JUNE 8, 1959

WELDING HIGH-STRENGTH CASE

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

AN AMERICAN AVIATION PUBLICATION

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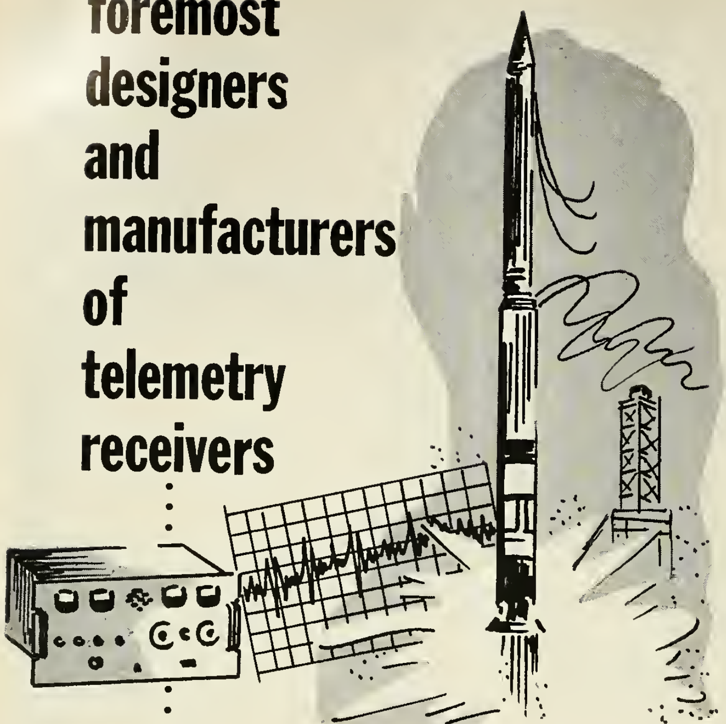

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missiles and rockets
MAGAZINE OF WORLD ASTRONAUTICS

JUNE 8 HEADLINES

ASTRONAUTICS ENGINEERING

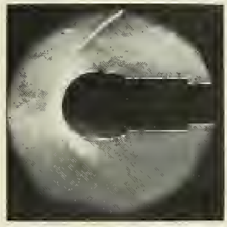
MISSILE SUPPORT

MISSILE ELECTRONICS

THE MISSILE WEEK

DEPARTMENTS

COVER: For what happened to Diversey Engineering's near 'perfect' rocket case, read the story on p. 23.

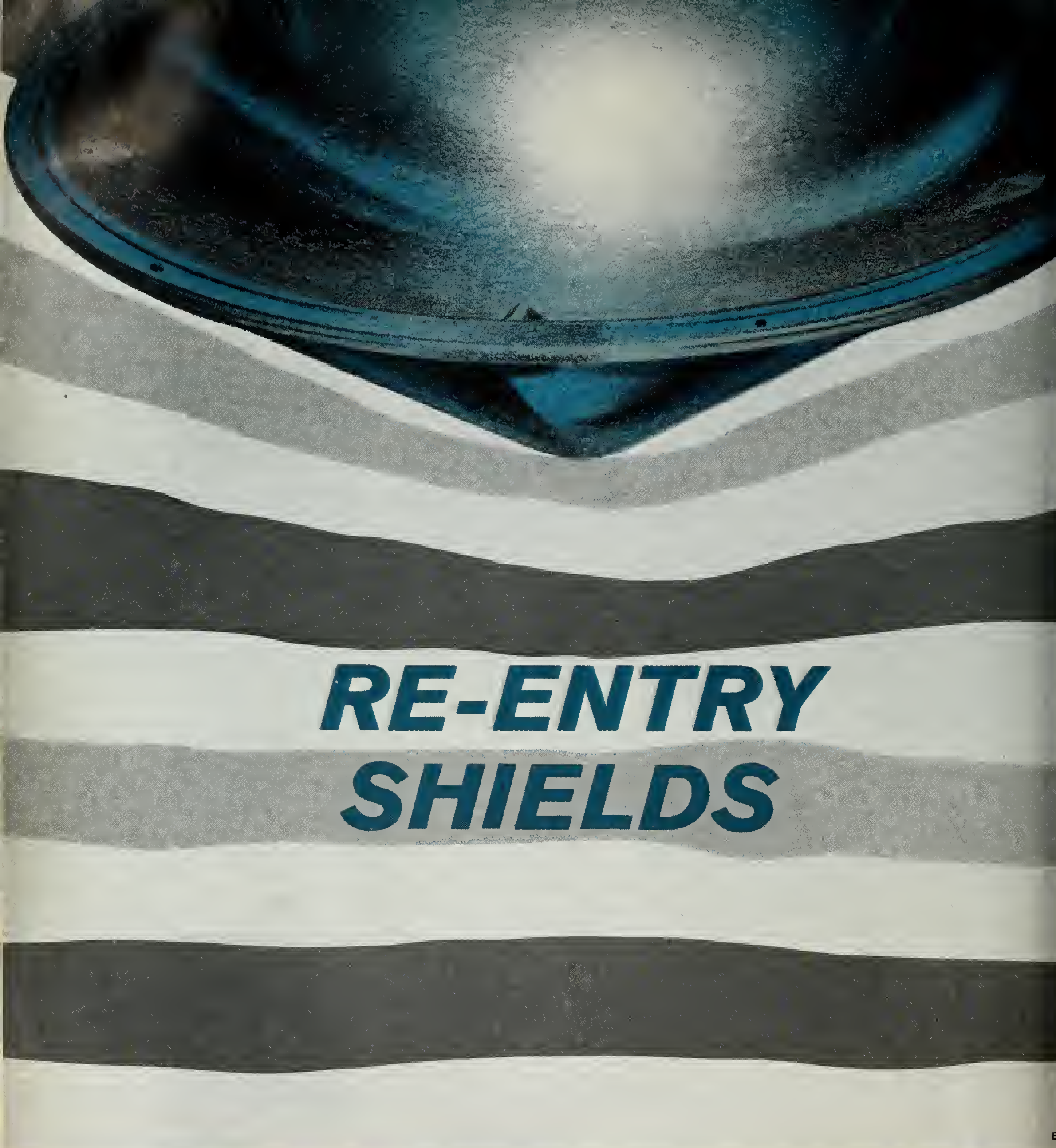


NOSE CONES, both heat sink and ablation, are discussed by GE engineers beginning on p. 16.

HIGHEST standards are required for welding the Army's *Redstone* missile. See p. 29.

NEW MARKET for missile support equipment is opening with the Navy's FBM submarine. See p. 31.

MARS vehicle could use new plasma engine under development by Republic. See p. 34.


RE-ENTRY
SHIELDS

A Long Look at Renegotiation

Congress this week is considering legislation of tremendous significance to our space efforts and to our national security. This is legislation to extend the Renegotiation Act of 1951.

The House has passed HR 7086, which extends the Renegotiation Act for a period of four years, and the bill is now under consideration by the Senate Finance Committee.

The purpose of renegotiation is to provide for an after-the-fact review of all defense and applicable contracts to assure that the contractors do not make excessive profits. The Act itself is unique in that for all practical purposes it gives one agency of the government the power to overrule decisions of another government department.

In recent hearings before the House Ways and Means Committee, all of the testimony submitted by industry—both large and small—recommended against extension of the Act or called for its substantial modification to provide for precise definition of excessive profits.

Representatives of the Department of Defense, the Air Force and the Renegotiation Board itself—Robert Dechert, DOD general counsel; Max Golden, USAF general counsel, and Renegotiation Board Chairman Thomas Coggeshall—recommended to the committee a continuation of the Act for a period of two years and three months, or until Sept. 1, 1961.

Chief proponent of permanency for the Renegotiation Act was Congressman Carl Vinson, Chairman of the House Armed Services Committee.

The proposal for a long extension of the Act—and the recommendation that it be made permanent—obviously imply that the aircraft/missile/space industry is and has been making excessive profits. This assumption is not substantiated by the available facts and may be due to the hypnotic affect of large figures.

Boeing, for instance, earned in 1958 a profit of $29 million. That's a huge sum. But it was only 1.72% of net sales. A smaller company making a profit of $29 thousand at 1.72% wouldn't attract anybody's attention.

Actually, the earnings of the aircraft/missile/space industry historically have been substantially less than those of other manufacturers. Since 1951, when the Act was first passed, they have been less than half the average earnings recorded by all manufacturing companies in the U.S.

Lockheed Aircraft Corporation in 1958 devoted 40% of its effort to missile and space work and in so doing faced a tremendous expansion program. Robert E. Gross, chairman of the board, told the committee:

"In the last three years . . . we have spent $56 million of our own funds on plant additions, and the dollar value of company-owned facilities has increased 64%. I might point out that in these same three years our total earnings after taxes amounted to just $50 million."

In a comprehensive study of the same companies whose profits in many cases the Renegotiation Board is now finding excessive, the Investigating Subcommittee (Chairmanned by Congressman Hébert) of the House Armed Services Committee, on July 13, 1956, reported:

"The Subcommittee concludes on the evidence that there has been no showing that on the average the profits allowed are excessive."

This report, incidentally, was signed by Carl Vinson, then as now chairman of the House Armed Services Committee, and now leading the proponents of permanent re-enactment or lengthy extension of the Renegotiation Act.

Since the 1956 report, both the Hébert Subcommittee and the House Committee on Ways and Means, which has actual jurisdiction, have recommended that studies and a review of the entire renegotiation process, including the Act and its administration, be undertaken. No such review has been made or attempted.

We are in complete agreement that management of our public funds is a matter for the closest official scrutiny. We believe that it is of the utmost importance to our national security and our economy that proper and adequate measures be established to insure that no industry makes excessive profits from government contracts.

