolic paths in the vicinity of the target occurs. Accordingly, guidance accuracy for the collision course is less severe. The large entry angles, however, would essentially preclude the possibility of using atmospheric deceleration to expand excess energy. Reliance upon powered landing would be required.

To orbit about the target planet in preparation for a deorbiting maneuver requires that the approaching vehicle be guided into a fairly narrow circumferential band at which point the vehicle velocity relative to the planet must be adjusted downward to appropriate orbital speeds. Unless atmospheric braking is obtained this deceleration must be accomplished in a powered maneuver. To graze the atmosphere—a very thin band relative to the planet diameter—requires the greatest precision in the guidance and control.

The problem of landing on an airless planet places greater requirements on the flight control system (and of course a rocket fuel supply) than those of going into orbit or landing in an atmosphere. Terminal guidance requirements, however, are somewhat less severe. Here the initial objective is to move into a trajectory which has zero angular momentum with respect to the intended landing point. This presents a relatively simple computational problem since Mercury and all the airless moons of the solar system for which observations are possible have a rotational period equal to their orbital period, i.e., they present the same face to the parent body. Thus, the landing point is under continuous observation for a long time.

• **Fuel-saving trick**—Corrections to the hyperbola of approach should be made as early as possible to conserve fuel, just as in the other cases being considered for the same reason. Deceleration to land using retro-rockets should be postponed as long as possible compatible with the maximum tolerable "g" limit. Probably the most satisfactory terminal navigational aid is a radar that makes use of pulses for ranging and Doppler shift for velocity of approach. With this information the retro-rocket thrust can be programmed for proper descent.

Special problems arise in the last few hundred feet. Accurate measurements of height become difficult because the time interval between pulse and return is very short (on the order of one microsecond). The large ion cloud from the rocket exhaust would certainly render any microwave velocity measurement useless by masking the small doppler shift existing. No automatic control system appears to have been devised that improves on the possibility of human observation and control of the actual landing. This is probably very desirable, anyway, since selection of the exact landing spot to avoid rock or crevasses can be done by a human pilot. The control system should be designed to handle like that of a VTOL aircraft, for which adequate training and experience is readily available.

Significantly, the problem of landing upon the surface from an orbit about a planet is nearly in the dress rehearsal stage at this time in Project *Mercury*. Certainly the important major framework associated with this problem is fairly well understood essentially as a legacy of the ballistic missile program. Challenging problems exist in all areas; however, the encouraging and exciting fact remains that no insurmountable factors exist to prevent man's exploration of space.

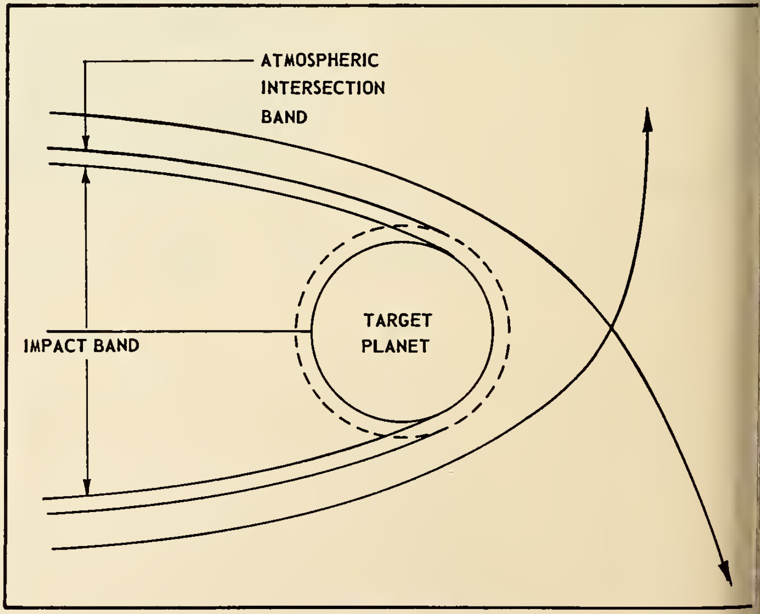


FIG. 3—Hyperbolic Approach Orbits.

Falling Behind Engineering Advances

by **Dr. T. C. Helvey***

ORLANDO—The limitations of the human organisms are probably the most restrictive in astronautics. Engineering has solved the problems of boosting a projectile into orbit about the earth and of escape from the earth's gravity. If it were desired, the engineers probably would be able to shoot a small object out of the solar system—perhaps even from the galaxy. But a whole host of separate questions must be answered—indeed several new sciences must be developed—before men can travel safely any great distance in space.

Nevertheless, we can predict that our species will solve these problems if they can be solved. Man is a proud creature. His ambition knows no limit.

One of the limitations the human organism probably will impose for the next few centuries is in travel radius. Since medical science is unlikely to prolong the average human life beyond 120 years and it is hardly likely that the speed of light will be exceeded, the presumed maximum length of a manned trip is 100 light years. This would set an action radius of 50 light years if we plan a return to earth.

But our own galaxy, the Milky Way, has a diameter of 200,000 to 300,000 light years. The 50-light year radius would restrict travel to a tiny segment of the galaxy.

To extend this action radius, there are two approaches that do not require artificial tampering with the human organism. One is to slow the normal body functions to retard aging. Scientists in the fields of biophysics and biochemistry are studying suspended animation. Although this would involve loss of consciousness for very long times, amazingly little psychological aversion has been aroused by discussion of this method. The other approach is based on the dilatation of time implied by Einstein's theory of relativity. The theory states that time slows down for all objects traveling at speeds approaching that of light. In this case, consciousness would not be lost, but the extremely low perception rate would sharply reduce the effectiveness of human observations en route.

* *Research Division, Radiation, Inc., Orlando, Fla.*

HUMAN capability of performing a certain psychomotor function while under acceleration. (Fig. 1)

• **Genetic attack**—A more radical attack on the problem is that of genetics. Perhaps we can adapt man to greater endurance of the stresses inherent in space. Of course, the utilization of presently known principles of eugenics to breed astronauts would be time consuming. Such projects would last many centuries. But it is conceivable that controlled artificial mutation, brought about by some mutagenic agent or radiation, might speed the process. However, we must face the fact that there are deep philosophical implications to the thought of creating a *homo sapiens var. spatialis*. They must be realized as such.

In the closer future, we shall have to adapt the space machine as much as possible to the human limitations. By using symptomatica and possibly post-hypnotic suggestion we may make the astronaut more resistant to space stress.

What is the problem of space medicine in the immediate present? The primary task is to maintain the normal operational integrity of the human organism under space-equivalent conditions. We must consider human reactions in terms of performance, stress endurance, bodily changes and behavior.

Several overlapping sciences can serve us in controlling these factors. The fields are so strongly interwoven that subdivision is very arbitrary. One such division could be the following:

1. The approximation of terrestrial environment,
2. Biophysical and pharmacological aid to overcome or partially compensate for the alien environment,
3. Psychological considerations,
4. Prevention and alleviation of pathological problems.

We shall discuss the above parameters quite elastically and show the main fields of interest and their interaction, without attempting to deal with the problems involved nor to go into great technical details.

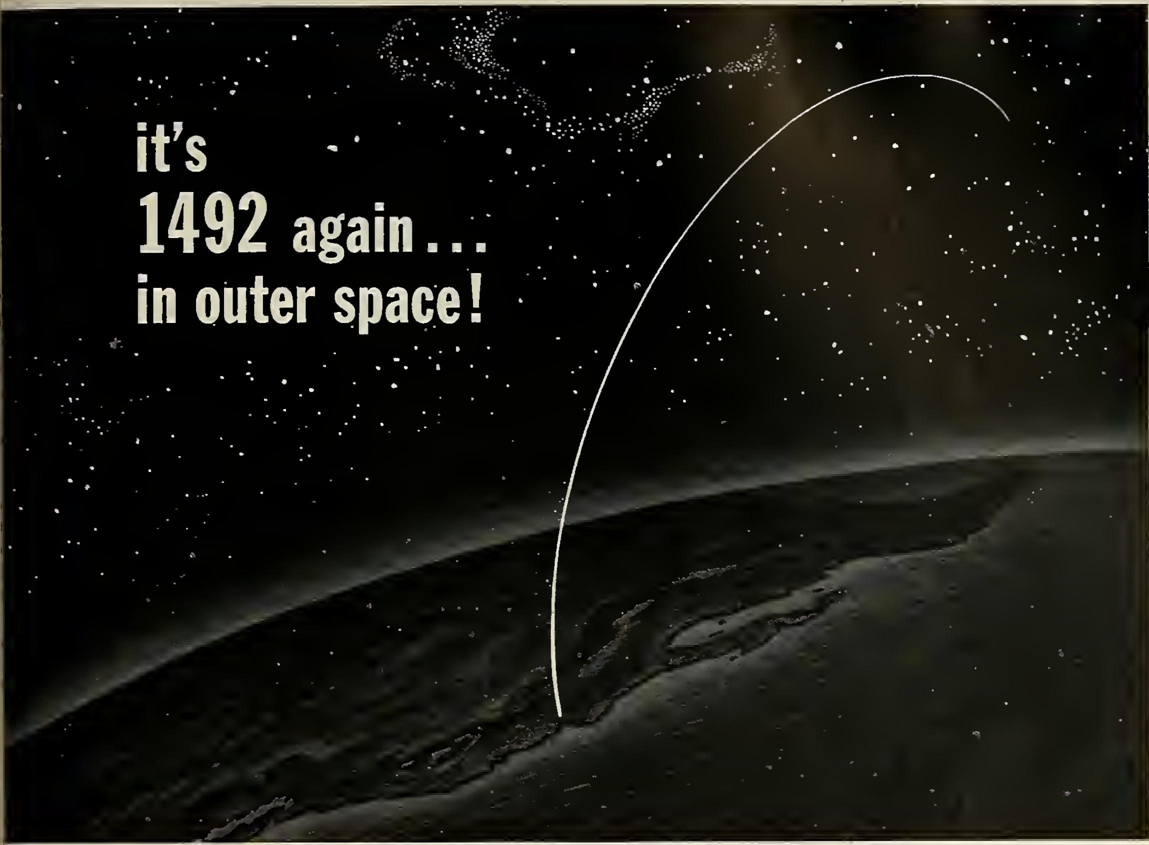
• **Artificial environment**—Although the assignment of proper values of importance is not possible, obviously the first item should be the artificial environment of the crew compartment.

An ideal environment, however, would suit "ideally" only the "average man." But we know that there is no "average man" thus the "ideal environment" is only an approximation and must have a significant spread to fit even a selected group of Western men. With these restrictions we can write the following set of factors:

Temperature: 68-72°F
Humidity: 40-50% R.H.
Acceleration: 0.8-1.2 G
Altitude: 900-1000 Millibars
Oxygen partial pressure: 18-21%
Carbon dioxide content: 0.3-0.5%
Ozone and atmospheric pollution: 0
Nuclear radiation (ambient flux): Less than 300 Milliroentgen/week
Ambient illumination: 5 Millilambert
Ambient random noise: 2 db
Air movement: 2 ft/sec and 100 ft^3/min
Clothing: Short sleeves
Minimum living space: 650 cft per capita

Any, even slight, deviation from the "ideal environment" places a stress on the individual. One of the prime functions of space medicine is to study the stress tolerance of the human organism and to find methods to adapt the ecosystem of the crew compartment to the human limits. Another task is to find pharmacological, biophysical and psychological means to extend the human tolerance limits to environmental stress.

• **Approximation of terrestrial environment**—For the near future and from the point of view of the operational integrity of the space crew, it would be ideal if the ecosystem of the crew compartment were identical to or just slightly divergent from the best terrestrial conditions. It is quite obvious that the provision of such conditions would be very expensive and in



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environment same as earth's . . .

many cases technologically impossible. Therefore the crew members will have to be satisfied with conditions that will differ strongly in many parameters from, what we may term, best laboratory conditions. It is in the realm of space medicine to provide the quantitative analysis for the maximum deviation from the ideal environment without causing significant performance decrement in the crew. For example, if the ambient temperature of the crew compartment is 75 to 77°F the crew will still be able to perform its duties without too much fatigue or discomfort. But should the temperature go to 85 or 90° the mission profile of the individual crew members must be radically changed due to the early deterioration of their work output.

Special emphasis must be given to multiple stresses. We must study thoroughly what effect deviation from the ideal conditions in more than one environmental parameter will have on the performance of certain psychomotor tasks. The main reason for this is that in physiology and psychology multiple stresses are not additive but may influence the result by factors of 2 or more. Not only are these multiple stress factors non-linear but the performance of the crew is further complicated by other dependent variables such as the non-linear human gain control. The complexity of the question of human performance under multiple environment stresses is such that it cannot be computed or even closely approximated. Therefore research must provide the necessary information.

There is a wealth of information available in the literature on the endurance and work efficiency of a human exposed to individual environmental stresses. For illustration, let us consider the effect of peak acceleration on human transfer functions. In the relatively new science of ergology, that is the study of the human work output, the human transfer function is defined by the speed and accuracy by which the human organism translates a sensory stimulus into muscle action. As an example, the subject is indoctrinated that upon the flash of a red light he should punch a certain button with his right index finger.

Space flight has given great emphasis to the study of the effect of acceleration on the human performance. Since the pioneering work of Col. John Stapp valuable information has been gathered with the high performance human centrifuges operated by the Navy in Johnsville and by the Air Force at Wright Air Development Center in Dayton. The question of the human performance under acceleration stress has a number of parameters:

1. Direction of the acceleration force,
2. Peak acceleration,
3. Duration of the acceleration.
4. Rise time to peak acceleration.

• **Man under stress**—The human capability of performing a certain psychomotor function while exposed to acceleration stress can be shown by a three-dimensional graph (Fig. 1). On the transparent plate in the center of the illustration, a mannequin is fastened in such a position that the so-called transverse g-load shows horizontally and the vertical measures the positive and negative acceleration in g's. The third dimension, on a logarithmic scale, represents the rise time to peak g-loads. The shadows cast on the vertical and horizontal planes break the three-dimensional graph down into two two-dimensional illustrations.

We learn from this graph that with fast rise time the human operator will be operational only if exposed to very little acceleration. If the peak g-load is reached between a half and one second, the performance will be satisfactory even if the operator is exposed to a transfer g-load of more than 20 g's. But if the rise time is prolonged to 10 or 100 seconds, the performance radically decreases.

This strange behavior of the human organism can be explained as follows: With fast rise time to peak g-load, the impact or shock effect will set a limit to the proper human performance because time is needed before the muscles will compensate and the nervous system can coordinate muscle action. On the other hand, if the rise time is relatively long, then factors involving the rate of blood flow in the arteries and veins come into play. Much research is required for the understanding of this new field of hemodynamics. The flow of blood can by no means be compared to that of water in a system of iron pipes. Blood is a non-Newtonian liquid that does not behave as water. The arteries are pipes or tubes that are pulsing or changing their diameter. Their walls can be influenced by emotions. Obviously, we cannot make predictions based on computations for a system so complex. However, we can gather the necessary information by research.

We have here discussed only a small fraction of one of the parameters of the space equivalent environment. The other parameters cover the whole range listed in the earlier portion of this paper. In addition, there are the metabolic needs of solids, liquids and gases, waste disposal and hygiene. We can only throw a spotlight on fragments of space medicine in this paper to outline its scope.

• **Biophysical and pharmocological assistance of the space crew**—It was obvious from the beginning that for technological and economic reasons the ecosystem of the space capsule cannot be perfect. Therefore, the crew must be assisted to overcome or partially compensate for the alien environment. A number of difficulties will arise due to the weightless state during the coasting of the vehicle, which may last for weeks or months. Many symptoms caused by zero-gravity in the human organism can be predicted and certain countermeasures can be taken. The effect of zero-gravity of long duration can, however, only be studied when a man is placed into a satellite.

The establishment and the problems of the various cycles of the human ecosystem in the space capsule, such as the food cycle, the water cycle and the respiratory gas cycle can also be considered as a part of space medicine. For shorter flights, such as a moon mission, such commodities as water, food and oxygen can be carried from earth. For longer lasting missions, however, a re-cycling of food, water and oxygen is inevitable. The problem with the re-cycling of water is more or less solved. The utilization of unicellular plants, such as algae, for oxygen production and carbon dioxide elimination is under study. However, the utilization of photosynthesis for this purpose is very cumbersome.

Food for the crew poses a knotty problem. Due to weight considerations, it should be completely digestible. But we still do not know whether the human digestive system can adapt itself to a bulkless food without severe symptoms. If all the food is absorbed in the stomach and in the first turns of the duodenum, the emptiness of the major part of the digestive system may cause permanent hunger sensations. These in turn could build up nervousness and irritability to a degree where the whole mission might be seriously jeopardized. Possibly, medication could counteract such symptoms.

The excellent adaptability of the human organism makes for further concern. During a flight lasting months or perhaps years, anatomic and physiological changes would occur in the bodily functions. After return to earth, crew members would have to undergo very long lasting re-adaptation to terrestrial conditions. The problems arising in this connection are considerable. Since space navigation will require much skill and patience, the returning experienced crew will have to be used for new missions. But the adaption to space-equivalent conditions and the re-adaptation to terrestrial environment may be so uncomfortable that the crew will be reluctant to undergo the same experience again. In the present cultural and social structure of our society, it is unthinkable that the crew that signs up for a space mission should never be permitted to return to earth. This is another difficulty we must overcome.

• **Psychological considerations**—It is evident that space medicine must maintain the mental health as well as the physical well-being of the crew. The psychological problems associated with space flight are at least as severe as the physiological problems. Most problems revolve around the two main fields of fatigue and anxiety. Both of these factors and related ones can and would handicap the crew performance. There is where a new science, psychopharmacology, has a most promising field of application. This leads directly into another aspect of space group-psychology, namely the proper control of group interaction in the society of the crew compartment. It is obvious that means have to be found to optimize the cooperation of the crew members and to eliminate every element which may cause friction or hostility. This can be achieved by the proper combination of crew selection, indoctrination, training and again the application of psychopharmacology.

• **Prevention and alleviation of pathological problems**—It is of great concern to space medicine how to prevent malfunction of the bodies of the crew, or if it cannot be avoided how to cure them. Everybody will agree that a toothache of a crew member in a space craft could cause a severe situation. On the other hand, it is unlikely that complete dentistry equipment, can be carried in the vehicle or that a prerequisite for signing up for a space crew would be to pull all teeth. Although the crew and the crew compartment would be in a sort of semi-sterile state this, however, would not prevent the occurrence of a cavity and a subsequent inflammation with its severe consequences if left without care.

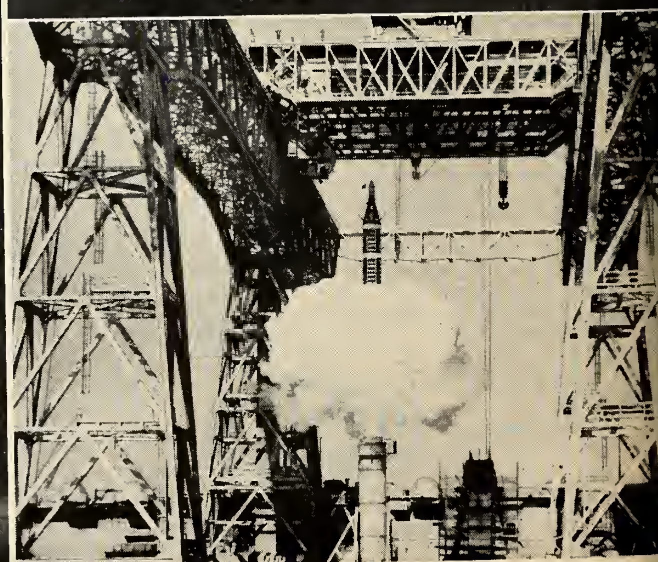
The probability that any of the crew members would suffer appendicitis is low under the prevailing conditions. Nevertheless, provision has to be made that in case of its occurrence the crewman should not be left to die. This raises the question of how far crew compartments should be equipped with surgical facilities.

The avoidance of contagious diseases can be achieved by proper preflight treatment of personnel and equipment. Yet it is conceivable that some of the harmless micro-organisms, such as the coliform bacteria in the intestines, may mutate under the influence of cosmic radiation and develop a strain that could cause severe symptoms and incapacitate the crew. These mutant bacteria might resist most of the antibiotics. Such an organism could be isolated and a life-saving serum could be developed if the necessary facilities were available. But it is quite unlikely that serum production could be incorporated into the payload. Thus space medicine also must decide on and coordinate with the mission profile the materials and equipment needed for safeguarding the bodily and mental health of the crew.

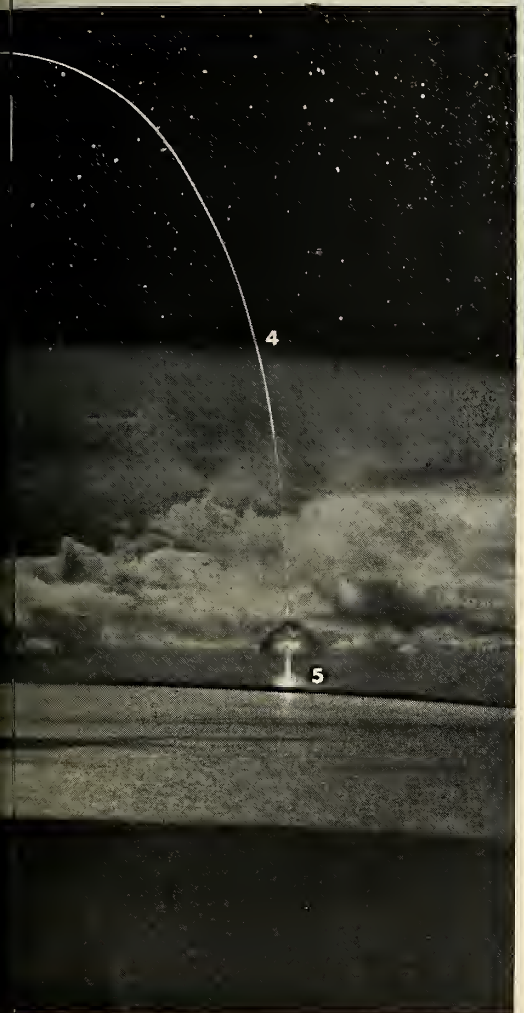
It is apparent from the foregoing that space medicine touches on all the fields of astronautics. When man is put into the space vehicle, all of its parameters must be adjusted to make the vehicle livable. Propulsion, the air frame, guidance, communications and engineering must be modified and new specialties must be developed to meet the peculiar needs of the human organism. Thus space medicine is a science that stands astride the disciplines.

The Lockheed-developed U.S. Navy POLARIS:

Missiles launched from ocean depths



Above: *Propulsion system firings* light up night sky at Lockheed Missiles and Space Division's 4000-acre test base in the Santa Cruz mountains, Calif. A nearby vertical test stand permits simulated flights of complete POLARIS missiles, to test their propulsion and guidance systems.



Left: *Nuclear powered U. S. Navy sub* (1) launches solid-propellant POLARIS missile which erupts from ocean depths (2)—then rockets its way on a ballistic missile trajectory high above the earth's atmosphere (3) into outer space. Re-entering the atmosphere (4) the re-entry body of the POLARIS plunges earthward to destroy its target (5).

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ft: *"Operation Sky-Catch" tests,* conducted jointly by S Navy, Westinghouse and Lockheed, reveal effects of n stresses. To prevent damage to POLARIS test missile nents, huge overhead assembly catches it in mid-air.

r eft: *Carrying awesome destructive power,* Navy's LRIS is markedly smaller than other U. S. ballistic ses of same range. To enable one submarine to carry an missiles, Lockheed scientists achieved miniaturi- ti breakthroughs on all major systems of POLARIS.

Launching an IRBM from submerged submarines involves technological developments that are unique in ballistic missile history.

As POLARIS Missile System manager and prime contractor, Lockheed's Missiles and Space Division is responsible for coordinating all phases of its design, development, and production.

The POLARIS, a solid-propellant missile, will be operational in 1960—ahead of schedule. The operational missiles will be delivered to U. S. Navy submarines in Lockheed ready-service transporters under controlled humidity and temperature conditions. And Lockheed's ACRE—Automatic Checkout and Readiness Equipment —will maintain the constant ready-to-fire capability of POLARIS missiles, right up to the moment of launch.

With an ultimate range of 1500 nautical miles, the POLARIS will become one of the most formidable deterrent weapons ever devised. For any significant military target on earth will be within range of its nuclear warheads.

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Industry Faces Tough Assignments

by David R. Hull

WALTHAM, MASS.—Accelerated study, research, and development brought on by the advent of *Sputnik* have caused daily advances in the vast and unsettled field of space and missile technology. Electronics is contributing immeasurably to these developments.

A quick examination of the space vehicle itself will determine the role that electronics is playing in the space activities during the current "first generation" of space technology. The rocket-powered flight vehicle contains four basic elements: the airframe, the rocket engine, the propellant, and the payload. And electronics varies from slight to dominant in degree of importance to these elements.

The industry has less impact on the airframe portion than on the engine and propellant because electronics provides only control of these elements. Not so regarding the payload—the main area of interest.

The possible use of ionized propulsion for thrust directly concerns the electronic industries to the extent of the need for electrical power generation and control devices. The payload, on the other hand, contains the electronic sensing, recording, storing and transmitting segment that is able to reach regions previously inaccessible and gather scientific data heretofore unobtainable. This element consists of TV cameras, infrared detection devices, radar gear and data recording and storage equipment. Putting the payload into orbit is the sole purpose of all the other elements of the space vehicle.

• **Guidance**—Without guidance, however, the space vehicle cannot fulfill its mission, and without electronics there can be no guidance. Guidance operations consist of the measurement of vehicle position and velocity, computation of control actions necessary to properly adjust position and velocity, and the delivery of adjustment commands to the vehicle's control system. Guidance operations may occur during the vehicle's take-off, during flight in space, or during the vehicle's return to earth.

Space-flight missions in the immediate future will use ballistic rockets, and the electronic guidance of such vehicles will be extensions of current ballistic missile guidance techniques. "Ascent guidance" for such missiles is used only during powered flight. The electronic guidance system determines the free-flight path.

When the desired combination of position and velocity is reached, guidance systems signal cut-off of the propulsion systems. Electronic control of this function is vital.

• **Margin for error**—The classic example is that an ICBM at a range of 5500 nautical miles will have an "impact miss-distance" in the direction of flight of about one nautical mile for an error of one foot per second in the magnitude of its cutoff velocity. At the same one foot per second error in magnitude of velocity at thrust cutoff, the miss-distance to the moon is 20-100 nautical miles, and to Venus it would be about 25,000 nautical miles.

Using modern electronic components and techniques, inertial guidance is accurate enough in most instances to establish earth satellites. Placing payloads on the moon's sursface and establishing satellites around the moon, however, requires refinement in such control techniques. Travel to the other planets of the solar system, on the other hand, will demand mid-course and terminal guidance systems to avoid the miss-distance.

Near-to-earth mid-course guidance can be executed with our present electronic navigational ground networks. But flights substantially far out in space will require a guidance capability in the vehicle itself. Such mid-course guidance will require measurements on board the spacecraft using such electronic instruments as radio telescopes, TV cameras and infrared sensing equipment.

These devices will base their measurements on star or planet sightings. Additional electronic instruments are necessary to compute suitable control actions and to signal operations to the rocket engines. Speed and reliability of equipments during these operations are mandatory.

Terminal guidance systems will require infrared radiation detection equipment and radar systems. Such radars employ repeater transmitters in the rocket, a ground computer, and a radio command link to the vehicle.

• **Communications**—The industry faces a stiff assignment in providing communications in space. Electronic equipment is needed to cope with strange space environments, severe size and weight limitations in space vehicles, large communications ranges and extreme requirements for lengthy unattended operations.

The industry is actively investigating countless possibilities for communications associated with space flight in such areas as electrical energy and power sources, radio frequency power innovation, data storage and data encoding, and receiver sensitivity. A 10-to-1 reduction in receiver noise is expected through the development and use of ultrasensitive devices such as cooled detectors and masers.

Highly directional space vehicle antennas will improve communications and achieve power savings. Successful operation of this system depends upon attitude stabilization of the spacecraft. This is another area of present electronic research and development. Radio astronomy, the air-defense surveillance net and current space flight tracking activities are building up a backlog of experience in the use of very large steerable ground antennas which will

About the Author

David R. Hull is vice president of the Raytheon Co. and president of the Electronic Industries Association. A retired electronics engineering officer and captain in the U.S. Navy, he has been an electronics industry executive for 10 years.

Hull, as a pre-war assistant to the director of the Naval Research Laboratory, coordinated the Navy's radar research and development program. During World War II, he had charge of design and development of radar, sonar, special electronic applications and countermeasures essential to naval operations. He directed the Federal Telecommunication Laboratories of the International Telephone and Telegraph Corp. for two years after he retired in 1948. Hull has been with Raytheon since 1950.

be needed to support space missions.

• **Reliability**—In communications as well as in other electronic space activities, further miniaturization, improved packaging of components and increased reliability is mandatory. Electronic gear must have a high degree of reliability to guarantee output not only for the duration of flight but also for a useful period after arrival in space or impact on a planet.

Keeping equipment working unattended for many months is possible. But the industry finds it requires careful design, extensive testing, and knowledge of the environment in which it will operate. This unquestionably will lead to the use of improved basic materials.

• **Observation and tracking**—Observation and tracking are other tasks that electronics must perform in this Space Age. Various forms of ground-tracking radio, infrared, and optical systems will be required by all space missions in order that vehicle trajectories may be observed and monitored from the earth. The rotation of the earth and the nature of the vehicle's trajectory and orbit generate a requirement for locating tracking stations around the globe. In addition, ground facilities containing electronics will be required for control, landing, and recovery of vehicles.

• **Infrared measurement**—Infrared detection systems mounted in space vehicles are playing a vital role in space exploration. Electronic sensors that measure infrared radiation have permitted man to understand the composition of the atmospheres of the planets and other celestial bodies. The obvious advantage of such probes is that scientists for the first time are able to examine the outer reaches of space without the hampering effects of earth's intervening atmosphere.

Electronic observation of the earth's atmosphere from an orbiting vehicle will permit measurements of cloud cover, water vapor and carbon dioxide concentrations, thus aiding meteorological observations. Infrared sensors in spacecraft will have utility for military reconnaissance and surveillance of the earth. In particular, especially large sources of infrared energy such as afterburning engines of supersonic vehicles and exhaust flames of ballistic missiles may be detectable from orbital platforms. When combined with spectral analysis, infrared sensors would permit clear identification of a planet which will assist the navigation and terminal guidance of space vehicles.

• **Accomplishments**—The electronics industry can boast of many accomplishments in space and missile technology. For example, miniature TV systems for satellites are being developed now to broadcast pictures to earth receivers as far away as one thousand miles. These systems are designed to operate for several years. Also, electronic data recording and reduction devices are improving in speed and reliability. Recent developments in the *Vanguard* data reduction facilities may speed up the processing of data two and a half times over the rate at which the data is gathered and received. This system is expected to study up to 10 million items of recorded and processed data telemetered by radio signals from the satellite—resulting in improved flight control of guided missiles and space vehicles.

The planet Venus has recently been contacted with use of a solid-state maser in a practical radar system, verifying that interplanetary communication is possible. Another accomplishment has been the discovery that about six satellites can provide coverage for navigation of the seven seas. About six communication types can provide reliable communications anywhere on earth. Infrared detection equipment is now sufficiently advanced to track satellites hundreds of miles away.

Transistors are employed increasingly in spacecraft. The development of micro-miniaturization solves the size and weight limitations posed by space vehicles. Solar cells, too, are playing an important role in furnishing power over a long period of time in satellites. By their means the energy for generating electrical and electronic devices is obtained from the sun.

• **Second generation**—As the Space Age matures, the electronics industry will find itself more closely involved in space activity. Improved electronic and scientific techniques will have initiated a "second generation" of the Space Age by making it possible for man to be sent aloft in earth-circling satellites. Greater sophistication will create the need for more refined electronic instrumentation and control equipment. For example, the vehicle will carry with it a life-sustaining environment and if the time of flight is to be extended over a long period of time then total regenerative air, water and food cycles are the only answer. Electronics, too, may control the processes of the cycle of photosynthesis reliably and automatically. Electronics will be employed in maintaining the delicate balance of secondary living organisms that will be required in the reconversion of wastes into nutrients, and electronics will guard against leakage of vital materials through detection equipments.

Also, controlling the rotation of the space vehicle which induces artificial gravity may be another important function of electronics.

The industry will be called upon

to an increasing degree to perform vital functions in the space and missile programs. It has already provided devices necessary for missiles and satellites even with limited payloads. The industry can and will keep abreast or ahead of the Space Age requirements including those sensing and control mechanisms which will be needed for manned space explorations.

But in all its efforts to help solve space and missile problems, the industry has not forgotten that many of its past military developments have been successfully converted to peacetime use. The industry envisions that new and expanding markets will evolve from the application of Space Age technology to production for commerce, industry, and the consumer.

• **Commercial application**—This impact will be felt more distinctly in commercial and public service activities. One television transmitter can serve a continent. Electronic devices placed in orbit will forecast the weather, aid ships in navigating any seas around the earth, improve world-wide communications by serving as relay stations for signals and permit long-range point-to-point communications at low levels—thus helping to conserve the already crowded radio frequency spectrum. In addition, satellites containing electronics will patrol for icebergs, warn of forest fires, map the earth's surface, and conduct geological surveys.

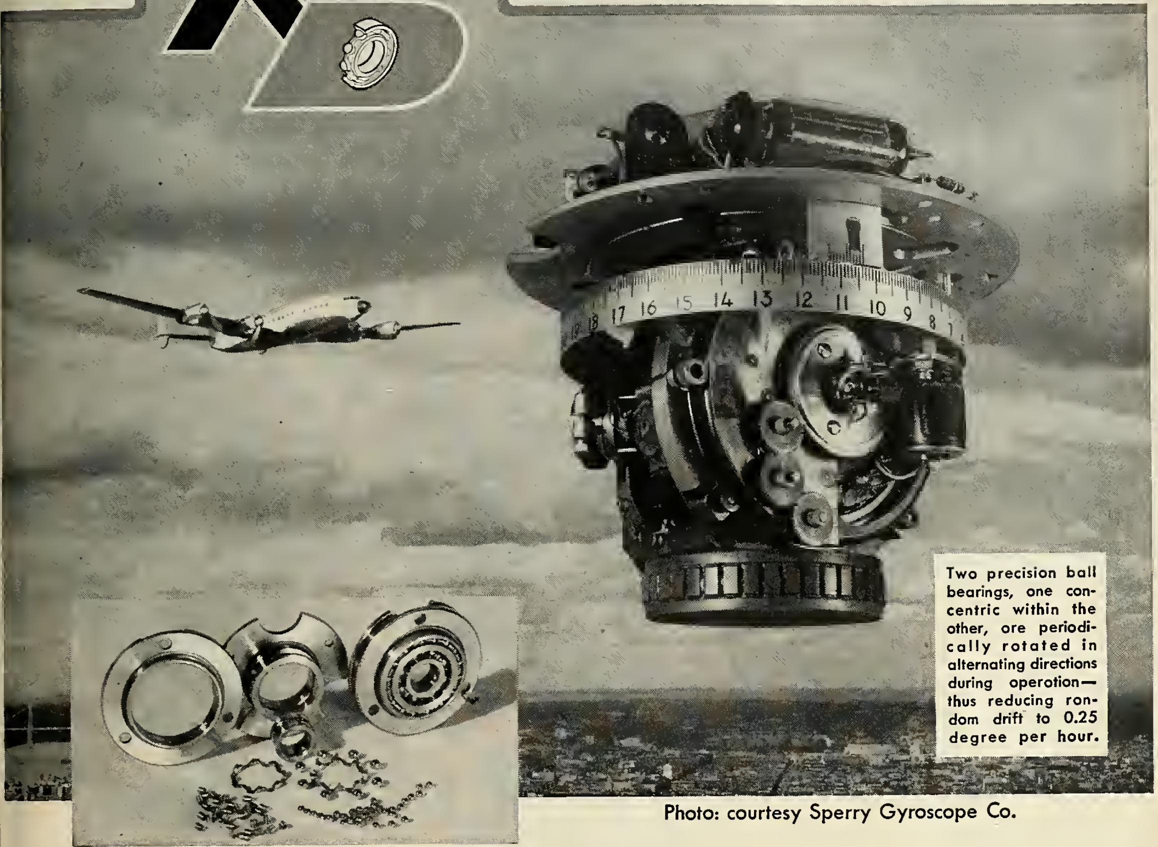
In the industrial area, automatic control devices are using advanced equipment and component designs that have been brought about by Space Age demands. Reduced costs and greatly improved product quality are seen resulting from these changes.

The impact of the Space Age on consumer electronic devices is apparent. One only has to observe miniaturization techniques in radios and other devices to see the relationship between consumer product compactness and the requirements of space technology.

Increased reliability is another byproduct of Space Age design that will continue to enhance electronic products in all market areas.

Because Space Age concepts are stimulating academic study, the gap between advanced ideas for the use of electronics and the level of present laboratory and production techniques may widen. It is also conceivable that this problem may be complicated further by the accumulation of new knowledge about our world and the universe made possible through orbital observations. Therefore, it is necessary that the electronics industry encourage the development and improvement of laboratory techniques and facilities that will convert new knowledge into useful functions for everyday living.

CASE HISTORIES



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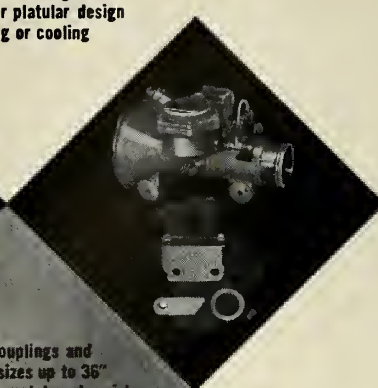

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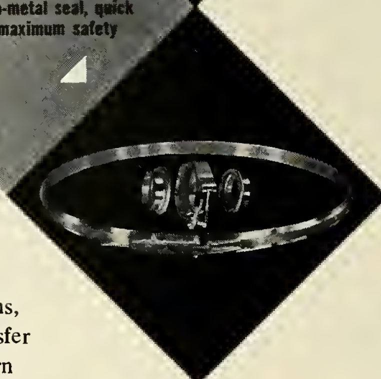

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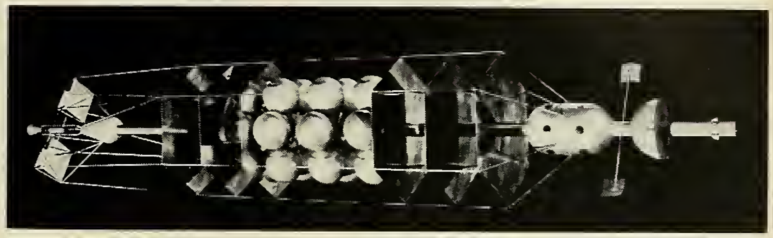
Considerable Theoretical Work Underway

Results are encouraging but experiments still are in the beginning. Here is the state of research, expected performance and the technical problems.

by Ernst Stuhlinger



NASA'S MODEL of a hypothetical spacecraft equipped with the components of a nuclear rocket propulsion system.

HUNTSVILLE, ALA.—The use of electric propulsion devices will be restricted to low-acceleration systems operated in empty space. Wherever these restrictions can be accepted, electric systems may prove advantageous because of their very favorable payload-to-takeoff mass ratios. The successful launching of satellites and lunar probes, and numerous study projects on lunar and planetary exploration, stimulate more and more interest in such propulsion systems. Experimental work on electric propulsion is presently under way at many places, sponsored both by government agencies and by private companies. The National Aeronautics and Space Administration recently established a powerful experimental working group for electric propulsion at the Lewis Flight Laboratory.

The possibility of using electrically accelerated particles for space vehicle propulsion was mentioned probably first by Goddard and by Oberth. Basic features of ion motors were discussed in several papers by others during the period from 1948 to 1954. A design study of a complete ionic propulsion system, published by the author in 1954, pointed out that the design and construction of a system using cesium ions should be feasible with presently available technical knowledge. In the meantime, a considerable amount of theoretical and experimental work has been accomplished with the result that electrical propulsion systems appear very promising for a number of applications. The present paper attempts to give a brief account of the state of research, of expected performance figures, and of existing technical problems. The discussion will be limited to ionic propulsion systems; arc-heated and plasma systems will not be considered.

• **Basic components**—In contrast to chemical rocket engines, electric propulsion systems require a separate source of energy. The only two sources that appear promising today are the sun and a nuclear fission reactor. In both cases, the magnitude of the energy-producing system aboard the space vehicle is dictated by the power level rather than by the total energy. The crucial figure is the power-to-weight ratio of the powerplant, α, measured in kw per kg. Several schemes to transform solar or nuclear heat into electrical power will be discussed later. With presently available technologies, the power-to-weight ratio α is still the figure that influences the thrust-to-weight ratio of electrically propelled space vehicles more than any other factor. Only a fraction of the heat produced by the powerplant can be transformed into electrical power.

The greater part must be absorbed by a heat-exchanging fluid, carried to a radiation cooler, and radiated into space. A large, low-temperature radiation area would be desirable from the standpoint of thermodynamic efficiency; however, a small, high-temperature radiator would lead to a smaller powerplant weight. The best size and temperature of the radiator will in any case be the result of an optimization study, which must also consider such factors as meteorite damage, corrosion effects and repair possibilities.

It may be advantageous to rotate the radiation cooler, and possibly the entire powerplant system, in order to cause the coolant to flow in the desired direction under the action of centrifugal forces. The propellant for electric propulsion systems must lend itself to easy ionization; it should have a large m/e ratio, and good storage properties. Depending on its mission, an electrically propelled space vehicle will carry an initial amount of propellant of the order of 10 to 50% of its total take-off mass.

• **Avoid feedback**—The ion motor, comprising ion source, accelerating chamber, electron emitters and beam neutralization system, will require

About the Author

Dr. Ernst Stuhlinger is director of the Research Project Laboratory, Development Operations Division, Army Ballistic Missile Agency, Huntsville, Ala. Born and educated in Germany, Dr. Stuhlinger was assistant professor of physics at Berlin Institute of Technology for five years before the outbreak of World War II. During the war, he was engaged for three years in nuclear physics research and then went into missile development at Peenemunde in 1943. He came to the U.S. in 1946 and worked on missiles at Ft. Bliss, Tex., and White Sands, N.M., until he went to Huntsville in 1950.

Air Force "Sunday Punch"

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Boosted into space by the fiery thrust of three huge rocket engines, the seven-story Atlas intercontinental ballistic missile roars upward from its Cape Canaveral launching pad. Quickly it sheds the frost encrusting the liquid oxygen tank and races to its predetermined destination in the far reaches of the globe. In its size and range and capability, the Air Force Atlas is a commentary, for all the world to heed, of the necessity to maintain the peace. RCA's Missile and Surface Radar Department has been privileged to design and develop ground check-out, launch control and cabling equipment as a major subcontractor to Convair (Astronautics) Division of General Dynamics Corporation, the Atlas prime weapons systems contractor.

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more development work than any other component. The ion source should have a high efficiency close to 100%; sputtering and erosion of electrodes must be avoided; the current density, limited by space charge effects, should be at least several mA per cm^2; electrons must be injected into the ion beam to form a neutral plasma, but any backflow of electrons into the ion source must be prevented.

A large number of ion sources were developed during the past decades, but only a few of them are suitable for electric propulsion systems. The contact ionization of alkaline atoms on hot tungsten surfaces is unsurpassed by any other source with regard to simplicity, high efficiency, and long operating life. The tungsten may be replaced by other metals of large work function and high vaporization temperature. The surface may be presented by a wire or ribbon grid, a woven structure, or a porous plug. Cesium, as the heaviest non-radioactive alkaline element and the one with the lowest ionization potential, would be the best choice. Metallic cesium is still relatively expensive at present, but indications are that its price will come down as soon as the demand for larger quantities rises.

Higher ion current densities may possibly be obtained from pinched-arc sources of the "duoplasma" type proposed by M. V. Andrenne. Ions of many kinds of atoms and molecules are readily produced by this source. Before its suitability for ionic propulsion systems can be appraised, more details about ionization efficiency, cooling requirements, erosion resistance, and operating life time must be investigated.

• **Beam neutralization**—The limiting influence of space charge effects is encountered twice in an electric propulsion system. First, these effects govern the density of the current between ion source and the accelerating electrodes; and second, they restrict the flow of the jet from the accelerating electrodes out into space. The current density inside the ion source and the accelerating chamber is a function of the accelerating voltage, and of the spacing between ion source and accelerating electrode. It appears that ion current densities as high as 5 to 10 mA cm^{-2} may be obtainable.

Space charges within the outgoing ion beam would render the formation of an ionic exhaust jet impossible unless at least the greater part of the positive charges were neutralized by negative charges. The situation is somewhat relieved by the lateral dispersion of the beam, which decreases the current density. However, injection of electrons into the ion beam will be necessary.

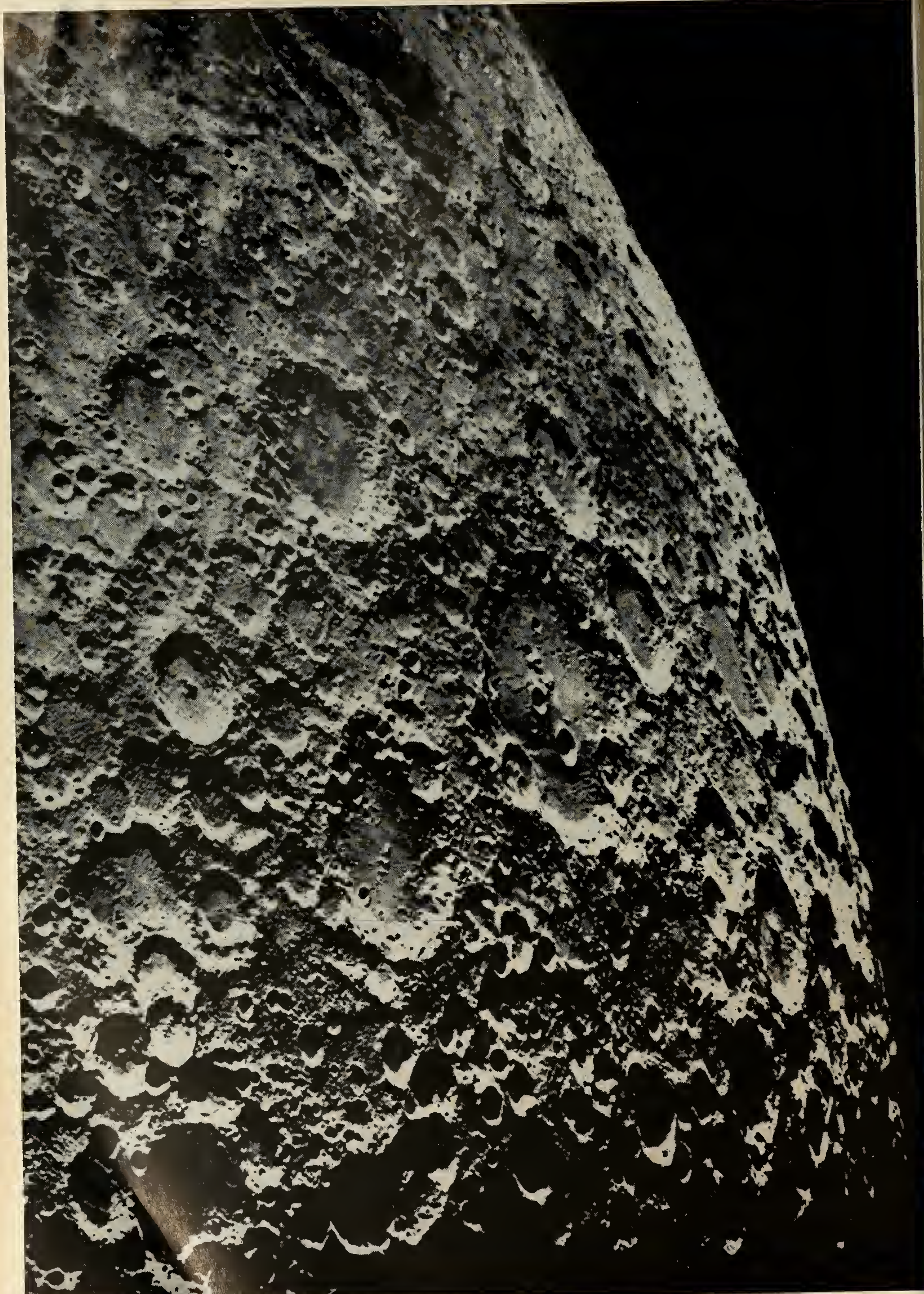
A considerable amount of theoretical work dealing with this problem has been done recently. The results are encouraging, but experiments are still in the beginning. The electrons most probably will be injected at low speeds into the beam, and will then begin to oscillate laterally through the beam, with a longitudinal velocity component of the order of the ion velocity. One proposal suggests that expendable surfaces be exposed to part of the ion beam; when striking the surfaces under grazing incidence, each ion knocks out numerous low-energy electrons, which then mix with the beam and contribute to its neutralization. The surfaces would be renewed as they are consumed by erosion.

• **Accelerating voltage**—The optimum accelerating voltage is a function of the mission under consideration, the specific power of the powerplant, the m/e ratio of the propellant particles, and the total available power. For cesium ions, it will be of the order of 3000 to 10,000 volts. From the standpoint of a large current density in the ion source, a higher voltage would be desirable. Research workers have suggested several designs of accelerate-decelerate systems that combine a high voltage across the ion source with a relatively low ion veloctiy at the exit of the thrust chamber. A design of this kind would probably lend itself favorably to an integrated system of high-yield ion source, efficient ion-optical collimation of the beam, and optimized exhaust velocity of the ions.

• **Power supply**—The unlimited supply of solar power continues to intrigue space vehicle designers. It has been proven that photo cells operate satisfactorily under space conditions. However, present efficiencies are of the order of 10 to 12% and manufacturing costs are high. While a multi-megawatt solar power supply is still too bulky and too expensive to be attractive as a power source for a large electric propulsion system, a solar supply for a system of a few kw appears promising.

As a source of heat power, the fission reactor seems to be superior to the bulkier solar mirror system. Even though nuclear reactors have not yet been operated in space, no excessive difficulties are expected. The reactor would be of the "fast" type with Na, NaK, Rb, He, or A as a working fluid, and with a simple shadow shield and probably a relatively large distance between the reactor and the rest of the vehicle. Heat exchange system, turbine, generator, cooler, and pumps or compressors should form a hermetically sealed unit to minimize the danger of leakages. The most severe problem is probably that of the high-speed bearings, which must operate unattended for a total period of 1 or 2 years under space conditions.

• **Electric generator**—The thermal energy from the prime power source may be transformed into electric power by a variety of methods. Turbogenerators, thermocouples, photocells and thermionic devices are the most promising conversion systems. A gaseous thermionic generator, using cesium



vapor between hot and cold electrodes, should theoretically yield an efficiency of 30 to 40%, but no technically useful design is available as yet. Turbogenerators may be expected to provide an overall efficiency of 12 to 15% under space conditions.

From an engineering standpoint, turbogenerators are the best-understood power-conversion systems. The generator may be an electrostatic rather than an induction type machine: since electrostatic generators must provide surfaces as compared to induction type generators which must provide volumes, the electrostatic generator will be considerably lighter. It appears that a specific power of about 0.2 kw per kg may be feasible, referring to the entire powerplant including fission reactor, heat exchanger, turbine, generator, radiation cooler, and pumps.

• **Lunar ferry**—Besides interplanetary space ships of a few hundred tons weight, smaller space vehicles may use electric propulsion systems to good advantage. An unmanned lunar ferry could carry 50 tons of droppable payload at a total initial weight of about 85 tons; it would cover the distance from a 300-mile earth satellite orbit to the moon in about 3 months, and the return trip in one month. The ferry could make a number of round trips before exhaustion of the nuclear power supply. The only mass to be reloaded, besides the payload, would be the relatively small amount of propellant needed for one round trip.

A small electric propulsion system of a few kw of solar power and a thrust of half an ounce might be very useful as a corrective system for satellites which must achieve orbital parameters of high precision, such as 24-hour satellites. The total velocity change to be accomplished over a period of weeks and even months would not be more than a few hundred meters per second. The thrust units could be applied to produce changes of the longitudinal, lateral, or radial velocity vectors, of the orbital plane, of the ellipticity, or of the attitude of the satellite. When the desired velocity or direction change is accomplished, the electric power will be used for communications, TV observations, or measurements.

If the transfer time is not at a premium, an unmanned heavy satellite can be transferred from a low orbit to a high orbit with an electric system. With transfer times of a few months, satellites of hundreds of tons can be spiralled into high-altitude orbits with propulsion systems that weigh, including propellant, only a small fraction of the total weight. After arrival in the new orbit, the electric power will be available for other purposes.

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Anti-submarine warfare equipment designed, developed and produced by *The Magnavox Company*, in conjunction with the Navy Department, provides patrol aircraft with eyes that see underwater by day and by night. The AN/ASA-16 Display System, together with SONOBUOYS, AN/ARR-26 Receiver systems and other associated equipment provide aircraft with a clear picture of the ocean-depths below them. They are part of the continuing contributions of *The Magnavox Company* in aiding the U.S. Navy to combat the growing submarine menace.

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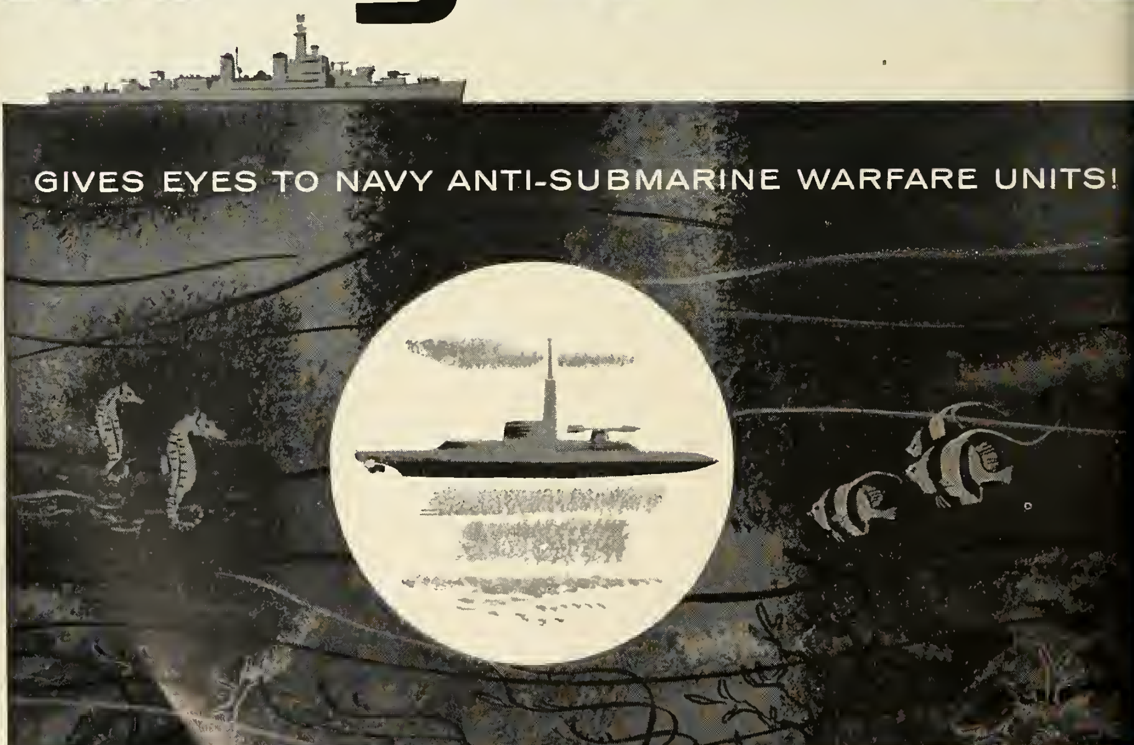

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Convair Has 'Advanced' Terrier in Production

POMONA, CALIF.—An advanced version of the *Terrier* surface-to-air guided missile is in production at **Convair (Pomona) Division of General Dynamics Corporation.**

The weapon—according to Convair—has vastly improved performance compared with the original *Terrier*, which has been operational with the Navy since January, 1956.

Under present shipbuilding programs, the advanced *Terrier* missile will become a major element in the Navy missile arsenal. The USS Dewey, a guided missile frigate to be commissioned late this year, will be the first ship to be armed with the advanced *Terrier.*

The nuclear-powered aircraft carrier USS Enterprise, as well as two conventional carriers, three guided missile cruisers and 18 more guided missile frigates also will be equipped with the new missile. Eventually the advanced *Terrier* also will be installed in the nuclear-powered guided missile cruiser Long Beach and the nuclear-powered guided missile frigate Bainbridge.

Like its predecessor, the advanced *Terrier* will be used from mobile ground launchers for the antiaircraft protection of U.S. Marine Corps detachments on land.

The advanced *Terrier* will be able to intercept any present-day supersonic bomber many miles from its intended target, Convair said. Like the original *Terrier*, the weapon is a supersonic missile powered by two stages of solid-fuel rockets. The first stage, a separate booster rocket, supplies high thrust for a short period to launch and accelerates the missile to supersonic velocity.

After the booster fuel is expended, the empty booster case falls away and the second-stage rocket ignites. The second stage is part of the missile proper and maintains the velocity required to match any evasive maneuver the target aircraft might take.

Guidance and control systems for the advanced *Terrier* were designed and are manufactured by Convair under the technical direction of the Applied Physics Laboratory of Johns Hopkins University, Silver Spring, Md. Propulsion work for the missile is done by **Allegany Ballistics Laboratory,** Cumberland, Md. The fuze was designed by the Naval Ordnance Laboratory, Corona, Calif., and the warhead by the Naval Ordnance Laboratory, White Oak, Md.

Heat Continues as Major Problem

Broad environmental criteria points up need for comprehensive materials R&D program. Here are the current research areas

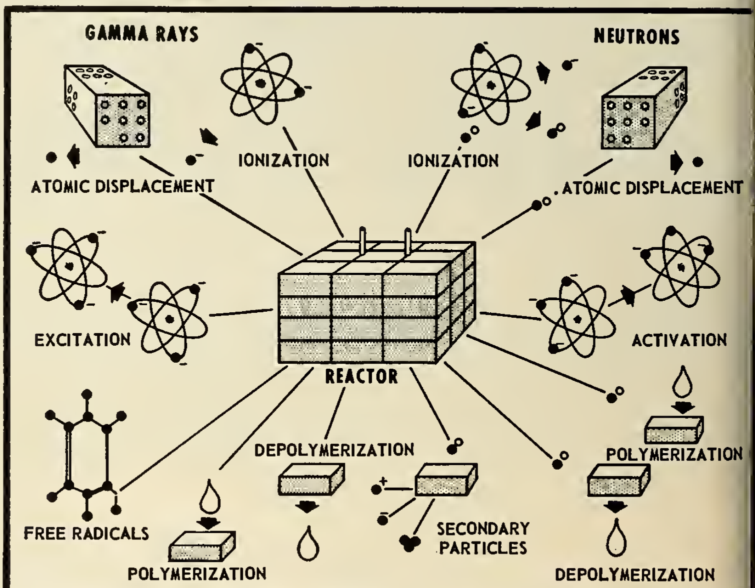
by
Lt. Col. Frederick C. Krug, USAF

WASHINGTON—The materials of which components of an aerospace vehicle are made and joined together are a common denominator basic to a successful weapon system.

Through the years, military departments have leaned heavily on civilian development of better materials from which new and improved equipment could be built. The need for such materials has increased rapidly during the past decade. We in the USAF have made known our requirements to the industrial and scientific communities. They have responded magnificently. One need only pick up and glance quickly through any recent trade or scientific journal to find hundreds of new materials announcements. To mention but a few at random—graphite cloth, energy conversion materials, extremely low thermal conductivity insulation, super-strength titanium alloys, ultra-high strength steels, very wide steel sheet, high-energy fuels, available rare metals with a wide range of properties, beryllium shapes, precipitation hardening stainless steels, sintered aluminum products, magnesium rare-earth alloys, flame-sprayed coating, ablation plastics; glass fibers with high modulus of elasticity and multi-directional magnetic steels. Yet in spite of such splendid advancements, materials problems continue to plague aeronautical vehicle designers.

• **Severe demands**—Contemplated weapon systems are placing these severe demands upon the basic materials of construction. These systems may be conveniently grouped into three broad classes:

a. Hypersonic Strategic Weapons
b. Ballistic Weapons
c. Satellite Weapons



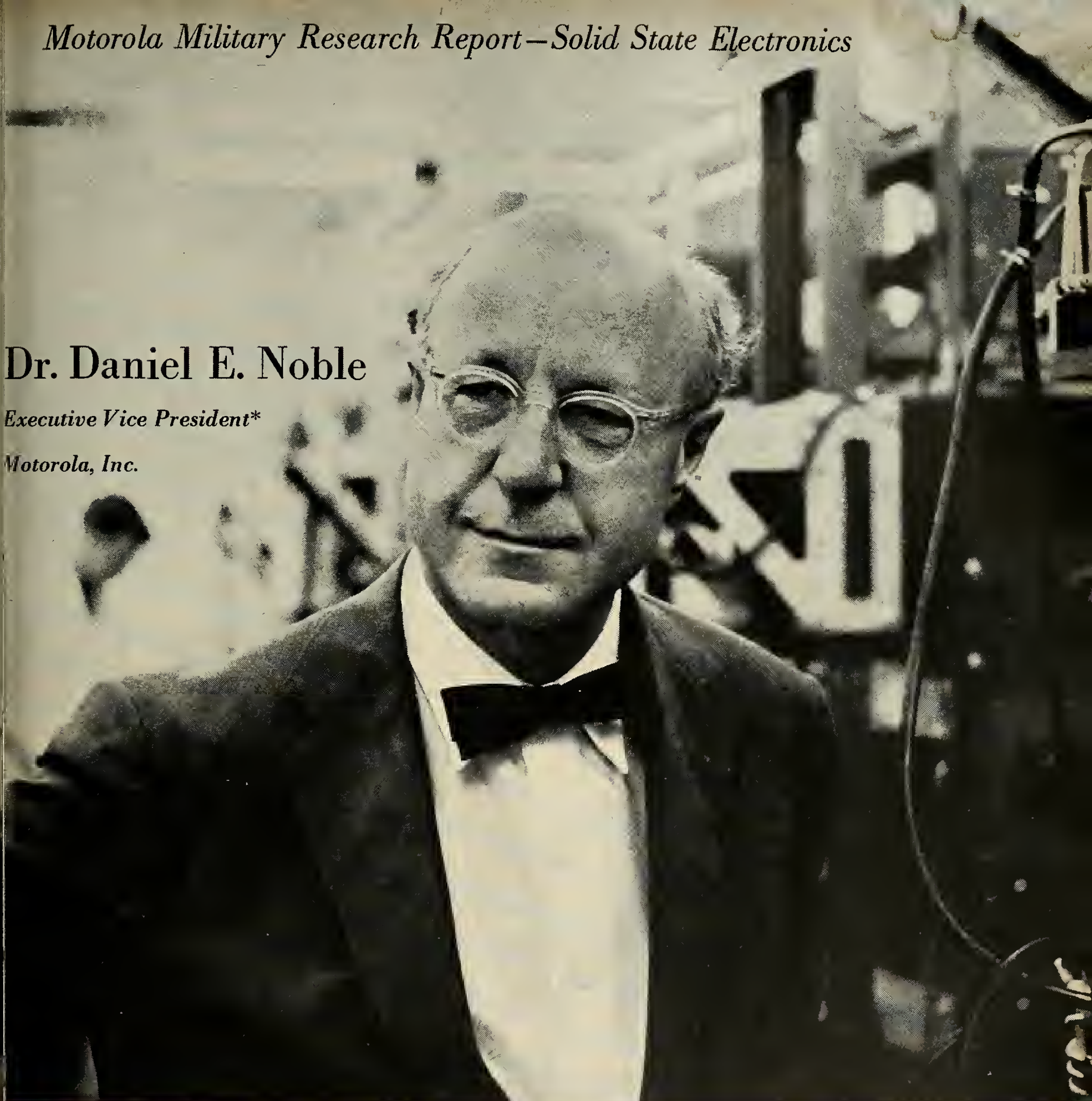
SOME OF the reactions that occur when materials are exposed to gamma rays an fast neutrons. Generally, the result is increase in strength.

Capabilities of High-Temperature Materials

ALLOY BASE	MELTING POINT, °F	RECRYSTALLIZATION TEMP. °F	$\frac{T_{RT}}{T_{MP}}$ =(°R)	X= $\frac{T_{100hr\text{-}20,000\ PSI}}{T_{MP}}$	ESTIMATED CAPABILITY BASED ON X=0.7in°F
NICKEL	2651	1110	0.51	0.73	
COBALT	2723			0.70	
IRON	1670*	840	0.62	0.82	
NIOBIUM	4474	1800	0.46		2990
MOLY.	4752	2066	0.48		3190
TANTALUM	5425	2327	0.48		3660
TUNGSTEN	6143	2849	0.50		4170

*= ∝ TO ɣ TRANSFORMATION

Figure I



Dr. Daniel E. Noble

Executive Vice President*

Motorola, Inc.

*DR. NOBLE IS VICE PRESIDENT IN CHARGE OF THE COMMUNICATIONS AND INDUSTRIAL ELECTRONICS DIVISION, THE SEMICONDUCTOR PRODUCTS DIVISION AND THE MILITARY ELECTRONICS DIVISION OF MOTOROLA, INC.

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Dan Noble

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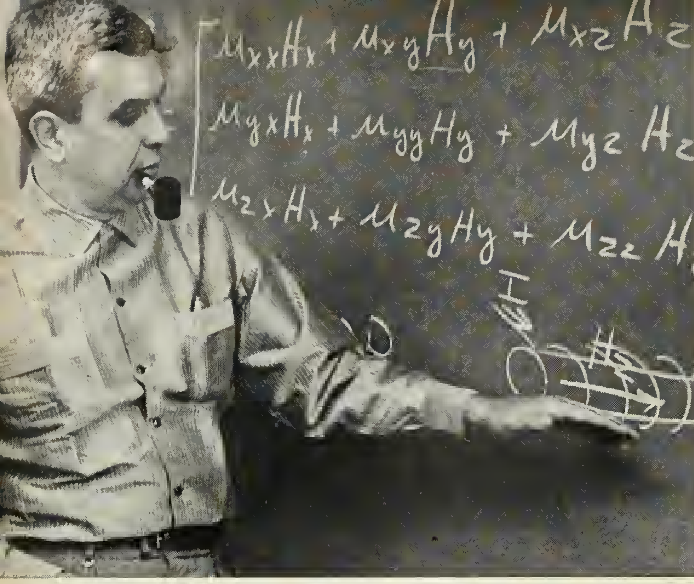
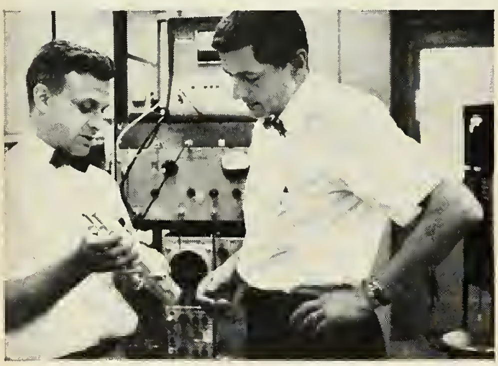


Ferrimagnetic principles are demonstrated by scien tist in charge of Motorola's Solid State progran Dr. H. William Welch, Jr., director of researc and development, Military Electronics Divisior Dr. Welch as a University of Michigan professo established that school's Solid State laboratory an introduced new curricula in Solid State devices an their applications. He holds an I.R.E. Fellow Awar for contributions to development of solid state device and microwave tubes.

Typical of solid state materials now being offered sale by Motorola are these ferrite rods and bars be examined by Donald L. Fresh, manager of the Sc State Materials Laboratory.

John C. Cacheris, right, manager of the Microwave Applications Laboratory, and a member of his staff inspect a parametric amplifier, one of several devices now being produced by Motorola's Solid State Dept.



Imaginative leadership plus the most modern of laboratory facili have helped foster a creative environment that is attracting top tal to Motorola. Here, Dr. Arthur L. Aden, associate director of resea and development for Motorola's Military Electronics Division, sh a new member of his staff equipment for photographing printed cuits. Dr. Aden welcomes inquiries from qualified engineers and ph cists who would like to join his department.

James R. Black, manager of Motorola Microelectronics Laboratory, heads work which leads toward the mass production of economical microelectronic components so small that several would fit on the period that ends this sentence.

How Solid State Electronics is shaping the future

MILITARY ELECTRONICS—industry as well—is being radically changed by rapid advances in solid state technology. Predicted for the near future are computers small enough to fit in the palm of a hand, receivers that will detect the weakest signals from distant satellites.

Motorola's highly experienced Solid State Department, in close cooperation with the Semiconductor Products Division, is advancing the state of the art on several fronts, one of the most promising of which is microelectronics.

By making use of crystalline functional circuit elements created in volume quantities by surface etching or film deposition methods, Motorola researchers anticipate they will soon be able to design equipment with component densities of tens of millions per cubic foot.

This high density will result in a great reduction in systems and computer size coupled with a significant increase in reliability, and it will lead to the development of self organizing computers for such complex tasks as the solution of military logistics problems and space guidance.

In microelectronics and in other areas, Motorola scientists, including those of the Semiconductor Division, are investigating the ferroelectrical, ferrimagnetic, piezoelectrical and pyroelectrical characteristics of monocrystalline and polycrystalline solids. New materials possessing these useful characteristics are created and produced in the Materials Laboratory. Typical applications: newly developed ferroelectrical or piezoelectrical materials to be used in transducers for submarine detection.

At present, the Applications Laboratory is making extensive use of ferrites and semiconductors in the development of broad lines of isolators, circulators and parametric amplifiers. The latter device has already demonstrated its worth in satellite-tracking radars, IGY research receivers, uhf television receivers and radio. In the study and design stage are new and advanced ferrimagnetic devices such as microwave switches, ferrimagnetic limiters and semiconductor switches.

Still another research frontier where striking preliminary results have been achieved is a low-voltage facsimile paper for the transmission of teletype and other information. Applications in the fields of combat surveillance, logistics control and other important military programs are foreseen.

Military Electronics Division's expanding capability in solid state electronics is described in a new booklet entitled: "Solid State Frontiers at Motorola." *Request your copy from Technical Data Service, Motorola, Inc., Military Electronics Division, 8201 East McDowell Road, Scottsdale, Arizona.*

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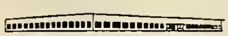

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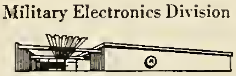

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As indicated, heat continues as the major environmental problem. High speed re-entry of ballistic and satellite vehicles will require materials capable of retaining structural integrity under heat fluxes of thousands of BTU/sq ft-sec. for possibly several minutes duration. Moderately stressed structures and propulsion systems employed in satellites will require materials whose properties must remain stable for many thousands of hours.

These broad environmental criteria point up the direction for a comprehensive materials research and development program. In addition to the operational high-temperature and long-life requirements, these problem areas include weight reduction, operation within a nuclear and cosmic environment, fatigue, reliability, and availability.

Speaking at the October, 1958, Joint Army-Navy-Air Force Conference on Elastomer R&D, J. R. Townsend, Special Assistant to the Department of Defense Director for Research and Engineering, stated:

"The persistent unreliability of some of our missile systems points to the dearth of materials with good properties in these extreme environments . . . To build reliability into these systems we must develop better materials in the laboratory, convert the laboratory product into a material of controlled properties capable of being shaped, and then design and manufacture the components to exploit fully the advanced properties of the new material."

In addition to the examples cited by Townsend, we can add such immediate problems as the short life of rocket nozzles, the failure of thin-shelled rocket cases, the incompatibility of seals and hoses with various high-energy fuels, and the exorbitant weight

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About the Author

Lt. Col. Frederick C. Krug is chief of the Metals and Ceramics Section, Materials Branch, Air Research and Development Command at Washington, D.C. A graduate of Pennsylvania State College, he has been an Air Force officer since 1943.

He has been a weather officer, a liaison officer and, since 1950, a specialist in metallurgy. He has been an Air Force member of the DOD Critical Materials Conservation Committee and the NACA subcommittee on Aircraft Structural Materials. Lt. Col. Krug has headed the Metals and Ceramics Section since 1955.

of nuclear shielding materials.

Therefore, the prime objective of the Air Research and Development Command's applied research program in materials is to provide the leadership necessary to extend significantly the useful range of application of aeronautical materials. The program includes metals, plastics and other synthetics, coatings and coating techniques, and unique methods for developing new materials.

• **Refractory metals**—New metallic materials are required to meet the needs of rocket and hypersonic airframe designers. This is primarily because of severe temperature extremes extending from below −400°F to over 5000°F. The super-alloys composed of such elements as nickel and cobalt give satisfactory long-time service (hours) to near 1700°F; but at temperatures over 2000°F, only several minutes of useful life can be expected. A class of metals known as the *refractory metals* holds potential for greatly extending this temperature limitation.

Four of these refractory metals are shown in Figure 1. Nickel, cobalt, and iron are included for comparative purposes. All have melting points exceeding 4400°F. The potential useful temperature of these metals has been estimated and is shown in the last column. Unfortunately, these refractory metals are subject to severe oxidation at elevated temperature and are brittle. Much research is needed to overcome these problems.

• **Coating techniques**—One approach to the oxidation problem of refractory metals is through the use of protective coatings, which must be impervious, resistant to thermal shock, and capable of withstanding a highly corrosive and erosive environment. The technique of applying such coatings is highly significant since uniformity and adhesion are particularly important.

The flame spray technique, which uses an arc plasma jet, is considered by many to be an outstanding metallurgical achievement of 1958. The temperature generated by an arc jet is so intense (15,000°F) that it can vaporize all known materials. Selected materials can thus be condensed as a coating on the component requiring protection. The potential of this arc plasma jet coating technique has yet to be fully exploited. With further development, for example, protection of nose cones and hypersonic leading edges may be greatly facilitated.

A direct development from the Air Force's program has been the "troweled" coating technique. By this procedure, heat-insulating coatings are laid up by hand-troweling of the ceramic material over a steel wire reinforcement.

The Air Research and Development Command is very much interested in coating development for oxidation and erosion protection of the refractory metals and graphites up to and beyond 5000°F.

• **Thermal protection**—As mentioned earlier, the Air Force has requirements for both long- and short-time thermal protection techniques. An example of the long-time requirement is the leading edge of a hypersonic system such as a boost glide vehicle. The short-time requirement is represented by ballistic nose cone and satellite re-entry. The refractory alloys hold promise for satisfying the leading edge and hot-spot structural problems of boost glide systems. However, much development combined with application studies are needed. Oxidation protection coatings will be required and a high degree of thermal shock resistance will be needed in the refractory bodies. At the present time, the potentially useful materials all appear to have limitations. These include low strength above 2500°F, lack of protective coating development, and lack of fabrication experience. Much work is required to overcome these deficiencies.

Designers and developers of nose cones for high-speed re-entry of the earth's atmosphere have been faced with one of this decade's most challenging technical problems. Obviously some sort of a protective shield is required. Fundamental to a solution is complete thermophysical materials property data. Lack of such data continues as one of the major limitations to design and development of Air Force weapons.

Based on the data available, several thermal systems show promise for applications in such an extreme heat flux environment; for example, systems based on the heat sink or ablation characteristics of materials. Comparatively, ablative materials consume up to 20 times as much heat per pound of material as can be absorbed by heat sink materials. An ablating system is depicted in Figure 2. As the material is exposed to progressively higher temperatures, large quantities of heat are consumed in the phase transformations that take place.

• **Beryllium materials**—Beryllium has many outstanding properties that make it an exceedingly attractive air weapon material. The element with atomic number 4, it is lighter than aluminum yet stiffer than steel. It is one of the best heat sink materials known. One of the most promising applications for beryllium is in guidance systems, which require a very light and strong material, dimensionally stable over a wide temperature range. Beryllium has provided the answer at a significant increase in performance as well as weight savings over its steel predecessor.

As an example of weight savings, a 13-lb. beryllium nose cone has the same heat sink capability as a copper cone weighing nearly 100 lb. Beryllium, or some beryllium compounds, offer potential as leading edge material for weapons exposed to severe aerodynamic heating.

Why, then, hasn't this potential of beryllium been exploited? The metal has been avoided because of its brittleness, scarcity, cost and toxicity. Adequate and effective techniques for joining (welding, brazing, etc.) have also been lacking. The Air Force is currently sponsoring development of beryllium alloys and fabrication techniques. With successful development of a ductile beryllium alloy or composite, a superior material will be available for many specialized applications. Furthermore, because of this metal's exceptional strength-to-weight ratio, it should find application in satellite and space weapons in which weight savings are vital.

• **Plastic materials**—Plastics have solved many Air Force problems. Their substitution for glass in aircraft gave significant weight savings; they contributed outstandingly to airborne radar. These uses are dwarfed by the potential of plastics in future weapons.

Plastics are practical as nose-cone material because of their outstanding ablation characteristics. In a simulated re-entry environment such as rocket blast or the plasma arc, reinforced plastic materials have shown superior performance to ceramics and high-temperature metals. While the original polyester plastics were limited to structural applications below 200°F, the development of heat-resistant silicone and phenolic resins has extended the maximum long-time operating temperature to 700-800°F. This temperature capability combined with the excellent strength-to-weight properties of plastics have provided the weapon designer with a highly versatile structural material from which rocket chambers, pressure vessels, and sandwich structures can be built.

Future Air Force weapons will need plastics with significantly extended strength and temperature ranges. For example, for rocket thrust chambers the present strength-to-weight ratio of reinforced plastics should be doubled.