Equally, we are concerned with the health and welfare of the aircraft/missile/space industry, which has the primary responsibility for providing the vehicles essential to our national security—and national prestige. Industry will not maintain its responsibility if it does not equally maintain a healthy financial condition.

We would therefore urge the Senate, which has the immediate action in the matter, to extend the Renegotiation Act—but only for one year.

We would further urge that Congress institute during that year the studies recommended by the two committees—studies not of the principle of recovering excessive profits, but of establishing an equitable formula for this recovery.

This seems to us the only fair way to resolve the wide divergencies of opinion which exist between government and industry and within government itself.

Clarke Newlon

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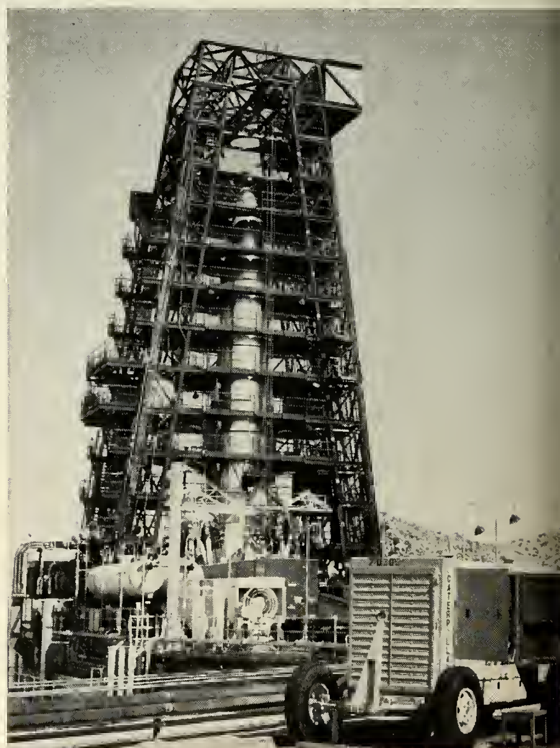

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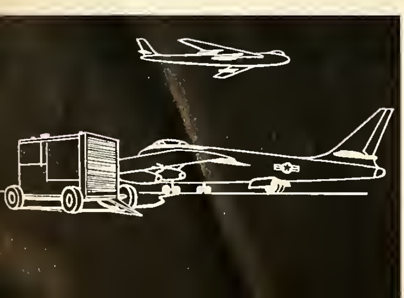

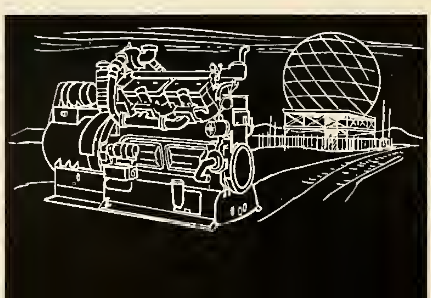

washington countdown

The Air Force successfully launched ARPA's *Discoverer III* June 3. The satellite carried four two-month old male mice—each wearing a small instrumented saddle. (See page 28)

IN THE PENTAGON

The budget-minded Administration appears to have no intention of buying an extra eight Convair *Atlas* squadrons as recommended by the House Appropriations Committee. They would cost about $800 million—a long way from the $85 million "downpayment" added to the defense appropriations bill by the committee.

• • •

The Martin *Mace-B*—also considered for use by European NATO troops—has substantially greater range than the more than 750-mile *Mace-A* and operates on a new inertial guidance system. In fact, the much extended range of the *Mace-B* is reported to be forcing the Air Force to transfer testing from Holloman AFB, New Mexico, to Cape Canaveral.

• • •

The $127,500,000 slashed by the House Appropriations Committee from the Air Force's *Mace* program would virtually strangle production of the *Mace-B*. But the cut would not halt the flow of *Mace-A's* to U.S. troops in Europe where they are taking the place of the *Matador*.

• • •

One of the big problems facing scientists working on feasibility studies for ARPA's Project *Orion* is radiation and fallout. *Orion*—a proposed multi-kiloton space platform—would be launched by a series of controlled nuclear explosions. General Atomic Division of General Dynamics is conducting the studies.

• • •

One of the main arguments being used by some top Pentagon scientists against the Western Electric *Nike-Zeus* is that it cannot cope with the vastly complicated ICBM threat expected by the mid-1960's. They argue that defense against a small number of ICBM's and radar decoys is one thing. But the attack they foresee, involving hundreds of warheads, jammers and decoys, is quite another.

A major reorganization of the Air Force Weapons Board involves establishment of advisory and review panels based on complete weapon systems. These include not only the weapon and related facilities but also personnel, training, maintenance and supply.

ON CAPITOL HILL

The House's deep cuts in the Boeing *Bomarc* program and the Senate's deep cuts in the Western Electric *Nike-Hercules* program are seen more as pressure plays than economy. Congressmen are tired of pumping billions into both the Air Force and Army programs. Now they are putting it to the Pentagon at point blank range: Make up your mind.

• • •

The flight of Baker and the late Able has stirred up a new congressional secrecy investigation. The House Information Subcommittee will soon be asking Pentagon and NASA officials to explain why space monkey business is secret some days and not on others.

AT NASA

Scientists at NASA have scheduled a satellite launching a week for three weeks beginning with one about mid-June. First will be a new attempt to launch *Vanguard III* with its extra proton-free precession magnetometer carrying an extra-sensitive magnetometer and an inflatable 30-inch balloon. Second will be *Explorer VI*. Third will be *Thor-Able III*—a space probe.

• • •

Two deep space probes—*Thor-Able IV* and *Atlas-Able IV*—are scheduled for later in July and August. Both are expected to follow *Mechta* and *Pioneer IV* into solar orbits. Scientists expect to be able to track them farther than either of the first two solar-powered satellites because they will be powered by greatly improved solar cells.

AROUND TOWN

U.S. officials say privately that Russian Premier Khrushchev's threat to establish missile bases in Albania is 100-proof Soviet hogwash. Reason: Russia already has submarine bases in Albania, and the Red subs are capable of launching missiles.

industry countdown

Cash position of missile/aircraft manufacturers will improve substantially under Air Force decision to ease requirements for liquidation of progress payments. Order has been forwarded from USAF headquarters to Air Materiel Command requiring that the rate at which advances must be liquidated will be subject to negotiation. Order is effective July 1 and covers both new contracts and deliveries made after that date. During 1957 drive to stay under national debt ceiling, progress payments were limited to 70% of incurred cost. As a result, 70% of the delivery price (on fixed price contracts) was withheld until progress payments previously made were fully liquidated by the company. New AF Procurement Instruction will spell out the new rules, which seemingly would allow contractors to retain up to 85% of earned profit on deliveries without running afoul liquidation of progress payment rules.

STRUCTURES

Team that actually wins *Dyna-Soar* development contract, insiders say, probably will be a "mixture" of members of the two teams in the contest. One team is headed by Boeing and the other by Martin and Bell Aircraft. Air Force scramble conceivably could split Martin and Bell; would be aimed at putting together best combination of subsystems contractors. One high Pentagon official says concepts for the rocket-boosted manned glider are so similar "you could put 'em all out on a table and not be able to tell them apart." Announcement of the contract is due shortly.

• • •

Wage demands for forthcoming bargaining talks with missile/aircraft and electronic employers will be hammered out at the first joint conference of the International Association of Machinists and United Auto Workers Unions starting Aug. 5 at Kansas City. Both UAW's Walter P. Reuther and IAM president Al Hayes will address conference delegates representing 600,000 missile industry employes. Joint action of the two unions follows six years of individual, but coordinated collective bargaining under a mutual assistance pact.

• • •

Industry observers are wondering if the naming of retired AF procurement chief Lt. Gen. C. S. (Bill) Irvine as a v.p. and planning director of Avco means the company will expand on the West Coast. Irvine has indicated he will headquarter in California and friends believe he hasn't switched plans.

PROPULSION

Look for E. I. duPont to get into solid fuel development race. Military officials have been wondering why the big chemical concern hasn't moved sooner . . . Meantime, Astrodyne Corp., McGregor, Texas, has won a $2 million AF contract for solid propellants.

ARPA is investing about $14 million in solid fuel research during fiscal 1959. Biggest percentage of the funds will be spent with private industry.

ELECTRONICS

Lockheed is the Air Force contractor on *Midas* and *Sentry* projects. Funding amounts to $10.8 million for *Midas* and $98.6 million for *Sentry* during 1959 FY. Air Force is executive agent for ARPA on the projects.

• • •

Answer to frequency spectrum and bandwidth saturation problem are new devices under development for analyzing data before transmission. STL's Dr. George C. Mueller says these new telemetry techniques would reduce bandwidth requirements by 1000 to 1.

• • •

Near perpetual motion temperature-operated clock went to W. J. (Jim) Mayo-Wells of the National Bureau of Standards—winner of the first annual telemetering award of the National Telemetering Conference. He initiated the first industry-military telemetering conference back in 1948.

ASTROPHYSICS

Analysis of photographic plates exposed to radiation 770 miles in space indicates inner Van Allen belt consists of masses of protons with a level of 1 roentgen per hour. University of California Radiation Laboratory physicists Dr. R. Stephen White and Dr. Stanley C. Freden found most of the protons had energies around 75 mev; 10% were in 300 mev range and about 1% were 700 mev or greater.

• • •

White and Freden calculate at 2000 miles radiation intensity rises to 100 roentgens per hour. This would yield in four hours a fatal exposure to an unshielded space traveler. Ten photographic plates measuring slightly less than two inches square were rocketed into space aboard a *Thor-Able* launched from Cape Canaveral in April. They were recovered along with the nose cone.