• **Emissivity coatings**—Many Air Force weapons of the future will not enjoy the natural protection of the earth's atmosphere and will be exposed to the total radiant energy of the sun. Temperature control of such vehicles will be highly dependent upon the materials of construction. The balance reached between absorbed solar energy

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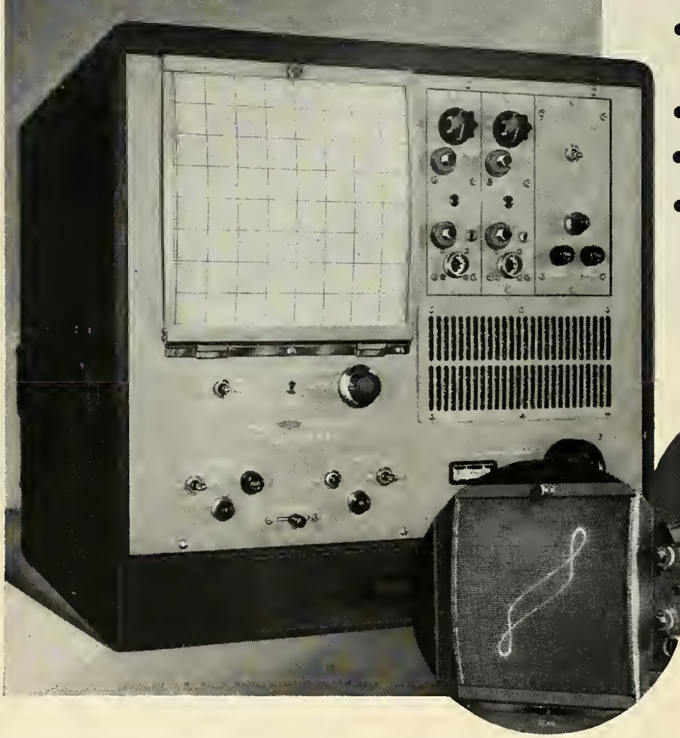

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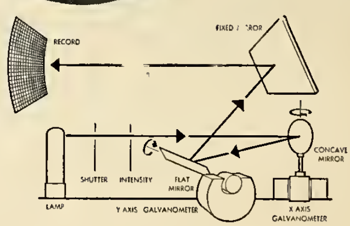

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OPTIONAL INTERCHANGEABLE PREAMPLIFIERS for each axis presently include the Model 850-1300B DC Coupling and Model 850-1200 Phase Sensitive Demodulator; a Carrier Preamplifier, High Gain Preamplifier and a time base generator are now in development. Driver Amplifiers are compact, fully transistorized plug-in units with single-ended input and output. Galvanometers are low resistance, low voltage units of rugged, enclosed construction; sensitivity and damping are independent of coil temperature. Accessible, unitized circuitry also extends to the power supplies—a front-panel plug-in for both preamplifiers and a second supply for both driver amplifiers. A built-in blower provides constant, forced filtered air cooling. The Recorder can be rack mounted in 15¾" of panel space, or housed in its own 20" x 20" x 21¼" optional portable cabinet.

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ınd re-emitted infrared radiation will letermine the skin temperature. It should be noted that the materials' properties of emissivity, absorptivity, and reflectivity are vitally important to he heat balance. To illustrate, consider he following: Metals are normally excellent reflectors, but poor emitters, of ong wave length radiation (infrared), vhile paints are generally poor reflecors but good infrared emitters.

What this boils down to—and has een verified by actual measurement—s that the equilibrium skin temperaure of painted surfaces will be much ower than polished metal surfaces. Although such coatings may provide excellent thermal balance, they will make nfrared detection correspondingly easer. Therefore, an optimum coating is eeded which protects the vehicle therıally and also from infrared or radar etection.

Although it appears that careful election of coating material can proide good temperature control, several ther considerations introduce an eleıent of caution into such a conclusion. 'irst, these temperature calculations igore internal heat; and, second, abraon or other surface attack may drascally alter the material properties of missivity, absorptivity, and reflectivity.

• **Tailoring materials**—Gone are the ays when the empirical approach of cut and try" could be relied on to ield improved materials. Furthermore, ıe inherent qualities of natural marials such as rubbers and greases are ıadequate for advanced weapon degns. Therefore, the trend to synthetally tailored materials has been great- accelerated. The Air Force's marials program has pioneered in mocular engineering through its plastics ıd elastomeric (synthetic rubber) apied research efforts.

The fluorinated silicones were taired for heat-resistant applications. ven these materials, however, have ıly modest temperature capability ith limited nuclear radiation and highıergy fuel resistance. As an approach significant improvement, materials ıgineers are attempting to tailor polymerize) rubber-like materials that nploy a metallic constituent, such as ı or boron.

Another urgent Air Force objective compatibility of seals, gasket, and ose materials with high-energy fuels. ydrazine, for example, seriously deades many of the best available elasmers. Applied research is therefore ing directed toward tailoring lastoeric materials that will be compatible ith new propellants.

• **Radiation damage**—Engineering ıaterials for future Air Force weapons ıust be capable of survival in a nuear environment, not only where nuclear power plants may be employe but also where exposure to cosmic o Van Allen radiation is anticipated. I radiation studies of components, sucl as radio receivers, motors, capacitors have shown that resultant damage is direct function of the resistance of th materials of construction.

Gamma rays and fast neutrons ar the prime triggers of radiation effect in materials. The illustration on pag 90 shows some reactions when ma terials are exposed to these radiation Atomic displacement and ionization oc cur in metals. Generally, the result i an increase in strength and hardnes but a decrease in ductility. This is nc considered serious. The exception t this conclusion is in solid-state device made of the semi-conductor element such as germanium. In such devices even slight atomic disturbances can not be tolerated.

Nuclear radiation can drasticall alter non-crystalline materials such a rubbers, lubricants and adhesives. Th chemical bonds between atoms of thes materials are quickly destroyed o changed. Greases may turn to gums adhesives and rubbers may harden an crumble. In such cases, the radiation i actually polymerizing or depolymeriz ing the materials. Therefore, supe imposed upon the Air Force's require ment for much improved thermal, co rosion, and erosion resistant material is significantly improved nuclear radi ation resistance.

Although additives (anti-rad) rais somewhat the radiation tolerances o some lubricants and polymers, this ap proach does not appear to offer signifi cant advancements. We must develo materials that are intrinsically stable t nuclear radiation. It was proven i 1958 that polyphenol ethers for o ganic fluids are many times superio to those lubricants containing addi tives. Concurrent with these develop ment efforts, we must continue a extensive testing program to study an evaluate the effects of a nuclear en vironment on all classes of air an space vehicle materials.

This has been a very brief look a the requirements, scope and directio of the Air Force's materials program At the 1958 ARDC Materials Sym posium, Maj. Gen. Marvin C. Demle now Director of Research and Deve opment, Hq USAF, stated, ". . . . ma terials research and development, stim ulated by the free thinking and creativ imagination which only a democrati society such as ours encourages, wi contribute significantly to Air Forc weapon supremacy." The resulting ma terials can significantly raise the lim itations now imposed by weight, ex tremes of heat, corrosive and erosiv environment and nuclear radiation.

on the countdown split-second communication for split-second *action*

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Sperry Duplicates FBM Sub Navigational Control

SYOSSET, L.I., N.Y.—An exac replica of a *Polaris* missile launchin submarine's navigational control cente has been put into laboratory operatio by **Sperry Gyroscope Co.**

For the first time, navigational in struments that will guide all Nav *Polaris* submarines are being system tested in a control center identical t that aboard a submarine.

Officially called the "Ashore *Polari* Navigation Center," it is more com monly referred to as the "Navigatio Island" by Sperry engineers. It is th nucleus of a test, integration an evaluation program assigned Sperry b the Navy, to assure performance fro this equipment before it takes to th open sea, under a schedule to hav *Polaris* operational by 1960.

The ashore test program is house in Sperry's new 52,000-square-foo Syosset, L.I., **Marine Division** plan which supplements existing productio facilities. Mission of this laborator center is to solve the assembly an operating problems of a combine complement of advanced navigation equipment.

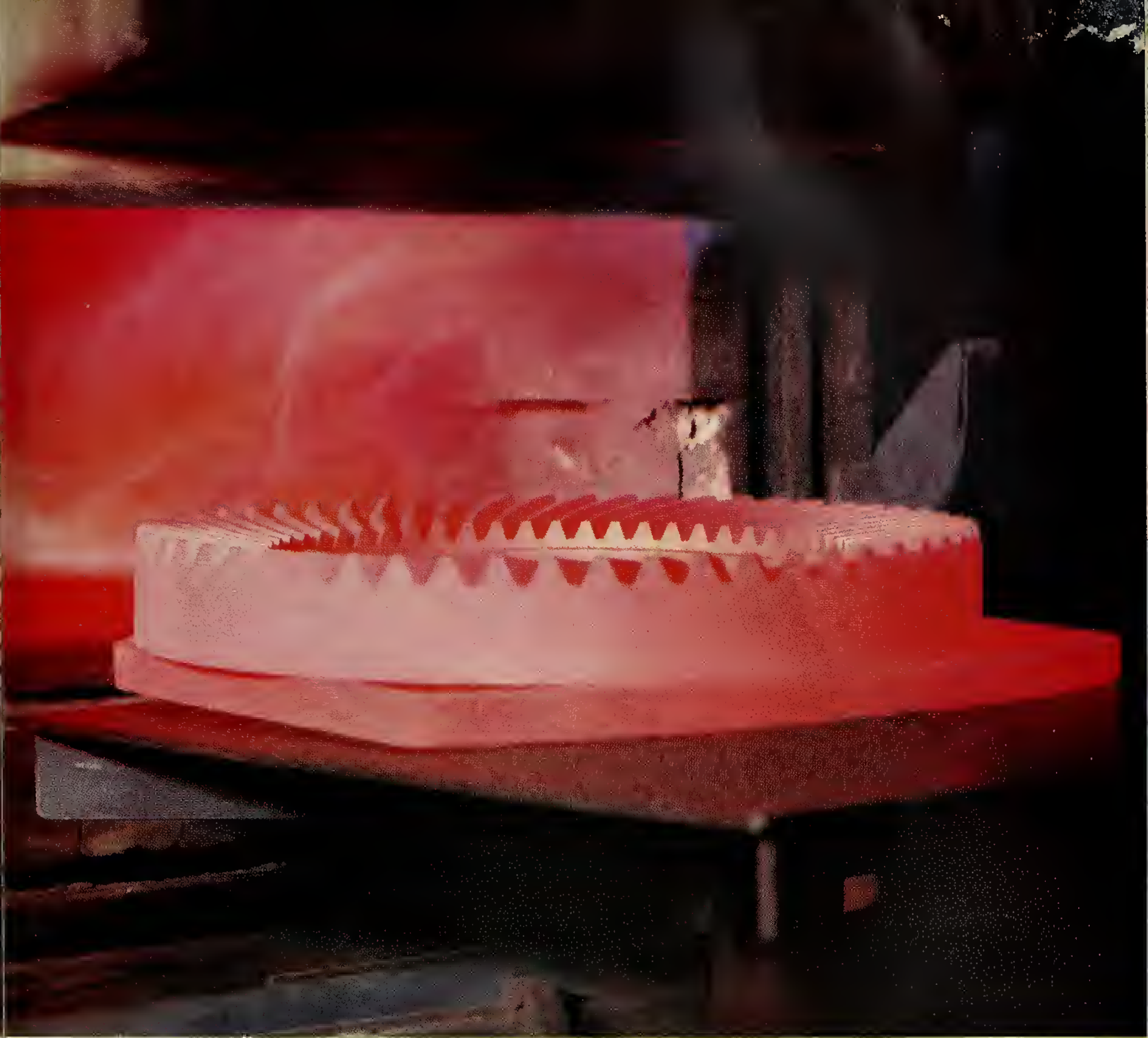
Sperry has had the responsibilit for developing inertial and other nav igation systems since the beginning c the *Polaris* program, together with th responsibility for integrating all of th seagoing navigation systems. The te program is now operating for the fir year of a three-year period under $1,570,000 contract.

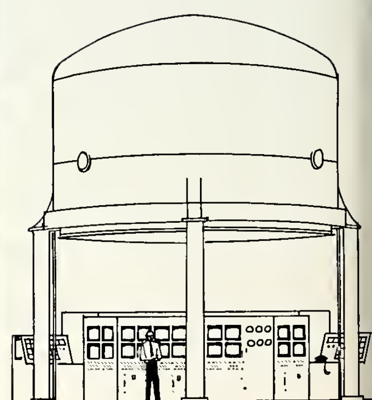
Among the major instruments an systems to be tested in the Ashor *Polaris* Navigation Center are NAVDAC (The Navigation Data A similation Center, a master computer SINS (the Ship's Inertial Navigatio System), the Type 11 Stabilized Per scope System (permitting celestial nav igation while submerged) and othe classified systems.

The dimensions, shape and cablin of the sub's navigation control cent have been reproduced exactly in th ashore test facility. The simulated hu section is a duplicate of the sub's na igation center.

Although much of this equipme has been used on other ships (i.e inertial navigators and NAVDA aboard Navy's test ships Observatio Island and Compass Island) this wi be the first time that all of the instr ments will be working in concert a complete system in the confined ar available on a submarine.

Sperry will develop casualty co trol procedures for emergency oper tion in the event of an injury to perso nel or damage to equipment.





The man:

...a U.S. airman-engineer—carefully selected through rigorous test procedures from Military personnel. He will have the combination of mental acuity, superb physical condition and emotional stability necessary for pioneering in space exploration.

The mission:

...satellite observatory—a vehicle arrangement similar to this could orbit a three-man astronomical crew for several weeks. Empty fuel tank is used for living quarters. Nose section serves as re-entry vehicle for return to earth. The astronomical telescope is gimbal-mounted. External equipment shown is mounted after orbit has been attained.

The means:

...Space projects are accelerated by research equipment like the Douglas high-altitude chamber at Tulsa, largest in the U.S. In it, space environment problems can be worked out under near-operational pressure conditions, shortening the time required for development.

Depend on **DOUGLAS**

The Nation's Partner in Space Research

more about the missile week

Diborane Applications Sought by Callery

Callery Chemical is negotiating for use of part of the U.S. Sunflower Ordnance Works, Lawrence, Kan., to develop, test and produce new high-energy rocket propellants—among them diborane.

The company said the Sunflower works offers facilities for exploring possible applications of diborane, which has 2½ times the density impulse (with LOX) of liquid hydrogen. Liquid diborane is 5 to 6 times as dense as liquid hydrogen, with a boiling point of −133°F, compared to −423°F for liquid hydrogen. Callery also will use the plant for advanced work on monopropellants, bipropellants and solids.

Aerojet-General and **National Research Corp.,** Cambridge, Mass., have worked out an agreement for commercial, large-scale production of solid fuels. Aerojet will use certain vacuum processes, equipment and techniques developed by NRC.

For NASA's *Scout,* **Hercules Powder** has come up with third- and fourth-stage motor cases fabricated from plastic, reportedly light as magnesium and strong as steel. Third stage of the $500,000 rocket weighs 2200 pounds and the fourth stage weighs 500. Both are solid-fueled motors.

New Rocket Steel

Jones & Laughlin Steel Corp.'s Stainless and Strip Division, Youngstown, Ohio, has been awarded a contract by Aerojet-General to develop an extremely high-strength strip steel for missile and rocket components. Specs call for mechanical properties "far in excess" of available commercial strip.

Hardware for NASA's Wallops Island project to measure high-altitude radiation is **Aerolab Development Co.** *Javelin.* The first 49-foot, 7400-pound vehicle boosted a 45-pound instrumentation payload to 750 miles July 7. Six more firings are scheduled before year's end.

The solid-fueled four-stage sounding rockets are composed of modified *Honest John, Nike* and *Vanguard* components. Last four firings will be with a 60-foot model weighing 13,000 pounds and capable of carrying similar payload to 1650 miles.

Contracts & Companies

Development and evaluation contract for $36,000 has been awarded **Ultrasonic Testing & Research Laboratory,** Van Nuys, Calif., by WADC. Object: find non-destructive techniques for detecting defective areas in solid-propellant motors . . . BuOrd has contracted with **Clevite Corp.'s** Mechanical Research Division to investigate property modification of materials such as tungsten for ultra high-temperature missile applications . . . At Hicksville, L.I., **Radar Measurements Corp.** is at full operation in a new plant . . . **American Bosch Arma** has acquired **Ensign Carburetor,** Fullerton, Calif., a maker of fuel injectors and similar products . . . **Ford Aeronutronics Division** *Shillelagh* (tank-launched missile for close-in troop support) may be rechristened *Pentomic* . . . More expansion for **Raytheon** is in the works. The company which a few weeks ago announced new plants at Lewiston, Maine, and Portsmouth, R.I., now says it will build a wholly integrated electronic warfare center at Santa Barbara, Calif. The plan calls for expanding its existing operation there by 220,000 square feet of space and employing a total of 1700 persons by 1964.

TRW Acquires Magna

Thompson Ramo Wooldridge has purchased controlling interest in **Magna Products Inc.,** Santa Fe Springs, Calif., a specialty chemical and electronics firm which recently won a Navy solid propellant research contract . . . Air Force logistics manager for the as yet unchristened **Douglas** ALBM (WS-138A) is the Ogden Air Materiel Area, Hill AFB, Utah . . . **Packard-Bell Electronics Corp.** stock was listed on the New York and Pacific Coast Stock Exchanges last week for the first time . . . **Transval Electronic Corp.,** Culver City, Calif., now has Washington representation—Jack Campbell . . . For more missile assembly space, **Horkey-Moore Associates** is constructing a new 13,500-square foot building at Torrance, Calif. . . . At Gardena, Calif., the **Jetstream Fastener Corp.** is moving into a new 14,000 square-foot building . . . and **The United States Chemical Milling Corp.** has acquired **Darco Industries Inc.,** missile component producer with plants at Glendale and El Segundo.

Aluminum Bar Cuts Aluminum Weld Costs

A new type aluminum back-up bar or metal inert gas-arc welding of luminum is cutting costs and speeding roduction at the **Reynolds Metals ompany** missile plant at Sheffield, Ala.

The new back-up bar is of a maineable aluminum alloy and has an asily replaceable T-shaped stainless eel insert. Previously, the back-up welding bars used in the plant were made entirely of stainless steel.

Charles M. Jenkins, production superintendent at the missile ballistic shell plant and leader in the development of the new back-up bars, said they offered two major advantages over conventional all-stainless bars:

One is that the aluminum bar dissipates the welding heat much more quickly than the stainless bars, making unnecessary the water jackets in use on some production stake welders. And faster heat dissipation keeps weldment distortion to a minimum.

The other major advantage is that the stainless steel inserts are cheap enough to be discarded after their grooves become burned and pitted.

Plant Manager M. C. Duke said the inserts can be replaced for less than half the average cost of repairing the all-stainless back-up bars previously used. There's also a definite saving in down time in the welding department.

Production is also speeded, Mr. Duke said, because inserts of different groove sizes for different sheet thicknesses can be put in much more quickly than was the case when the entire back-up bar had to be switched.

Reynold's missile plant has been using the new back-up bars for more than a year. It has not been necessary to replace any of the aluminum bars which hold the stainless steel inserts.

The aluminum bars and the stainless inserts can be produced either by extrusion or machining, plant officials said.

The Reynolds plant makes aluminum missile shells and tail sections for the *Redstone* and *Jupiter-C* vehicles. It also supplies aluminum in many forms for ABMA's *Jupiter* and many other rockets.

Circle No. 235 on Subscriber Service Card.

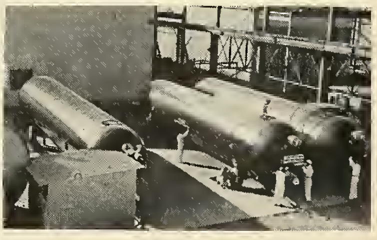
World's Largest Fly-Away uel Tanks Built for *Thor*

In a brand new hospital-clean dustee alloy manufacturing plant in the ntral manufacturing district of Los ngeles, more than 300 employees of **andard Steel Corp.** are building giant etal vacuum bottles for storage of quid oxygen, fuel for the Air Force's *or* missile.

Installed at Vandenberg Air Force ise in California, and flown to other *or* launching sites around the world, ese tanks represent one of the most acting alloy fabricating jobs ever empted.

Standard Steel Corp. delivers the nks to **Douglas Aircraft Co.,** Santa onica, Calif., through the **Cambridge orp.** Designed to hold 13,500 gallons liquid oxygen at 297.4° below zero, ey have a high-strength (type 5086) uminum outer jacket and a stainless steel (type 321) inner shell. Unusual fabrication techniques were developed so that the huge tanks, 52 ft. long and nearly 9 ft. in diameter, would be light enough to support 135,000 lbs. of liquid oxygen when full. They weigh 32,000 lbs. when empty. All of the ground support equipment for operational units of the Air Force *Thor* program is being built for fly-away shipment.

In Standard's new alloy fabricating plant, assembly of the vacuum bottle tanks is done in a dust-controlled room kept under slight pressure to prevent infiltration of dust. Concrete floors have been completely sand blasted and a special surface hardener applied to discourage dust accumulation. These floors are continuously vacuumed. All structural members, ceiling and walls are painted white. Welders and other skilled workmen don white uniforms, and special rubber-soled shoes have to



be worn when working inside the stainless steel and aluminum shells.

After complete assembly and thorough cleaning, the tank is positioned on Standard's testing pad located at the new plant. Liquid oxygen fills the tank to the ¼ mark and is held for 72 hours to check vacuum readings. Final pressurization is done with dry nitrogen before the tank, supported by a trailer undercarriage, goes to Vandenberg or a nearby airport.

Circle No. 236 on Subscriber Service Card.

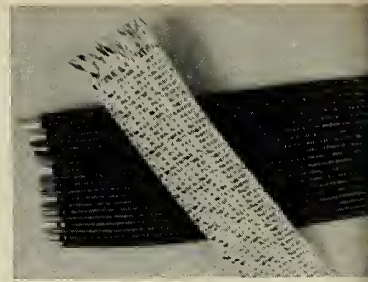
'Ribbon' Cable Has Specialized Applications

Multi-conductor cables in flat "ribbon" configurations for use in specialty and tight locations are now being produced in quantity by **Tensolite Insulated Wire Co., Inc.**

The cables are flexible in one plane, making it simple to run them around corners or around the inside edge of a container. This flexibility also makes them especially valuable for use with drawer pull-out type printed circuit assemblies.

One user has the cable installed on a spring-loaded spool which unrolls the cable as the board is slid out. Most major connector manufacturers make suitable ribbon cable connectors for the interconnection of these printed circuit boards.

The cables are frequently woven on looms similar to those used in the textile industry. Yarn ends—Teflon, Nylon, Fiberglass, Dacron, cotton or



other textile fibers—form the "warp" and the "woof" or "filling." The wires would be analogous to the "stuffer" yarns in a carpet. They lie lengthwise in the ribbon cable. The interlocking, or weaving, of the "warp" yarns and "filling" yarns bind the wires in place.

Metallic "woofs" such as silver-plated copper, tinned copper and stainless steel are also available. Primary insulation of the wire can be either Teflon or PVC. Any number of twisted multi-conductors, coaxial cables, and single conductors as small as 36 AWG may be used. It is not necessary that the individual wires be of the same gauge. Color coding is possible on each individual conductor.

Circle No. 237 on Subscriber Service Card.

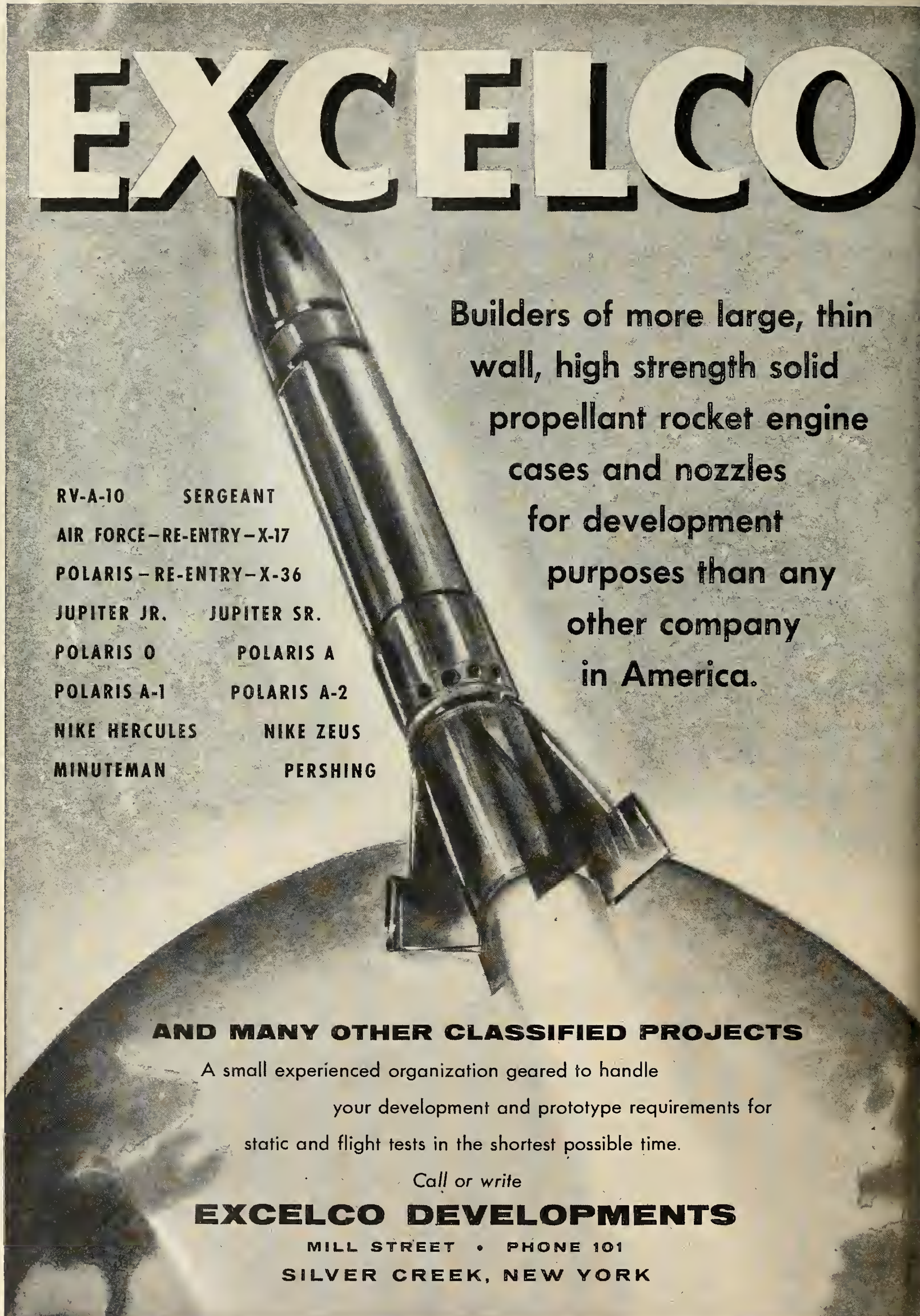
Resin Retains Strength After Exposure to 600°F.

A silane modified phenol-formaldehyde resin, which retains its strength after exposure to temperatures of 600° F for hundreds of hours, is available in commercial quantities from **Monsanto Chemical Company's Plastics Division.**

The new material, tradenamed Resinox SC-1013, was developed especially for use with fibrous glass and asbestos reinforcements to make radomes for supersonic aircraft. Because of its excellent performance in the 500 to 600 F temperature range, it is expected to be used in other applications where such temperatures have prohibited the use of plastics.

Radomes must be lightweight and "transparent" to radar beams, yet strong enough to withstand the high temperatures produced by a combination of high speed friction and the high-frequency radar impulses passing through them.

According to Thomas W. Sears Jr. sales manager for industrial resins, this is a critical problem area for which there has not been a satisfactory material. "Resinox SC-1013 has high frequency electrical properties and high temperature performance characteristics several times better than conventional phenol-formaldehyde resins an


EXCELCO
Builders of more large, thin wall, high strength solid propellant rocket engine cases and nozzles for development purposes than any other company in America.
RV-A-10
SERGEANT
AIR FORCE–RE-ENTRY–X-17
POLARIS–RE-ENTRY–X-36
JUPITER JR.
JUPITER SR.
POLARIS 0
POLARIS A
POLARIS A-1
POLARIS A-2
NIKE HERCULES
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MINUTEMAN
PERSHING
AND MANY OTHER CLASSIFIED PROJECTS
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we believe that it will make important contributions to the development and use of high-speed radar domes," he said.

Late last year the company announced the development of a special phenol-formaldehyde resin, Resinox SC-1008, to protect missile nose cones against the super high temperatures, well above 10,000°F, generated by friction during the short period they are plunging through the earth's dense atmosphere from high altitudes.

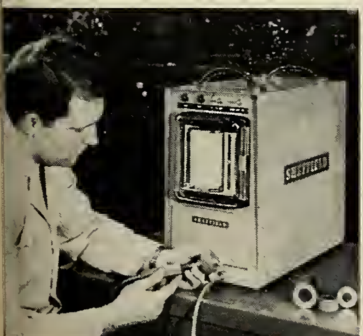
Both products are the results of a special research program to develop materials for aircraft, missile and rocket parts and components at the company's resin products laboratories.

Circle No. 238 on Subscriber Service Card.

Instrument Air Gages and Records Simultaneously

Data gathering for dimensional quality control charts or a chartered record to serve as a size certificate can be made faster and to machine accuracy with a new gaging and recording instrument recently developed by **The Sheffield Corporation.**

The new instrument, which uses hand or fixture-type air gage tooling, makes an automatic record showing a part's plus or minus deviation from nominal size on a 4" wide strip chart



uring gaging. The standard model is upplied with continuous chart drive nd will inspect a single dimension.

Where desired, the Air Gage Reorder can be obtained also to check vo dimensions as well as being quipped with optional features such s maximum and minimum signal ghts, and an index drive to move the hart approximately 1/8 of an inch on ach gaging operation.

Back-pressure type air gage tooling used as the size-sensing elements, icluding Open-jet, Balljet, and Blade t spindles, Air Snaps and Air Rings,

Circle No. 99 on Subscriber Service Card.

and Plunjet gaging cartridges. Existing flow-type tooling up to 2000 to 1 amplification generally can be modified to suit the instrument.

The new inspection-recording device is the approximate size of a portable TV set, measuring 9½" wide x 19½" deep x 17" high. It connects to the regular factory air line and 110 volt, 60 cycle ac. The back-pressure gaging unit, air pressure regulator, and pen and ink strip chaet recorder are housed in the modular-type unit which has a Plexiglass window at the front for viewing the chart.

The present non-automatic "hand and eye" method, in which the "eye" notes the gage reading and the "hand" writes the figure down on a tally sheet, has a number of inherent weaknesses. For example, production-conscious personnel may not make the actual number of checks required for a true statistical sample.

Data tally sheets can be filled out by checking just a few parts and then extending the trend or by writing in similar figures for the rest. Also, hand written figures are often illegible, hard to read, subject to error in transcribing, and they can be changed. As a result, the success or failure of a quality control program may depend, in final analysis, on the accuracy with which the original gage data is recorded.

Circle No. 239 on Subscriber Service Card.

High Stability Claimed for Carbon Resistor

A unique deposited-carbon resistor filled with silicone oil and hermetically sealed for maximum stability under heat and high voltage is announced by **Key Resistor Corp.**

Soldering is done by an exclusive fluxless machine process which permits filling the units with oil. Resistors are 100% X-ray inspected and seal tested. This construction insures long life under load, plus extreme stability under heat and high voltage.

Resistance elements are up to 52%

larger in area than on conventional types, and hence run cooler.

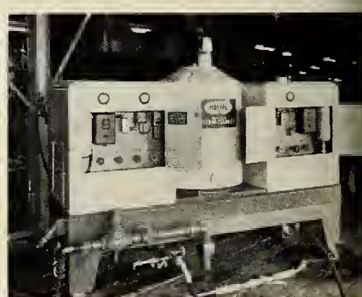
Units are designed for use in circuits requiring small size and high reliability. These resistors meet all Mil. Specs., including MIL-R-10509C, Characteristic B. Available in all military sizes, plus ⅛ watt and ⅒ watt . . . in resistance values from 5 ohms to 20 megohms.

Circle No. 240 on Subscriber Service Card.

Advanced Steam Cleaner Has Support Applications

An advanced steam cleaner, designed initially for missile ground support equipment application, has been put into production by the **Kelite Corp.**

Designated the Mark IV, the new unit may be used to clean and phosphatize large structures such as missile launching ramps prior to painting. The steam gun design which supplies hot cleaning and phosphatizing solution at 600 gallons per hour, is reported to eliminate the disadvantages of former syphon gun equipment. The machine may also be used for high-capacity



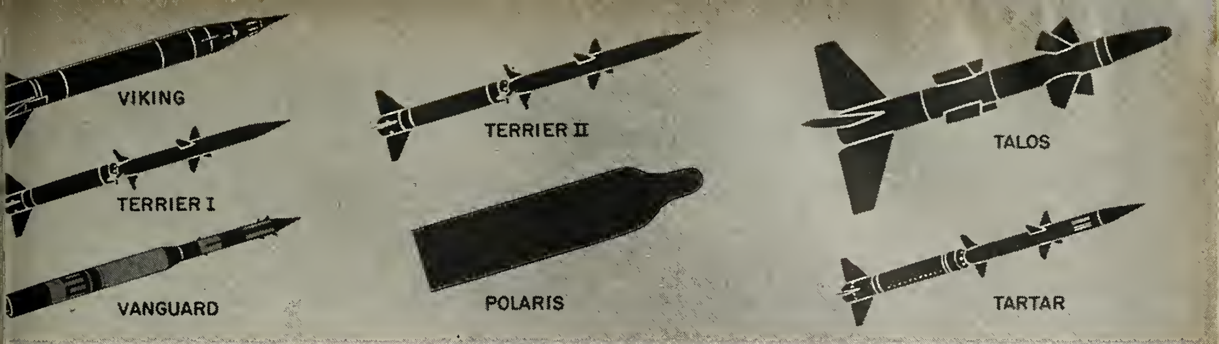
steam cleaning operations and/or high-pressure water rinse.

The Mark IV is available in both direct fired (gas) and fireless models. Latter may be used if a steam source is available. Direct fired model operates on either city or bottled gas. To conserve cleaning solution and personnel time, the gas supply and positive displacement pumps are controlled by a lever at the steam gun.

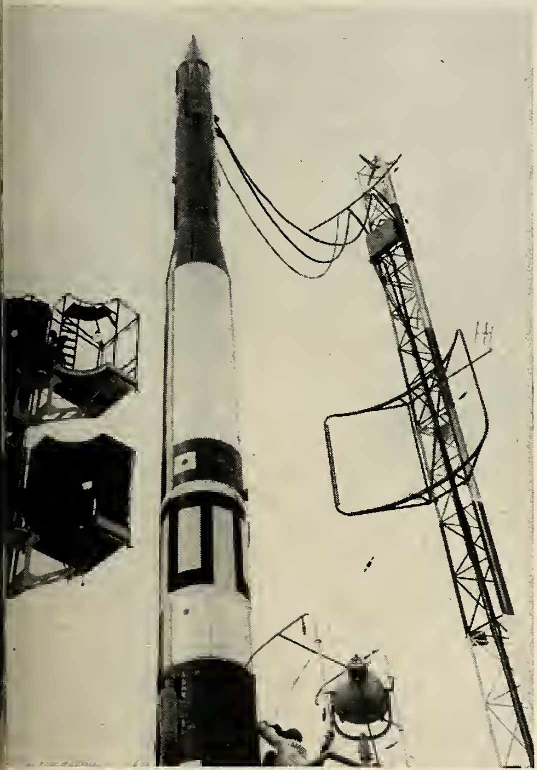
Circle No. 241 on Subscriber Service Card.

High Performance Rating Claimed for New Gyros

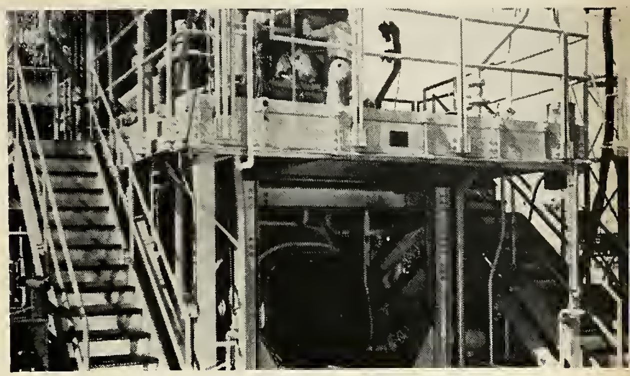
Kearfott Co., Inc. has announced the availability of a new series of high-accuracy miniature floated rate integrating gyros designed specifically for use in missiles or severe missile-like environments.



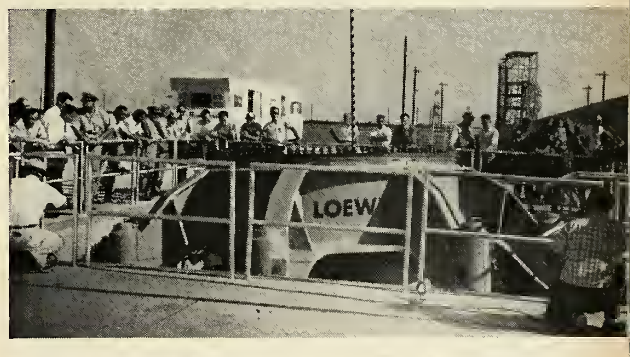
Loewy-Hydropress has been engaged in building handling, stowage and launching systems for these rockets and missiles.



nguard rocket being readied for launching on March 17, 1958.



Testing and firing installation for Viking and Vanguard rockets.



Ship motion simulator for test-firing U.S. Navy's guided missile "Polaris" under seagoing conditions.

Loewy ground handling and launching systems in successful operation and in progress

iant and unusual facilities for handling, testing and launch- g missiles and rockets have been built and put in operation y Loewy-Hydropress for the U.S. Navy's Fleet Ballistic rogram and for the joint IGY Program of the Navy and the ational Academy of Science. These installations have proven eir brilliant effectiveness under the most trying circumstances.

Loewy-Hydropress has also been chosen to design systems r the protection, handling and launching of surface-to-air personic missiles and missile components for the Navy's rst nuclear-powered cruiser, *Long Beach*.

Another Loewy system is in development for supersonic missiles which will be installed on Navy aircraft carriers.

Loewy engineers build all kinds of handling, stowage and launching facilities for guided rockets and missiles of various sizes and operating ranges.

They also specialize in the design and construction of radio telescopes and related space communication systems.

Avail yourself of the experience and ingenuity of the Loewy organization, which coordinates all other B-L-H divisions that are actively engaged in the specialized fields. Just write us at Dept. S-7.

Loewy-Hydropress Division

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Two inches in diameter and 2¾ inches long, these components consist principally of a gyro motor, a torque motor, a signal generator, and a constant damping device. Unique design combines the torque motor and the signal generator in a single unit, or "torsyn," together with a restraint-trimming tertiary winding.

The gyros are said to exhibit performance characteristics that are superior to those of any other unit of comparable size now in use. Designed for maximum adaptability to precision mass productions methods, these gyros can be produced having a variety of performance characteristics tailored to specific applications.

There is said to be no limit to the altitude at which these components operate, and no performance deterioration with altitude.

Performance Characteristics: Mass unbalance, 1°/hr. max. untrimmed (along input and spin axes); Restraint: 0.5°/hr. max. untrimmed; Standard deviation (short term); azimuth—.05°/hr.; vertical—.03°/hr.; Max. drift rate: .015°/hr./g^2 steady accel.; .008°/hr./g^2 vibratory accel.; Damping: input-output angle ratio - 0.2; Characteristic time: .0035 sec. or less; Gimbal freedom: ±3° minimum; Warmup time: 10 minutes from –60°F; Weight: 0.7 lbs.; Life: 1000 hrs.

Circle No. 242 on Subscriber Service Card.

Simplified 5 Volt Recording System Produced

A simplified 6- or 8-channel direct writing oscillographic recording system has been developed by **Sanborn Company** specifically for computer readout, telemetry recording, dc monitoring and similar applications requiring no preamplification.

The Sanborn Model 358-5480 system consists of a 6- or 8-channel control panel for input signal control and a 6- or 8-channel recorder-amplifier unit.

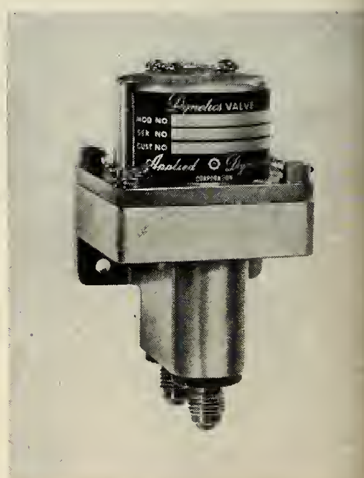
System linearity is 0.5% of full scale (max. chart width 50 divisions); sensitivity is 0.1 volt/division; frequency response is 3 db down at 150 cps at 10 division peak-to-peak amplitude. The system has hysteresis of less than –0.1 division and gain stability better than 1%.

The control panel provides position, smooth gain and attenuator controls, and an internal calibration signal. Single-ended input connections of 100,000 ohms impedance can be made either on the front or the rear of the cabinet.

The $17\frac{1}{2}''$ fully transistorized recorder-amplifier-power supply package has current-feedback amplifiers and velocity feedback damping. Galvanometers are rugged, low impedance, low voltage units with enclosed construction. The recorder features inkless recording in true rectangular coordinates. Displaying a full eight inches of chart, it loads easily from the front and has a built-in paper footage indicator and take-up. There are nine electrically controlled chart speeds selected by push-button, or the recorder can be remotely controlled.

The entire 358-5480 system, complete with power panel, wiring harness and built-in blower, occupies only 57 5/8" of panel space. The recorder assembly, control panel and master power panel may be purchased separately for individual 19" rack mounting.

Circle No. 243 on Subscriber Service Card.



Pressure Regulator Has Integral Relief Valve

The development of Model 30-301 Dynectics Pressure Regulator with a built-in relief valve has been announced by the **Applied Dynamics Corporation.** Typical applications of the unit include airborne or ground electronic system pressurization, air or gas system pressure control.

The model 30-301 regulator is designed for control of system pressure. Function of integral relief valve is to prevent pressure build-up due to thermal expansion of air or line surges.

The regulator is designed for: an inlet pressure of 40 to 60 psig and an outlet pressure of 15 to 30 psig, a burst pressure of 500 psig at inlet and 80 psig at outlet, a pressure variation

at set point of ±1 psig, and reset of relief valve not to exceed 1 psig above set temperature. The regulator operating temperature range is –70 to +175°F, and will withstand salt spray test at 95F for 48 hours.

Circle No. 244 on Subscriber Service Card.

Tiny Radar Device Can Fit Into Attache Case

A miniature radar-like device that detects and measures movements up to thousands of feet away was demonstrated here publicly for the first time today by the **Singer Military Products Division.**

Named the Standing Wave Area Motion Indicator (SWAMI), the device is small enough to fit into an attache case and is virtually impossible to confound with countermeasures.

The SWAMI sensor is a sealed vacuum tube envelope containing an ultra-high-frequency radio oscillator pulsed at a low-frequency repetition rate. This apparatus is shock-resistant, and its service life will compare favorably with that of vacuum tubes used conservatively in more conventional applications.

Any motion in or intrusion into the area under surveillance induces a change in the low-frequency repetition rate which, in turn, is detected by an FM detector. The detector transmits this intelligence to the monitor in a central control station in the form of voltage fluctuation of high amplitude, touching off the alarm.

Any attempt to tamper with the connecting cable leading from sensor to monitor will actuate the alarm.

Power source for the sensor may be either an ordinary household 115-volt outlet or a battery with enough power to supply an ordinary household night light. Any type of battery, wet or dry cell, will serve.

A SWAMI unit has effective range from a few inches to several thousand feet and, operated without auxiliary equipment, is omnidirectional. However, the propagation angle may be reduced by installation of a reflector around the antenna. The practical lower limit for portable, highly mobile units, such as might be carried in the field by light infantry, is approximately 15 degrees.

Restriction of the propagation angle would be desirable, for example, if friendly activities were to be carried on within range of the SWAMI. The instrument would then be focused through a narrow angle covering only the area where a hostile movement is anticipated, but would be screened off in such a way that it would not respond to intentional activities elsewhere within the normally effective range of operation.

Relative speed of a target can be determined with a single SWAMI unit, and, if the instrument is positioned to focus directly along the line of motion, it will determine the absolute speed. A unit could be beamed directly along a straight stretch of highway so that traffic is moving directly toward or away from the instrument, and a count of the half wavelengths read as a calibration of absolute speed.

Units positioned within range of one another will act in a complementary way to reinforce the amplitude of each.

In line with a sustained effort to diversify its product line in the military field, Singer-Bridgeport several months ago entered into an agreement with the **Product Development Corporation,** of Boston, an organization which specializes in helping private concerns find new products it can manufacture and sell profitably. Singer-Bridgeport said its acquisition of the right to SWAMI were directly attributable to operations of PDC.

Circle No. 245 on Subscriber Service Card.

New 5000° R&D Furnace Available

A resistance furnace for laboratory use, which operates to 5000°F and costs only 1/3 the amount of comparable furnaces, is available for immediate delivery from the **Curtiss-Wright Corporation.**

The furnace uses an inert gas for interior atmosphere with a graphite heating element and carbon insulation. It can be readily modified for special use for materials testing or processing studies.

The standard Curtiss-Wright unit has a heating chamber 4" in diameter by 8" high. The size of the chamber can be varied to meet specific requirements. Large production units have been designed for special processing needs. A hearth lowers out of the heating chamber for easy access to the interior of the unit. Two sighting tubes, at top and side of the furnace, allow sighting for temperature readings and automatic control purposes.

Outside dimensions have been held to a minimum and are only 12" diameter x 24" high.

The furnace is available with or without automatic temperature controls. However, power supply, gas control valves, pyrometers and necessary fittings for cooling are included so that the furnace is a self-contained unit. Power input is 15 kilowatts, at a temperature of 4500°F. With standard power supply, a maximum temperature of 5100°F is attainable.

Circle No. 246 on Subscriber Service Card.

Advanced Design Aids Electrical Connectors

New single-conductor plugs and receptacles called Supercon electrical connectors are now available in 50 and 100 ampere ratings for use in portable or stationary power and distribution panels.

According to the manufacturer, **Superior Electric Co.,** Supercons incorporate the first major design changes in this type of connector in many years—a functional positive-grip plug design; simplified, quick assembly; a wide range of colors.

All current carrying parts are of brass, gold-plated for stable electrical

Save Design/Engineering Costs!

USE STOCK UAP

COLD PLATES

FOR COOLING

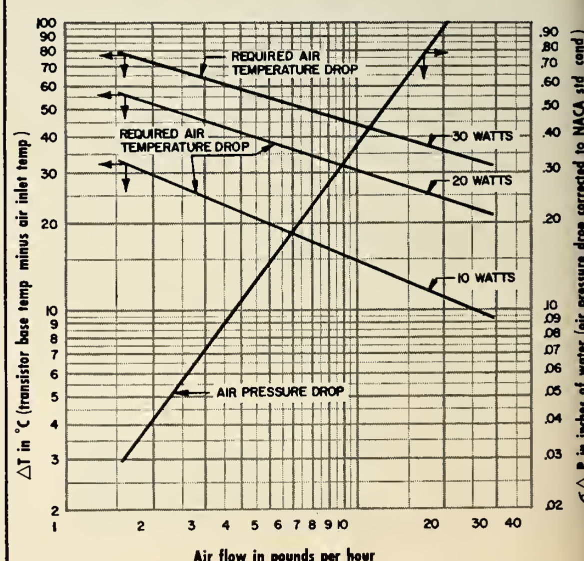
TRANSISTORS/DIODES

JEDEC* Nos. Transistors TO-3; TO-6; TO-10; TO-13; TO-14; TO-15; TO-26; TO-31; Diodes DO-4; DO-5.
**Joint Electronic Device Engineering Council*

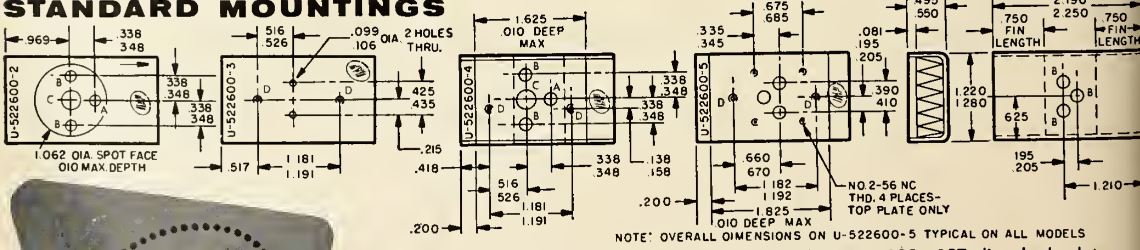
Now, you can use *stock* UAP aluminum cold plates to control heat generated by power transistors and diodes used in electronic circuits. Heat is transferred by conduction through the mount to cooling air forced through the cold plate. Cooling air can be ducted from any suitable source.

Adaptability of this cold plate to specific cooling requirements can be easily determined. The maximum allowable transistor or diode base temperature and dissipation must be known or calculated. Then, using any one of the three parameters on the curve, the remaining conditions are indicated. Example: Using a transistor base temperature of 71°C at a dissipation of 20 Watts, and assuming air inlet temperature of 36°C, gives a △ T of 35°C, an air flow of 6.4 lbs./hr., with .20 inches of water pressure drop.

Overall envelope dimensions are 2.250″ length, 1.280″ width, .550″ depth. Weight, approximately 1 oz. Finish, alodine. For complete information on prices and delivery, call, wire or write direct to UAP.



STANDARD MOUNTINGS



NOTE: OVERALL DIMENSIONS ON U-522600-5 TYPICAL ON ALL MODELS

Hole "A" .185—.197 dia., top plate only; Hole "B" .185—.197 dia., both plates;
Hole "C" .279—.291 dia., both plates; Hole "D" 5—40NC thds., top plate only.

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contact and resistance to corrosion. Plastic parts are molded of durable nylon for high dielectric strength and excellent resistance to corrosive chemicals, oil and grease, abrasion and impact, chipping and cracking.

Both plugs and receptacles are available in red, white, blue, black, yellow and green. For maximum flexibility, plug wiring can be either by soldering or by fastening with two cable fastening screws. Socket plug grips are of a simple, two-piece threaded construction for quick assembly. Pin plugs are assembled by a single nut after cable connection.

Receptacles have color-matching caps and bodies to permit more rapid and accurate circuit identification in front and back of panel.

Circle No. 247 on Subscriber Service Card.

'One-Way' Mercury Switch Now Available

A new type of mercury switch has been announced by **American Designed Components, Inc.** Because of its novel construction, the Type UZW switch controls mercury flow in such a way that a momentary wipe contact is produced when tilted 10 degrees or more in one direction, with no contact upon return to original position.

Using this basic orifice principle and inserting additional electrodes permits the company to offer a variety of circuit arrangements. For example, two wipe contacts and two make/break contacts may be incorporated into a single switch.

A standard-size switch measures less than 2¾" in length, less than ½" in diameter. It is capable of carrying 5 amp at 115 v, with inrush overloads of up to 10 amp. Even smaller sizes and tilt angles are available to suit specific requirements. The switch is unusually low in cost for this type of circuit arrangement; average list price is $2.

AM-DE-CO mercury switches offer several unique advantages. By using a special hard glass and solidly fused-in ceramic spark shields, operating capacities of up to 100 amp and inrush overloads to 500 amp may be handled, at temperatures up to 250°F. Being hermetically sealed, these switches offer positive precision control for many types of equipment.

Typical examples are paint sprayers, washing machines, waste disposal units, oil burners, pumps and compressors, textile machinery, welding apparatus, motors and generators.

Circle No. 248 on Subscriber Service Card.

Potentiometer Uses Carpenter's Level Bubble

Hamlin, Inc. announces the introduction of a new EP 1012, Gravity Sensing Electrolytic Potentiometer which provides operation dependent upon the motion of an air bubble in a curved glass tube, similar to that found in a carpenter's level.

Three electrodes are sealed in a curved glass tube which is partially filled with an electrolytic solution. Electrodes are arranged so that when unit is in a horizontal position, the resistance from the two operational electrodes to the common electrode is equal. When unit is tilted, air bubble moves, causing resistance to increase on one operational electrode and decrease on the other.

If the EP 1012 is used as one-half of a bridge circuit in a 1000 Ohm bridge, with 12v applied, zero output results at the horizontal position. Tilting the unit ¼°, 4v of output results and at ½°, 8v. Designed to give an error signal with a small amount of deviation from the horizontal, unit reaches saturation at approximately ¾°.

Circle No. 249 on Subscriber Service Card.

Hydraulic Actuators Have Support Applications

A new line of rotary power hydraulic actuators has been introduced by **Vard, Inc.,** a subsidiary of **Royal Industries, Inc.,** Pasadena, Calif.

The actuators have an unusually high torque/inertia ratio and are designed especially for critical ground applications. They provide power for rotary vibration testing, angular load testing and high-powered angular positioning in flight simulation tables and missile exercise launching and handling equipment.

Model 30-87-120 is in depth 8" x 8½" wide and has a dry weight of 36 lbs. Its stall torque at 3000 psi in 8700 in-lb. and its internal leakage is .20 gpm. There is no internal snubbing in this model and its frequency response is rated at 0-200 cps.

The stall torque of Model 30-100-90S is 10,000 in-lb. at 3000 psi. This model, 7¾" x 8⅝" with a dry weight of 50 lbs., has 15-degree internal snubbing, .25 gpm internal leakage and a frequency response of 0-200 cps.

Last in this new series is Model 30-190-120, 10 3/8" x 10", with a dry weight of 80 lbs. Its stall torque at 3000 psi is 19,000 in.-lb. with no internal subbing.

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- ✓ **Liquid Fluorine**
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"Nitric Acid, Fuming"—29 pages—Including detailed product description of both red and white fuming nitric acid, chemical and physical properties, corrosion data, directions for storage and handling.

"Fluorine"—21 pages—Including extensive data on the chemical and physical properties of this most powerful oxidizing agent, a description of materials and equipment for handling gaseous and liquid fluorine, safety precautions.

"Chlorine Trifluoride"—35 pages—Including the chemical and physical properties of chlorine trifluoride and other halogen fluorides, recommended materials for use in halogen fluoride systems, directions for safe handling.

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- ☐ "Fluorine" (PD-TA-85413)
- ☐ "Handling Elemental Fluorine Gas In The Laboratory" (PD-TA-85413A)
- ☐ "Liquid Fluorine Unloading Procedure" (PD-TB-85411)
- ☐ "Chlorine Trifluoride" (TA-8532-2)
- ☐ "Chlorine Trifluoride Vapor Pressures" (DA-85321)

Name________________________

Title________________________

Company________________________

Address________________________

City__________Zone____State______

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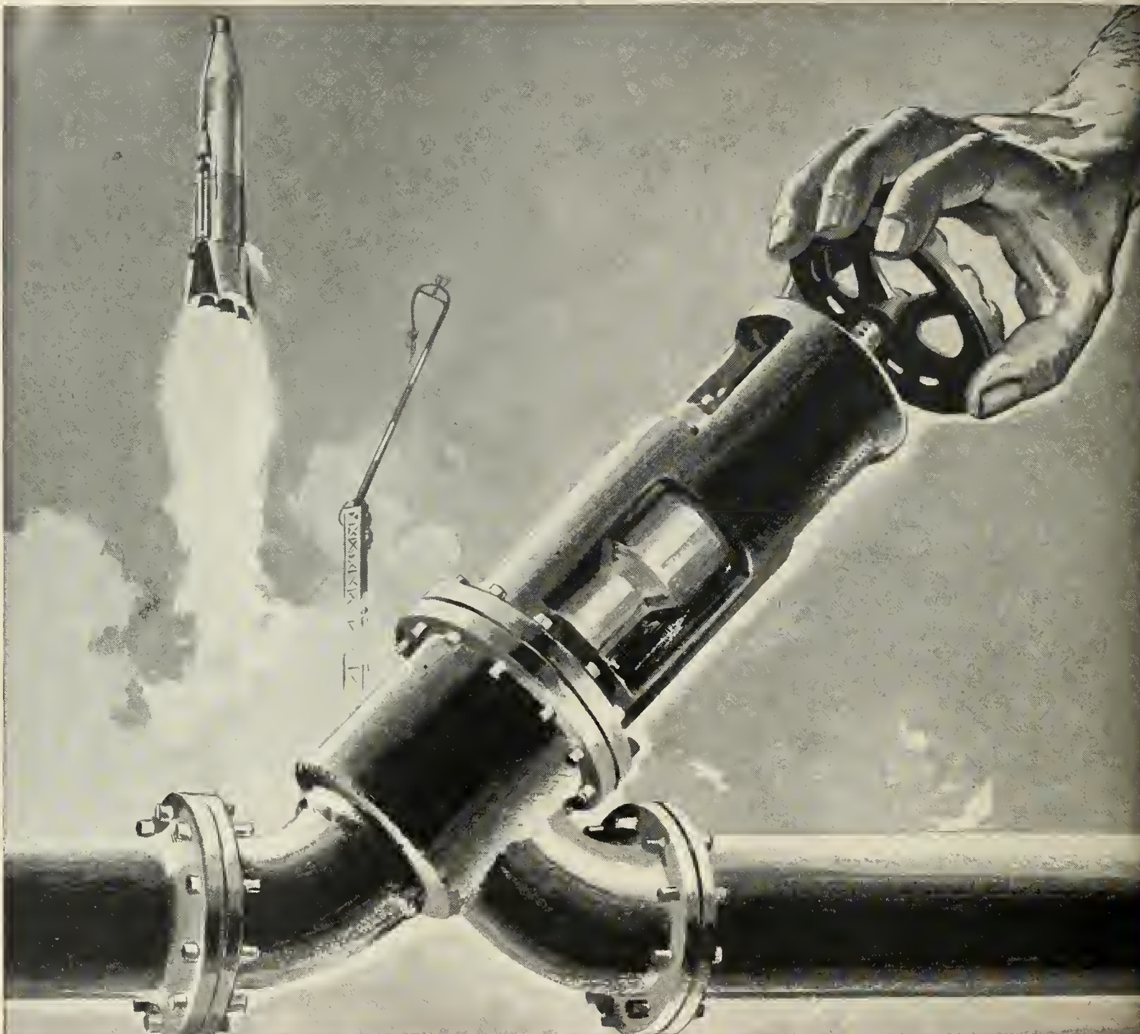

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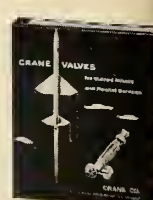

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contracts

ARMY

$7,309,594—Hughes Aircraft Company, Fullerton, Calif., for 12 months' development work to improve the Missile Monitor antiaircraft defense system.

$1,937,078—The Martin Company, Orlando, Fla., for fire intergration equipment in conjunction with the Missile Master system.

$1,002,477—Minneapolis-Honeywell Regulator Co., Hopkins, Minn., for a classified project.

Dynatronics, Inc., Orlando, Fla., has received a "more than a quarter of a million"-dollar contract for research, development and production of a complex camera timing system to be used on the Atlantic Missile Range.

$600,000—Avion Div., ACF Industries, Inc., Paramus, N.J., for production of radar beacons (subcontract from **Radio Receptor** Co.).

$59,800—Strand Engineering Co., Ann Arbor, Mich., for data recorder.

NAVY

$6,000,000—The Martin Co., Orlando, Fla., for production of *Bullpup* air-to-surface missiles for the Air Force.

$539,100—Dale Benz, Inc., San Diego, for construction of *Nike-Zeus* test facilities, Point Mugu, Calif.

$392,499—Atlantic Research Corp., Alexandria, Va., for research to design a rocketsonde system.

$385,295—Minneapolis-Honeywell Regulator Co., Minneapolis, for 160 altitude control kits for M-1 autopilots.

$144,086—General Mills, Inc., Minneapolis, for research on defense against ballistic missiles.

$136,532—Technical Operations, Inc., Burlington, Mass., for research on defense against ballistic missiles.

$129,750—Consolidated Systems Corp., Monrovia, Calif., for telemetry data processing system.

$100,761—Industrial Research Associates, Inc., Baltimore, for research on defense against ballistic missiles.

$97,191—Fairchild Engine & Airplane Corp., Alexandria, Va., for engineering services, facilities and materials necessary to conduct studies of the Pacific Missile Range.

$93,895—Chance Vought Aircraft Inc., Dallas, for study of Roosevelt Roads Guided Missile Training Range.

$80,000—University of Michigan, Ann Arbor, for research on hypersonic flow with dissociation and ionization.

AIR FORCE

Radiation, Inc., Florida Division, has received a "multi-million" dollar contract for an advanced digital telemetering system for the *Minuteman* missile program (subcontract from Boeing Airplane Co.).

[illegible],667,000—Ryan Aeronautical Co., San Diego, for production of the advanced version of the *Firebee* target missile.

8,000,000—Airborne Instruments Laboratory, Div. of Cutler-Hammer, Inc., for 20 pieces of equipment designed to eliminate unwanted interference on radar screens used in the SAGE air defense system.

$6,500,000—Vitro Laboratories, Div. of Vitro Corp. of America, N.Y., for operation and maintenance of the Eglin Gulf Test Range for the Air Proving Ground Center.

$5,000,000—Hoffman Laboratories Div., Hoffman Electronics Corp., Los Angeles, for production of specialized test equipment to be used with TACAN.

$1,017,028—Del Mar Engineering Laboratories, Inc., Los Angeles, for target system, external tow, rocket and missile, type A/A 37U-2, 66 each, technical and engineering data and related spare parts.

$209,000—RCA, Moorestown, N.J., for one real time data handling system and ancillary equipment and data.

$102,540—Continental Electric Co., Geneva, Ill., for various electron tubes (two contracts).

$84,000—Eitel-McCullough, Inc., San Carlos, Calif., for various electron tubes.

$71,250—Sylvania Electric Products, Inc., N.Y., for various electron tubes.

$58,000—University of California, Berkeley, for research on "tolerance and adaptability of the brain to environment imposed by space flight."

NASA

Hercules Powder Co., Philadelphia, has received a contract to supply fuel and plastic case for the third and fourth stages of Project *Scout* rocket (amount not disclosed).

MISCELLANEOUS

$2,250,000—Federal Pacific Electric Co., New York City, for 5 kv metal-clad switchgear, control consoles and low-voltage controls for diesel generating units for missile launching and tracking facilities.

$642,986—Microwave Associates, Inc., Burlington, Mass., contracts include one from the Navy for study and development in the field of Varactor diodes and parametric amplifiers, and two from the Air Force for design and development of a parametric amplifier for radio-astronomy use and microwave switching tubes.

$250,000—Hallamore Electronics, Division of The Siegler Corp., Los Angeles, for design and production of a complex radio frequency signal generator for use in an advanced air-to-air missile (subcontract from Hughes Aircraft Co.).

propulsion engineering

Missile applications of flame-plating . . .

are spelled out for M/R by H. V. Mosby, new products department, **Linde Company** division of **Union Carbide Corp.** (See this column, March 30.) Among the propulsion applications, Mosby suggests combustion chamber plating, pump seal coatings, valve coatings, fuel injector rings. Here are details on these "Plasmarc" applications:

Liquid-fuel combustion chamber . . .

can be plated internally with tungsten carbide or other metallic carbides to reduce erosion and oxidation, improve performance and reliability. The plasma arc process can apply aluminum oxide coatings to high-performance engines to cut down overheating and reduce problems caused by corrosive fuels.

Turbine pump shaft seals . . .

plated with tungsten carbide can operate at high rpm in hot gas environments. Mosby says parts flame-plated with tungsten carbide operate up to five times longer than chrome-plated parts.

Valves . . .

plated with aluminum oxide show considerable improvement in controlling hot gas flow.

Fuel injector rings . . .

can be flame-plated with tungsten carbide to eliminate localized hot spots that develop during ignition and cut-off. Without plating, fuel injector rings often are scarfed by impingement of oxygen or fuel mixtures rich in oxygen.

Tungsten carbide and aluminum oxide . . .

are only two of the coatings that can be applied by the flame-plating process. Actually, Mosby says, coatings can be made from almost any material that does not decompose on melting. Some materials available now include tantalum, molybdenum, palladium, platinum, rhenium, zirconium diboride. Also, some of these combinations can be flame-plated: tungsten alloyed with chromium, molybdenum, rhenium; tungsten blended with zirconia, alumina and other metal oxides. Linde Company says its scientists are making rapid progress on many other types of high-temperature coatings.

Plasma arc coating . . .

works this way: Oxygen and acetylene are fed into a special "gun." Powdered particles of the desired coating are then fed in and suspended in the mixture. Following ignition, detonation takes place, the detonation wave carries the particles at 10 Mach through the gun barrel to the surface to be plated. At the same time, the detonation heats the particles to plasticity. When they hit the surface to be plated, the particles embed themselves in the surface, and a small welding action takes place at the site.

Temperatures are reasonable . . .

although temperatures inside the equipment or "gun barrel" reach 6000°F, the surface temperatures seldom exceed 400°F. This means that the material to be coated gets hot enough to do the job—to embed and adhere—but the surface under treatment does not get hot enough to warp or to change its properties. Linde says this about finishes produced by the technique: "Flame-plated coatings have an as-coated smoothness of 125 microinches rms, and can be finished down to better than one microinch rms." Coatings have a porosity of less than 1%.

Tools for the industry . . .

will be made better, also thanks to the plasma arc technique. Tools can be made temperature-resistant, harder, corrosion-resistant with flame-plated coatings. Examples: Spindles, bushings, gages, mandrels, dies, and core rods.

Praise for Reporting

To the Editor:

In your June 22 issue, the article "Prospects for Thermoelectricity" by Hal Gettings is of extreme interest to my department here at **Westinghouse, Aircraft Equipment Department,** Lima, Ohio. I would like to reproduce this article for the education of our Sales and Engineering personnel.

Incidentally, in my personal opinion the article is more comprehensive than any I have read to date on this subject. Please accept by sincere congratulations on a fine piece of reporting.

Stan McNair
Advanced Systems Application
Department, AED Sales
Westinghouse Electric Corp.
Lima, Ohio

Units—Another Viewpoint

To the Editor:

There seems to be much concern about the use of units in astronautics (M/R, April 27, p. 21). This is of course not a new situation—it has indeed been with us in physics, chemistry and technique for a long time.

Basically, there are two ways to develop a system of units:

1. The "naive" way—you just want to give factual information regarding velocity, time, place, etc.

Here any accepted and well-defined unit is sufficient. The metric systems are in this class—the use of nonmetric systems should be recommended, because their definitions are often unprecise (knot, foot, etc.)

Furthermore, convenience is the only other criterion—avoid all philosophy. So we demand such simple conversion factors as one, or powers of ten. The metric system again is clearly superior to the nonmetric systems.

2. The "theoretical" way—the number shall give ready information about the nature of the measured phenomenon. Mach number is an outstanding example.

In astronautics the analogue to the velocity of sound seems to be the parabolic speed. As this is a strong function of distance, and ill-defined in practical multi-body problems, its scientific meaning is not very pronounced. Therefore, besides the statement that a certain velocity is clearly hyperbolic, etc., no system of units should be built around parabolic velocity.

Reference to the speed of light is not to be recommended at all because of the uncertainity of the unit. "Einstein-Numbers" can be defined in various ways, but are obviously of little concern today. If one wants to use them, clear definitions as to coordinate system and way of measurement are mandatory. Summarizing, it is my feeling that in this fundamentally less-precise Class Two we do not need more than the elliptic, etc., velocity, or for very advanced work some kind of well defined Einstein number.

Sometimes of course the nature of the phenomenon being considered forces us to use a special set of units, because the knowledge is better in this set than in any other. A good example is the distance-measure "Astronomical unit" within the solar system: This of course disguises only lack of knowledge, because whenever this situation arises, the unit itself is not well known. Still it may be practical to use the "natural units" (Astronomical Unit, year, etc.), but then again there is no speculation about the "best system of units." This question has meaning only for one particular problem, eg. motion is the solar system.

There is only one basic weakness of the metric system of units—the units of time are nonmetric. As it seems to be extremely difficult to change this because of its world-wide use, there appears to be no room for a better system. Just another system will only add to the confusion without improving the situation.

Difficulties arising from units of mass and force, and some others in the electromagnetic field, have their source partly in inconvenient names, and partly in lack of training or understanding.

"To get small numbers by convenient units" is of course a fallacy, as meaningless digits can always be expressed as an exponent of a convenient base, usually

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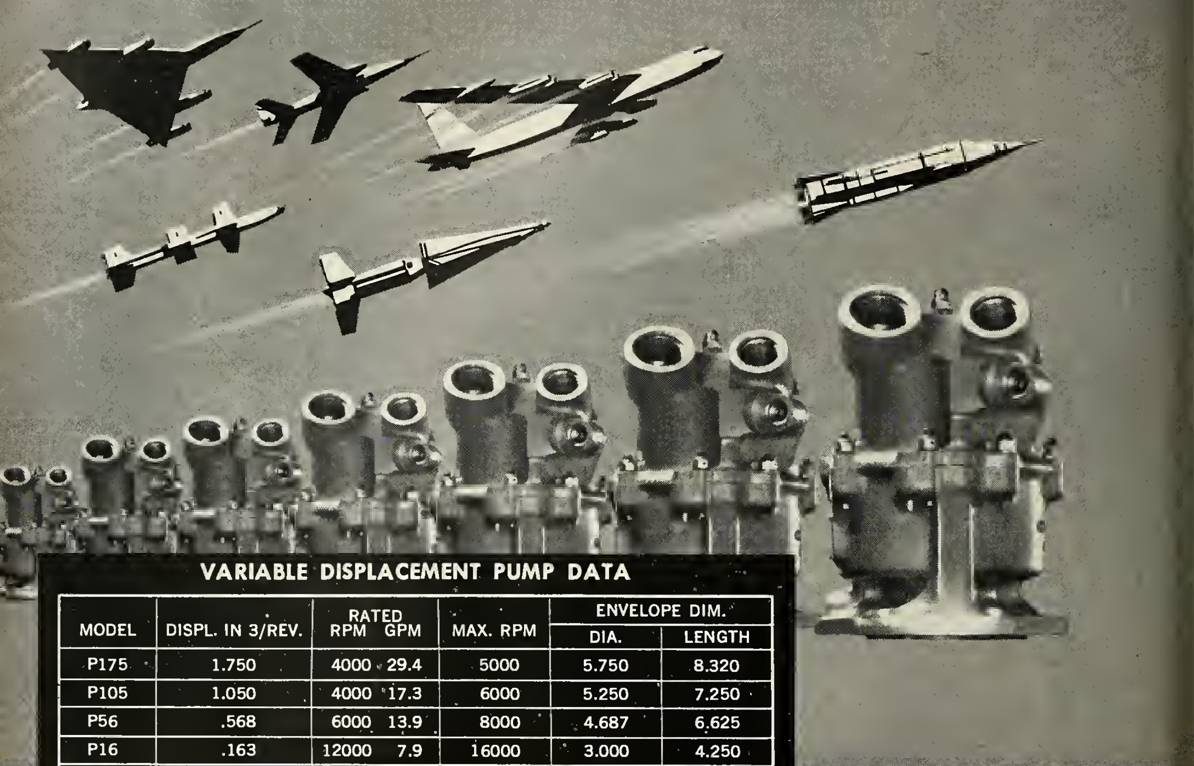

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P16	.163	12000	7.9	16000	3.000	4.250
P11	.115	12000	5.5	16000	2.750	3.625
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ten, and the meaningful digits have only to do with the accuracy of the information, and not with the unit.

Harry C. Ruppe
Lunar and Interplanetary
Flight Unit, S & M Lab
ABMA
Redstone Arsenal, Ala.

Inverted Silo Data

To the Editor:

Can you refer us to a source of information regarding the inverted launching silo mentioned in your May 4 editorial? We would like to know whom to contact regarding the requirements of construction.

A. P. Brietzke
Professional Engineer
Northern Engraving & Mfg. Co.
La Crosse, Wis.

Air Force Ballistic Missile Div., Los Angeles 45, Calif., and the Los Angeles District Corps of Engineers . . . Ed.

Operation Skycatch

To the Editor:

We were quite pleased with the fine treatment you gave us on the index page of your May 18 issue on our "Operation Skycatch" concerning the *Polaris* launching system.

I did want to point out one small error in the caption, however, in case any of your sharp-eyed readers should pick it up. In the last sentence of the caption, you indicated that **Westinghouse** was the prime contractor under **Lockheed** for the launching system. Actually, Westinghouse is prime contractor under the Navy for the development of the launching system for the *Polaris*.

R. V. McGahey,
Manager
Technical Publicity
Westinghouse Electric Corp.
Pittsburgh, Pa.

Facing the Facts

To the Editor:

I should like to express my appreciation of what may be called the "boldness" of information given through M/R. Information concerning the rocket field offered by our daily newspapers seems to be a playing ground and training ground for little would-be Joe Goebbelses particularly ambitious to ignore dangerous performances of the people behind the Iron Curtain. M/R, however, gives the impression that your people keep their eyes open and that there are men to strain their brains and financial resources in order to keep and come abreast and to overtake THEM.

E. Jaeger, ing. diplômé
6 Hettlerstrasse
Weiningen ZH
Switzerland

Objection Overruled

To the Editor:

In the news item concerning the scientists' protest against secrecy (June 22, p. 39), M/R used the phrase "consensus of opinion." This is incorrect English; correct usage is "consensus of 17 Nobel . . .," or "opinion of 17 Nobel . . ."

E. St. Thomas
Patrick AFB, Fla.

Webster says "consensus of opinion," while still objectionable to some, is now generally considered to be correct usage.

RECYCLING REFERENCE

To the Editor:

Your article on space feeding (June 15) seemed to strike a chord but it has taken me some time to track down the quotation. With reference to the paragraph commencing "Water Recovery" I would suggest you read . . . II Kings, Chap. 18, Verse 27 . . .

F. H. Smith
Librarian
The Royal Aeronautical Society
London

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Circle No. 84 on Subscriber Service Card.

New Contracts to Push Thermoelectric Research

WASHINGTON—Contracts totalling over $1 million for continuing research work in thermoelectricity were awarded during the last quarter of FY '59 by Navy Bureau of Ships, coordinator for the armed services program in this field.

About half this amount is for two five-kilowatt generators. The balance is for development of new semiconductor materials and high-temperature research. A number of additional contracts are expected to be awarded this month after the beginning of FY '60.

New contracts listed include the following:

- Naval Engineering Experiment Station, Annapolis—$25,000/year
- Naval Boiler and Turbine Laboratory—$50,000/year
- **RCA** (Laboratories Division, Princeton)—$147,000
- RCA (Sarnoff Research Center)—$77,000
- **National Carbon Company**—$240,000
- University of Pittsburgh—$17,000
- **Carrier Corporation**—$194,000
- **Westinghouse Electric**—$342,475

Earlier efforts in this field, under the supervision of BuShips, have already produced significant results (M/R, 22 June). Most of these efforts have been in the so-called Areas B and C—the temperature range below 1500°K. For useful applications in missile and satellite auxiliary power, however, which require radiation cooling of the cold junction, this range must be extended up to the 2000°K mark. At higher temperatures the common semiconductors used in the successful work to date cannot be used: they melt, become bipolar-conductive, or oxidize. Thus, progress apparently depends upon finding new and better materials.

As mentioned, the highest temperature requirements are in the radiation-cooled systems. Here, fortunately, power per pound is more important than efficiency and very low thermal conductivity is not desirable. According to calculations, a space vehicle generator operating at an acceptable two percent efficiency could deliver a 10-amp current and would weigh somewhere between 45 and 208 pounds per kilowatt.

Considerable work is also being done on the reverse of thermoelectric power generation: Peltier cooling. Applications have already been made in infrared detector cooling and a wide field of electronic temperature control is being explored.

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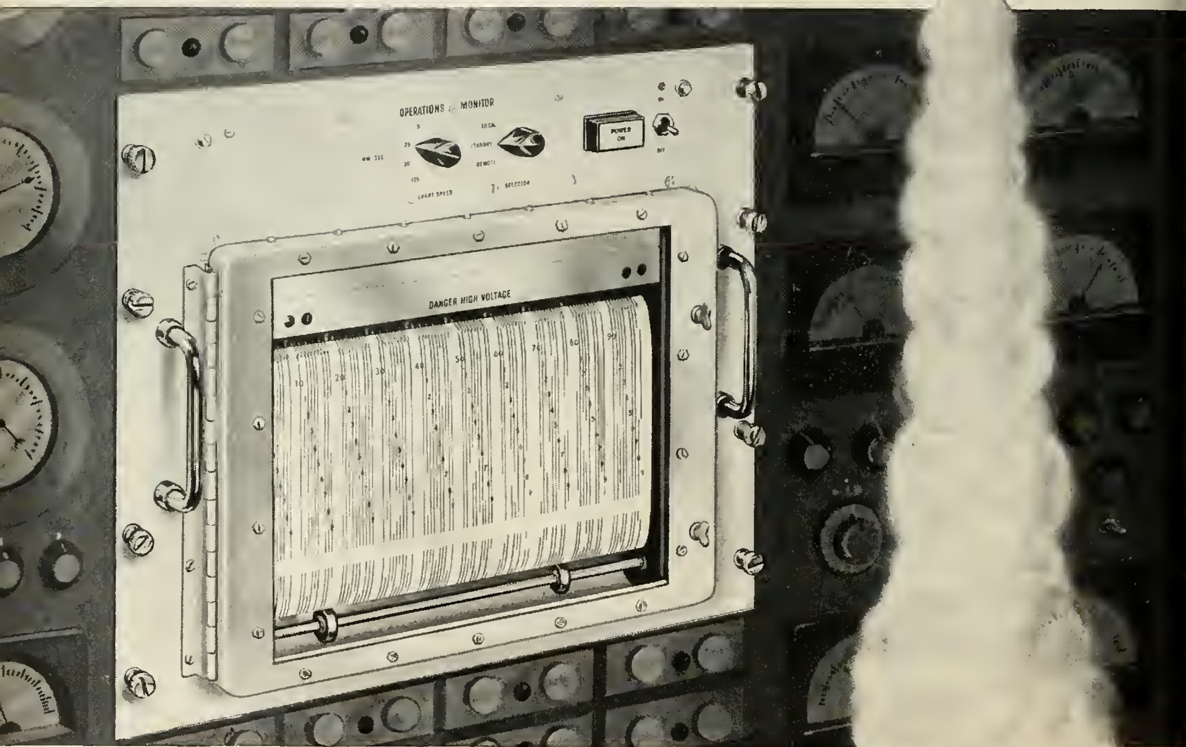

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JULY

The American Rocket Society, Propellants and Combustion Committee, "Propellants, Thermodynamics and Handling Conference," Ohio Union, Ohio State University, Columbus, July 20-21.

Second Annual Institute on Missile Technology, Chief of Research and Development, U.S. Army, University of Connecticut, Storrs, July 26-Aug. 7.

The Denver Research Institute of the University of Denver, 6th Annual Symposium on Computers and Data Processing, Stanley Hotel, Estes Park, Colo., July 30-31.

AUGUST

nstitution of Investigation of Biological Sciences, sponsored by Air Force Office of Scientific Research-Aeromedical Div., and World Health Organization. Montevideo, Aug. 2-7.

ssociation of the U.S. Army, Annual Meeting, Sheraton Park Hotel, Washington, D.C., Aug. 3-5.

merican Astronautical Society, Second Annual Western Regional Meeting. Ambassador Hotel, Los Angeles, Aug. 4-5.