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missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

Army Expanding 'Breakout' Policy

Congress sees increased opportunities for small business with Army taking 'standardized' components away from primes and buying under competitive bidding

by Erica M. Karr

WASHINGTON—The Army's greatly epped-up "breakout" policy, recently vealed in hearings before the House efense Appropriations Subcommittee, bound to jostle to some extent the tire structure of its missile procure-ent pyramid.

Breakout is the process through ich missile components, as they be-me stabilized are taken away m the prime contractor and con-cted for directly by the Army. Esti-ted savings, the Army says, will n to hundreds of millions of dollars en its hoped-for goal of 50% break-ct on missile systems is reached.

Affected is the prime, his subcon-tctors, the Army's own procurement s up and, Congress hopes, the tax-per.

Prodded last year by a Congress wich felt that the primes were get-tig too much, the Army, which had bn making small motions in the dection of breakout, went all-out uler an August, 1958, directive from th Deputy Chief of Staff for Logistics. T directive stresses early identifica-ti of components "susceptible to bakout," and the encouragement of pine contractors to "identify items ar components which can be pro-cued on a competitive basis in order to broaden the subcontracting struc-tu."

Latest Army procurement policies ar spelled out in a directive dated Mch 23, 1959 (#145-715). It will reain in effect for two years.

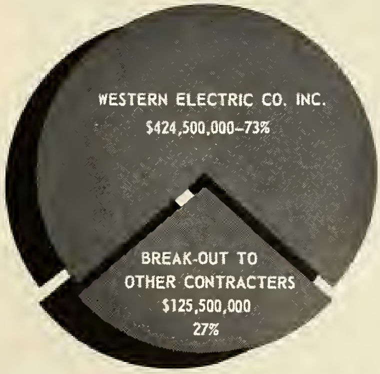
• **Shopping around**—With or with-ou his help, the prime contractor who wa given the whole pie in the be-giring is likely to find pieces nibbled awy. If he or his subcontractor have de loped a piece of missile-related ha ware to the proven-out stage, he may well find it missing from the renewal contract next time around, because the Army has shopped around and found itself a better deal.

He may also find his proprietary items designed out of the system. Despite the fact that he will have no control over many important components in the system, he will be charged with responsibility for overall system reliability.

Moneywise, he stands to lose the approximate 3 to 6% profit he was making by riding herd on the subcontractor—about 10% if it was an "in-house" item.

Does the subcontractor make more profit if he deals directly with the Government? Possibly less, says the Army, since it is likely to scout the market more carefully to get the best possible price.

• **Savings touted**—The Army procurement staff will have to be stepped up to administer its increasing responsibility as that of the primes decrease. But the Army claims that the added administrative costs will be a drop in the bucket, compared to the savings.



HERE's how 'breakout' program has affected Western Electric's *Nike-Hercules* program.

The Army points out that breakout of *Nike-Hercules* components from prime Western Electric has so far resulted in a savings of about $4.7 million despite the increase in Government's administrative costs. Estimate on total savings for *Nike-Hercules* runs to $20 million and, Army points out, this does not include savings through competition. Western Electric, which started with 84% of the program, is now down to 73%.

Another example is *Sergeant*, scheduled for a final breakout within two years which will cut down Sperry Utah Engineering Lab, awarded 91% of the $40 million funded in Fiscal 1959, to 71%.

In addition, the Army anticipates a 30% dollar breakout from prime contractors on *Hawk* (Raytheon Manufacturing Co.) and *Lacrosse* (Martin Co. and Thiokol Chemical Corp.). Breakout is now in the works for *Nike-Zeus* (Western Electric) and *Pershing* (Martin Co.).

In addition to major item breakout, procurement of replenishment repair parts will be sought outside the prime.

Carrying this process one step further, the Army is now working on breakout from breakout—taking away from the new "sub-prime" contractor additional items which have stabilized if potential cost savings warrant it.

Under scrutiny is a direct contract with Douglas Aircraft Corp., originally subcontracted by Western Electric for launching area items of *Nike-Hercules*. Douglas may well find a big chunk of this taken away under "sub-breakout."

• **The process**—Breakout during the various phases of an Army missile program shapes up this way:

1) Development, Test and Pre-Production—Because major engineering at this point requires numerous

changes breakout is generally not desirable. The Army, however, may and frequently does procure directly items which will not substantially affect engineering compatibility with prime-supplied items. These would include nose cones, adaption kits, booster motors and fuzes.

2) First Production Order—Beginning of item stabilization gets breakout into gear. Easy marks for breakout are supports units such as fueling and power equipment and electric and hydraulic cables.

3) Placement of Follow-on First Repeat Order—At this phase the system prime contractor's end product is usually stabilized. System components which no longer require close control for compatibility and which are not part of the prime contractor's end products will be broken out and procured directly. This could include launchers, support equipment and certain missile metal parts. At this point repair parts will be procured directly through competition. It is at this point, too, that the system prime contractor's fee is negotiated downward in relation to the reduction in subcontracting.

4) Additional Repeat Orders—The government now analyzes major assemblies and important elements of the prime's end items to see whether these should be directly procured and furnished to the prime or if the prime should continue procuring them competitively if other sources are available. During this stage the government takes over direct control of engineering changes. Breakout possibilities here are guidance packages, sustainer motors, frames. Additional repeat orders are placed through fixed-price contracts "whenever possible."

• **Background**—In a statement prepared for the House Appropriations Subcommittee, Gen. John B. Medaris, commander of the Army Ordnance Missile Command, describing evolution of the original "system prime contractor" to the present "system prime contractor with breakout", said the concept was years in development.

He reported:

"When originally approached on this breakout concept, the prime contractors refused to accept it, contending that they were production industries and that they would not maintain a staff of engineers for the production of equipment by others. However, three major advances in missile system contracting helped pave the way toward a 'breakout' philosophy acceptable to the Government and the contractors."

First of these advances, said Medaris, came about through competitive negotiation on the *Honest John* reaffirming the Army's interpretation of the patent and proprietary rights and data clauses in missile development contracts. In general, this held that the reproduction rights of any item de veloped under government funds wer property of the government.

Next step was inclusion in produc tion contracts of a clause requiring th contractor to report to the governmen before production, any proprietar items in the system. "When the impac is major, and reproduction rights ca not be obtained economically, a d velopment program is established whe ever feasible to design the item out the system. Restriction of procureme to a selected few is reduced to a min mum."

Through what he calls "the late major advance" in Army contractir concepts, Medaris pointed out that t systems contractor is charged wi maintaining "system engineering r sponsibility throughout the life of t system no matter how, where or fro whom the parts of the system are pr cured."

Of the total Army missile expend tures, 81% is expended by priva industry.

Rep. Gerald R. Ford (R-Mich.), member of the House Defense Appr priations Subcommittee and a breako booster, says the committee is inte ested in the fact that breakout increas opportunities for small business in t defense picture.

"Anything legitimate that hel smaller companies, is on the rig track," Ford said recently. "The b are getting bigger to the exclusion the small companies who can make great contribution to the defense effo I certainly feel the Army breako system is right."

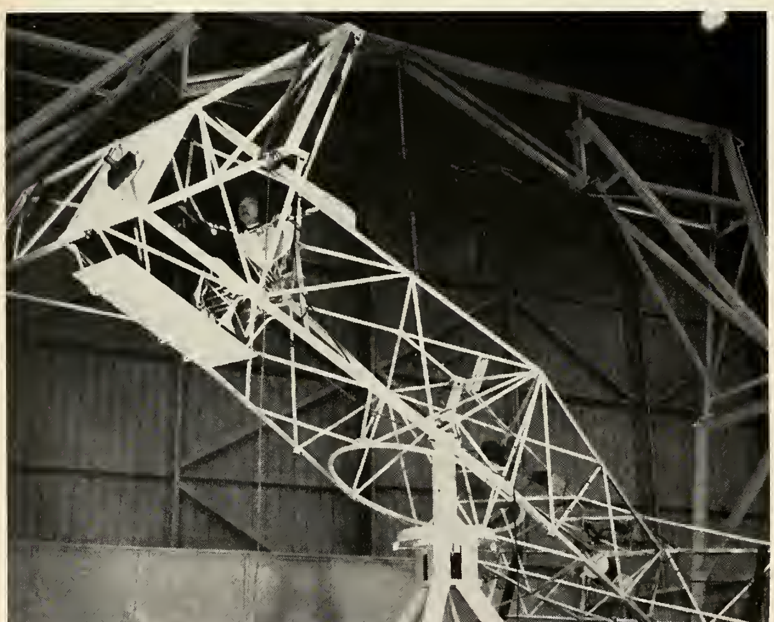
More emphatically, he told Br Gen. J. E. Engler, Army's Director Procurement-Logistics, at the rece appropriations hearings that if breako was not pushed as far as possib Congress might write it into law:

"I think your program is good a is a good illustration of response Congressional interest, but if the pr sure is not kept on it could well that legislative provisions might be i cluded in an appropriation bill otherwise which would take flexibil away from the services . . . arbitra restrictions . . . which would be mu more difficult as far as they (the pri contractors) are concerned, and a gr deal more difficult as far as the Arn the Navy and the Air Force are c cerned.

"It is not impossible to write leg lation which would make their p blems as prime contractors very di cult . . . So let us get them to go alc with you in what you are trying to d

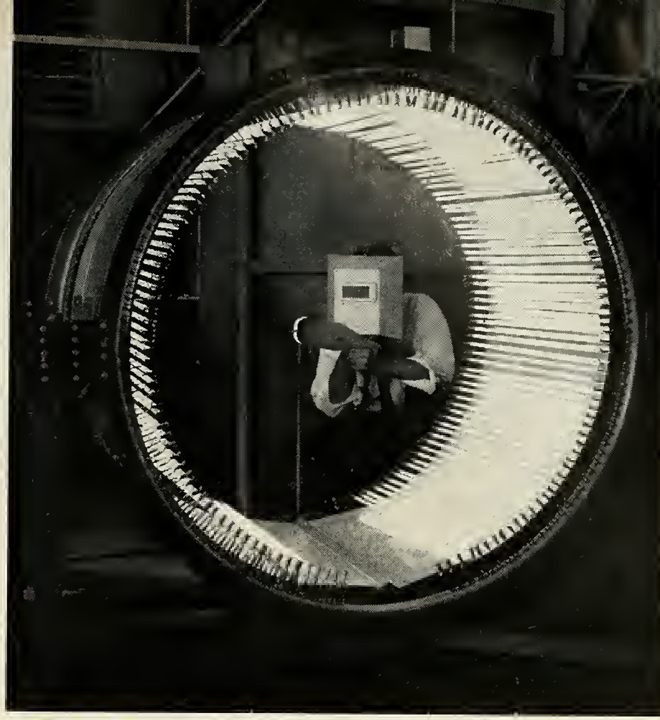
Ford told M/R later Congr would check progress to make s there would be no "dragging of feet."

Space Vehicle Simulator

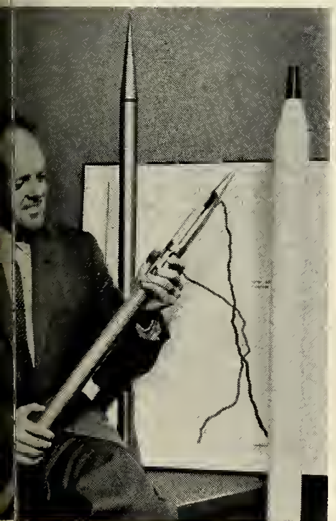


BOEING SIMULATOR, which rides atop a near-frictionless air-bearing, is being used as a test-bed for trying out various methods of controlling position. Compressed gas gives various attitudes for pitch, roll and yaw.

Industry Does It This Way

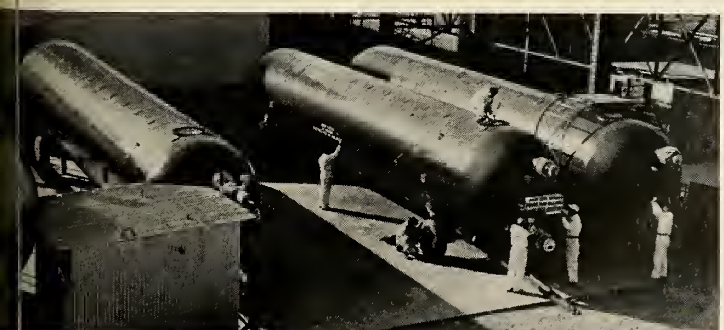


THIS OVEN—capable of testing components at 3000°F—is part of Convair's recently-opened High Temperature Structures Research Lab.



LECTRONICS, Borg-Warner Corp. s leveloped the *Owl* meteorological ck for ARDC to provide wind direc- n nd velocity information at altitudes hh as 240,000 ft.

FIRST released photograph of Boeing's *Bomarc* production line. These IM-99A missiles will be installed at Northeast air defense bases.



STANDARD STEEL Corp. is delivering vacuum-jacked LOX tanks for *Thor.* Holding 13,500 gallons, the 52′ tanks have a high-strength aluminum outer jacket and a stainless steel inner shell.

NOSE CONES: *The Case for Heat Sink*

Designs are limited to relatively low values of the ballistic parameter and require considerable attention to manufacturing tolerances

by Dr. J. D. Stewart

PHILADELPHIA—As nose cones using the ablation system for thermal design have gained more and more prominence in recent days, the question is naturally raised, "Why did General Electric select a heat sink design for the thermal protection of the ballistic missile re-entry nose cone in the first place?"

Before attempting to answer that question, let us consider a few of the characteristics of a ballistic missile. Basically it is composed of two separate systems, the nose cone and the booster system. The nose cone is accelerated by the booster system to a given velocity and altitude in space. At this point, it separates from the booster, follows a ballistic trajectory through space and re-enters the earth's atmosphere. The velocity and angle at which it re-enters are dependent on range and trajectory.

The design of the nose cone depends almost entirely on conditions encountered during the re-entry phase, when it is subjected simultaneously to large decelerations and large thermal loads. The decelerations which result from aerodynamic pressure-drag reach peak values around 50 g's. Depending on the configuration of the nose cone, the peak thermal loads are measured in 1000's of BTU/ft^2-sec.

Heat is transferred to the re-entry body by several means. During re-entry, the blunt-nosed body is surrounded by high-temperature air. This air will be partly dissociated and, to a lesser extent, ionized, and it will be at temperatures of the order of 15,000°F at ICBM ranges. This hot gas can transfer heat to the body by convection and by radiation. The former mechanism is the prime contributor of heat, which the body can dissipate by conduction and radiation. For heat sink designs which have low melting temperatures, conduction is the more important.

The heat transferred to the body by convection or friction is approximately equal to the product of the thermal conductivity of the air and the difference between the temperature of the hot gas and the temperature of the wall divided by the boundary layer thickness. The boundary layer near the nose of a blunt body is a few thousandths of an inch thick.

The peak heat flux to a ballistic re-entry vehicle is a function of the ballistic parameter, defined as the ratio of the weight of the vehicle per unit frontal area divided by the aerodynamic drag coefficient. For given re-entry conditions, the lower the ballistic parameter, the lower the peak flux.

The heat flux to the stagnation point of a blunt body is inversely proportional to the square root of the [...] radius. Thus, the smaller the nose [...]dius, the higher the convective flux [...]

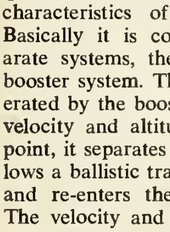
• **Requirements**—Transcending [...] other considerations, the primary [...]pose of the ballistic nose cone i[...] provide thermal protection for the [...]load. Since internal components ar[...]stricted to relatively low temperat[...] insulation requirements are of ext[...] importance in selecting nose cone [...]terial.

The nose cone, in spite of its se[...] environment, must maintain struc[...] integrity during re-entry, and [...] strength characteristics of many r[...]rials are seriously reduced at high [...]peratures. Moreover, the design o[...] vehicle must be adequate to withs[...] high deceleration loads as well as [...]sure loads, particularly at high [...]peratures.

By 1955 the ballistic missile [...]gram had reached the stage whe[...] decision was needed on selectio[...] material to protect the payload o[...] *Atlas* re-entry nose cone at IC[...] ranges. The Missile and Space Ve[...] Department of the General Ele[...] Company was given this responsi[...] by the Air Force.

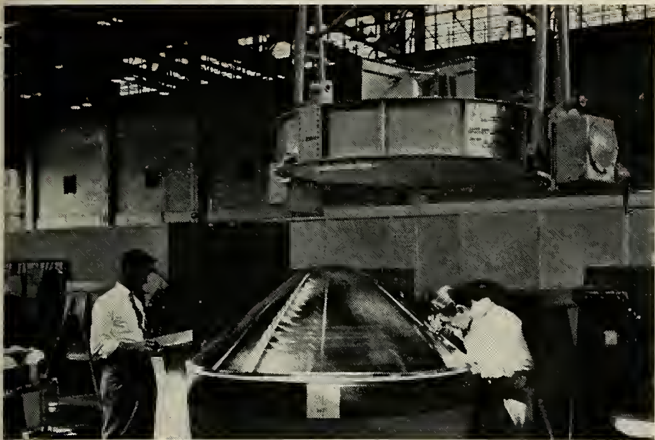
• **Sketchy data**—Very little [...] available to aid in choosing mate[...] There was practically no test dat[...] an aerodynamic environment c[...]sponding to that which would be [...]countered by a re-entering bal[...] missile. Some aerodynamic and the[...]dynamic test data had been obtain[...] low supersonic speeds in wind tu[...] and shock tubes, but informatio[...] the blunt shapes required for bal[...] vehicles was lacking.

Furthermore, theoretical cal[...]tions for blunt bodies in hyper[...] flows were in the early develop[...] stage. Lees, of the California Inst[...]



ABOUT DR. J. D. STEWART

Dr. Stewart was awarded a B.A. Sc. in aeronautical engineering in 1949, an M.A. Sc. in 1950, and a Ph.D. in 1952, all from the University of Toronto. In 1952-53, he conducted airframe studies for the National Research Council of Canada. During the next four years, he carried out supersonic airframe structure and missile structure feasibility studies for Convair. He has been with GE's Missile and Space Vehicle Department since 1957, specializing in hypersonic missile structure design.



OVERALL surface finish of GE's copper heat sink cone severely restricts pits and scratches, placing heavy responsibility on quality control.

echnology, had derived for a blunt
in high Mach number flows, a
lion for the stagnation point heat-
g rates and for laminar flow away
o the stagnation point; but his the-
y had not been checked experimen-
ll Opinions varied as to whether the
idary layer on the nose cone would
nin laminar or whether it would be-
n turbulent, resulting in higher heat
ix.

a the field of materials, a consid-
ale amount of information was
able on properties of such metallic
atrials as copper, aluminum, and
cl at elevated temperatures. The
enal, as well as the structural, char-
teistics were known to some degree
function of temperature. There
as ome data on more exotic mate-
ils such as graphite and beryllium.
er little was known about the char-
teistics of plastic materials, partic-
ar under the extremes to which
ey would be subjected during a re-
tr trajectory.

nother consideration was the
igt of the re-entry vehicle. Since
s ould be limited by booster sys-
n capabilities, an upper limit was
ic on the heat protection system,
hing the insulation requirements.