Villiam Frederick Durand Centennial Conference, The Problems of Hypersonic and Space Flight, Stanford University, Stanford, Calif., Aug. 5-7.

ircraft Structural Fatigue Symposium, sponsored by ARDC'S Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio, Aug. 11-13.

nstitute of Radio Engineers' Professional Group on Ultrasonic Engineering, First National Ultrasonics Symposium, Stanford University, Stanford, Calif., Aug. 17.

nstitute of Radio Engineers, Western Electronic Show and Convention, Cow Palace, San Francisco, Aug. 18-21.

FOSR/Propulsion Research Division, Directorate of Aeronautical Sciences Office of Naval Research, Office of Ordnance Research & National Aeronautics and Space Administration, Symposium on "The Dynamics of Ionized Cases," Northwestern University, Evanston, Ill., Aug. 24-25.

merican Rocket Society, Gas Dynamics Symposium, Northwestern University, Evanston, Ill., Aug. 24-26.

nstitute of the Aeronautical Sciences' National Specialists Meeting, A Symposium on Anti-Submarine Warfare (classified), San Diego, Aug. 24-26.

nternational Astronautical Federation, 10th Annual Congress, Church House, Westminster, London, Aug. 31-Sept. 5.

rmy-Navy Instrumentation Program, Annual Meeting, Symposium and Industry Briefing, Statler Hilton Hotel, Dallas, Aug. 31-Sept. 2.

SEPTEMBER

ir Force Office of Scientific Research and General Electric Company's Missile and Space Vehicle Department, Conference on Physical Chemistry in Aerodynamics and Space Flight, University of Pennsylvania, Philadelphia, Sept. 1-2.

niversity of California, 1959 Cryogenic Engineering Conference, Berkeley, Calif., Sept. 2-4.

ir Force Association and Panorama: send reservations to AFA Housing Bureau, P. O. Box 1511, Miami Beach. Sept. 3-6.

FOSR/Directorate of Aeronautical Sciences, Office of Naval Research, National Science Foundation, Sixth Midwestern Conference on Fluid and Solid Mechanics, University of Texas, Austin, Sept. 9-11.

nstitute of the Aeronautical Sciences, Western Regional Meeting on Frontiers on Science and Engineering, Los Angeles, Sept. 16-17.

tandards Engineering Society, Boston Section Eighth Annual Meeting, Hotel Somerset, Boston, Sept. 21-22.

nstrument Society of America, Conference, and Exhibit, Chicago, Sept. 21-25.

ndustrial Nuclear Technology Conference, sponsored by Armour Research Foundation of Illinois Institute of Technology, Nucleonics Magazine and Atomic Energy Commission, Morrison Hotel, Chicago, Sept. 22-24.

nstitute of Radio Engineers, 1959 National Symposium on Telemetering, Civil Auditorium, San Francisco, Sept. 28-30.

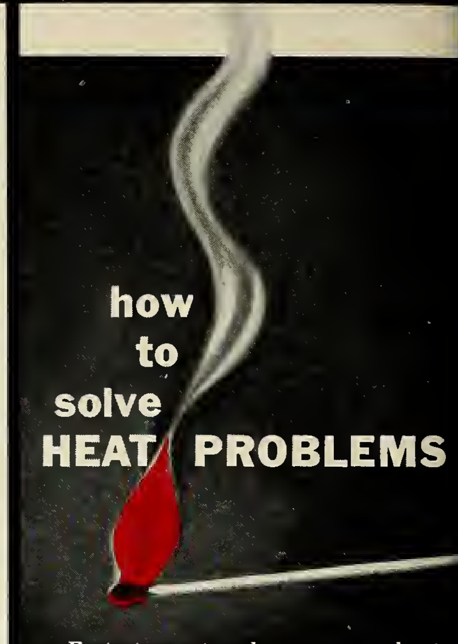
FIREBEE···THE HIT OF PROJECT WILLIAM TELL

"I'll never want to fire at towed targets again!"

That's the typical reaction of Air Force interceptor pilots after they fired at Ryan Firebee jet targets during the recent "Project William Tell" Weapons Meet.

78 Firebees, launched off the Florida coast, brought combat realism to the 10-day meet. Acting as "enemy" jet bombers, the free-flying Firebees streaked in at over 500 mph, from 14,000 to 42,000 feet, and flew an average of 31 minutes each.

Air Force pilots and weapons systems crews met this realistic test with the most impressive teamwork and skill ever displayed at a weapons meet.



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Ryan hot parts are giving outstanding service in turbo-jets, afterburners, prop-jets, ramjets, rockets, and piston engines. That's why Ryan has the answers to high-temperature problems—from hot parts to complete engine packages.

Six major types of Navy aircraft will be equipped with Ryan continuous-wave Doppler navigation systems under an initial $20-million contract awarded by the Navy to Ryan's Electronics Division.

Developed in cooperation with the Navy, these advanced electronic systems are the lightest, simplest, most compact, most reliable of their type.

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Ryan Aeronautical Company, San Diego, Calif.

Third Annual

GUIDED MISSILE ENCYCLOPEDIA

1959

An Exclusive Weapon System Roundup for Industry

Compiled and Written by

MISSILES & ROCKETS' Editors

Directed by James J. Haggerty, Jr., M/R Contributing Editor

Some of the specifications and performance figures given for the missiles and rockets in this encyclopedia have been calculated and have not necessarily been officially confirmed.

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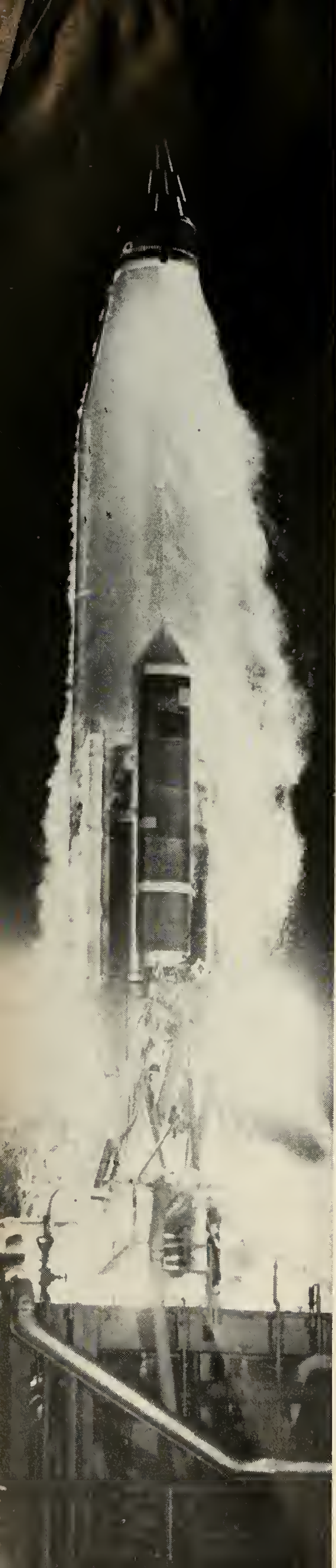
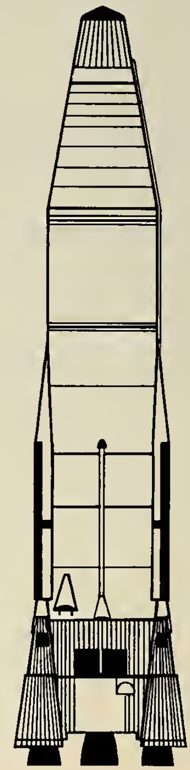


ATLAS *U.S. AIR FORCE Surface-to-Surface*

The first United States intercontinental ballistic missile, *Atlas* is going through the final stages of its development and is rated by the Air Force as having "initial operational capability." Missiles are being delivered to the first operational user, the 576th Strategic Missile Squadron at Vandenberg Air Force Base, Calif.

Also known as *WS-107* and *SM-65*, *Atlas* has been fired about 30 times since its first flight in June, 1957, with varying degrees of success. A full-range flight of more than 6300 statute miles was made in November, 1958. The following month, an *Atlas* was launched into orbit as part of the USAF's space research program.

Designed to impact a target more than 5500 nautical miles distant with an error of less than two-tenths of one per cent, *Atlas* is guided over approximately the first 10% of its flight. Three liquid-propelled rocket engines generate launch power. The two boosters drop away after about two minutes blast output and the missile continues on the power supplied by its lower thrust sustainer. Two verniers located on the lower portion of the body supply roll control and thrust adjustment throughout second-stage flight.



SPECIFICATIONS

DESIGNATION: SM-65 (WS-107A-1)
PRIME CONTRACTOR: Convair (Astronautics) Div. General Dynamics Corp.
STATUS: Development and initial operation
RANGE: 5500 nautical miles plus
VELOCITY: 17,000 mph

FRAME
- Stages: 2
- Manufacturer: Convair
- Length (Overall), ft: 81
- Diameter (Body), ft: 10
- Weight (Gross), lb: 260,000
- Material (Major): Steel

GUIDANCE
- Manufacturer: GE/Burroughs; Arma
- Type: Radar-Doppler Command (later models all-inertial)

POWERPLANTS
- First Stage (Booster)
  - Manufacturer: Rocketdyne
  - Propellants: Liquid oxygen and kerosene
  - Type & Number: Regenerative liquid (2)
  - Thrust, lb: 150,000 each
- Second Stage
  - Manufacturer: Rocketdyne
  - Propellants: Liquid oxygen and kerosene
  - Type & Number: Regenerative liquid (1)
  - Thrust, lb: 60,000

WARHEAD
- Type: Nuclear

GROUND SUPPORT MAJOR CONTRACTORS
- Launcher: Consolidated Western Steel; National Steel
- Fueling: AiResearch Mfg. Co; Reaction Motors
- Radar & Ground Control: Norden, A Div. of United Aircraft
- Handling & Services: Goodyear Aircraft
- Transport Vehicles: Goodyear Aircraft
- Checkout Equipment: Radio Corporation of America; Consolidated Systems Corporation; Minneapolis-Honeywell

*LAUNCHING of *Atlas 10B* sent into orbit on Dec. 18, 1958, largest U.S. satellite

TITAN *U.S. AIR FORCE Surface-to-Surface*

The second part of the USAF's *WS-107* intercontinental ballistic missile project, the *SM-68 Titan* made its first test flight on Feb. 6, 1959, at the Atlantic Missile Test Range and has had several tests since.

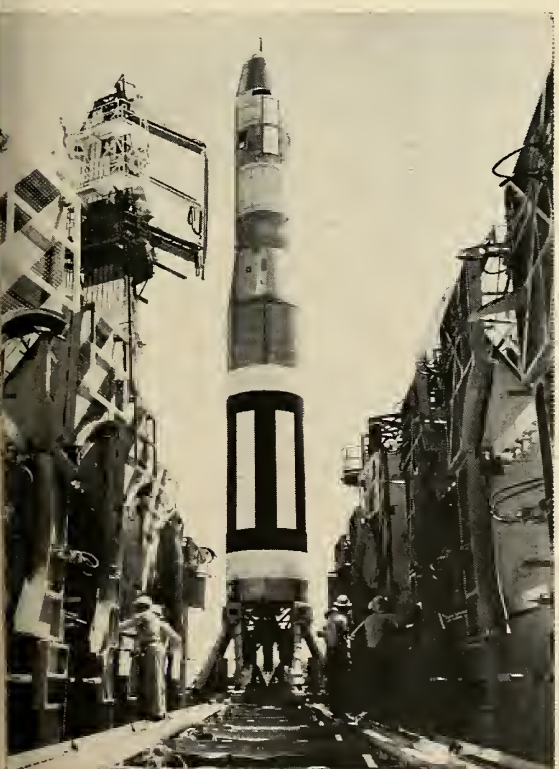
A complement, rather than a duplicate of *Atlas, Titan* employs a different flight technique than its companion ICBM. A two-stage missile, it is launched initially by a 300,000-pound-thrust booster. At burnout, the first stage separates from the remainder of the missile and a second liquid engine pushes the nuclear payload to high speed and altitude. The second stage also drops after burnout and the nose cone coasts the rest of the way in a free-fall path without power or guidance.

Titan, though larger than *Atlas,* is also lighter. It will be based in "hard sites," with underground silos providing protection from weather during storage period and from blast effect in combat. Initial contract of $384,000,000 was awarded Martin for design, fabrication and testing.

SPECIFICATIONS

DESIGNATION:	SM-68 (WS-107A-2)
PRIME CONTRACTOR:	Martin
STATUS:	Development
RANGE:	5500 nautical miles plus
VELOCITY:	15,000 mph
FRAME	
Stages:	2
Manufacturer:	Martin
Length (Overall), ft:	90
1st stage length, ft:	54
2nd stage length, ft:	37 (incl. nose cone)
Diameter, ft:	8
Weight (Gross), lbs:	220,000
Material (Major)	Aluminum
GUIDANCE	
Manufacturers:	Bell Telephone Laboratories Remington Rand UNIVAC
Type:	Initially, radio inertial; later, all inertial

POWERPLANTS	
First stage (booster)	
Manufacturer:	Aerojet-General
Propellants:	Liquid oxygen and JP-6
Thrust, lbs:	300,000
Second stage:	
Manufacturer:	Aerojet-General
Propellants:	Liquid oxygen and JP-6
Thrust, lbs:	80,000
WARHEAD	
Manufacturer:	AVCO
Type:	Nuclear
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Kaiser Steel, Baldwin-Lima-Hamilton, Space Corp.
Fueling:	Air Products
Radar and ground control:	Hallamore Electronics
Transport vehicles:	North American



READY for static testing, *Titan* is framed by its erector.

HURTLING spaceward, a *Titan* passes first test at the Cape.

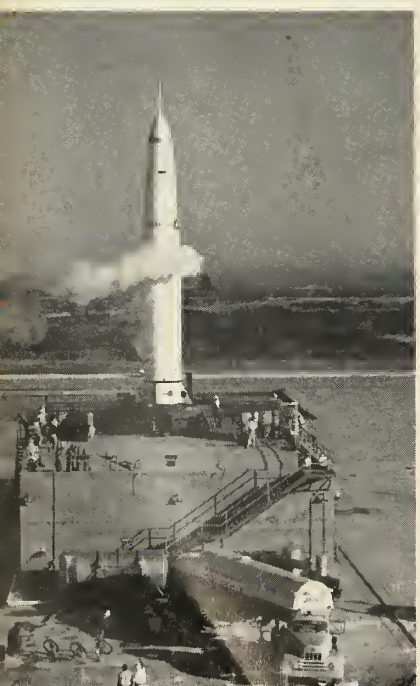
THOR *U.S. AIR FORCE Surface-to-Surface*

The first American intermediate range ballistic missile to achieve operational status, *Thor*, or *WS-315A*, was deployed to Europe in September, 1958, under an agreement whereby the United States furnished a number of the IRBM's to the United Kingdom.

Thor is a single-stage missile capable of being transported by air on a transporter-erector trailer which also serves as the missile erecting arm.

Thor has been used as the main propulsion system for several space experiments. It is the primary vehicle in the *Discoverer* program and was used to launch the lunar probe of Oct. 11, 1958.

Power is supplied by a Rocketdyne 150,000-plus-pounds-thrust engine which burns liquid oxygen and RP-1, a high-grade kerosene. Thrust adjustment and roll control are obtained by two vernier engines at the base of the missile; the sustainer is also provided with gimbaling action.

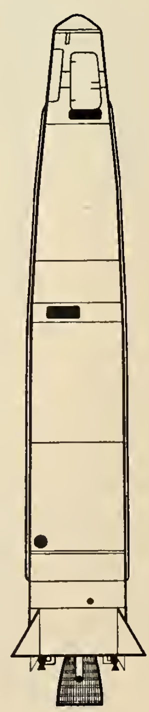


PREPARING for launch of versatile *Thor*.

TAKE-OFF with 150,000 lbs. thrust.

SPECIFICATIONS

DESIGNATION:	WS-315A (SM-75)
PRIME CONTRACTOR:	Douglas, Space Technology Laboratories
STATUS:	Production
RANGE:	1500 nautical miles
VELOCITY:	10,000 mph
FRAME	
Manufacturer:	Douglas
Length (overall), ft:	65
Diameter, ft:	8
Weight (gross), lbs:	110,000
Material (major):	Aluminum
GUIDANCE	
Manufacturer:	AC Spark Plug
Type:	Inertial
POWERPLANT	
Manufacturer:	Rocketdyne
Propellants:	Liquid oxygen and RP-1
Thrust, lbs:	150,000 plus
WARHEAD	
Type:	Nuclear
Nose cone:	General Electric
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Food Machinery
Fueling:	Air Prod., Cambridge Corp.
Handling and service:	Douglas, Food Machinery
Transport vehicles:	Food Machinery



SNARK *U.S. AIR FORCE* *Surface-to-Surface*

A complementary weapon to the ir Force's long range ballistic mis-les, the *SM-62 Snark* is an interconti-ental missile of the air-breathing va-ety, particularly useful in tactical pplications which call for low-altitude rget penetration. It is boosted by a air of solid rockets and sustained in ght by a turbojet engine.

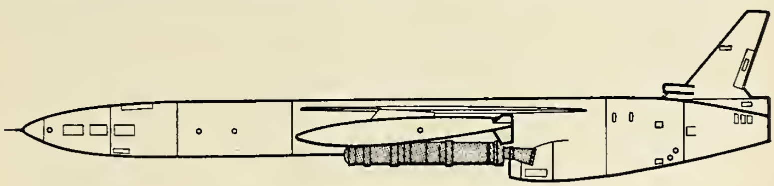
Similar in appearance to a jet ghter, *Snark* has slim fuselage lines ith a high aspect ratio wing mounted ear the top and slightly forward of e center of the fuselage.

For economy in test operations, the '-foot, 30-ton missile is fitted with re-actable gear to allow landing after st flight.

In the last year, *Snark* has been ed successfully 5000 miles down e Atlantic Missile Range. On one ght, it was fired 1300 miles and turned to land at the launching site. he first production model made a 00-mile test flight on April 7, 1959.

SPECIFICATIONS

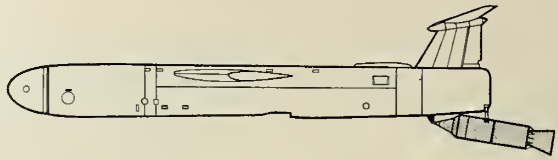
DESIGNATION:	SM-62	Propellants:	Solid
PRIME CONTRACTOR:	Norair	Type & Number:	Cast JATO (2)
STATUS:	Production, service use	Thrust, lb:	66,000 @ 33,000
RANGE:	5500 nautical miles	Sustainer	
VELOCITY:	Mach 0.9	Manufacturer:	Pratt & Whitney
FRAME		Propellants:	Liquid
Manufacturer:	Northrop	Type & Number:	J-57 turbojet (1)
Length (Overall), ft:	67.2	Thrust, lb:	11,000
Diameter (Body), ft:	4.5	WARHEAD	
Span, ft:	42	Type:	Nuclear
Weight (Gross), lb:	59,936	GROUND SUPPORT MAJOR CONTRACTORS	
Material (Major):	Aluminum, magnesium		
GUIDANCE		Launcher:	American Car & Foundry
Manufacturer:	Northrop	Fueling:	GFE
Type:	Inertial	Radar & Ground Control:	Hallamore Electronics, Radiophone Co.
POWERPLANTS		Handling & Service:	GFE
Booster		Transport Vehicles:	GFE
Manufacturer:	Aerojet		



'T-TESTED *Snark* shown awaiting another trial at Patrick AFB, where it has been launched and successfully returned.

SKY-BOUND *Mace* with flaming booster.

MACE U.S. AIR FORCE Surface-to-Surface



Designed to replace *Matador*, the *TM-76 Mace* became an operational weapon in 1959 and was deployed to Germany in the spring with the 38th Tactical Missile Wing.

Mace uses either an inertial guidance system or ATRAN, a map-matching system, depending on its mission. The ATRAN version is *TM-76A*, the inertial *Mace TM-76B*.

A relatively low-cost missile, it ru about $250,000 including Governme furnished engine, booster and guidan package. *Mace* was first fired in 19 and placed in production in 1958.

SPECIFICATIONS

DESIGNATION:	TM-76
PRIME CONTRACTOR:	Martin
STATUS:	Operational
RANGE:	Over 650 miles
VELOCITY:	Transonic
FRAME	
Manufacturer:	Martin
Length (Overall), ft:	44.2
Diameter (Body), ft:	4.5
Span, ft:	22.9
Weight (Gross), lb:	13,800
Material (Major):	Aluminum, magnesium
GUIDANCE	
Manufacturer:	Goodyear/AC
Type:	ATRAN/inertial
POWERPLANTS	
Booster	
Manufacturer:	Thiokol
Propellants:	Solid
Type & Number:	Cast JATO (1)
Thrust, lb:	100,000
Sustainer	
Manufacturer:	Allison
Propellants:	JP
Type & Number:	J-33-A-41 turbojet (1)
Thrust, lb.	52
WARHEAD	
Type:	Nucle
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Goodye
Fueling:	Goodye
Radar & Ground Control:	Reeves Instr ments, Kaustine C
Handling & Service:	Goodyear, Tra mobi
Transport Vehicles:	Goodyear, Fo Wheel Drive C

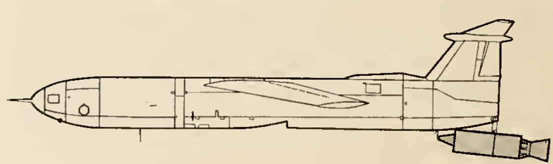
MATADOR U.S. AIR FORCE Surface-to-Surface

In operational service in Germany since March 9, 1954, *Matador* was the first USAF missile to attain service status. Controlled electronically by ground personnel, *Matador* carries either conventional or nuclear bomb-load. Based in Taiwan and Korea well as in Germany, *Matador* uni will be re-equipped with *Mace*.

STAND-BY *Matador* is being replaced.

SPECIFICATIONS

DESIGNATION:	TM-61
PRIME CONTRACTOR	Martin
STATUS:	Operational
FRAME	
Manufacturer:	Martin
Length (Overall), ft:	39.6
Diameter (Body), ft:	4.5
Span, ft:	28.7
Weight (Gross), lb:	12,000
Material (Major):	Aluminum
VELOCITY:	650 + mph
POWERPLANTS	
Booster	
Manufacturer:	Thiok
Propellants:	Sol
Type & Number:	Cast JATO (
Thrust, lb:	52,0
Sustainer	
Manufacturer:	Allis
Propellants:	
Type & Number:	J-33-A-37 turbojet (
Thrust, lb:	46
WARHEAD	
Type:	Nucle



BOMARC *U.S. AIR FORCE Surface-to-Air*

A supersonic pilotless interceptor, ie *IM-99 Bomarc* is an intermediate inge air defense weapon designed to tack enemy bomber formations be- re they reach target areas. It was de- gned to be complementary to, rather ian competitive with, point defense issiles such as the Army's *Nike*.

Bomarc is launched vertically from 1 automatically opening launcher- ielter. Initial power is supplied by a booster rocket; at high speed, two ram-jet engines take over for cruise power.

Latest version of the *Bomarc* is the "B" model, with double the previous range and nuclear warhead capability. The "B" employs a Thiokol solid rocket for boost power, instead of the Aerojet liquid booster in the original version. Speed and altitude capability of the "B" model is also greater than the predecessor version.

Boeing, manufacturer of the *Bomarc*, is operating a *Bomarc* training school at Harbor Island in Seattle, and the USAF is setting up another at Chanute AFB, Ill. A total of 16 *Bomarc* sites had been announced prior to 1959 Congressional hearings on the air defense master plan, which might cause revision in *Bomarc* plans. The first site, McGuire AFB, N.J., was scheduled to be operational by fall of 1959.

COMPLETED *Bomarc* **is lowered to the factory floor in Boeing's Seattle plant.**

SPECIFICATIONS

:SIGNATION: IM-99B

:IME CONTRACTOR: Boeing

ATUS: Production in service test quantities

\NGE: 400 miles

:LOCITY: Mach 2.7

:AME

- Manufacturer: Boeing
- Length (overall), ft.: 46.7
- Diameter (body), in.: 35
- Span, ft.: 18.2
- Weight (gross), lbs.: 16,000
- Material (major): Aluminum, stainless steel and magnesium

GUIDANCE

- Manufacturer: Westinghouse
- Type: Command

POWERPLANTS

1. Booster
   - Manufacturer: Thiokol
   - Propellants: Solid
   - Thrust, lbs.: 50,000
2. Cruise power
   - Manufacturer: Marquardt
   - Type and number: 24" ramjets (2)
   - Thrust, lbs.: 50,000

WARHEAD

- Type: Nuclear or high explosive

GROUND SUPPORT MAJOR CONTRACTORS

- Launcher: AMF, Food Machinery
- Fueling: Minneapolis-Honeywell, Brown Instruments
- Radar and ground control: Westinghouse, Remington-Rand
- Handling and service: Burns & Roe, Farnsworth Electronics
- Transport vehicle: Burns & Roe, AMF

FALCON *U.S. AIR FORCE Air-to-Air*

Falcon is the name of a family of air-to-air missiles for use in conjunction with fighters of the Air Defense Command. Hughes Aircraft has produced five versions to date, the latest being the *GAR-3* and *GAR-4*. Previous versions included *GAR-1*, *GAR-1D* and *GAR-2A*.

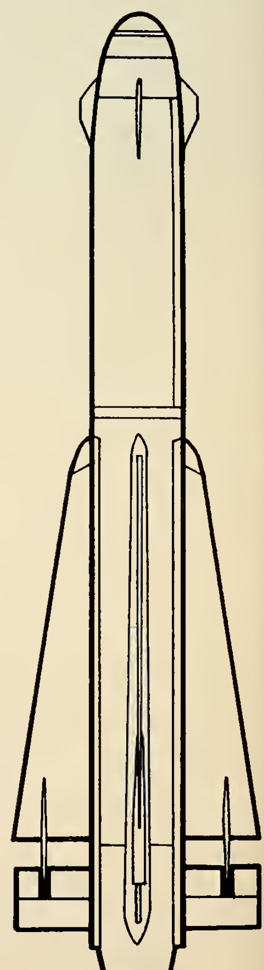
GAR-1D and *GAR-2A*, smallest missiles in the USAF inventory, have been in operational service since 1956 on F-89, F-101 and F-106 aircraft. The *1D* version is radar guided, the *2A* guided by an infrared homing device. The interceptor planes can carry the *Falcons* in mixed loads, permitting selection of either type of guidance.

GAR-3 and *GAR-4* are improved versions of the two *Falcons* already in service. The *GAR-3*, scheduled for early operational service, employs a semi-active radar seeker type of guidance. *GAR-4* will have the infrared system, permitting the same "mix" as with earlier *Falcons*.

The *GAR-3 Super Falcon* features a new solid-propellant engine with greater burning time, providing increased range and speed. Principal ex ternal change is a longer and mor pointed nose cone which adds severa inches to the overall length. The nev *Falcon* also has slightly increased win span and the stabilizers have been ex tended so they reach beyond the cer ter of the airframe.

Specifications below are for th basic *Falcon*, the *GAR-1D*. By com parison, the *GAR-3* measures 7.1 fee in length and has a wing span of tw feet. It is being manufactured a Hughes' Tucson plant.

AT LEFT, *GAR-3*, soon to be operational. Right, *GAR-1D*.



SPECIFICATIONS

DESIGNATION:	GAR-1D	Material (Major):	Magnesium
PRIME CONTRACTOR:	Hughes	GUIDANCE	
STATUS:	Operational	Manufacturer:	Hughes
RANGE:	5 miles plus	Type:	1D, 3—radar
VELOCITY:	Mach 2 plus		2A, 4—infrared homing
FRAME		POWERPLANT	
Manufacturer:	Hughes	Manufacturer:	Thiokol
Length (Overall), ft:	6.5	Propellants:	Solid
Diameter (Body), ft:	0.54	Type and number:	Cast (1)
Span, ft:	1.7	Thrust, lbs, 1D:	6000
Weight (Gross), lbs:	100	WARHEAD:	High explosive

GENIE *U.S. AIR FORCE Air-to-Air*

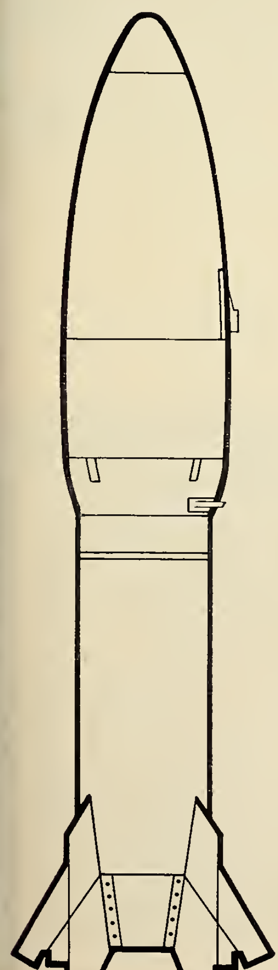
An unguided rocket, the *MB-1* *enie* was the first air-to-air weapon to equipped with a nuclear warhead. he nuclear head was developed by os Alamos Scientific Laboratory.

Genie was first fired from an air-aft on July 19, 1957, during Opera-n *Plumbob* at the Atomic Energy ommission's Nevada test site. It was clared operational and added to the apons inventory of Air Defense ommand in January, 1958, and is rt of the armament of F-89, F-101 d F-106 aircraft.

The relatively small missile is powered by an Aerojet-General solid-propellant rocket. An extensive testing program, continued after the weapon became operational, is nearing completion.

SPECIFICATIONS

DESIGNATION:	MB-1	Diameter (Body), ft:	1.25
PRIME CONTRACTOR:	Douglas	POWERPLANT	
STATUS:	Operational	Manufacturer:	Aerojet-General
RANGE:	1.5 miles	Propellants:	Solid
FRAME		Type and number:	Cast (1)
Manufacturer:	Douglas	WARHEAD	
Length (Overall), ft:	8	Type:	Nuclear



F-89 carries *Genie* under wing; F-101, F-106 use bay.

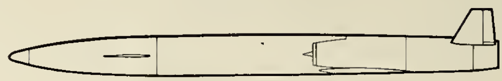
RELATIVELY small, the *Genie* nonetheless is equipped to deliver a nuclear wallop.

HOUND DOG *U.S. AIR FORCE Air-to-Surface*

TEST MODEL of *Hound Dog* attached to B-52, whose range it will soon be expanding.

Hound Dog is designed to extend the capability of Strategic Air Command's heavy bombers. Designated *GAM-77,* the missile will be able to deliver a nuclear payload on a target more than 500 miles from launch point. It is launched from a B-52.

GAM-77 is powered by a Pratt & Whitney J-52 turbojet, which can push the missile to supersonic speed. It was first tested on a limited range flight from the Atlantic Missile Range on April 23, 1959.



SPECIFICATIONS

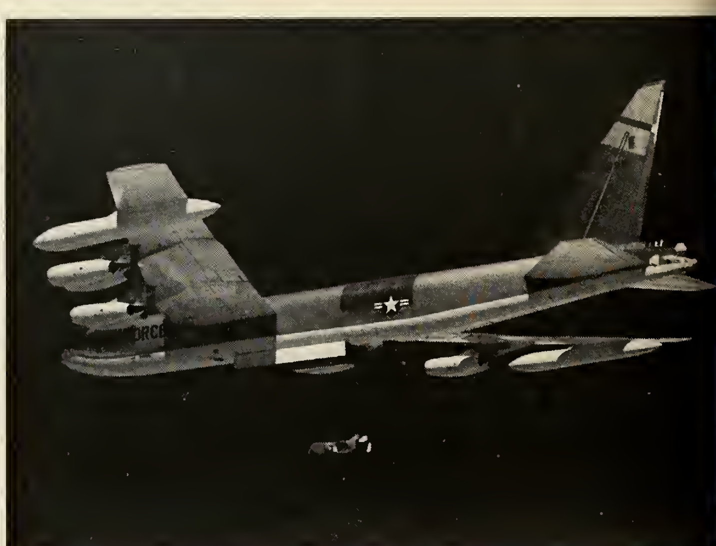
DESIGNATION:	GAM-77
PRIME CONTRACTOR:	North American
STATUS:	Development (operational in 1959)
RANGE:	500 plus miles
VELOCITY:	Mach 1 plus
FRAME	
Manufacturer:	North American
GUIDANCE	
Manufacturer:	Autonetics
Type:	Inertial
POWERPLANT	
Manufacturer:	Pratt & Whitne
Type & number:	J-52 jurbojet (
Thrust, lbs:	75(
WARHEAD:	Nucle
PARTICIPATING CONTRACTORS:	AiR search, General Controls, Marquard Stewart Warner, Sundstrand Avi tion, Thompson, Vickers, Bendix-Re Bank

QUAIL *U.S. AIR FORCE Air-to-Surface*

First flight tested in 1958, the *GAM-72 Quail* is a diversionary missile for use by Strategic Air Command. Air-launched from B-57 or B-52 bombers, its purpose is to assist in target penetration by diverting enemy attention from the bombers. A small missile, the decoy is powered by a General Electric J-85 turbojet.

SPECIFICATIONS

DESIGNATION:	GAM-72
PRIME CONTRACTOR:	McDonnell
STATUS:	Development
WARHEAD:	None
FRAME	
Manufacturer:	McDonnell
Length, ft:	13
Wing span, in:	65
POWERPLANT	
Manufacturer:	General Electric
Type and number:	J-85 turbojet (1)
Thrust, lbs:	2000
SUPPORT EQUIPMENT	
Manufacturer:	Bell Aircraft
ELECTRONICS	
Manufacturer:	Ramo-Wooldridge



B-52 launches a *GAM-72 Quail,* designed to confuse the defenses of an enemy

J.S. AIR FORCE Missiles of the Future

ALBM

Following a series of feasibility studies with test vehicles, the Air Force decided to proceed with plans for an Air Launched Ballistic Missile. An important project, the missile is designed for use with B-52 and B-58 bombers, providing mobile aerial launch capability for missiles of 1000 nautical miles range or more. Initial concept called for a solid-fueled missile about half *Polaris* size. Douglas was awarded contract in June, 1959, calling for design, performance and cost study to be completed by year-end.

CROSSBOW

An adaptation of the drone aircraft to combat use, *Crossbow* is an air-to-surface missile designed to attack enemy defenses by homing on ground radar. To weigh about one ton, it will be subsonic with a range of about 200 miles. Power will be supplied by a small turbojet. Radioplane is prime contractor.

DYNA-SOAR

A combination of missile and manned airplane, *Dyna-Soar* is a hypersonic boost-glide bomber in early development stage. It will be boosted by high-thrust powerplants to near-orbital velocity at altitudes of about 100 miles, depending on mission. It has theoretical range of several earth circuits as reconnaissance vehicle, one circuit as bomber, coasting on its initial momentum with assist by small rocket sustainers. After intensive design studies involving a dozen companies, Boeing and Martin sought prime system responsibility.

GAR-9

An advanced version of the *Falcon* family of air-to-air missiles, *GAR-9* will combine the nuclear capability of *Genie* with the *Falcon's* accurate guidance. It is slated to become prime armament for North American Aviation's Mach 3 F-108 interceptor now in development status. North American and Hughes are collaborating on the system development; Aerojet-General will provide the powerplant.

MINUTEMAN

Operational requirements for a long-range missile with more rapid reaction time than the liquid-fueled ICBM's developed earlier brought about a contract, in 1958, for development of an all-solid ICBM, the *XSM-80 Minuteman*. With a maximum range of 5500 nautical miles, *Minuteman* will have greater flexibility in that it can be used for lesser ranges by dropping off one or more of its three stages. It will be a highly sophisticated weapon, incorporating the best developmental features from earlier ICBM experience.

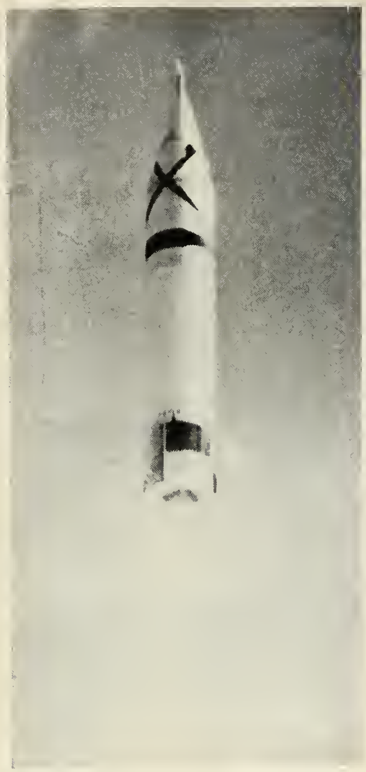
Designed for operational use about 1963, *Minuteman* will be a "hard-based" missile, stored in underground bomb-proof silos ready for instantaneous action. First of the second generation long-range ballistic missiles, *Minuteman* will be smaller, lighter, less complex and considerably less expensive than its first generation counterparts. The program is under the management of ARDC's Ballistic Missile Division. In October, 1958, Boeing was named principal contractor for assembly and test.

WAGTAIL

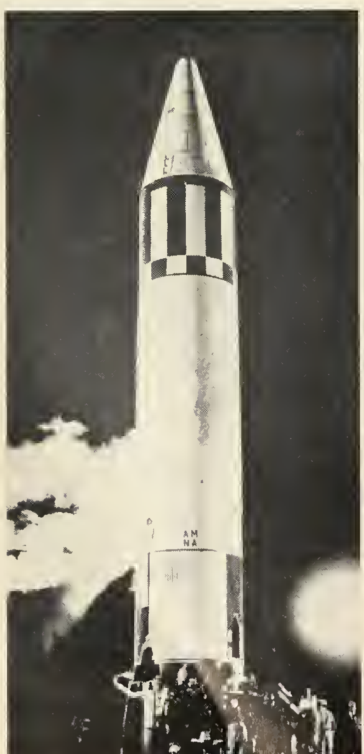
An air-to-ground missile, *Wagtail* is designed for greater penetration effect through low-altitude launch. Concept calls for use of forward-firing rockets after launch and before ignition of primary power plant. This will permit very low velocities while guidance system adjusts to target. The sophisticated guidance system will then permit the weapon to climb over obstacles, like hills and trees, and attack at low level. Minneapolis-Honeywell is prime contractor for the *Wagtail* system.

WHITE LANCE

Another air-to-ground weapon, designed for use with fighter bombers of Tactical Air Command, *White Lance* is an advanced version of the Navy's *Bullpup*. Martin is prime contractor. Initial deliveries to Air Force scheduled for near future, will include missiles almost identical to *Bullpup*. Later version will have increased range and be equipped with a greatly improved guidance system.



WORKHORSE ***Jupiter*** **rises from Cape.**



TWO-PART missile is field-assembled.

JUPITER *U.S. ARMY Surface-to-Surface*

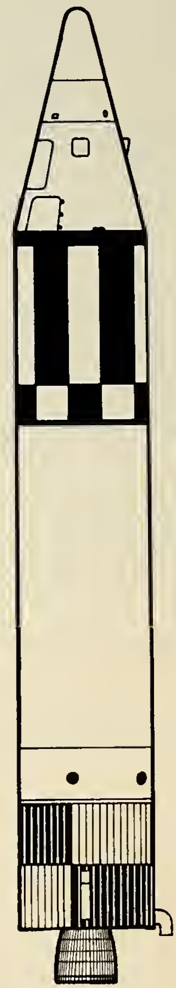
Developed by the Army Ballistic Missile Agency, the *SM-78 Jupiter* was the first American intermediate range ballistic missile to be launched successfully. In a Department of Defense decision on missile roles and missions, the *Jupiter* was turned over to the Air Force for operational employment, with training of USAF crews to be handled by ABMA.

The Air Force's 864th Jupiter squadron recently completed training at Redstone Arsenal, Huntsville, Ala. A second squadron, the 865th, is now in training there. The *Jupiter* system is scheduled to go to Italy this year.

Jupiter was designed to deliver a nuclear payload over a range of 1500 nautical miles. It is composed of two parts which are assembled in the field immediately prior to launchings. They are the "thrust unit," containing the rocket engine and fuel tanks, and the "warhead unit," which can contain either nuclear or conventional warheads and fuzing systems. Guidance is by the Delta Minimum self-contained all-inertial system of ABMA.

The *Jupiter* program was started in mid-1955 and first contract for engineering and production work was awarded Chrysler Corp. in June, 1956. *Jupiter* test vehicles have figured prominently in space research experiments including first recovery of a full-scale, heat-protected IRBM nose cone in May, 1958, and launching of a nose cone containing special instrumentation and a live monkey in addition to the warhead on Dec. 13, 1958.

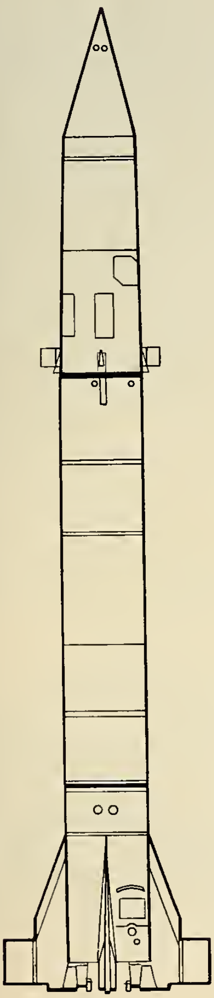
First Chrysler-built, operational-type *Jupiter* was successfully launched on Jan. 22, 1959.



SPECIFICATIONS

DESIGNATION:	SM-78
PRIME CONTRACTOR:	Chrysler
STATUS:	Operational
RANGE:	1500 nautical miles
VELOCITY:	10,000 mph
FRAME	
Manufacturer:	Chrysler
Length (overall), ft.:	60
Diameter (body), ft.:	8.75
Weight (gross), lbs.:	110,000
Material (major):	Aluminum
GUIDANCE	
Manufacturer:	Ford Instrument Co.
Type:	Inert
POWERPLANT	
Manufacturer:	Rocketdy
Propellants:	Liquid oxygen and kerose
Type & Number:	Regenerative cooled (
Thrust, lbs.:	150,C
WARHEAD	
Type:	Nucl
Nose Cone:	Goodyear Aircr
GROUND SUPPORT MAJOR CONTRACTORS	
Ground Support (General):	Ha Aircr
Transporters:	Frueh

REDSTONE *U.S. ARMY Surface-to-Surface*



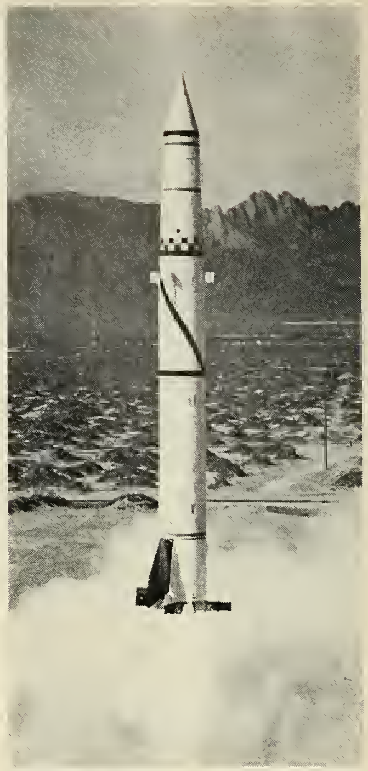
Developed by the Army Ballistic Missile Agency, the *Redstone* is a high-accuracy missile used to extend and supplement the range and fire power of artillery cannon. It is a mobile system which can be fired from portable launching pads. A well-trained unit can move into a previously surveyed position, fuel the missile, set the guidance and fire in about two hours.

Range of the weapon is 200 miles. Power is supplied by a 75,000-pound-thrust Rocketdyne liquid-propellant engine. Graphite vanes located in the exhaust of the rocket supply thrust control; and external fins provide aerodynamic stability. *Redstone* is cylindrical in shape with a conical nose and cruciform tail surfaces.

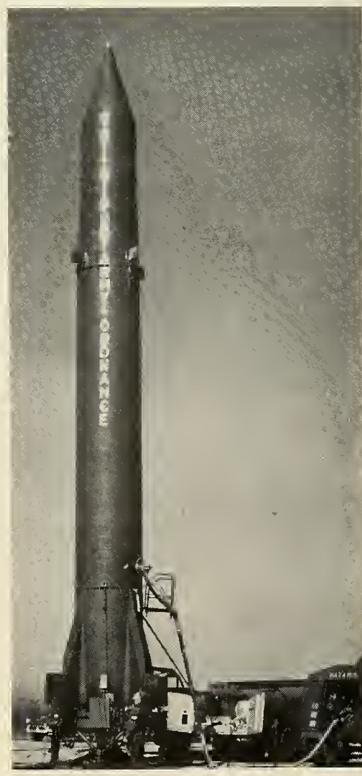
The missile's inertial guidance system is entirely self-contained. Prior to launch, the desired flight program is fed into a program device, which plays back the information to the various elements of the control system that guide the missile in flight.

The *Redstone* has nuclear capability, but it can also be armed with conventional explosives. The weapon is designed so that it may be transported by air, rail or truck, including the complete launching system. It is composed of three component parts which can be assembled in the field prior to launching: the powerplant unit, the fuel tank unit and the warhead and control unit. The missile is launched in the vertical position from a platform five feet high.

Redstone has been operational since early last year. Two Army Missile Groups *(Redstone)* are overseas.



RELIABLE *Redstone* **is highly mobile.**

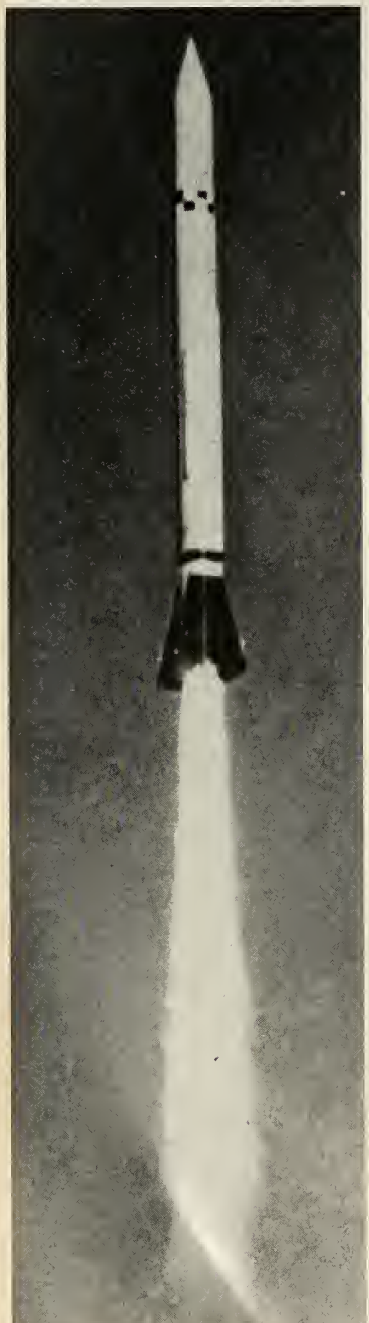


FIVE-FOOT platform is high enough.

SPECIFICATIONS

DESIGNATION:	SSM-A-14
PRIME CONTRACTOR:	Chrysler
STATUS:	Operational
RANGE:	200 mi.
FRAME	
Manufacturer:	Reynolds Metal Co., Chrysler
Length (overall), ft.:	63
Diameter (body), ft.:	5.8
Span, ft.:	12
Weight (gross), lbs.:	61,000
Material (major):	Aluminum
GUIDANCE	
Manufacturer:	Ford Instrument Co.
Type:	Inertial
POWERPLANT	
Manufacturer:	Rocketdyne
Propellants:	Liquid oxygen and alcohol
Type & Number:	Regenerative cooled (1)
Thrust, lbs.:	75,000
WARHEAD	
Type:	Nuclear capability (warhead separates)
GROUND SUPPORT MAJOR CONTRACTORS	
Fueling:	Air Products

CORPORAL *U.S. ARMY Surface-to-Surface*



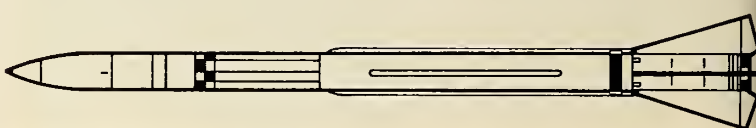
SOARING up from White Sands range.

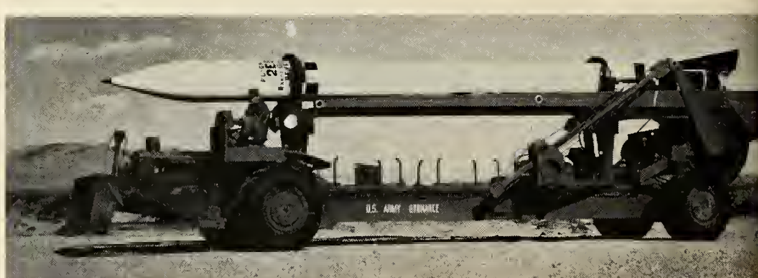
A 30-inch diameter Army artillery missile, *Corporal* was the Army's first ballistic-type weapon. It is in operational service and battalions have been deployed to Europe. A 75-mile-range missile, it is scheduled for replacement by the more advanced *Sergeant*.

The Corporal program has two prime contractors. Firestone Tire and Rubber Co.'s guided missile division has responsibility for production of the missile and for ground handling and launch equipment. Gilfillan Brothers, Inc., handles radar and other ground guidance equipment. Gilfillan also serves as subcontractor to Firestone for some of the guidance components in the missile.

Corporal is guided by a preset and command system. Basic firing data is computed for the guidance equipment and entered as "dial settings" before the missile is launched. After firing, minor corrections are made to the trajectory to insure accurate impact.

In service use, a *Corporal* battalion has 250 men. Each battalion has two batteries, a firing battery and a headquarters service battery. There are two operational launchers in each battalion. The *Corporal* carries either a conventional or nuclear warhead in the eight-foot nose section. Below lies the guidance stowage section, followed in sequence by a cluster of cells to carry compressed air to pressurize the propellant tanks, the propellant valve system, the rocket engine and the guidance vanes and rudders. The missile assembly measures 46 feet.





TACTICAL transporter-erector for *Corporal*. Battalions have been deployed in Europe.

SPECIFICATIONS

DESIGNATION:	XM4E1
PRIME CONTRACTOR:	Gilfillan, Firestone
STATUS:	Operational
RANGE:	75 miles
FRAME	
Manufacturer:	Firestone
Length (overall), ft.:	46
Diameter (body), ft.:	2.5
Weight (gross), lbs.:	11,000
Material (major):	Steel
GUIDANCE	
Manufacturer:	Gilfillan, Clary Multiplier Co.
Type:	Preset & command
POWERPLANT	
Manufacturer:	Ryan
Propellants:	Nitric acid and aniline
Type & Number:	Liquid propellant (1)
WARHEAD	
Type:	High explosive or nuclear
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Firestone
Fueling:	Firestone, GFE
Radar & ground control:	Gilfillan, Motorola
Handling & service:	Firestone
Transport Vehicles:	GFE

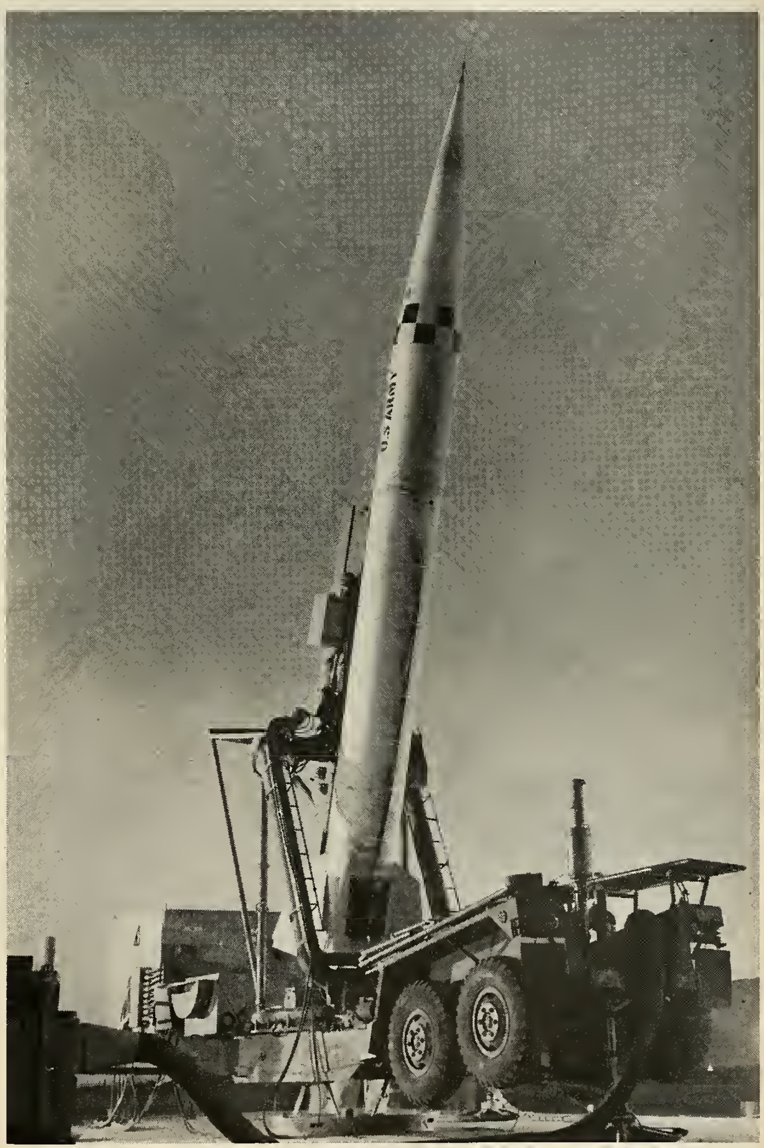
SERGEANT *U.S. ARMY Surface-to-Surface*

Sergeant is a solid-fueled ballistic-type battlefield missile designed to replace the six-year old *Corporal.* It incorporates many improvements over its predecessor in mobility, reliability and accuracy, although range is approximately the same.

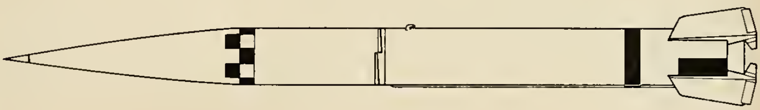
Like *Corporal*, the *Sergeant* can carry either a nuclear or conventional warhead, is air transportable and can be rapidly emplaced and fired under all conditions of weather and terrain by a comparatively small crew. The use of solid propellants and inertial guidance have minimized system maintenance requirements and simplified ground handling procedures and equipment. The missile is launched in a near-verticle position from an erector-launcher.

Development of the *Sergeant* to its current state of refinement is the result of a joint effort between Jet Propulsion Laboratory and Sperry Utah Engineering Laboratory. Production of the weapon system, including erector-launcher, servicing, handling and maintenance equipment, is the responsibility of Sperry Rand Corporation. Sperry received the prime contract for production of the missile system in 1956.

The *Sergeant* is currently entering first hardware production at Sperry's Salt Lake City manufacturing facilities.



LAUNCHED in near-vertical position, *Sergeant,* like *Corporal,* is easily handled.



SPECIFICATIONS

DESIGNATION:	FAGMS-S
PRIME CONTRACTOR:	JPL/Sperry Rand
STATUS:	Development production
RANGE:	75+ miles
FRAME	
Manufacturer:	Sperry
Length (overall), ft.:	34
Diameter (body), ft.:	2.6
Span, ft.:	5.9
Material (major):	Aluminum and Steel
GUIDANCE	
Manufacturer:	Sperry
POWERPLANT	
Case manufacturer:	Sperry
Propellant loading manufacturer:	Thiokol
Propellant type:	Solid
Thrust, lbs.:	50,000
WARHEAD	
Type:	Nuclear capability
GROUND SUPPORT MAJOR CONTRACTORS	
Launching station:	Sperry
Check out equipment:	Sperry
Handling and transport:	Sperry

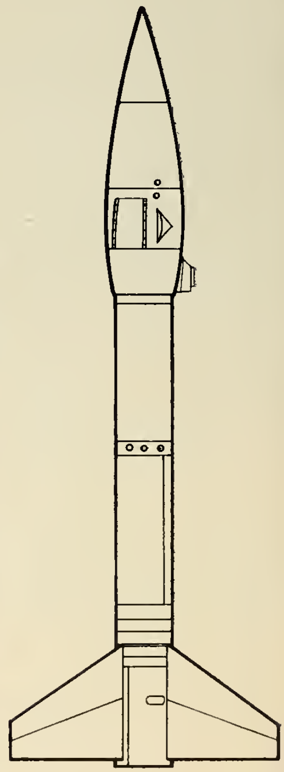
HONEST JOHN *U.S. ARMY Surface-to-Surface*

Originally developed by Army Ordnance, *Honest John* is an artillery rocket designed to provide close fire support for ground operations. It is mounted on and launched from a highly mobile self-propelled launcher.

Honest John, originally designated *M-30* but now known as *M-31A1C*, is a free-flight rocket having no electronic controls. It features extreme mobility and simplicity, and it can be fired by a crew of six. It can carry a variety of warheads, including conventional high-explosives, nuclear or chemical loads. Its range is equivalent to that of medium-to-long range artillery.

Major parts of the *Honest John* rocket—the head compartment, fins, pedestal and power plant—are assembled at the factory or arsenal. Final assembly takes place near the firing site, and the completed rocket is then moved forward to the battle zone on its self-propelled launcher.

Honest John has been under development since 1950 when Army Ordnance first outlined to Douglas Aircraft Co. the basic idea for a large calibre artillery rocket. First tests, conducted at White Sands in 1951, dictated a series of improvements. Further tests with modified rockets led to large-scale contracts.



SIX-MAN crew can handle and fire *Honest John*, shown on its self-propelled launcher.

SPECIFICATIONS

DESIGNATION:	M-31A1C
PRIME CONTRACTOR:	Douglas, Emerson Electric
STATUS:	Operational
RANGE:	16.5 miles
VELOCITY:	750 mph
FRAME	
Manufacturer:	Douglas, Emerson
Length (overall), ft.:	27
Diameter (body), ft.:	2.5
Span, ft.:	8
Weight (gross), lbs.:	5800
Material (major):	Steel
GUIDANCE	
Type:	Unguided
POWERPLANT	
Manufacturer:	Hercules
Propellants:	Solid
Type & Number:	Cast (1)
WARHEAD	
Type:	High explosive
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Rock Island Arsenal
Transport Vehicles:	OTAC

LITTLE JOHN *U.S. ARMY Surface-to-Surface*

Designed and developed by the Army's Redstone Arsenal as a supplement to *Honest John,* the *XM-47 Little John* is also a free-flight rocket without electronic controls, featuring a high degree of accuracy, simplicity of design and ease of operation. Its range is comparable to that of medium and heavy artillery.

Little John is about half as long as *Honest John,* has a body diameter of only 12½ inches compared with 30 for *Honest John,* and weighs only 800 pounds, less than a sixth as much as its companion weapon. Lightweight launchers and ground equipment are adaptable for an extremely high degree of mobility on the ground. They can also be airlifted by either fixed-wing aircraft or helicopters.

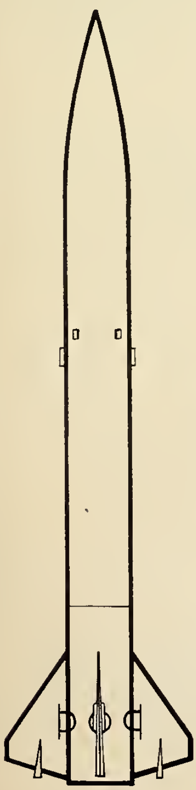
Although not yet officially designated operational, *Little John* rockets were turned over this year to the 101st Airborne Division, Fort Campbell, Ky., for training and development of combat techniques.

Little John was developed under a "crash" program that started at Redstone Arsenal in February, 1956. It was first test fired in June of that year.

Propellant for the solid-fueled rocket is produced by Allegheny Ballistics Laboratory, with Consolidated Western Steel supplying motor parts. Frame is built by Emerson Electric and the Army's Rock Island Arsenal provides the small, compact launchers.

SPECIFICATIONS

DESIGNATION:	XM-47
PRIME CONTRACTOR:	Emerson Electric
STATUS:	Development production
RANGE:	10 miles
VELOCITY:	Supersonic
FRAME	
Manufacturer:	Emerson Electric
Length (overall), ft.:	14.5
Diameter (body), in.:	12.5
Span, ft.:	2.5
Weight (gross), lbs.:	800
Material (major):	Steel and aluminum
GUIDANCE	
Type:	Unguided
POWERPLANT	
Manufacturer:	Allegheny Ballistics Lab.
Propellants:	Solid
Type & Number:	Cast (1)
WARHEAD	
Type:	High explosive or nuclear
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Rock Island Arsenal



TAKING FLIGHT from White Sands range.

NOT YET officially operational, *Little John* has been turned over to training troops.

LACROSSE *U.S. ARMY Surface-to-Surface*

Developed out of the experiences of the Pacific campaigns of World War II, where it was difficult to get artillery hits on targets like caves and bunker entrances, *Lacrosse* is designed to replace heavy artillery in strikes against strong points delaying advance of ground troops.

A highly accurate weapon, *Lacrosse* has its own missile automatic checker which automatically tests all phases of its operation just before firing. The *Lacrosse* system consists of the missile, a launcher mounted on a standard two-and-one-half-ton truck, and the guidance system, which is controlled by a forward guidance station acting in a capacity similar to a field artillery observation post. Like *Honest John* and *Little John, Lacrosse* features extreme mobility.

Lacrosse weighs slightly more than a ton and can carry a wide variety of conventional or atomic warheads, depending upon the tactical situation. The missile body has three major assemblies: nose section, center and tail. Fo swept wings and four movable tail fi control pitch, yaw and roll.

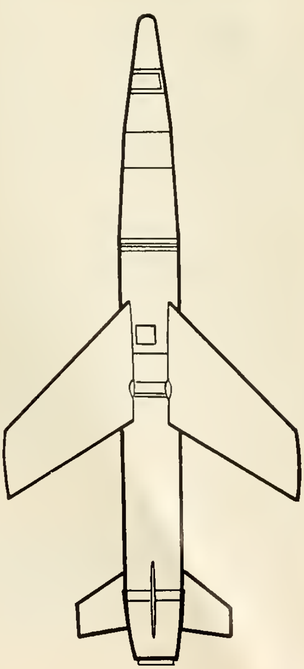
The first two units employing *L crosse* were activated in June, 195 They are the 5th Missile Battalio 41st Artillery, and the 5th Missile Ba talion, 42nd Artillery, both located Fort Sill, Okla. Each has approximate 170 officers and enlisted men. The mi sile was developed by Cornell Aerona tical Laboratory and put in productic by The Martin Co. at its Orlando plan

ACCURATE *Lacrosse* replaces artillery.

SPECIFICATIONS

DESIGNATION:	SSM-A-12
PRIME CONTRACTOR:	Cornell Aero Lab., Martin
STATUS:	Production
RANGE:	20 miles
VELOCITY:	Mach 2
FRAME	
Manufacturer:	Martin
Length (overall), ft.:	19.2
Diameter (body), ft.:	1.7
Span, wing, ft.:	9
Span, fins, ft.:	4.7
Weight (gross), lbs.:	2300

GUIDANCE	
Manufacturer:	Federal Telephone Lab
POWERPLANT	
Manufacturer:	Thiok
Propellants:	Sol
Type & Number:	Cast (l
WARHEAD	
Type:	Nuclear capabili
GROUND SUPPORT MAJOR CONTRACTORS	
Radar & Ground Control:	Federal Tel communication, Farrand Optic



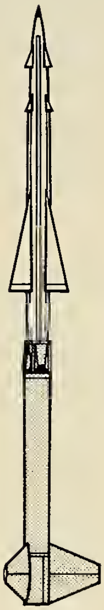
NOW IN hands of artillerymen, *Lacrosse* has lightweight launcher, automatic checker.

NIKE-AJAX

U.S. ARMY Surface-to-Air

Nike-Ajax, the first American sur-
ıce-to-air operational missile, has now
een phased out of production and will
radually be replaced by *Nike-Hercules*
nits, although it is still operational in
number of metropolitan sites. Still
ıpable of combating known types of
omber aircraft, it has been in service
se since 1953. About 10,000 *Nike-*
jax's were built and about 3000 have
een fired in the Army's various test
nd training programs during the past
x years.

ORIZONTALLY positioned on launcher.

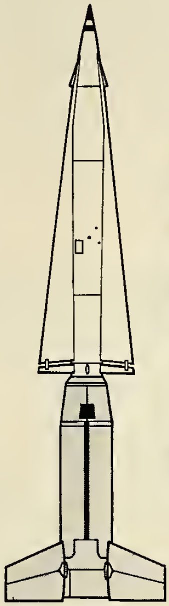


SPECIFICATIONS

ESIGNATION:	SAM-A-7
IME CONTRACTOR:	Western Electric
ATUS:	Operational
NGE:	25 miles
LOCITY:	Mach 2.5
AME	
Stages:	2
Manufacturer:	Douglas, Borg-Warner (booster)
Length (overall), ft.:	31
Diameter (body), ft.:	1
Span, ft.:	4
Weight (gross), lbs.:	2300
Material (major):	Aluminum, magnesium and steel
UIDANCE	
Manufacturer:	Western Electric
Type:	Command
WERPLANTS	
First Stage (Booster)	
Manufacturer:	Goodyear
Propellants:	Solid
Type & Number:	Cast uncooled (1)
Second Stage	
Manufacturer:	GFE
Propellants:	Nitric acid and JP
Type & Number:	Liquid, cooled (1)
Thrust, lbs.:	2600
ARHEAD	
Type:	High explosive

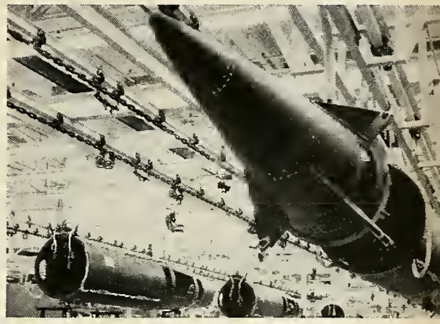
NIKE-HERCULES

U.S. ARMY Surface-to-Air



An advanced member of the *Nike* family, *Nike-Hercules* offers greater range, speed and destructive power than its predecessor, *Nike-Ajax. Hercules* is scheduled to be sited at Strategic Air Command bases and to replace *Nike-Ajax* installations around metropolitan areas. About 50 batteries have been converted to *Hercules* weapons.

Hercules has both nuclear and conventional warhead capability and has been operational in certain sites since October, 1958.



FINAL assembly line for the *Hercules.*

SPECIFICATIONS

DESIGNATION:	SAM-A-25
PRIME CONTRACTOR:	Western Electric
STATUS:	Operational
RANGE:	80 miles
VELOCITY:	Mach 3+
FRAME	
Stages:	2
Manufacturer:	Douglas, Goodyear, Borg Warner
Length (overall), ft.:	39
Diameter (body), ft.:	2.5
Span, ft.:	7.5
Material (major):	Aluminum, magnesium and steel
GUIDANCE	
Manufacturer:	Western Electric
Type:	Command
POWERPLANTS	
First Stage (Booster)	
Manufacturer:	Radford Arsenal
Propellants:	Solid
Type & Number:	Cast uncooled (4)
Second Stage	
Manufacturer:	Thiokol
Propellants:	Solid
Type & Number:	Cast, uncooled (1)
WARHEAD	
Type:	Nuclear

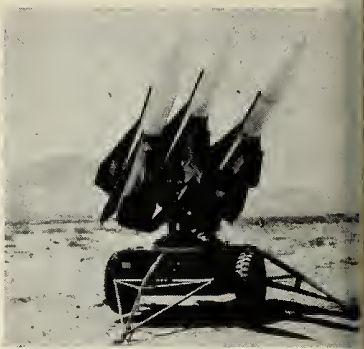
HAWK *U.S. ARMY Surface-to-Air*

One of the Army's newest air defense weapons, the *Hawk* is designed to be used primarily against low-flying enemy aircraft. It is a mobile system, to be used by both Army and Marine Corps troops in the field. Fired from a small two-wheel launcher, *Hawk* has a ceiling capability ranging from less than 100 feet to more than 38,000 feet. Unusual radar instrumentation provides effectiveness in the "blind zone" of conventional radars. The weapon system also has a high rate of fire, since three missiles can be fired from a single launcher.

Hawk is powered by a solid-propellant system developed by Thiokol and in production at Aerojet-Sacramento.

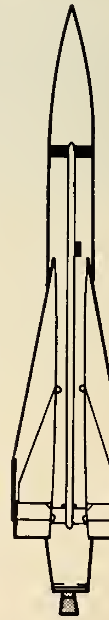
First *Hawk* emplacements will be located in New York and Washington to complement *Nike* defenses. A *Hawk* battery consists of 36 missiles, with three missiles to each of 12 launchers. The launcher emplacements are covered by balloon-like domes to protect the missile from the weather. The missile can be fired through the dome.

The *Hawk* system features simple, rugged equipment, easy to maintain. It is air transportable by helicopter or medium-sized fixed-wing aircraft. *Hawk* is scheduled to be operational in 1960.



THREE *Hawks* can be fired from one uni

VERSATILE ARMY *Hawk* sits poised for launching at the White Sands Proving Grounds.



SPECIFICATIONS

DESIGNATION: XM3
PRIME CONTRACTOR: Raytheon
STATUS: Development production
VELOCITY: Supersonic
RANGE: 20 miles
FRAME
- Stages: 2
- Manufacturer: Northrop, Raytheon
- Length (overall), ft.: 16.8
- Diameter (body), ft.: 1.2
- Span, ft.: 4
- Weight (gross), lbs.: 1275
- Material (major): Steel

GUIDANCE
- Manufacturer: Raytheon
- Type: Radar homing

POWERPLANTS
- First Stage
  - Manufacturer: Aerojet, Thiokol
  - Propellants: Solid
  - Type & Number: Cast (1)
- Second Stage
  - Manufacturer: Aerojet, Thiokol
  - Propellants: Soli
  - Type & Number: Cast (1

WARHEAD
- Type: High explosive by Picatinny Arsena

GROUND SUPPORT MAJOR CONTRACTORS
- Launcher: Northrop, Food Machiner
- Radar & Ground Control: Raytheon
- Handling & Service: Raytheon, Northrop, Food Machiner
- Transport Vehicles: Northrop, Food Machiner

U.S. ARMY MISSILES OF THE FUTURE

PERSHING

A selective range, surface-to-surface two-stage ballistic missile, *Pershing* is designed as eventual replacement for *Redstone*. Both stages will be solid-propelled, permitting ease of handling in the field. With a new transporter-erector-launcher, *Pershing* will have the mobility of the smaller missiles in the Army battlefield family. It will deliver a nuclear warhead up to 700 miles. *Pershing* will be smaller than *Redstone*—about 50 feet overall compared with *Redstone's* 63 feet—and considerably lighter than its predecessor.

Martin-Orlando has the prime system responsibility. Fuzing and arming subcontractor for the nuclear warhead is Bulova Watch Co. Bendix Eclipse-Pioneer is developing the inertial guidance stable platform and associated equipment. Thiokol will provide the solid-propellant rockets and Thompson Products Accessories Division is developing the new transporter-erector-launcher.

NIKE-ZEUS

An advanced air defense weapon, *Nike-Zeus* is being developed to provide a defense against all forms of air threat, with special emphasis on defense against ballistic missiles. A solid-propelled weapon, it will have a nuclear warhead and a command guidance system. *Zeus* will be about the same length as *Nike-Hercules,* but considerably heavier. A high thrust powerplant of 450,000 pounds thrust will boost it to Mach 7 speed. Range will be about 200 miles.

Prime contractor is Western Electric, with Douglas building the frame. Thiokol will build the large booster and Grand Central the sustainer rocket.

SS-10, SS-11

Already in production, the *SS-10* and *SS-11* are anti-tank guided missiles. They are wire-guided and employ solid propellants. They can be launched from a fixed emplacement, from a ground vehicle, a helicopter or an airplane. *SS-11* is an advanced version of *SS-10,* having twice the range and higher speed. Both weapons are built by Nord Aviation in France and are being procured in service and evaluation quantities.

SHILLELAGH

A lightweight missile system being developed for close-in support of ground troops, *Shillelagh* is designed to provide "greatly increased firepower," probably nuclear, against armor, troops and fortifications. In one application it will be vehicle-mounted. Expected to be operational in the mid-1960's, its prime contractor is Aeronutronics Division of Ford Motor Co. (The system is also known as *Pentomic.*)

REDEYE

A shoulder-fired, bazooka-type air defense missile, *Redeye* is designed to provide individual troops with defense against low-level air attack in forward areas. Marine Corps is also interested in the development program. Guidance will be infrared homing. Prime contractor is Convair-Pomona.

DAVY CROCKETT

Another weapon for the pentomic Army, *Davy Crockett* is a light, nuclear-tipped weapon designed to be fired by one or two men in the field. It is being developed as a family. Prime contractor is Martin.

LOBBER

Not a weapon but a cargo ballistic missile, *Lobber* is a nine-foot solid-propellant ballistic missile designed to carry a 50-pound payload over a 50-mile range. Fired from a portable launcher, it was first tested last December. Basic idea is to move priority equipment such as medical supplies in the battlefield area. *Lobber* is first step in a program to study feasibility of moving much larger priority payloads, ultimately including men. Convair has been awarded a *Lobber* development contract by the Army.

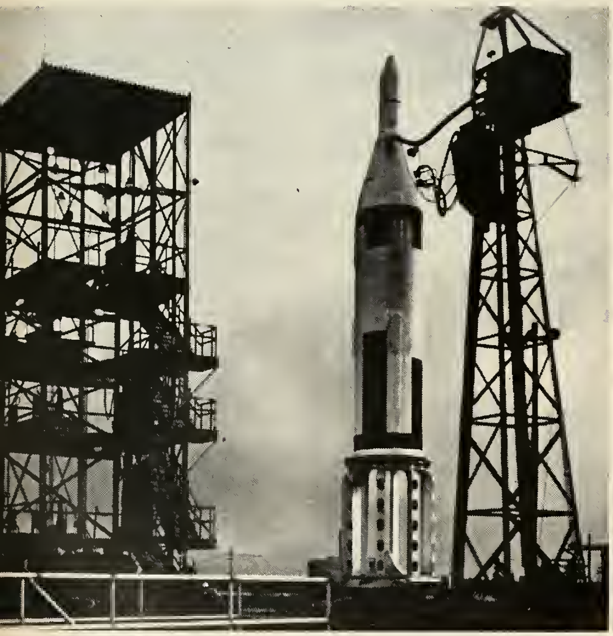
POLARIS *U.S. NAVY Surface-to-Surface*

One of the most important missiles in the American arsenal, *Polaris* adds a new dimension to naval warfare in the atomic age. Launched from mobile, underwater bases it has range equivalent to land-based intermediate range ballistic missiles. The Navy calls it an FBM (Fleet Ballistic Missile).

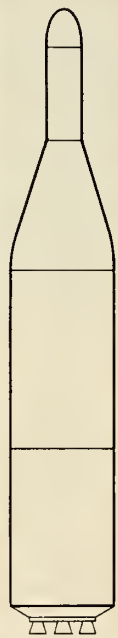
Of advanced design, *Polaris* is considerably smaller and lighter than its land-based counterparts. A single FBM submarine, specifically designed for the *Polaris* system, can carry 16 missiles. Missiles are carried aboard the sub in individual containers. At launch time, inert gases propel the missile above the water. Its rocket booster then takes over to provide initial boost. At altitude, a second-stage rocket cuts in to put the weapon on its ballistic trajectory toward target. Guidance is inertial, and both rocket stages are solid.

Tied in with the *Polaris* system is the Ship Inertial Navigation System (SINS) developed by Sperry, which provides at any given time the latitude, longitude, local vertical and precision azimuth.

Although designed primarily for use with the new FBM subs, *Polaris* can be launched from surface ships equipped with SINS or from land installations. Under present shipbuilding programs, nine *Polaris* FBM subs have been authorized; six of them are under construction. The *Polaris* system is scheduled for operational use late in 1960.



NAVY'S *POLARIS* should be ready for operational use next year.



BLAST OFF—Test vehicle leaves Cape.

SPECIFICATIONS

PRIME CONTRACTOR:	Lockheed Sunnyvale
STATUS:	Development
RANGE:	1500 nautical miles
VELOCITY:	6000 mph (average)
FRAME	
Stages:	2
Manufacturer:	Lockheed
Length (overall), ft.:	46.5
Diameter (body), ft.:	9.3
Weight (gross), lbs.:	28,000
Material (major):	Steel
GUIDANCE	
Manufacturer:	GE/MIT, Sperry Gyro
Type:	Inertial
POWERPLANTS	
First Stage (Booster)	
Manufacturer:	Aerojet
Propellants:	Solid
Type & Number:	(1) Cast, uncooled, 4 nozzles
Thrust, lb.:	80-100,000
Second Stage	
Manufacturer:	Aerojet, Thiokol
Propellants:	Solid
Type & Number:	(1) Cast, uncooled, 3 nozzles, jetavators
WARHEAD	
Type:	Nuclear
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Westinghouse, Sperry Gyro
Fueling:	Aerojet
Radar & ground control:	G.E.
Handling & service:	Westinghouse
SINS	Sperry

REGULUS *U.S. NAVY Surface-to-Surface*

Regulus I, the first operational attack missile to join the fleet, resembles a swept-wing jet fighter. Under development since 1948, it achieved operational status in 1954. Currently, four conventional submarines and four cruisers have *Regulus* capability. The missile was phased out of production in 1958, but is expected to remain on operational duty for some time. A total of 514 of the missiles were built by Chance Vought.

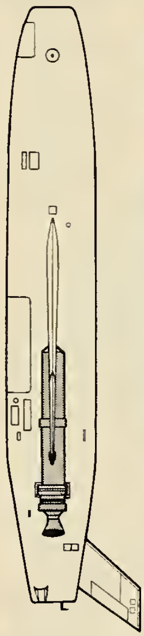
The 900th launch of the recoverable missile was accomplished in April. 1959, from the cruiser USS Toledo.

Also in 1959, *Regulus* participated in Post Office Department experiments in carrying "missile mail." One *"Reg"* carried mail on a training operation out of Point Mugu, Calif., in May. In June, a mail launch was effected from a submarine far at sea to the naval base at Mayport, Fla.

Regulus I is launched from a short rail launcher, where it rests on four slipper fittings. Launching boost is from two rockets which accelerate it to flying speed in about two seconds, when its turbojet sustainer takes over.

Regulus II, an inertially guided successor to *Regulus I,* with considerably greater speed and range, was cancelled by the Navy in December, 1958, after the missile had completed 90% of its development program. It had made 48 test launches, including launches from both a submarine and a surface ship.

REGULUS—with umbilical cord attached.



WHEELED CART is used to move *Regulus* on carrier deck.