I addition to the technical consid-
tins of strength and heat protec-
n here were other factors of equal
pc ance. Was the selected material
ible in the quantities required for
dction? What would be the manu-
tung problems? What about relia-
ity of the heat protection system?
ul local melting be tolerated?

T answer some of these questions,
ta ground rules were specified. The
t rotection system must have high
al ity. No surface melting should
u The nose cone must be delivered
a iven schedule.

• **Decisions**—After weighing all factors, GE decided to use a solid heat sink nose cone on the re-entry vehicle. There still remained the question of material. A few of the thermal characteristics of some of the more probable materials are listed in the table below.

Settling on the heat sink for thermal protection meant that the aerodynamic configuration was, of necessity, one with a relatively low ballistic parameter. To provide some thermal margin, use of aluminum, iron, or nickel was not possible because, at ICBM ranges, the surface temperature during re-entry would exceed the melting point of these materials.

Because of the low heat capacity of silver per unit weight, it, too, was eliminated from consideration. The nose cone would have been too heavy.

Beryllium would provide a small thermal margin for the vehicle being considered. However, at the time, it was not available in the quantities required. Beryllium manufacturing problems had not been overcome when the material selection was required.

Tungsten gave an adequate thermal margin but was in short supply and had been placed on the critical materials list. It also had the disadvantage of operating at a surface temperature high enough to put a severe design requirement on insulation needs.

Graphite introduced manufacturing problems. And it also operates at high temperature, creating insulation problems.

Molybdenum suffers severe oxidation at high temperatures. Manufacturing solutions had to be found before it could be used in the nose cone design. Here again, the high surface temperature creates an insulation problem.

The remaining material, copper, met the requirements for no surface melting at ICBM ranges for the configuration being considered. Copper was in plentiful supply and presented no major manufacturing difficulties. Hence it was decided to construct the heat sink nose cone from copper.

• **Smooth design**—The GE 3.1 configuration is basically a blunt, sphere-cone forebody with a relatively low ballistic parameter. The flow over the forebody behind the detached shock wave is subsonic at all flight speeds.

If the boundary layer on the heat sink transits from laminar to turbulent flow, heat flux will be considerably higher. Since very little test data was available on effects of surface finish on transition, it was decided to make the surface of the shield as smooth as possible. In addition, plans were made to flight-test scale models of the GE 3.1 configuration on a research rocket vehicle which would fly at hypersonic velocities. These models were designed with surface finishes of the order of 2 microinches. Controlled roughness patches were placed on the models, and both the smooth and rough surfaces were instrumented with thermocouples, from which heat fluxes could be determined.

The copper heat sink was plated with a thin film of nickel, used to reduce the heat absorbed by the body from the radiating hot gas which surrounded the nose cones.

The overall surface finish of the copper heat sink severely restricts the number of pits and scratches permitted on the surfaces. These requirements on the surface finish of the nose cone placed a heavy responsibility on the quality control for the heat shield.

Thermal Properties of Ablative Materials

MATERIAL	MELTING POINT °R	DENSITY lb/ft³	SPECIFIC HEAT BTU/lb°R	THERMAL CONDUCTIVITY BTU/ft-sec-°R	THERMAL DIFFUSIVITY ft²/sec
Aluminum	1680	169	0.215	0.0366	0.00101
Beryllium	2800	114	0.52	0.0255	0.00043
Copper	2440	559	0.092	0.0632	0.00123
Graphite	6790	137	0.39	0.0051	0.000095
Iron	3260	492	0.11	0.0121	0.000224
Molybdenum	5220	637	0.061	0.0235	0.00060
Nickel	3110	556	0.105	0.0148	0.00025
Silver	2210	655	0.056	0.0672	0.00183
Tungsten	6630	1206	0.032	0.0323	0.00084

It can be seen that the use of the heat sink design for long-range ballistic missiles is limited to relatively low values of the ballistic parameter and requires considerable attention to manufacturing tolerances.

• **Testing**—To verify the theoretical design techniques developed during the design phase of the nose cone, an extensive flight test program was prepared for the full-scale vehicle.

The nose cone and afterbody of the re-entry vehicle were extensively instrumented with pressure and temperature sensors. The measured pressure data would be used to verify data obtained in such ground-based test facilities as the Jet Propulsion Laboratory supersonic wind tunnel and the AEDC "hotshot" hypersonic tunnel. The pressures would also be used to check out a theoretical, real-gas, blunt body, flow field solution which was developed by MSVD personnel.

The thermocouples are located a few thousandths of an inch below the surface of the heat shield. The measured temperature rises at various stations on the nose cone are used to calculate the fluxes to the surface of the vehicle at various times during the re-entry trajectory.

Accelerometers and vibration sensors are among the other measuring devices which are used during each flight.

To determine the effect of surface finish on the heat fluxes to the body, controlled roughness patches were installed along one meridian line of temperature sensors. These patches had roughnesses of 62 and 100 microinches. The former roughness is characteristic of a good machine finish, whereas the latter is representative of the roughness which would be caused by micrometeorites impacting on the surface. If these roughness patches did not result in transition, the nose cone manufacturing problem would be eased considerably.

• **Getting data**—Three methods of getting the measured flight test data back to the engineer are used. The first and primary source of data return is by direct telemetry to nearby receiving stations. This method has one severe drawback: during a portion of the hypersonic re-entry trajectory, the ionized sheath of hot gases which surrounds the body attenuates the transmitted signal, resulting in "blackout."

In order to obtain data during this "blacked-out" portion of the trajectory, the measured data is stored on a tape. When direct telemetry is again possible, this playback data is transmitted to the receiving antenna. This will, naturally, result in a loss of recorded data during playback, but this is not serious since the major portion of the heat pulse has been completed.

The final method of obtaining data is to record the measured data on tape later stored in a data capsule. During the late stages of the re-entry trajectory, the data capsule is ejected from the nose cone. A recovery system has been developed by MSVD engineers for locating the data capsule in the ocean. No allowance has been made for attempting the recovery of the heat sink nose cone itself.

• **High success**—The copper heat sink re-entry vehicle has been successfully flight tested over a wide range of re-entry conditions. Direct telemetry and playback telemetry data have been obtained on all successful firings to date. The data capsule has survived water impact and has been recovered intact from a large number of flights.

Because a heat sink nose cone is used, the measured temperature data received on all the flights is excellent for comparison with the various theories used in thermal design. To date, a large amount of extremely useful data has been obtained. Stagnation point, laminar, turbulent, and separated flow heating rates have been measured.

The temperature rise at the stagnation point of the copper heat sink has agreed to within less than 5% of predicted temperature rise. The over the forebody has remained nar for longer periods of time were originally estimated. Afte heating rates are lower than pre The copper heat sink design ha vided the necessary thermal prot for internal systems. The aerody performance of the re-entry vehic been good. And the nose cone h vived ballistic re-entry conditic predicted.

The development of the heat sink nose cone has been ju by flight tests and has met ground rules laid down. Local s melting has not occurred. I components receive the require mal protection. The cone was de on schedule.

Data from actual flight tes proved invaluable, because it ha vided the necessary verification theoretical methods used in th sink design. Moreover, the des the more advanced nose cones, use ablation materials, is more because of the heat sink work.

The use of the heat sink nos as designed by the Missile and Vehicle Department of the C Elctric Company for 'the first I and ICBM's has been justified b tests. Furthermore, it is in pro as an IOC weapon until more ad cones become available.

Cell Produces Power Directly from Gas

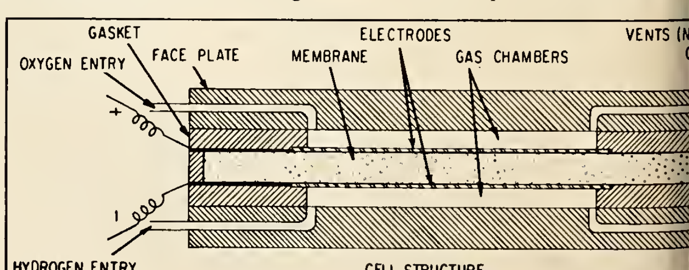
SCHENECTADY, N.Y.—A practical "fuel cell" that generates electricity directly from hydrogen and oxygen in the air has been developed by the General Electric Research Laboratory.

Such a device, under study by scientists for more than a century, promises much more efficient power generation than by conventional methods. Thermal efficiencies of over 60% have been obtained which compare with approximately 40% from present steam turbines. The device operates at room temperature and normal atmospheric pressure.

The cell uses an ion exchange membrane as an electrolyte. Hydrog oxygen are introduced on o sides of this membrane which electrode in contact with each

At one electrode, the hy molecules divide into electro positive ions. The electrons esta negative charge on this electro the positive ions pass through th brane to the other electrod electrical current is thus crea tween the two.

A number of experiment have been operating for mo 100 days. One producing 9/ furnishes power to a small fan.



NOSE CONES: *The Case for Ablation*

GE engineers report that proper ablating materials have been found and re-entry tests prove the system enhances protection

by Henry G. Lew, Sinclaire M. Scala and George W. Sutton

PHILADELPHIA—The design of ballistic missiles and re-entry satellite capsules for hypersonic flight requires the consideration of heat protection against the high-temperature environment encountered by these vehicles during re-entry into the earth's atmosphere.

For ballistic missiles, typical speeds of 14 times the velocity of sound lead to equilibrium gaseous temperatures in the order of 13,000°F in the shock layer. The heat transfer rate to ballistic missiles is therefore very large, with peak values of about 2000 BTU/ft²-sec at the stagnation region. For re-entry satellite vehicles, the heat rate is much lower (peak values of 70 to 100 BTU/ft²-sec), but the time of exposure (upwards to 300 seconds) leads to a large total heat pulse.

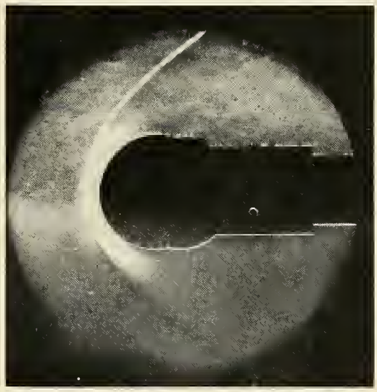
The use of heat sinks, which absorb the aerodynamic heating by temperature rise, has a limitation imposed by the thermal conductivity of the heat sink material. For the larger peak heat flux associated with ballistic missiles, the heat cannot be conducted away from the exposed face of the heat sink into the interior rapidly enough, and catastrophic melting occurs. This is exactly what happens to metallic meteors, since metallic meteorites generally exhibit large cavities after entry into the atmosphere.

Calculations indicate that the recovered fragments represent only a fraction of their original size. Stony meteors generally fare somewhat better during re-entry, since part of the stone absorbs heat by vaporizing. This process of melting during re-entry is called ablation, and is actually a type of self-regulating mass transfer process.

• **Plastics researched**—Stone, of course, is not an acceptable structural material, and hence a search was initiated to find suitable ablation materials for hypersonic re-entry. The discovery of appropriate materials actually started from tests on rocket motor materials. In the course of searching for better nozzle and jet vane materials for the *Hermes* Project, (1950-1954), plastics reinforced with glass fibers were investigated. Although these materials eroded badly in these initial tests, they did not erode completely. This was surprising because this type of plastic was generally used for service below 500°F.

Since one may regard these materials as being part ceramic and part plastic, at first it was felt that this was simply a convenient method of fabricating inorganic oxides into a structure which is not susceptible to thermal shock. This ability to withstand thermal shock stems both from the high strength of glass fibers—up to 500,000 psi—and from the certain amount of flexibility that the fibrous construction gives to the structure. After considerable development, glass-reinforced plastics were perfected to the point where they became suitable for use as rocket motor parts exposed to environmental temperatures up to 5000°F.

• **Nose cones**—The arrival of the ballistic nose cone program and its attendant high temperature environmental problems brought the problem of thermal protection into focus again. It was not obvious immediately that the type of material used in rocket motors would be suitable also for hypersonic re-entry, where environmental temperatures are of the order of



HOT GAS gap generated at high speeds created with 2500 kw AC air-stabilized free jet, proved out models.

ABLATED QUARTZ model. Up to 100% pure silica has been tested successfully, but shielding value drops in re-entry.

13,000°F, and the air is highly oxidizing. (Generally, rocket engine flames are reducing).

The possibility existed that the resin would burn exothermically with air, and the reinforced plastic would fail catastrophically. Therefore, research programs leading to the development of ablation materials for hypersonic flight were initiated by the Aerosciences Laboratory of the Missile and Space Vehicle Department of the General Electric Company, under contract with the Ballistic Missile Division of the Air Force and by the Army Ballistic Missile Agency, which was developing the *Jupiter* missile.

The Air Force required a method of obtaining flight data from nose cones. This called for the use of a data capsule which could be ejected from the nose cone at high speed, survive re-entry, and then impact the water at 400 ft./sec. and still remain functioning. On the basis of strength and weight requirements, it appeared imperative to use reinforced plastics as the outside material. To determine the hypersonic ablation characteristics of the reinforced plastic, models were tested in a rocket motor exhaust jet which simulated flight velocities up to 13,000 ft/sec. and yielded stagnation temperatures of approximately 5400°F, stagnation pressures between 200 and 300 psi, and heat transfer rates of 800 to 1800 BTU/ft^2-sec.

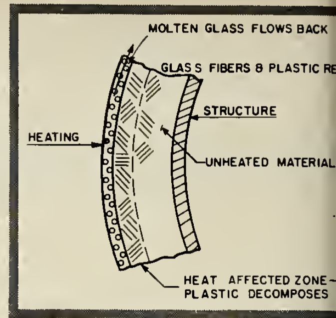
• **Reinforced plastics**—Using this facility, the discovery was made that "E" fiberglass reinforced plastics could absorb up to 2000 BTU for each pound of material which ablated. As the plastic ablated, the resin pyrolized into a carbonaceous structure and a gas flowed into the gaseous boundary layer, while the glass melted and flowed back along the surface.

The low thermal conductivity of this plastic kept the heat-damaged region close to the surface. If the aerodynamic skin friction and pressure gradient were sufficiently low, the glass usually vaporized, leaving a carbon surface.

A second discovery was made at this point: if the "E" glass, which is a low melting point glass, is replaced by the H. I. Thompson Co.'s Refrasil (96% silica), the plastic then absorbed 6000 BTU for each pound ablated in rocket exhaust tests.

This is 40 times better than a copper heat sink, on a weight basis. This property is due to the higher viscosity of molten silica, which allows it to partially vaporize before the melt flows downstream.

On the basis of these experiments, GE's data capsule was placed in production in the summer of 1957, and



REINFORCED plastic protects struct

was the first production vehicle to made from an ablating material thermal protection during hypers re-entry.

The Army Ballistic Missile Age also stimulated by early experim on rocket motor parts, started sim research for *Jupiter* nose cones. In t program, hundreds of ablation terials were tested in rocket engine hausts at the Redstone Arsenal. results of the two programs were s lar and an ablating nose cone demonstrated and recovered on IRBM trajectory by a *Jupiter 'C* October, 1957.

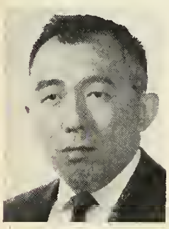
• **Plasma jet development**— though the rocket exhaust was us the temperature simulation was lim to IRBM re-entry conditions. Th fore a more severe environmental which would simulate ICBM co tions was needed with temperature the order of 13,000°F. A water st ized plasma arc, on which ori work was conducted in Germany Maecker in 1951 and Weiss in 1 was selected for test and evaluatio

Constructed by the Chicago way Laboratories under GE sub tract, the water stabilized arc bec test operational late in 1956. facility produces a flow of dissoc steam at a temperature of app mately 23,000°F at subsonic flow cities, resulting in heat fluxes of order of 400 to 3000 BTU/ft^2-sec

Using the water stabilized arc important discovery was made tha organic "E" glass fibers could b placed with nylon, with an increa performance to about 10,000 BTU in this test facility. This was expl in part by the evolution of a molecular weight gas as the r pyrolized. This gas thickened boundary layer and absorbed en considerably reducing the heat fl the surface.

Although the stagnation entl of the water stabilized arc was pl for re-entry studies, its chemica vironment did not simulate flight ditions. This led to the developme

ABOUT THE AUTHORS



Dr. Henry G. Lew, *Manager, Gas Dynamics, has been associated with GE's Aerosciences Laboratory since 1957. Previously he was Professor of Aeronautical Engineering at the Pennsylvania State University. He received his Ph.D. from the Polytechnic Institute of Brooklyn. His fields of interest and publications have been in the boundary layer and heat transfer theories, with emphasis on control and mass transfer and plate and shell theory. His recent interest has been in the two phase boundary layer problem.*

Dr. Sinclaire M. Scala, *Consulting Research Engineer, High Altitude Gas Dynamics, has been associated with the Aerosciences Laboratory since 1956. He had previously been employed at New York University Westinghouse Electric Corporation and Princeton University where he received his Ph.D. His special field of interest is hypersonic aerodynamics, and he has published many technical articles dealing with mass transfer in chemically reacting hypersonic boundary layers and ablation, as well as other aspects of hypersonic molecular interaction problems.*

Dr. George W. Sutton, *Consultant Research Engineer, Energy Transfer, joined the Aerosciences Laboratory in 1956. He received his Ph.D. at the California Institute of Technology and had been with the Lockheed Missiles Systems Division Research Laboratory prior to joining the General Electric Company.*

His main field of interest for the past three years has been in the analysis of the response of ablation materials to aerodynamic heating and he has published several papers on heat sink analysis, melting ablation, mass transfer cooling with combustible gases, and the ablation of reinforced plastics.

small gas stabilized plasma arc, which ally culminated in the development the large 2500 kw AC air stabilized e jet. The latter facility was availle for testing in 1958. About 2500 was added to an air stream and nperatures of the order of 12,000°F re obtained. Using the air arc, it s discovered that the combustion of plastic would degrade its ablation rformance only slightly, but catasphic burning would not occur.

• **Ablation theories**—Since experints are best complemented by the, it was clear at the outset that re than an order of magnitude type analysis would be required if the gineering designer was to have conence in this radically new type of tem for the thermal protection of entry vehicles.

This was particularly true when it s understood that the conditions enntered during hypersonic re-entry, nely stagnation enthalpy levels of order of 13,000 BTU/lb., temperaes of approximately 13,000°R and ssures up to 100 atmospheres, could be successfully simulated on the und for times of the order of one ute (ca 1956). Theories were therec required which would predict the ormance of ablation materials over ide range of hypersonic flight conns.