SPECIFICATIONS

DESIGNATION:	SSM-N-8	Type:	Command
PRIME CONTRACTOR:	Chance Vought	POWERPLANTS	
STATUS:	Operational	First Stage (Booster)	
RANGE:	500 miles	Manufacturer:	Aerojet
VELOCITY:	Mach 0.9	Propellants:	Solid
FRAME		Type and Number:	JATO (2)
Manufacturer:	Chance Vought	Thrust, lbs.:	66,000 @ 33,000
Length (overall), ft.:	34	Second Stage	
Diameter (body), ft.:	4.5	Manufacturer:	Allison
Span, ft.:	21	Propellants:	JP
Weight (gross), lbs.:	14,000	Type & Number:	Turbojet (1)
Material (major):	Aluminum	Thrust, lbs.:	4600
GUIDANCE		WARHEAD	
Manufacturer:	Sperry	Type:	High explosive or nuclear

WEAPON ABLE

U.S. NAVY Surface-to-Surface

A 500-pound, 12.75-inch antisubmarine rocket, *Weapon Able* is installed on destroyers and frigates. A special fire control system aims the weapon, which carries a conventional explosive charge, at enemy subs; it is unguided in flight. The rocket sinks rapidly and covers a larger ocean area than old-type depth charges. It is in operational service.

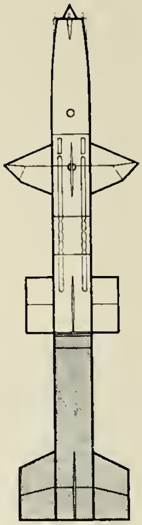
TALOS *U.S. NAVY* ***Surface-to-Air***

Designed originally as an air defense missile to protect the surface fleet from attacking enemy aircraft, *Talos* has indicated in testing that it can also be used as a bombardment weapon against ships or shore targets, or as a long range anti-submarine weapon when equipped with a nuclear warhead.

Talos recently became operational as the principal armament of the guided missile ship USS Galveston. It was first fired at sea from the Galveston on Feb. 25, 1959. Under the present shipbuilding program, seven cruisers, one of which will be nuclear-powered, will have *Talos* capability.

The missile is accelerated to high speed by a solid-propellant rocket. The booster is jettisoned upon attainment of cruising speed, and a 40,000 pound-thrust ramjet provides cruise power. The weapon carries a conventional high explosive charge with proximity fuzing. Employing beam rider guidance, it can reach targets at a range of 65 miles and altitudes above 75,000 feet.

Talos stemmed from the Navy's *Bumblebee* program and was originally developed by the Applied Physics Laboratory of Johns Hopkins University. The system was turned over to Bendix for production. A land-based Army version of *Talos* has been cancelled.



USS Galveston, first ship to be equipped with *Talos*, shows off its lethal weapon.

SPECIFICATIONS

DESIGNATION:	SAM-N-6
PRIME CONTRACTOR:	Bendix
STATUS:	Operational
RANGE:	65 miles
VELOCITY:	Mach 2.5
FRAME	
Manufacturer:	McDonnell
Length (overall), ft.:	20 (booster 10 ft.)
Diameter (body), ft.:	2.5
Span, ft.:	9.48
Weight (gross), lbs.:	7000
Material (major):	Steel
GUIDANCE	
Manufacturer:	Farnsworth Electronics, Sperry
Type:	Beam rider
POWERPLANTS	
First Stage (Booster)	
Manufacturer:	Bendix
Propellants:	Solid
Type & Number:	Cast (1)
Second Stage	
Manufacturer:	McDonnell
Propellants:	JP
Type & Number:	18" ramjet (1)
Thrust, lbs.:	40,000
WARHEAD	
Type:	High explosive or nuclear
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	GE, RCA, American Machine & Foundry, North Ordnance
Radar & ground control:	RCA
Handling & serv.:	GE, Northern Ordnance

TERRIER *U.S. NAVY Surface-to-Air*

Another offshoot of the Navy's *Bumblebee* program, *Terrier* was designed to intercept enemy aircraft at ranges and altitudes beyond the capability of conventional anti-aircraft guns.

Terrier has been operational for five years and it is currently installed on the guided missile cruisers USS Boston and USS Canberra, and on the guided missile destroyer USS Gyatt. Under present shipbuilding programs, 27 additional ships will have *Terrier* capability. These will include: two Forrestal-class carriers, three guided missile cruisers, 1 nuclear-powered guided missile cruiser, 19 guided missile frigates, one nuclear-powered guided missile frigate, and one nuclear-powered aircraft carrier.

Terrier is also suitable for beach-head operations by the Marine Corps. The First Medium Anti-aircraft Missile Battalion, which is stationed at the U.S. Marine Corps Base, Twenty-nine Palms, Calif., is equipped with the missiles.

Booster-launched, the weapon travels to the target by beam-radar guidance.

On shipboard installation each *Terrier* launcher is served by its own magazine and missile overhauling and servicing room. The missiles and their boosters are stored vertically in a ready service ring, one for each arm of the two-missile launcher. The missile is selected, positioned, loaded and placed on its launching rail in a matter of seconds.

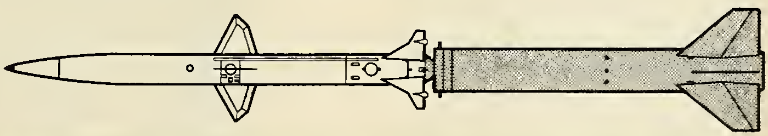
Terrier was developed by the Applied Physics Laboratory of Johns Hopkins University, at Silver Spring, Md. Production is handled by Convair/Pomona, Calif., a division of General Dynamics Corporation.

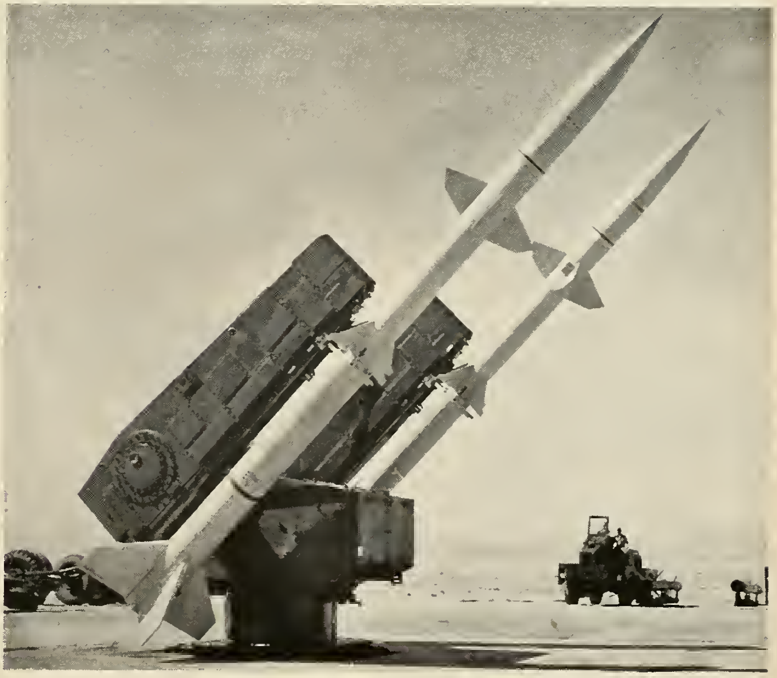
ADVANCED TERRIER

Under development is an *Advanced Terrier* incorporating improved guidance and with substantial improvements in coverage. A larger weapon than the basic *Terrier*, it is expected to have about double the range. Convair is prime contractor. The new missile will eventually replace *Terrier*.

SPECIFICATIONS

DESIGNATION:	SAM-N-7
PRIME CONTRACTOR:	Convair
STATUS:	Operational
RANGE:	10 miles
VELOCITY:	Mach 2.5
FRAME	
Stages:	2
Manufacturer:	Convair
Length (overall), ft.:	15 ft., 27 with booster
Diameter (body), ft.:	1
Span, ft.:	3.5
Weight (gross), lbs.:	2500
GUIDANCE	
Manufacturer:	Reeves/FTL, Sperry
Type:	Beam rider
POWERPLANTS	
First Stage (Booster)	
Manufacturer:	Allegheny Ballistics, The Hicks Co.
Propellants:	Solid
Type & Number:	Uncooled, cast (1)
Second Stage	
Manufacturer:	Allegheny Ballistics
Propellants:	Solid
Type & Number:	Uncooled, cast (1)
WARHEAD	
Type:	High explosive
GROUND SUPPORT MAJOR CONTRACTORS	
Launcher:	Northern Ord.
Radar & ground Control:	Sperry Gyro, Western Elec., Reeves Instr.
Handling & service:	Baker-Raulang, Wash. Tech. Associates
Transport vehicles:	Baker-Raulang





TWIN carriers in reloading position frame two supersonic surface-to-air *Terriers*.

SIDEWINDER *U.S. NAVY Air-to-Air*

Sidewinder holds the distinction of being the first guided missile to destroy an aircraft under combat conditions. This occurred in September, 1958, when the weapon was used by planes of the Chinese Republic against Chinese Communist aircraft.

Sidewinder is a rugged, inexpensive missile with fewer than two dozen moving parts. Personnel require no specialized technical training to handle and assemble it.

The missile has a passive infrared guidance system which permits it to home on the tailpipe of the target aircraft. The seeker occupies the first four inches of the missile, followed by the guidance section. Servo motors are located between the forward fins. Warhead is high explosive.

Developed by the Naval Ordnance Test Station (NOTS), China Lake, Calif., *Sidewinder* became operational in July, 1956, and is now the guided missile most widely used by Navy squadrons with the Sixth Fleet in the Mediterranean and the Seventh Fleet in the Western Pacific. *Sidewinder* will also be used by the USAF and several allied nations.

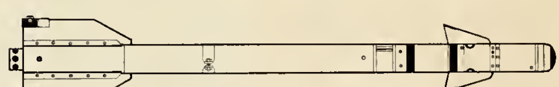
SPECIFICATIONS

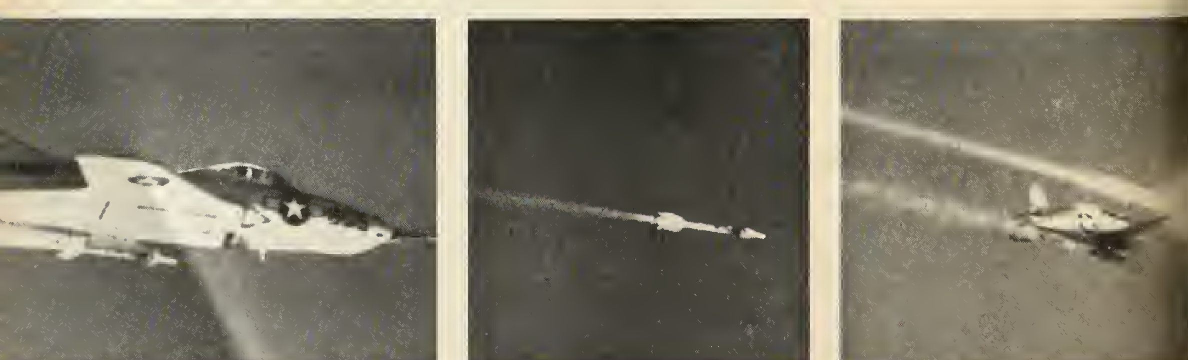
DESIGNATION:	USAF GAR-8 (USN) AAM-N-7
PRIME CONTRACTOR:	Philco, GE
STATUS:	Operational
RANGE:	6-7 miles
VELOCITY:	Mach 2.5
FRAME	
Manufacturer:	Hunter-Douglas, Norris Thermador
Length (overall), ft.:	9.3
Diameter (body), ft.:	.42
Span, ft.:	2
Weight (gross), lbs.:	155
Material (major):	Aluminum
GUIDANCE	
Manufacturer:	Philco, GE
Type:	Infrared homing
POWERPLANT	
Manufacturer:	Naval Powder Plant
Propellants:	Solid
Type & Number:	Uncooled, cast (1)
WARHEAD	
Type:	High explosive
GROUND SUPPORT MAJOR CONTRACTORS	
Check-Out Equipment:	Philco

SAILORS load combat-proven *Sidewinders* on a Navy F9F jet.

SIDEWINDER 1-C

Under development at Naval Ordnance Test Station, China Lake, Calif., is a second-generation version of *Sidewinder*, known as *Sidewinder 1-C*, which will have higher speed and greater range capability. Philco Corp. is prime contractor with NOTS.





SEQUENCE shows *Sidewinder* firing against an F6F drone. The missile's passive infrared guidance lets it home on tailpipe.

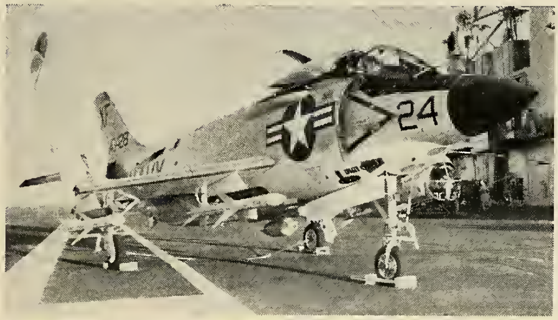
SPARROW III *U.S. NAVY Air-to-Air*

A fleet air defense weapon attaining a speed of 1000 miles per hour immediately after launching and a top speed of more than 1500 miles per hour, *Sparrow III* became operational in August, 1958. It replaced *Sparrow I,* phased out of production.

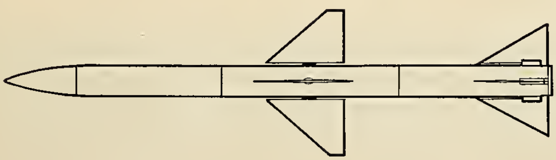
First deployment was with McDonnell F3H-2 squadrons in the Western Pacific. A new version with higher capability will be launched from the supersonic all-weather fighter, the F4H-1. The *Sparrow III* gave the fleet two features not available in earlier missiles of this type: all-weather capability and the ability to attack high-performance enemy aircraft from any direction, including head-on.

Guidance is by radar homing, which becomes active in the first seconds of flight by launching aircraft. Guidance signals deflect the wings of the missile and direct a collision course to the target, even under evasive action.

The now-obsolete *Sparrow I,* which became operational in the spring of 1956, was produced by Sperry-Farragut Co. *Sparrow II,* now cancelled, was an experimental weapon not intended for fleet use. Douglas Aircraft Corp. was prime contractor on *Sparrow II.*



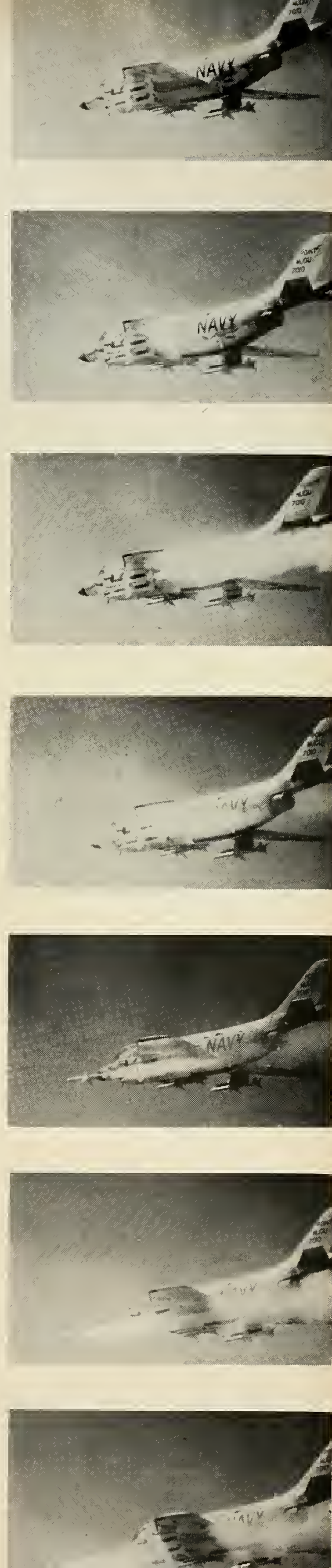
MISSILE on F3H-2 interceptor on flight deck of Midway.



SPECIFICATIONS

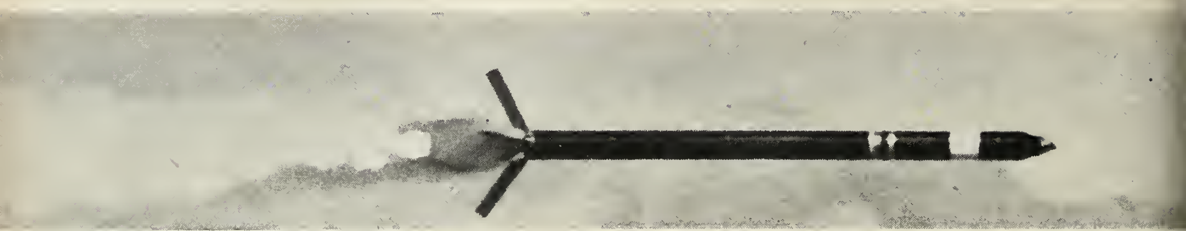
DESIGNATION:	AAM-N-6
PRIME CONTRACTOR:	Raytheon
STATUS:	Operational
RANGE:	5-8 miles
VELOCITY:	Mach 2.5-3
FRAME	
Manufacturer:	Raytheon
Length (overall), ft.:	12
Diameter (body), ft.:	.75
Span, ft.:	3.25
Weight (gross), lbs.:	380
Material (major):	Aluminum and magnesium

GUIDANCE	
Manufacturer:	Raytheon
Type:	Radar homing
POWERPLANT	
Manufacturer:	Aerojet General
Propellants:	Solid
Type & Number:	Uncooled, cast (1)
WARHEAD	
Type:	High explosive
GROUND SUPPORT MAJOR CONTRACTORS	
Handling & Service:	Elgin National Watch Co.

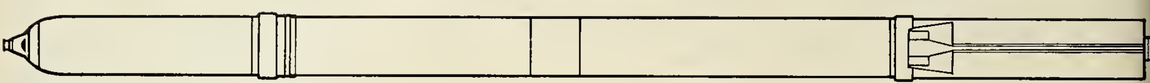


ACTION series shows *Sparrow III* being launched from F3H-2, which can carry four.

ZUNI *U.S. NAVY Air-to-Surface*



IN FLIGHT, ***Zuni*** **clearly shows its blast-operated fins, which fold away and allow the rockets to be carried compactly.**



The Navy's *Zuni* was designed chiefly as a rocket for use by fighter and attack aircraft against ground targets. However, one of the four interchangeable warheads for the weapon permits it to be used against aircraft targets. The other three warheads are (1) general purpose, (2) antitank and antipersonnel, and (3) flare. *Zuni* has blast-operated folding fins, a feature that allows rockets to be carried compactly in expendable launchers each with four rounds. The rocket and its launchers were developed by the Naval Ordnance Test Station, China Lake, Calif., for the Bureau of Ordnance.

Zuni has been approved for operational use, but has not yet made its debut.

Zuni is effective against vehicle convoys, tanks, troop concentrations, gun emplacements, trains, and small ships. In night attack, one *Zuni* can illuminate two square miles of surface area with its flare head, while a second burst can deliver high-explosive warheads to destroy the target in the same pass by the attacking aircraft. Its high velocity and short time-to-target assures it a high-kill potential in air-to-air attacks as well.

Zuni, because it is an unguided weapon, has several advantages: immunity to countermeasures, all-weather capability, high reliability, and simplicity. Because of these advantages and because it does not require any field maintenance or checkout, it is especially well suited to sustained carrier operations in which aircraft complete a mission, land, refuel, rearm, and take off again.

SPECIFICATIONS

PRIME CONTRACTOR:	NOTS
STATUS:	Production
RANGE:	5 miles
VELOCITY:	Mach 3
FRAME	
Manufacturer:	Hunter-Douglas
Length (overall), ft.:	9.17
Diameter (body), ft.:	0.42
Weight (gross), lbs.:	107
Material (major):	Aluminum
GUIDANCE	
Type:	Unguided
POWERPLANT	
Propellants:	Solid
Type & Number:	Extruded (1)—1 nozzle
WARHEADS	
Type & Number:	High explosive—4 interchangeable
FUZES	
Type & Number:	Proximity, point-detonating, base (3)

NAVY plane shown carrying four expendable launchers, each containing four ***Zunis.***

BULLPUP *U.S. NAVY Air-to-Surface*

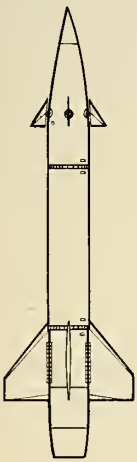
Designed for air launching outside ıe effective range of enemy fire, *Bull-up* provides light attack aircraft with reater capability against tactical surace targets, such as tanks, airfield intallations, truck convoys, oil tanks and ailroads.

Relatively inexpensive, highly accuate and simple in design, *Bullpup* beame operational aboard the USS Lexington on April 25, 1959.

The weapon is guided by radio signal guidance under direct pilot control. Changes in direction are caused by pilot commands on a hand switch in the cockpit. These changes are transmitted to the missile where they are translated to movement of the control vanes.

The missile is divided into three major parts: the nose, containing the guidance control system; the center section, carrying a 250-pound warhead; and the tail, carrying propulsion and tracking flares. Power is supplied by a single solid rocket. The whole assembly weighs less than 600 pounds.

Bullpup is launched by several planes—the FJ-4B Fury, A4D-2 Skyhawk and F-100.



FIVE *Bullpups* can be attached to wings of FJ "Fury" for assault on ground targets.

SPECIFICATIONS

ESIGNATION:	ASM-N-7
RIME CONTRACTOR:	Martin
TATUS:	Operational
ANGE:	4 miles
ELOCITY:	Mach 1+
RAME	
Manufacturer:	Martin
Length (overall), ft.:	11
Diameter (body), ft.:	1
Span, ft.:	2.7 (approx.)
Weight (gross), lbs.:	571
Material (major):	Aluminum
UIDANCE	
Manufacturer:	Martin
Type:	Visual reference radio command
OWERPLANT	
Manufacturer:	Allegheny Ballistics
Propellants:	Solid
Type & Number:	Cast, uncooled (1)
ARHEAD	
Type:	High explosive

TECHNICIANS prepare A4D Skyhawk for attachment of assembled *Bullpups*.

U.S. NAVY MISSILES OF THE FUTURI

ASROC

A sophisticated anti-submarine rocket, *ASROC* is designed for launching from surface ships to seek subs at longer ranges than were possible with cancelled *RAT* (up to 10 miles through air plus limited underwater range). An acoustic homing device provides underwater guidance. Minneapolis-Honeywell has been awarded a research and development contract from Navy BuOrd.

ASTOR

A sub-launched weapon for use against enemy subs, *ASTOR* (Anti-Submarine Torpedo Ordnance Rocket) will carry a nuclear warhead. In development by Westinghouse Ordnance, it is electrically-propelled and wire-guided as it takes off from the launching submarine.

CORVUS

Designated *XASM-N-8, Corvus* is an air-to-surface missile specially designed for carrier-based aircraft, but also adaptable to shore based Navy and Marine planes. Its guidance system will home on enemy radar. Temco has development contract; Reaction Motors Div. of the Thiokol Corp. will supply the solid rocket; Texas Instruments and W. L. Maxson are working on electronic components.

EAGLE

A new trend in air-to-air missiles, *Eagle* is designed for use with relatively slow launching aircraft, with high performance built into the missile instead of the launching plane. This "standoff" weapon will have long air-to-air range—about 100 miles—and can be nuclear-fitted. The contractor is Bendix Aviation; so far, it has reached only the early stage of its long-range development.

GIMLET

A highly accurate unguided air-launched rocket. Its existence has been confirmed by Department of Defense, its contractor has not been identified. Status: now in development.

SUBROC

Goodyear Aircraft has a $65,000,000 contract for research and development work on *Subroc*, an anti-sub missile which can be launched from above or below the surface. *Subroc* system can detect enemy sub at long range (25-50 miles), compute its course and fire the missile. *Subroc* is expected to be defensive weapon for *Polaris* subs. Working with Goodyear are Librascope, Inc. and Kearfott Co., all under the technical direction of the Naval Ordnance Laboratory, at White Oak, Md.

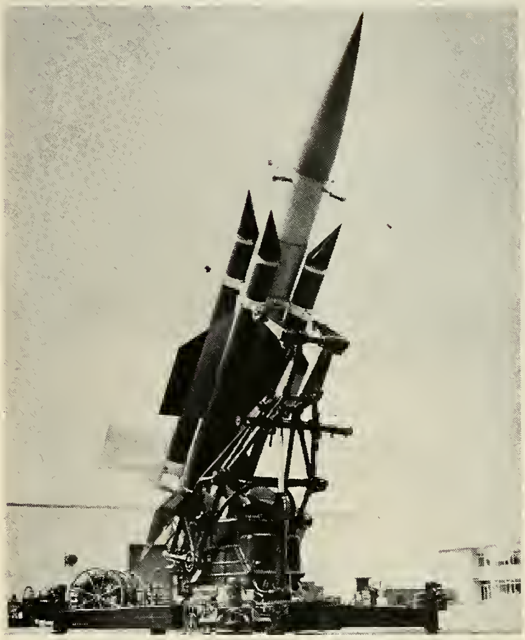
TARTAR

A surface-to-air missile designed for use aboard destroyers, *Tartar* is a junior version of *Terrier* but it has about the same range. It employs beam rider guidance and is powered by a single solid rocket of about 15,000 pounds thrust. In advanced development, it is scheduled for early fleet use aboard three guided missile cruisers and 18 destroyers. Range is about 10 miles, speed above Mach 2 and warhead conventional. Prime contractor for the *Tartar* system is Convair/Pomona, a division of General Dynamics Corp.

GREAT BRITAIN

BLUE STREAK

Britain's only long-range missile project, *Blue Streak* is an intermediate range ballistic missile designed to carry a thermonuclear warhead over distances up to 2000 miles. Ten feet in diameter, *Blue Streak* is more than 60 feet long, roughly the size of the American *Thor*. It is intended to be a "hard-based" missile, launched from underground bombproof silos. Prime contractor and coordinating authority is de Havilland Propellers Ltd., with Rolls Royce, de Havilland Aircraft and Sperry Gyroscope Ltd. as associated contractors.



SOLID-FUELED *Thunderbird* **elevated on mobile launcher.**

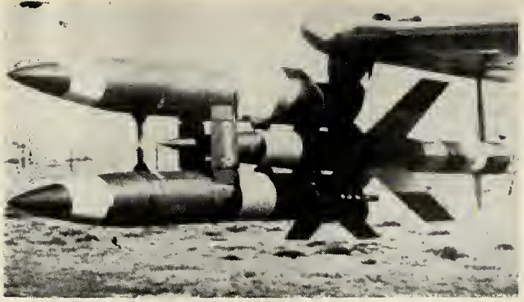
THUNDERBIRD

A surface-to-air missile for use by both the Royal Army and the Royal Air Force, *Thunderbird* is similar in performance and operational use to the American *Nike-Hercules*. Designed for mobility and ease of handling, it is fired from a compact wheeled launcher. The solid-fuel *Thunderbird* is 21 feet long and has a wing span of 5 feet, 3 inches; the center section has a diameter of 21 inches. English Electric is prime contractor. Missile is in production.

BLOODHOUND

Another British surface-to-air weapon, *Bloodhound* is boosted by a solid-propellant rocket to a velocity of 1500 feet per second and sustained on the rest of its flight by two Bristol 16-inch Thor ramjets delivering 15,000 pounds of thrust. *Bloodhound* is 15 feet long and 16 inches in diameter. Guidance is by semi-active homing. Cooperating contractors are Bristol Aeroplane, which manufactures frame and engines, and Ferranti Ltd., which supplies the guidance system. *Bloodhound* is in production for the Royal Air Force.

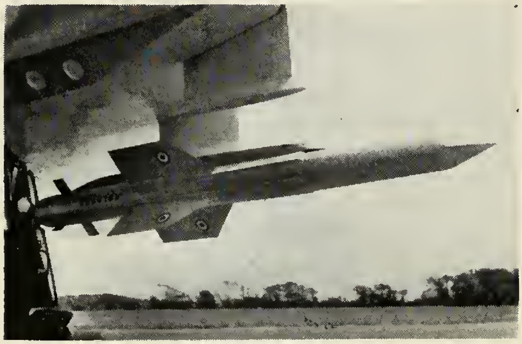
RAF's *Bloodhound* **on guard, North Coates, Lincolnshire.**



DEVELOPED early, *Fireflash* is now a standard weapon.

FIREFLASH

Britain's first operational air-to-air missile, the Fairey *Fireflash* went into development shortly after World War II and was first tested in 1953. *Fireflash* has no sustainer rocket; it is launched by two solid-propellant boosters wrapped around the missile. Body is tubular with cruciform wings. Guidance is by Marconi beam rider. *Fireflash* is carried as armament on the Supermarine Swift MK. 7, the Hawker Hunter and the Australian-built Avon-Sabre. It is now used as a training weapon for the Fighter Command.



INFRARED-guided *Firestreak* attached to a Sea Vixen.

FIRESTREAK

In development for the past six years, *Firestreak* is a more advanced air-to-air missile than *Fireflash*. *Firestreak* is a slim, tubular weapon 7 feet long with cruciform wings and fins. Power is supplied by a single solid-propellant rocket. Range is about eight miles. An infrared detection system which homes on enemy engine exhaust provides guidance. *Firestreak* is carried on under-wing mounts on the Gloster Javelin, English Electric P1 and de Havilland Sea Vixen. Prime contractor is de Havilland Propeller. The missile is in service with the Royal Air Force and in production for both the RAF and the Royal Navy.

FIRING a *Seaslug* from triple launcher of destroyer.

SEASLUG

A fleet defense weapon for the Royal Navy, *Seaslug* is a surface-to-air weapon carried aboard guided missile destroyers of the Hampshire Class. It is fired from triple deck launchers which automatically compensate for ship roll. Guidance is by semi-active homing, integrated with the destroyer's radar. *Seaslug* is powered by a solid-fuel sustainer rocket and boosted initially by four dry rockets mounted concentrically around the missile. The boosters are jettisoned after burnout. Prime contractor is Armstrong Whitworth; General Electric Co. Ltd. has guidance responsibility and Sperry the control system.

HEAVIEST tanks are vulnerable to solid-fueled *Vigilant*.

VIGILANT

An Army short-range battlefield missile, *Vigilant* has a pistol-like firing mechanism which guides it toward its target. Primarily an anti-tank weapon, it is carried in a portable launching cannister which weighs only 45 pounds and can be handled by one man. Solid-fueled, the missile is 53 inches long and has a wing span of less than one foot. Prime contractor is Vickers Armstrong Ltd.

FRANCE

SS-10, SS-11

A versatile missile which can be launched from jeeps, tanks, aircraft or helicopters, *SS-10* and *-11* are short-range battlefield weapons designed primarily for anti-tank use. They are wire-guided and solid-propelled. The missiles have been ordered by nine countries, including U.S. *SS-11* is longer-ranging version. Contractor is Nord Aviation.

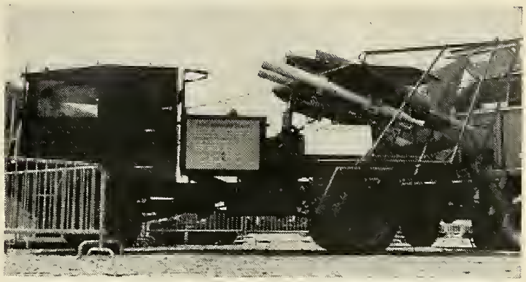
FRENCH Alouette helicopter with four deadly *SS-11's.*

ENTAC

Built by DEFA, *Entac* is similar in use and nearly identical in range and velocity. Also wire-guided and solid-fueled. In production.

SE 4200

A product of Sud Aviation, *SE 4200* is a short-range winged missile. It is launched from a truck-mounted ramp by solid boosters which drop off. Range is about 60 miles. High-explosive charge is carried beneath the missile in a pod.



TWO French Army battalions are armed with the *SE-4200.*

PARCA

In production, the DEFA (Army Arsenal) *Parca* is a surface-to-air weapon with a maximum speed of close to Mach 2 and a range of 14 miles. It is a beam rider and its warhead is detonated by proximity fuze. Power is supplied by a liquid rocket plus four solid boosters. Missile weighs slightly more than one ton.

TAKE-OFF of surface-to-air *Parca,* **now in production.**

SE 4300

A surface-to-air weapon similar in principle to *Nike,* Sud Aviation's *SE 4300* is used as a training vehicle by the French Army. Subsonic, it has a range of 12 miles. Liquid-fueled, it weighs one ton.

MARUCA

Subsonic, *Maruca* is a short-range anti-aircraft missile for use on ships of the French Navy. Fifteen feet long, it has a 5 foot, 3 inch span. Liquid-propelled, it has a range of about 10 miles. It is built by Ruelle Naval Arsenal.

LIQUID-fueled *Maruca* **guards fleet against air attack.**

WITH same job as *Maruca, Masurca* is bigger and faster.

SEMI-TRAILER carries the solid-boosted MATRA *R. 422.*

MASURCA

Another product of the Ruelle Naval Arsenal, *Masurca* is a larger anti-aircraft weapon. Supersonic, it has a 15-mile range. It is 18 feet 8 inches long and has a span of 3 feet 3 inches. Solid-propelled, it weighs slightly more than one ton with boosters.

MASALCA

The Latocoere *Masalca* is a small interceptor missile for use on small ships of the French Navy. It is designed to stop enemy aircraft at ranges up to 60 miles.

TRIDENT

A pilotless aircraft type of surface-to-air weapon, *Trident* is similar in principle to the American *Bomarc.* Liquid-propelled, it is built by Sud Aviation.

TYPE 422

Capable of speeds over Mach 2, the MATRA *R. 422* is a two-stage surface-to-air missile fired from a mobile launcher-transporter. It has a solid booster and a solid sustainer in the second stage. Built and tested in limited numbers, it employs a command guidance system. An advanced "B" version has a range of 30 miles.

TYPE 510, 511

These are MATRA-built air-to-air weapons to be used by various fighters of the French L'Armee de l'Air. *M. 510* is 10 feet long, weighs 350 pounds and has a speed capability of close to Mach 2. It is in production. *M. 511,* externally similar, features an improved guidance system.

TYPE 5103

Built by Nord, the *5103* is an air-to-air missile using beam-rider guidance. Powered by a solid-fuel booster and a solid sustainer, it is in production.

AA.20

A MATRA-built air-to-air weapon, the *AA.20* is used on Mystere A and B fighters. In production, the liquid-propelled missile has a speed of Mach 1.5 and a range of one mile.

R.051

Also built by MATRA, the *R.051* is a solid-fueled air-to-air weapon, about 10 feet long and weighing 350 pounds. It is used on Mirage and Voutour fighters. Speed is Mach 1.5. In production.

BB-10

A guided-bomb type of weapon, *BB-10* features cruciform fins, an annular shroud wing and canard surfaces. It is radio-controlled.

ITALY

AIRONE

Built by Polverfizi Giovanni Stacchini, *Airone* is a short-range surface-to-surface weapon. Solid propelled and unguided, it has a range of about 6 miles.

C-7

Centro Studi Propulsione a Reazione builds the *C-7*, an air-to-air missile. A solid-fuel engine provides power and the missile is guided to its target by an infrared homing system.

ORIONE SAR

A Stacchini product, *Orione Sar* is a limited-range surface-to-air weapon. Winged, with a 15-foot span, it is about 6 feet long.

ROBOTTI

Robotti is the name for a family of battlefield rockets under development by Motofides. The basic rocket is unguided, supersonic, about 16 feet long and 4 feet in diameter.

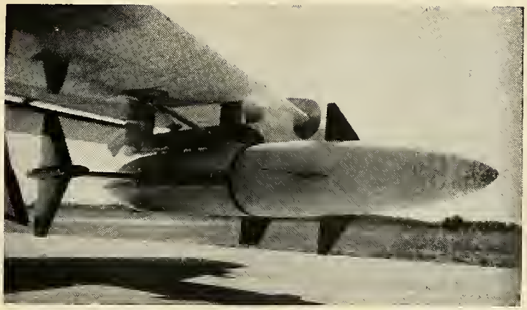
SWEDEN

TYPE 304

About 12 feet long with winged tail and small forward control fins, the Bofors *Type 304* is a tactical air-to-surface missile. The SAAB-32 Lansen all-weather attack plane carries two of these missiles on underwing mounts.

TYPE 315

This is a surface-to-surface weapon, deck-launched from destroyers. About 14 feet long with booster, it has a cruciform tail and small control fins in the nose section.



TACTICAL air-to-surface ***Type 304*** **mounted on aircraft.**

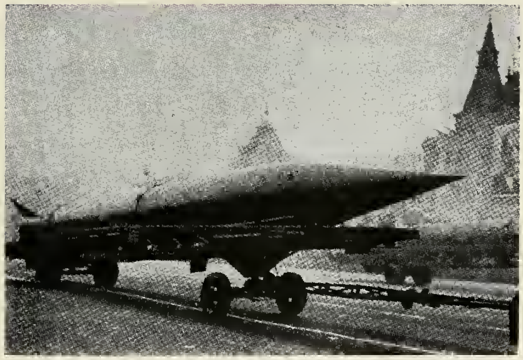
SWITZERLAND

TYPE 54

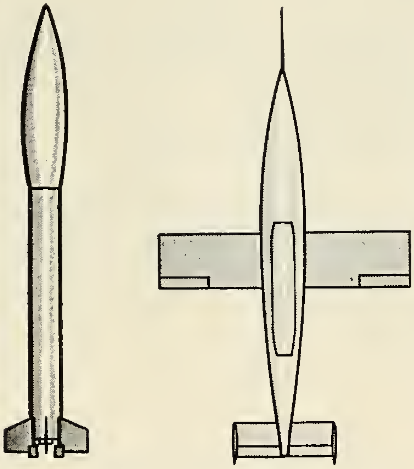
A surface-to-air anti-aircraft weapon, *Type 54* is built by Oerlikon. Twenty feet long, it has a 16-inch diameter and weighs about 800 pounds. A 2000-pound-thrust liquid rocket provides power. Guidance is by beam-riding; warhead has proximity fuze. Advanced versions known as *Types 56* and *57* are in development; *Type 54* is in production.

ALPINE setting for the big ***Type 54.***

SOVIET UNION



NUCLEAR warhead-packing *T-1*, copied from German *V-2*.



M-100A J-2

UNGUIDED *T-5B* artillery rocket shown in Moscow parade.

M-100A

Although little is known of Soviet air-to-air missiles, this type made its first appearance in Korea as an unguided rocket. Later version is believed to have infrared guidance. About 8 feet long, it has a range of about 5 miles. It is solid-propelled. Speed is Mach 2-plus.

J-2

Basically a target drone, *J-2* is a pilotless aircraft type of vehicle also adaptable as a surface-to-surface missile or as an anti-submarine weapon. Subsonic, its range is in the 500-mile category. It is launched by a pair of solid boosters and sustained by an axial-flow turbojet. It is radio-guided.

J-3

An advanced version of *J-2*, the *J-3* is also a pilotless aircraft type, but with swept wings rather than the straight wings on its predecessor. It has four boosters for launch, and in addition to the turbojet sustainer it has a 15,000-pound-thrust ramjet engine which gives it supersonic capability. Its range is 450 miles and it is radio/radar-guided. *J-3* is 38 feet long and has a span of 23½ feet. It carries a one-ton warhead.

M-2

M-2 is a two-stage surface-to-air weapon developed from the German *Rheintochter*. In service, it is launched from mobile units. The 25-foot missile has a speed in excess of 1500 miles per hour. Guided by radar and infrared, it employes solid propellants in both stages.