It is clear that the theoretical deination of the rate of ablation of skin of hypersonic re-entry vehicles ires an understanding of the moler interactions between a surface its environment. As is usual in ics, such problems are described system of conservation laws, and ist of the conservation of mass, the ervation of momentum and the ervation of energy.

n addition, chemistry is involved, the thermal degradation of a ma1 may involve pyrolysis, depolyzation, melting, vaporization, and bustion, all resulting in interphase transfer.

n comparison with the voluminous ture dealing with design for ordinonvective heat transfer, knowledge e beginning of this program was er regarding the art of design of aterial which degrades thermally yet does not fail as a structural d.

hus, it was clear that the theoreanalysis of the complex ablation em required a sophisticated effort. ct, the first rigorous theoretical on to the problem of determining ate of ablation of a ballistic nose required the use of high speed onic computers, including the 704 and the Reeves REAC.

his solution was presented in the er of 1957 at the Mass Transfer Cooling for Hypersonic Flight Conference sponsored by the Air Force Office of Scientific Research and the Rand Corporation. The solution showed that the heat blocking and heat absorption of a reinforced plastic could be of the order of thousands of BTU/lb. It has also been calculated that the magnitude of the "effective heat of ablation" of a material is not a constant, but depends critically on the environmental conditions to which the material is exposed.

The theory indicated quantitatively the magnitude of the separate contributions of the following to the heat of ablation:

a) the heat blocking due to mass transfer (as a consequence of the thickening of the boundary layer),

b) the heat absorbed or released due to phase changes and combustion during the gasification of the solid,

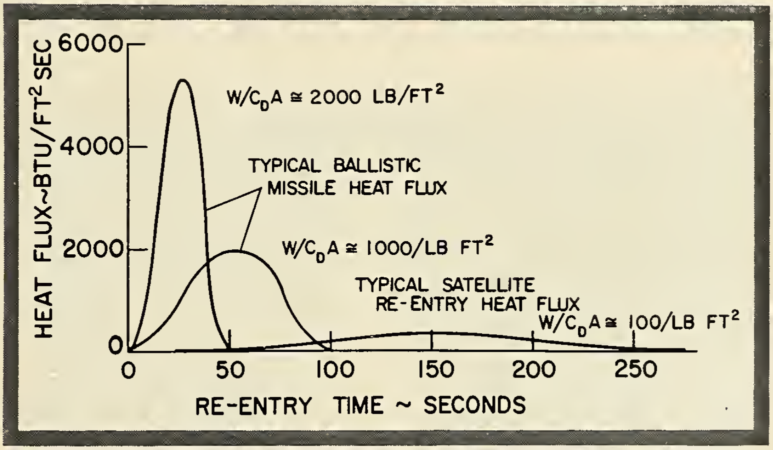
c) the heat blocked by convection in the liquid phase.

The dependence of the blocking term (a) on enthalpy has been experimentally verified in water arc plasma jets, rocket motor exhaust jets, and air arc plasma jets and tunnels. It was found that tests conducted in rocket motor exhausts, which have a considerably lower enthalpy than high energy plasma jets, in general will result in an underestimate of the potential of an all plastic ablating material.

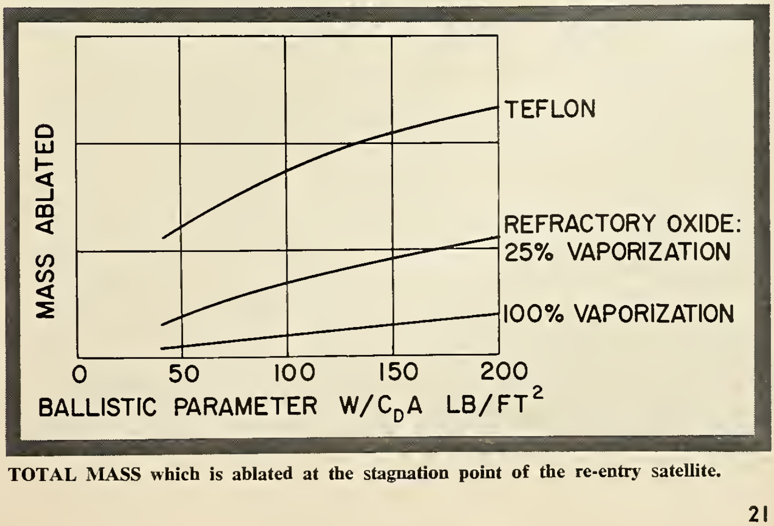
• **Ablation theories**—Since experiablating materials fall into the following categories:

1. Pure plastics
2. Plastics, reinforced with organic or inorganic fibers
3. Silica or other oxides
4. Carbon or graphite

Ablation theories have been developed for each of these classes, although the main line of development was directed toward reinforced plastics. When the reinforcement is "E" glass fiber, the percentage of glass is usually taken as that which gives the highest strength. The same is true when the reinforcement is nylon. When refrasil



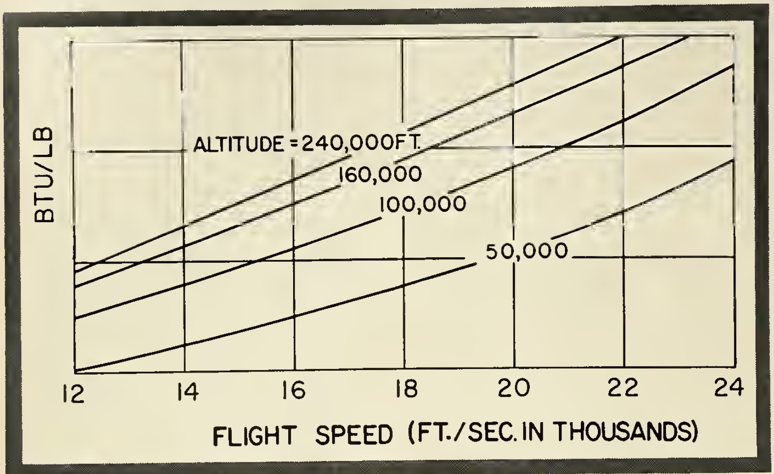
HEATING GRAPH shows typical ballistic missile and satellite re-entry heat fluxes.



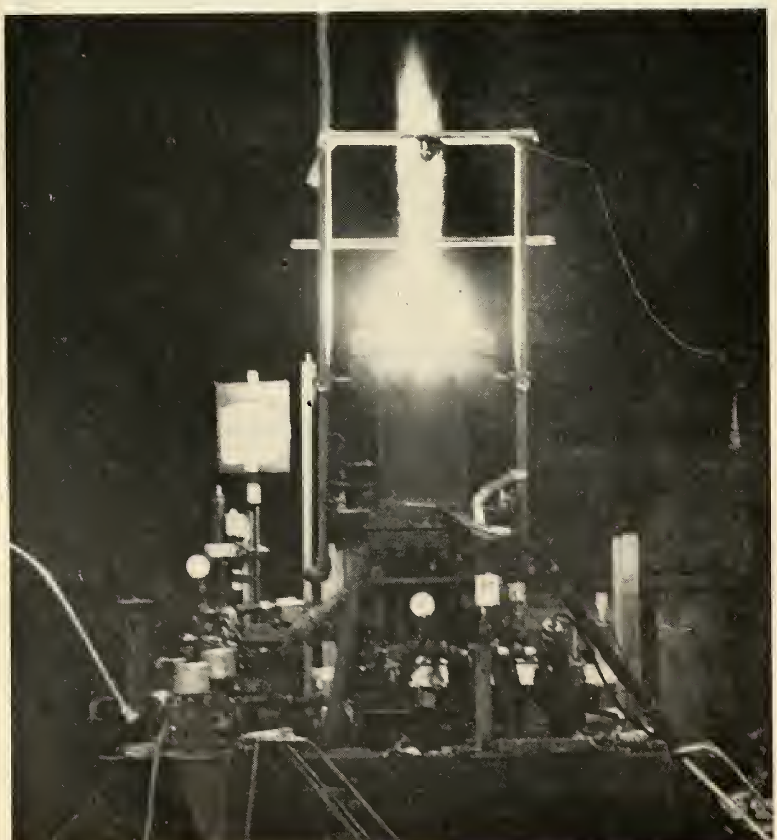
TOTAL MASS which is ablated at the stagnation point of the re-entry satellite.

or fused silica fibers are used, successful tests have been obtained with as little as 10% silica, and as much as 100% silica. Of course, the latter type of material with 100% silica is really not a reinforced plastic.

For pure fused silica, a theoretical prediction which has been verified experimentally: i. e., that liquid layers, which flow downstream under the influence of pressure gradients and aerodynamic skin friction tend to not vaporize as the environmental pressure rises.



EFFECTIVE HEAT absorption of ablating material runs up to thousands of BTU's/lb.



STABILIZED 2500 kw AC air arc obtaining temperatures of the order of 12,000°F was developed to provide chemical environment simulating flight conditions.

Thus, the peak stagnation pressur encountered during hypersonic re-ent retard the gasification of the materi minimizing the contributions of he blocking and heat absorption, and r sulting in a reduced "effective heat ablation." During re-entry the stagn tion enthalpy drops and the stagnati pressure rises. Hence one finds that t effectiveness of fused silica as a therm shield decreases all along the re-ent path.

The ability of plastics to ablate a satisfactory manner has focused tention on thermo-plastics which, wh heated, depolymerize to the monom The monomer usually has sufficien high vapor pressure so that it vap izes immediately, giving the requi mass transfer into the boundary lay A polymer typical of this class Teflon.

These thermo-plastics are dist guished from the resins of reinforc plastics in that no carbon char is l

Another class of ablating materi is one which combusts only at the s face. This surface combustion usually diffusion controlled, and resu in ablation rates which are less th any of the other usual ablation m terials. Graphite is typical of this cl of materials. Aside from the us problems of fabricating suitable la parts from graphite, common grades graphite have a large thermal cond tivity and hence are not selfinsulat as are other ablation materials.

• **Application to design**—In ap cation to design, the designer n merely divide the aerodynamic h transfer by the effective heat of al tion to determine the amount of m terial erosion. In addition, a heat c duction calculation, allowing for moving boundary, predicts the pe tration of heat within the undama substructure.