COMET

This is a family of surface-to-surface missiles which originally started as a research vehicle. *Comet 1* is a short range (100 miles) single-stage weapon in operational service, reportedly also used as a sub-launched missile. It is powered by a single solid-fuel engine. *Comet 2* has a greatly improved powerplant and an inertial guidance system. Its range is in the 500-600 mile class. The 44-foot missile is in production.

ME (IGOR)

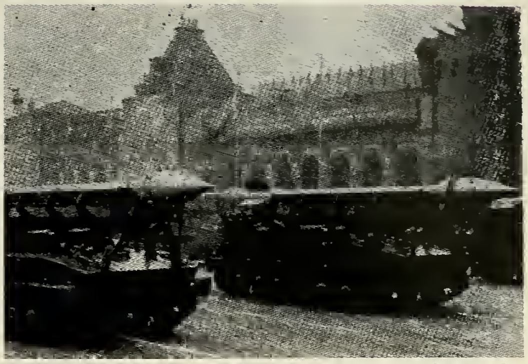
One of the earliest Soviet missiles, the *ME* is an anti-tank rocket of the bazooka type. It is two feet long and has a diameter of 3 1/3 inches. It is powered by a sulphur-based solid rocket with a three-second burning time. The weapon supposedly has a maximum range of two miles but its effective range against tanks is about 1000 yards.

T-1

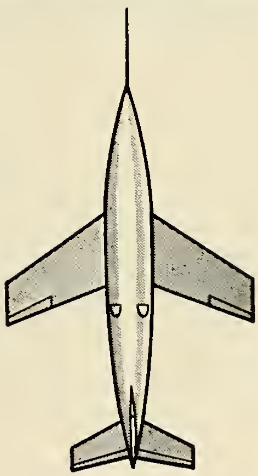
A Soviet copy of the German *V-2, T-1* is a surface-to-surface missile in the medium-range bracket. Frequently seen in Red Square parades, *T-1* has been operational for some time. It is equipped with a mobile, self-propelled launcher. About 50 feet long, *T-1* employs a liquid-fuel rocket engine. It is guided by a radio-inertial system. Grossing about 20 tons, it is equipped with a nuclear warhead.

T-2

The mainstay of the Soviet missile arsenal, the *T-2* has been deployed to a number of bases in Soviet Europe and reportedly has also been concentrated along the southern flank of the satellite countries to cover American air bases in North Africa. Although it stemmed from the German *V-2, T-1* is a greatly advanced version, with a range of more than 1500 nautical miles. A two-stage weapon, it grosses about 60 tons and overall length is more than 100 feet. It has a liquid-propellant (oxygen/alcohol) powerplant in each stage, and guidance is supplied by a radio-inertial system. Warhead is nuclear.



SOLID-powered, *T-5C* **is smaller and lighter than** *T-5B.*



J-3

M-2

REAR view of the highly mobile, operational *T-1,* **guided by a radio-inertial system.**

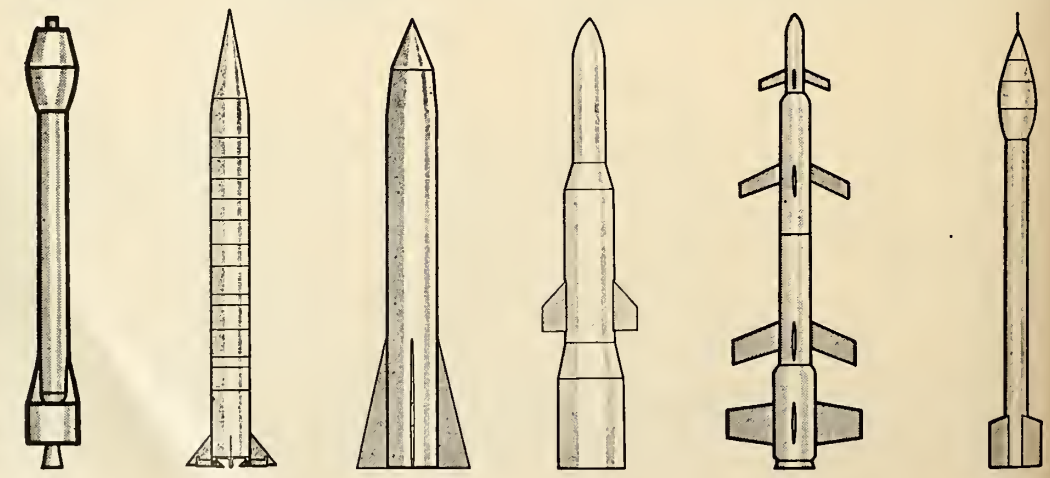
TWO-STAGE surface-to-air *M-2* travels at better than 1500 mph and is guided by both radar and infrared.

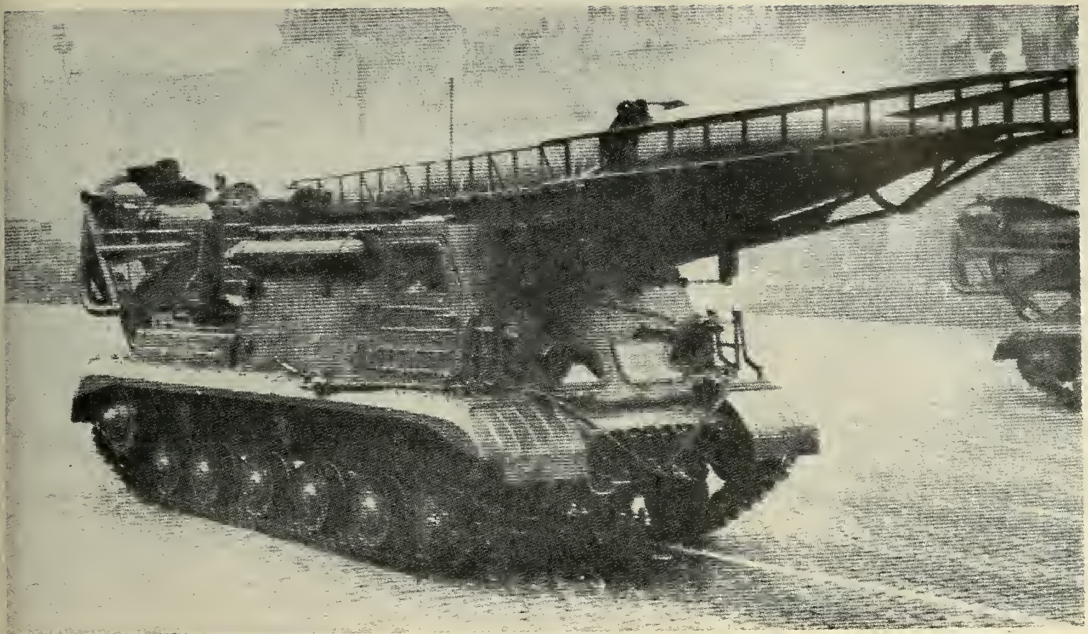
T-3

The much-discussed Soviet intercontinental ballistic missile, *T-3*, according to qualified authorities, is scheduled for operational service in 1959. Like the American *Atlas* and *Titan*, it is designed to carry a thermonuclear warhead more than 5000 miles. It is a two-stage missile employing high-thrust liquid-fuel engines in both stages; estimates of the amount of thrust vary widely. The missile has an overall length of 100-125 feet and it grosses about 85 tons. Guidance is radio-inertial. An advanced version of this weapon is known as *T-3A*. This version, in development production status, has an estimated range of more than 6000 miles and a velocity of 16,000 miles per hour. Like *T-3*, it is a two-stage liquid-fuel missile with a higher thrust engine in the first stage.

T-4

Capable of delivering a one-ton warhead over a distance of 1000 miles, *T-4* falls in the medium-range ballistic missile category. It is 50-55 feet long and has a diameter of 6½ feet. Grossing 35 tons, it is a two-stage weapon, both stages liquid-fueled. Warhead is nuclear.





OPERATIONAL *T-7A* is comparable to U.S. Army's *Corporal* and has a range of 70 miles and solid-fuel powerplant.

T-4A

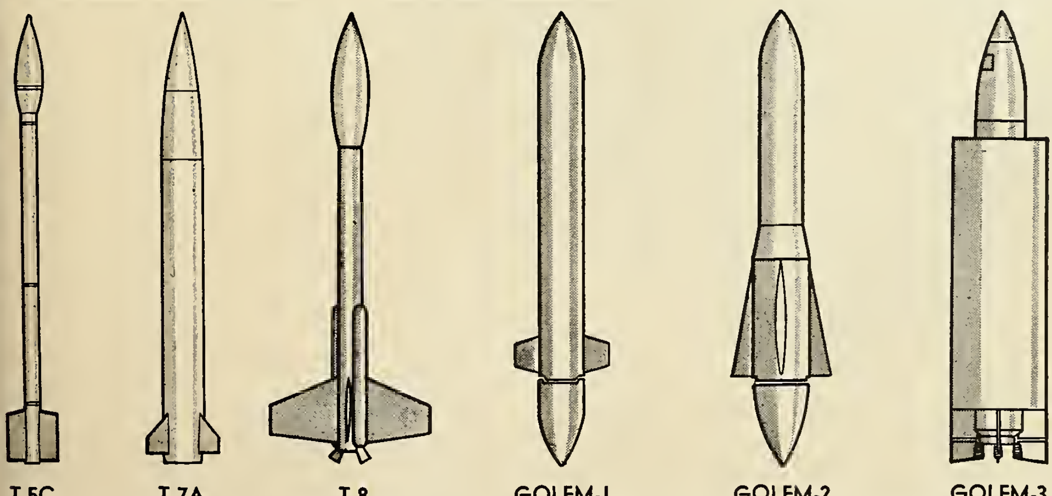
This is the Soviet counterpart of the American *Dyna-Soar* boost glide bomber, stemming from German *Saenger-Bredt* antipodal bomber in design status at the end of World War II. Although reliable sources have reported that the U.S.S.R. is working actively on this project, its status is unknown.

T-5

A short-range artillery rocket, *T-5* is one of the earlier Soviet missiles. Grossing about 2½ tons, it is 32 feet long and 3 feet in diameter. A *T-5* field battery has six launchers each. The rocket is unguided.

T-5B, T-5C

Also artillery rockets, *T-5B* and *T-5C* are later versions of the basic *T-5*. Both have been seen frequently in Moscow parades and both are in operational service. They are carried on self-propelled tank-like launchers. *T-5B* is 30 feet long and has a range of 25 miles. *T-5C* is a smaller weapon, 25 feet long and about a foot and a half in diameter. It has a solid-propellant powerplant. Both weapons are unguided.



T-6

Another surface-to-air weapon, *T-6* is a two-stage missile with a service ceiling of about 60,000 feet. The weapon grosses two tons and has a speed in excess of 1500 miles per hour. Its first stage has four solid boosters and there are two more solid rockets in the sustainer power plant for the second stage. It is radar-guided and carries a high explosive warhead with proximity fuze.

T-7A

The *T-7A* is an adaptation of a research rocket to military use as a short-range surface-to-surface missile. In service, it is about 25 feet long and about 2½ feet in diameter. Where the original version was liquid-propelled, the operational weapon has a solid-fuel powerplant. Comparable to the American *Corporal,* it has a range of 70 miles.

T-8

An anti-aircraft weapon, *T-8* is the Soviet counterpart of the American *Nike-Ajax*. In service for several years, it has a range of 15 miles and carries a high explosive-proximity fuzed warhead. Speed is Mach 2-plus. The missile is boosted by two solid-propellant rockets; a larger liquid rocket of 4600 pounds thrust powers the second stage. Fired from mobile launchers, it is used by field batteries in non-permanent positions.

GOLEM-1

Another missile adapted from German World War II work, *Golem* is an underwater-to-surface weapon launched from a chamber which is towed by a submarine. In production, it has a range of about 400 miles. It has a liquid-fuel engine which burns oxygen and alcohol and it employs a radio inertial guidance system. Grossing 16½ tons, it is 54 feet long.

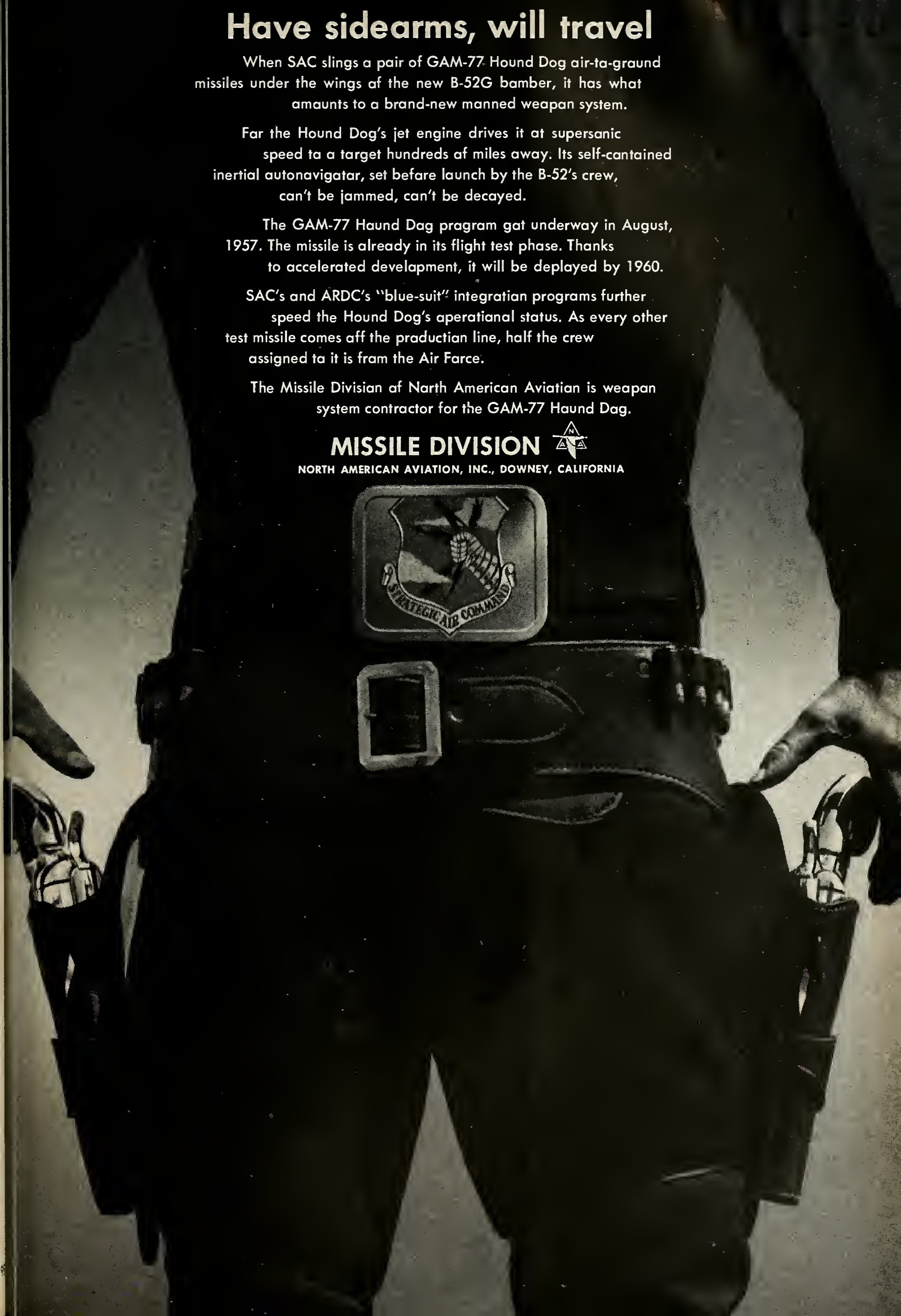
GOLEM-2

A longer-ranging underwater-to-surface missile, *Golem-2* is reportedly a naval version of the *T-2* IRBM. A two-stage weapon like *T-2,* it has liquid-fuel engines. Launching is from the towed underwater chamber, as in *Golem-1*. *Golem-2* is 57 feet long, 7 feet in diameter and has a range of about 1200 miles. It is still in developmental status.

GOLEM-3

An anti-aircraft weapon designed for launch from a submarine or surface vessel, *Golem-3* has a range of about 8 miles and reportedly has underwater launch capability. It is 17 feet long and 2 feet in diameter. Power is supplied by a 15,000-pound-thrust solid-fuel engine. The missile weighs 2.2 tons and is guided to its target by an infrared system.

MODEL of *Sputnik III* satellite dramatizes peaceful use of launching capability. Inset shows "ion trap."



Have sidearms, will travel
When SAC slings a pair of GAM-77 Hound Dog air-ta-graund missiles under the wings af the new B-52G bamber, it has what amaunts to a brand-new manned weapan system.
Far the Hound Dog's jet engine drives it at supersanic speed ta a target hundreds af miles away. Its self-cantained inertial autonavigatar, set befare launch by the B-52's crew, can't be jammed, can't be decayed.
The GAM-77 Haund Dag program gat underway in August, 1957. The missile is already in its flight test phase. Thanks to accelerated develapment, it will be deplayed by 1960.
SAC's and ARDC's "blue-suit" integratian programs further speed the Hound Dog's aperatianal status. As every other test missile comes aff the praductian line, half the crew assigned ta it is fram the Air Farce.
The Missile Divisian af Narth American Aviatian is weapan system contractor for the GAM-77 Haund Dag.
MISSILE DIVISION
NORTH AMERICAN AVIATION, INC., DOWNEY, CALIFORNIA
STRATEGIC AIR COMMAND

Saturn's Test Tower To Be Ready by Sept. 1

HUNTSVILLE—Construction work was completed last week on the modification of the 145-foot rocket engine static test tower at Redstone Arsenal to accommodate the 1½-million-pound-thrust *Saturn* booster.

The Department of Defense says it expects the tower will be ready for use when support facilities are finished Sept. 1. The *Saturn* test vehicle will be delivered to the Army Ballistic Missile Agency's Test Laboratory in November. The first static testing is due in December.

ABMA is developing the *Saturn* booster, a clustering of eight H-1 liquid propellant motors—for the Advanced Research Projects Agency, Department of Defense, for heavy space applications. The booster will stand 75 feet tall and have a diameter of 22 feet.

Steel pilings were driven down to bedrock, in some cases as far as 60 feet, to provide structural support for the test tower. The $850,000 job has been in progress since January. In addition to a new structural steel test position the work consists of an enlarged blast deflector pit, a steel buttress for additional horizontal strength, and two 101-foot steel girders that help support a super-structure housing a crane hoist atop the concrete tower.

Earlier, ARPA announced selection of a modified **Aerojet** first *Titan* stage and a new **Pratt-Whitney** and **Convair** *Centaur* rocket as the second and third stages of the *Saturn* project, which is to provide a reliable system for lifting multi-ton loads into high orbit and deep space by 1962 or 1963.

The three-stage *Saturn* will weigh at liftoff about 580 tons of which about 500 tons will be propellants, and will stand about 200 feet tall.

The modified *Titan* second stage will be somewhat longer than its regular 54 feet and will be 10 feet in diameter. It will provide a 360,000-pound thrust. The third-stage *Centaur* will use two rocket engines with combined thrust of 30,000 pounds and be 10 feet in diameter.

The vehicle will have an all-inertial guidance system to automatically compensate for loss of thrust if one of the booster engines should fail.

The third-stage *Centaur* is being developed by Pratt & Whitney, and Convair.

CLASSIFIED

TRUAX

Capt. Robert C. Truax, USN, (Ret.), former national president of the American Rocket Society, has joined Aerojet-General Corp. as director of Advanced Development at its Liquid Rocket Plant in Sacramento. Truax, 42, who has spent almost his entire professional career in the development of rockets, guided missiles and satellites, received the Robert H. Goddard medal in 1951 for his outstanding work in rocket development and last year was awarded the Navy's Legion of Merit decoration for his contribution to the *Polaris* program. (See M/R profile, November, 1957, p. 114.)

WAWRA

Aerojet also has named **Cecil W. Wawra** of Paris director of European Operations. He will coordinate the company's activities in Western Europe, concentrating on projects in which A-G is associated with European companies in national or NATO defense programs. From 1951 to 1956, Wawra represented the General Tire and Rubber Co., parent-company of Aerojet, at Rome, and since 1956 has represented both General Tire and Aerojet-General in Paris.

MILLER

Dr. Curt E. Miller, a specialist in aero and space medicine, has joined the Aeronautics Division of Wiancko Engineering Co., where he will conduct research on animal instrumentation and the effects of inertial forces and other space environmental factors associated with getting man into space.

Matthew H. Portz became the National Aeronautics and Space Administration's Western Public Information Officer on July 13. Located at the NASA Western Coordination Office, 150 Pico Boulevard, Santa Monica, Calif., he will be responsible for information activities in Southern California and neighboring states. Portz is transferring to the new post from the NASA Lewis Research Center, Cleveland, where he has been Information Officer since August, 1956. His successor at Lewis is **Harry J. McDevitt Jr.,** formerly of the General Electric Co. News Bureau.

LUNGER

Election of **Wilbur E. Lunger** as staff vice president of manufacturing, and **H. Ben Young** as staff vice president of engineering and research of ACF Industries, Inc., has been announced. Both of the new corporate vice presidents were officers in ACF operating divisions—Lunger as vice president of manufacturing with American Car and Foundry division in New York City, and Young as director of engineering and research at W-K-M division, Houston.

Henry P. Steier, former M/R electronics editor, has been named corporate director of Public Relations for Lear, Inc. Immediately prior to joining Lear, Steier was special assistant for Technical Information to E. R. Quesada, Federal Aviation Agency administrator. He was with American Aviation Publications, Inc., publishers of M/R, from 1955 to 1958 after holding increasingly responsible positions in the electronics engineering field. Steier was a major contributor to the design and development of the first high-production cathode ray tubes for commercial television and holds patents in the field of electron optics and secondary emission techniques.

A "TIME-TABLE" FOR SPACE CONQUEST

BY **1963** – INSTRUMENTED PLANETARY SOFT LANDING

BY **1968** – SPACE STATION FOR STAGING TO MOON AND PLANETS

BY **1970-75** – MOON BASE

These predictions were made by Alexander Kartveli, Vice-President for Research & Development at Republic Aviation, and one of the most optimistic of the 56 leading space experts of the world who were consulted by the U.S. House of Representatives Committee on Astronautics & Space Exploration for its report: "The Next 10 Years in Space, 1959-1969."

JOIN REPUBLIC IN AN **INTEGRATED ATTACK** ON PROBLEM AREAS OF **SPACE EXPLORATION**

It's the fervent conviction of engineers and scientists at Republic Aviation that the courageous "Space Time-Table" above is entirely feasible – given a tradition-free, integrated approach to the problems. Such an approach is evident at Republic Aviation. Here, groups of specialists from many disciplines are working in close collaboration to solve problems across the entire spectrum of space technologies, which limit today's interplanetary and upper atmosphere flight capabilities.

Expanded by $35,000,000 last year, Republic's integrated Research and Development program has already produced signal advances in space guidance concepts; in new propulsion systems (plasma, nuclear); in radiation physics; in new materials and processing techniques; in unique hypersonic configurations; and in prototype development of hardware (as an example: hydraulic systems that operate reliably up to 1000°F).

Professional men—who can meet new challenges with enthusiasm and dedication – are urged to look into openings with our R&D groups, working in an atmosphere of exhilarating intellectual adventure.

Electronics

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Theoretical Gasdynamics
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Hydromagnetics
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Combustion and Detonation
Instrumentation
High Power Pulse Electronics

Nuclear Propulsion and Radiation Phenomena

Nuclear Weapons Effects
Radiation Environment in Space
Nuclear Power & Propulsion Applications
Nuclear Radiation Laboratories

Send resume in complete confidence to: Mr. George R. Hickman, Engineering Employment Manager, Dept. 4G-4

REPUBLIC AVIATION

Farmingdale, Long Island, New York

— reviews —

ZIRCONIA: ITS CRYSTALLOGRAPHIC POLYMORPHY AND HIGH TEMPERATURE POTENTIALS. B. C. Weber and M. A. Schwartz, Aeronautical Research Laboratory, WADC, 26 pp, available from OTS, U.S. Department of Commerce, Washington 25, D.C.

Zirconia (ZrO_2), with its melting point of 4850°F, is one of the most promising materials for high-temperature applications, according to this report. In addition to being among the most stable of the refractory oxides, it has very high strength, good corrosion resistance, hardness, high thermal shock resistance, and high thermal conductivity—qualities important in rocket, ramjet, and missile applications. The report clarifies some of the controversial data presented in literature concerning this refractory metal, reviews the chemistry of zirconia, and presents some of its future potentialities.

Also described are advancements in metal-modified oxides. According to the report, the usefulness of zirconia is now dependent on controlling its crystallographic transformation.

CTR-292 FIBER GLASS AND GLASS LAMINATES, 1930-58, available from OTS, U.S. Department of Commerce, Washington 25, D.C.

A catalog of technical reports which lists all reports of research in the fields of fiber glass and glass laminates has been published by the Office of Technical Services, U.S. Department of Commerce.

Many of the reports listed are the result of research conducted for the Army, Navy, Air Force, and other agencies of the U.S. Government. Others are German documents captured by the Allies during World War II.

SOVIET RESEARCH IN LUBRICANTS AND LUBRICATION: Dec. 1958, 27 pp, available from OTS, U.S. Department of Commerce, Washington 25, D.C.

Russia and her satellites were not ahead of the United States in the field of lubricants and lubrication at the beginning of 1958, but were trying to gain headway by studying the work of others, Soviet literature indicates.

According to a survey of published Russian literature by a U.S. Government agency, "It appears that Soviet scientists are not ahead in any process, products, or applications." The study included material on lubrication, lubricants and additives, and formulation of lubricating compositions.

The review of abstracts of Russian technical reports appearing from 1950 to the end of 1957 showed that Red researchers were apparently concentrating on areas fairly well known and defined by U.S. scientists.

This may mean, the survey concludes, that while the Soviets realized the potential importance of the field, they were not especially proficient in it.

A large amount of research, the report observes, was being expended on hydrocarbon chemistry, an effort which could lead to new petroleum processes and products.

ON THE PROBLEM OF RE-ENTRY INTO THE EARTH'S ATMOSPHERE, A. C. Robinson and A. J. Besonis; WADC, U.S. Air Force. 68 pp. $1.75. Available from OTS, U.S. Department of Commerce, Washington 25, D.C.

Problems concerned with safely recovering a manned satellite after it has orbited the earth or gone around the moon are presented in this Air Force report from the standpoint of deceleration, heating, and accuracy of impact.

The study indicates further that simple, non-lifting re-entry will be feasible from satellite orbits. It appeared possible to achieve impact accuracy sufficient for ground installation, suitably alerted, to find the vehicle. The lunar re-entry, however, presents a severe total heat problem, and accuracy requirements are such that some lift or other control will probably be required.

Deceleration and peak heating rates were found to be no larger than those encountered in ballistic missile re-entries, but the total heat input was much larger because the heating lasts longer.

ORBITAL STORAGE OF CRYOGENIC FLUIDS, D. R. Cramer, WADC, U.S. Air Force. 13 pp. Available from OTS, U.S. Department of Commerce, Washington, D.C.

This Air Force report indicates that simple, multi-layer reflective-type shielding provides the answer to the problem of storing low-boiling point propellants during long space flights.

A study was made to determine if research on combined regenerative and radiative heat transfer techniques was necessary for the development of storage containers. It was found that for most containers of probable capacities, yearly liquid hydrogen losses can be maintained below an acceptable 5% if sufficient reflective layers are used.

Research specifically in the heat transfer area is not required for the development of such containers, the report concludes.

WELDING AND BRAZING OF MOLYBDENUM, N. E. Weare and R. E. Monroe, Defense Metals Information Center, Battelle Memorial Institute for Office of Director of Defense Research and Engineering, Department of Defense. 47 pp, $1.25. Available from OTS, U.S. Department of Commerce, Washington 25, D.C.

The report identifies the best methods, as drawn from the published literature, for welding molybdenum to itself.

It also provides guidelines for producing the most useful molybdenum joints. Metallurgical considerations involved in joining the metal are discussed, as well as cleaning and testing techniques.

Joining processes examined include fusion, resistance, and solid-state welding, and brazing.

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From Little Acorns...

Recently, one of NASA's procurement chiefs showed me a photostat of the first U. S. Government airplane contract, dated Jan. 27, 1908. It called for construction by Wilbur and Orville Wright of a heavier-than-air machine sufficiently "demountable" to be carried on "an ordinary Army wagon." The contract pricc was $25,000. Scribbled in the margin of the document in faded ink was the prophetic phrase: "from little acorns . . ."

As space technology moves out of the acorn stage, the success of the United States program will continue to be in direct ratio to the quality of teamwork between government and industry. NASA's predecessor, the National Advisory Committee for Aeronautics, achieved a high degree of teamwork with the aircraft industry. When NASA was formed, it was determined that its space mission should not interfere with the type of service NACA used to provide.

Therefore, NASA was divided into two separate technical branches: the Office of Aeronautical and Space Research and the Office of Space Flight Dcvelopment. Although the former will naturally be involved in research for NASA's own operational needs in space flight, it will also continue to provide research advice and assistance to the industry. However, most leaders of the aircraft/missile industry realize that NASA's principal mission for some time to come is research and development. They are also aware that an R&D organization seldom, if ever, deals in large production contracts.

Civilian-oriented science programs do not require busy assembly lines producing quantities of rockets and space vehicle components. With the possible exception of some workhorse vehicles, such as the relatively inexpensive *Scout,* the new large rockets designed for civilian purposes will be produced in limited quantity.

Thus, NASA will not be stockpiling vehicles and parts as the military programs must. The situation differs only slightly in the case of scientific payloads. Even in a series of experimental projects, such as the *Pioneer* space probes, the payload packages vary with each shot, according to the data to be collected. One type of vehicle will be used to launch several types of payloads. Both rockets and payloads, however, call for a very high degree of reliable design and assembly.

We have determined, for example, that further reliance upon *Juno II's* and *Thor-Ables* is uneconomical for space science purposes because they have limited load-carrying capacities and lack versatility. Neither vehicle has upper-stage guidance. so the payload must be spin-stabilized, thus restricting both its mass distribution and gross weight. Hence NASA's Fiscal Year 1960 *Juno II* and *Thor-Able* launching schedules have been curtailed and more funds and effort are being devoted to development of *Thor-Deltas* (which have coasting guidance) and to the larger *Vegas* and *Centaurs.* Future NASA vehicles — *Thor-Deltas, Vegas,* and *Centaurs*—can lift heavier payloads far more cheaply and efficiently than the *Juno II's* and *Thor-Ables.*

What, then, is the incentive for a company to develop a rocket or a scientific payload for NASA, only to have it become obsolete very quickly, with no production contracts to look forward to?

The answer lies in what rocket-industry leaders themselves have said repeatedly. They consider their work for NASA vital to the future of their companies because this agency is in the forefront of space research. These industry officials know that the positions and continued growth of their companies depend on the vigor of their research divisions. They also point out that despite the relatively small size of the NASA budget request for Fiscal Year 1960 ($485,300,000), NASA's priority is second only to that of national defense. Moreover, as NASA develops, its budget, too, will inevitably grow in the years ahead.

In final analysis, however, the greatest stimulus of all is the challenge to industry's technological capabilities.

Alex V. Topchiyev, a prominent member of the Soviet Academy of Sciences, once told a news conference that *Lunik* was ". . . a natural result of the free development of science and technology under socialism where boundless scope is given to human talent and genius."

If this situation can prevail in the USSR, then imagine what can be accomplished in a free society.

NASA is confident that our industry-government team will prove to the world's uncommitted peoples what we have always known; namely, that in the space realm, as in other fields of endeavor, democracy provides far and away the best climate for talent and genius.

DR. T. KEITH GLENNAN
Administrator, NASA

T. (for Thomas) Keith Glennan has been Administrator of NASA since it was created in 1958. An electrical engineering graduate of Yale, he served through World War II as director of the Navy's Underwater Sound Lab at New London. He then was associated with Ansco until becoming president of Case Institute in 1947. During 1950-52, Glennan served as a member of the AEC. He holds several honorary Doctor's degrees and is a Fellow of the American Academy of Arts and Sciences.

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NEW PRODUCT BRIEFS

EQUIPMENT. It may soon be pos- to locate and permanently record roduction speeds lack of bond in ad honey-comb sandwich—both flat curved shapes. The new Thermo- aic method is now receiving final aation in the engineering-research cties of Magnaflux Corporation, hgo, where several aircraft plants e co-operating in tests. The method oces an exact pattern of every point od bond between the core material skin, and of over-heavy braze as el The dark brown pattern remains eranent, fixed on the skin's surface nt removed by a solvent, thus per- itg photography for records, and ital examination of the section or ar n both vendor and customer plants sired. Installations will include full utatic control, conveyorized spray eves and controlled heat application.
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ES SHELLS. Thor Ceramics, Inc. an- ou es a new range of epoxide resin el for encapsulating all types of com- on ts. Available holes and leads facili- te assembling operations on winding rn The low water absorption charac- ri cs of thermosetting epoxide resin ot t the enclosed components from at and atmosphere. Sealing is ac- m ished with liquid epoxy resin at ing the material of shell. The shells v high tensile strength and operate a maximum temperature of 150° . eir excellent electrical qualities ov a dielectric constant of 3.70 at 60 rcl with a low loss factor of 0.009. ari ions in shapes from tubular to ct gular may be ordered. Diameters ng from 1/8" to one inch and heights om /4" up. Identifying colors may also dered.
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EF LING VALVE. A refueling valve #-1755-000) is now available from er Supply Mfg. Co. which is readily da ble to unusual flow rates and to nc exotic and high energy fuels and he fluids. Normally the valve is built h dle a flow rate of 200 g.p.m. with erating pressure of 50 psi. Oper- in temperatures range from —65° - 60°F., fuel and ambiet.
rc No. 231 on Subscriber Service Card.

FUNCTIONAL MICROSOURCE. SIE (Southwestern Industrial Electronics Co.), a division of Dresser Industries, Inc., announces the introduction of its latest series of K-1 Microsource. The new K-1 Microsource is designed for use with any standard oscillator within its frequency range to produce small, known, controlled test signals. In addition, an internal battery and associated polarity-reversing switch are now incorporated to allow testing high-gain dc amplifiers. An added feature is the spring-loaded, momentary-on position in the dc "on-off" switch to allow generation of positive or negative test pulses. The new K-1 consists basically of a potentiometer, a rectifier type voltmeter and a shielded step attenuator. Voltages are set on the meter by the potentiometer, and multiples of the voltage selected by the step attenuator. Output is read directly on the front panel meter, and is continuously variable from zero to 10 volts, with a db scale also provided. The K-1 continues to feature the human-engineered appearance and functional ease of use pioneered by SIE in its Advanced Design Instrument line.
Circle No. 232 on Subscriber Service Card.

CONTACTOR. A new secondary contactor which can be used with any dc welding power source to interrupt high amperage welding current has been announced by Air Reduction Sales Company. The unit is specifically designed as auxiliary equipment for Aircomatic (Airco's gas-shielded metal-arc process) and Heliweld (Airco's tungsten-inert-gas process) applications where the power source employed does not have a primary contactor. Rated at 600 amperes, the unit operates on 115 volts, single phase, 50 or 60 cycle current, and will effectively interrupt welding currents up to capacity at 100% duty cycle.
Circle No. 233 on Subscriber Service Card.

PLIER. Mathias Klein & Sons, has introduced a new oblique cutting plier designed with high leverage to do many of the jobs too tough for a conventional oblique cutter to handle. "Handform" handles assure greater ease and comfort in cutting. Catalog No. 228-8. Length—8 inches.
Circle No. 234 on Subscriber Service Card.

MISSILES AND ROCKETS
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MISSILE LITERATURE

CHECKOUT TECHNIQUES. Ling Aviation Inc. has published a booklet reviewing automatic systems checkout as related to techniques instaad of equipment to permit broadest coverage of approaches applicabla to design of automatic systems checkout equipment.
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SEMICONDUCTORS. Ohio Semiconductors, a new company producing compound semiconductor devices and materials, offers full descriptive literature on the MS-41 Magnetoresistor, HS-51 Halltron, Hr-31 Halltron, MC-1 Magnetic Circuit and TA-11 "Thermo-Cell" Thermoelectric Junction. Each piece gives basic specifications, examples of applications and charts showing performance characteristics.
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CATALOG. Electronic Speciality Co. announces the publication of a new 40-page catalog, No. AV-100, describing the complete facilities and products of the Avionics Division of the Company. Products covered by this publication include static time dalays, standard time delays, missile fuzes and programmers, flashers, voltage and frequency sensors, meter relays, power supplies and inverters, automatic check-out equipment and specialty devices. Included also are descriptions of the application of these products in complete systems developed by the Electronic Specialty Co. Typical systems included are Miss-Distance Indicator, Terrain Clearance System, Zero Delay Radar Augmenter, Proximity Fuze, Command Guidance Receiver, Word Warning, Coded Flasher, Autopilot, Aircraft Electrical Supply Sensor and Controller, and Flight Control System analyzer.
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DIODE CATALOG. A four-page catalog on silicon glass diodes is now available from Silicon Transistor Corp., manufacturer of silicon diodes and power transistors. The two-color spec sheet lists some of tha firm's high reliability general purpose and fast switching diodes and includes curves, charts and other pertinent data.
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BROCHURE. Capabilities for tha isolation and reproduction of a wide variety of environmental characteristics are described in a new brochure entitled Environmental Facilities, publishad by the Missile and Space Vehicle Department of the General Electric Company. Reproducible environments discussed in tha brochure include conditions of vibration, with varying temperatures and eltitudes; humidity; tension and compression; shock; acoustics; acceleration; and pressure. Also described are chambers designed to simulate natural conditions of rain, sunshine, sand, salt spray, and fungus culture.
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GYROS. The new four-page, two-c brochures—one on floatad frae g and one on rate gyros—ara now a abla from Daystrom Pacific. Exploc view, airbrush drawings show typ gyro designs. Major dasign features application advantages are pointad Complete specifications are providad two series of free gyros, FC35, FC45, and for ona series of rate gy R-51.
Circle No. 214 on Subscriber Service C

FASTENERS. A technical file folde cluding a new MS conversion table fasteners has just been released by Century Fastener Corporation. folder attempts to answer all quest pertaining to pracision, accuracy dependabla service for screws, b stop-nuts and special screw req ments.
Circlo No. 215 on Subscriber Service

POWER SUPPLIES. The Electronic search Associates, Inc., announces availability of a four-page catalog w describes their Magitran line of state regulated power supplies. T supplies combine the features of r netic and transistor regulators, and many novel features not presently a able in conventional designs. The c log sheet provides information several new intermediate current u as well as new specification data high current models. The catalog s provides full descriptive mate graphs, specifications, physical data related information.
Circlo No. 216 on Subscriber Service

COMPUTERS. A 6-page illustr bulletin describing the new G-15 di computer with particular emphasis the magazine-loaded photo tape ra is offered by the Bendix Computer Also included are descriptions of PC and INTERCOM 1000 programming tems; accessory punched card, magr tape and paper tape equipment; eral special purpose devices and specifications. Copies will be mailec request.
Circlo No. 217 on Subscriber Sorvice

MAGNESIUM HYDRIDE. Immec availability of a new technical bul on magnesium hydride is announcec The Dow Chemical Company. The page manual includes a general cussion of the metal hydrides with tions covering properties, reactions, and handling precautions for ma sium hydride. The unusual combina of properties in magnesium hyc suggests a wide range of uses such Captive hydrogen for foaming; hydrogen for drying operations source of highly reactive magnesiur source of readily released hydroge reducing agent; energy for propel or explosives; a polymerization cat
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