It has been shown theoretically t for slow satellite re-entry, additio insulating material usually is requi behind the ablating skin to keep backface temperature within the lir which can be tolerated by the paylo

On the other hand, during the listic re-entry of a nose cone, wh involves much more severe heat tr fer rates than satellite re-entry, the face of the ablating material recede the same rate that the heat penetr into the interior.

These developments and disco ies have been verified by the Air Fo General Electric Company *Thor-A* flights, where several ablating n cones have successfully re-entered earth's atmosphere at hypersonic v cities after a 5000 mile ballistic tra tory. Thus, the task of finding proper types of ablating materials been completed.

'NEAR PERFECT' case on cover looked like this after hydro-static test.

COVER STORY

Notch Sensitivity – Barrier to Solid Rockets

Challenge is to increase large motor case strength without cost in weight and reliability

WASHINGTON—Despite all the glamor in storybook and stock market, and despite the exotic nature of their missions and technological challenges, rockets usually work or don't for some pretty grubby reasons. One of the grubbiest is the motor case—the pressure vessel that contains and directs the hot, high-velocity gases of the burning propellant.

In fact, the failure of large motor case know-how to keep up with other states-of-the-art makes this the limiting factor today in solid rocket motor development. And, as a result, the unglamorous manufacturing end of the business has suddenly become the site of one of rocketry's more exciting scientific challenges—one for which a great many millions of dollars have been earmarked and in which a large number of companies and missile projects have a large and important stake.

Take the "desired" performance figures of such projects as *Minuteman, Polaris, Eagle, Pershing, Subroc, Mercury* etc., for example. Ultimately their range, payload and reliability hang heavily on how fast large motor case technology advances.

The basic challenge is to increase large motor case strength without incurring any more cost in weight or any reduction in reliability. In order, this means finding out why materials that exhibit high strengths in the testing laboratory fail at fractional stresses when fabricated into a motor case; and—having found out why—determining what to do about it.

• **Answer coming?**—Only recently have the first hints of an answer begun to emerge. But even at this early stage, R&D results point to some important do's and don't's for large motor case designers and fabricators. Some appear pretty contradictory at first glance, such as for example this admonition: To get a high-strength case, heat treat to a lower strength than you want. The reason: Notch sensitivity, a peculiarity of high-strength materials that may provide the means of breaking through the solid rocket motor case strength barrier—if we can but understand it well enough.

The problem is one of vital national importance. In the fancier areas of solid rocket technology, like propellant chemistry, interior ballistics, etc., the big challenges have been met and won.

Propellant mixes and burning patterns have been developed which are capable of producing solid rocket motors with specific impulses that nudge the 300 mark; with burning pressures graduating from as low as 100 pounds per square inch up to the thousands of psi of pure detonation; with accelerations as low as one or two g's and as high as you please; with burning times from a fraction of a second to many minutes; and with a tolerance to environmental conditions ranging from the near-0° Kelvin temperatures of interstellar space, to the 1000°F and up of supersonic aerodynamic heating.

This is the first of a two part series prepared by the technical staff of M/R on the problems of high-strength, thin-wall solid rocket motor cases. Part one covers the newly discovered phenomenon, notch sensitivity. Part two, in the issue of June 22, will deal with biaxial stress, motor case test procedures, manufacturing techniques and some of the new materials.

• **The trouble:** There are no motor cases capable of reliably putting this know-how into air or space. And no matter how advanced a solid propellant grain may be, it's still just a costly glob of highly dangerous chemicals with a fancy geometry until someone puts a suitable can around it—a can light enough to meet mass ratio requirements, strong enough to produce in volume and at a cost commensurate with national need.

Today's motor case requirements include wall thicknesses down to 0.020" and less, materials strengths in excess of 290,000 psi for steel and 100,000 psi for aluminum, strength at temperatures up to at least 1000°F—all this and reliability too. Briefly it boils down to a high-modulus motor case with a strength-to-weight ratio of at least 1,000,000 inches, compared to the 760,000 we're struggling to obtain now. It is a problem that encompasses materials, manfacturing techniques, test methods and more thorough approaches to stress analysis.

On M/R's cover this week is the best of one state-of-the-art approach to making high-strength, thin-wall solid rocket motor cases. "A gem of the craftsman's art," the project manager said when he first saw it. "The best of the whole program!" On these pages you see how it looked after hydro-static test! The question that has plagued and continues to plague rocketry is: Why?

• **Case history**—The rocket case on the cover was fabricated from machined forged rings of 5%-chrome hot-worked die steel girth-welded together. This is still thought to be a very promising basic approach to high-performance solid rocket motor case manufacture.

Case diameter was 31 inches; length, 11 feet; wall thickness, 0.098 inches. Tolerance on the wall was held to ± 0.002". Ovality and banana were negligible, and the maximum TIR (total indicator reading) was 0.080"! All welds were X-rayed before and after heat treatment. No weld repairs were necessary. The as-machined finish on the case was less than 64 microinches.

Test of both welded and unwelded coupon samples that accompanied the case through heat treatment showed the processed material to have a minimum yield strength of 241,000 psi, a hardness of $R_c = 53$ and an elongation in the transverse and longitudinal directions of 6% and 11% respectively. Numerous pull tests showed an ultimate tensile of 270,000 psi and 100% strength in the weld and heat-effected areas. There was no decarburization. A perfect case—or so it seemed.

Upon delivery to the customer, the case was subjected to 10 "low-pressure" hydrostatic cycles at 500 psi each "to check out strain gaging and instrumentation." Then, during the first of two full pressure static and one dynamic hydro-test, it failed at a pressure of 875 psi. Its design minimum was 1175 psi, or a hoop stress in the wall of 210,000 psi. Again the question: Why did it burst at such a low stress when every pre-test check indicated a minimum yield of 240,000 psi and a burst of 270,000 psi? And why, when it did fail, did it shatter as though it had been heat treated into the blue-brittle $R_c = 74$ range?

The answer to question number one is: Notch sensitivity. The answer to the second question is a recently appreciated peculiarity of the kind of biaxial loading you get in a cylindrical pressure vessel.

This case history is typical of the kind of frustration rocket motor case makers have run into ever since first efforts were made to achieve a steel case with a minimum yield strength in excess of 180,000 psi.

You get an idea of how important this problem is when you realize that Aerojet-General is buying *Polaris* motor cases from no fewer than seven different suppliers, in addition to its own in-house development work; and that Navy's Special Projects Branch and Aerojet together are conducting 30 different *Polaris* case development programs. Most are aimed basically at overcoming notch sensitivity in high-strength motor cases.

• **Notch sensitivity**—Like many other principles now beginning to be applied to rocket motor case manufacture, notch sensitivity has been known in laboratory research work in one form or another for many years. Rarely, however, has it been necessary to apply it to large pieces of production hardware. Now, all preliminary indications are that it *must* be taken into account in designing any motor case with a minimum yield strength-to-weight ratio in excess of 730,000 inches.

Technically, notch sensitivity is the ratio of the notch strength of a material to its smooth (unnotched) strength. Notch sensitivity increases as the ratio decreases. For all practical purposes the maximum value the ratio achieves is 1.05, where the notched specimen is stronger than one that is flawless. The ratio may get as low as 0.20. What this all means is that a flaw—even one too small to be detected by any currently available means—may radically change the strength characteristics of any given material.

Flaws, or notches, include: cracks in the material, inclusions (as in a weldment), occlusions, local brittle spots—any discontinuity in the structure of the material.

Essentially, these small flaws act as stress raisers, causing local increases in stress equal to many times the calculated case stress. Under these circumstances the flaw propagates as a fast-growing crack—usually with catastrophic results. This is the same thing that caused Britain's Comet jetliners to blow up a few years back, and, apparently this is what happened to the case on M/R's cover—though the company doing the hydrotest was taking movies at 24 frames a second (compared to 1000 frames used by most rocket motor companies) whi made it impossible to determine t initial failure and its subsequent pro gation.

• **Notch ductility**—The opposite notch sensitivity is notch ductility. T is a measure of the ability of a n terial to permit local plastic deforn tion to relieve high notch-induc stresses. This means that small volun of the parent material actually mc in such a direction as to relieve t stress without increasing the size the flaw—and thus starting a r crack.

Notch sensitivity—its causes a characteristics—is the object of a la amount of research and testing by su interested agencies as Naval Resea Center, Naval Gun Factory, Spec Projects Branch, Bureau of Ordnan ARDC, Redstone Arsenal, NASA, Materials being tested run the ga ut—X-200, 4130, 4340, 12 Mo S.S. 410, S.S. 301, S.S. 304, 64 AM-350, Vascojet 1000, etc.

Virtually all show that at the h strengths demanded today—220,0 to-240,000 minimum-yield—nearly materials tested show a high no sensitivity when heat-treated to th optimum unnotched tensile streng Results also indicate that a hig notch strength can be assured by h treating to a somewhat lower notched strength level. See the cu accompanying this article for U Steel's air-quenched missile boo material, X-200, and for the 5 chrome hot-worked die steel, Vasco 1000.

These figures don't mean that h strength cases can't and won't be m —every now and then. Indeed t have. What it does mean is that conventional fabrication methods, th can be no guarantee of repeatib on the assembly line—or of reliab in flight—not until materials can delivered and fabricated in a gua teed flawless condition; until inspec methods can be developed to spot such flaws (once spotted they can repaired); or until materials and fa cation methods are developed that not subject to notch sensitivity. three approaches are currently u exploration.

• **Random failures**—Notch se tive materials give the highest stren ever achieved—if there is no nc But if one case goes to 270,000 the next one may fail at 145,000; next at 230,000; others at 170, 255,000, 200,000, 150,000, 260, etc., even though materials and cessing may be identical in each All failures are random. There is pattern from which to predict fu performance, and thus no reliabilit the finished product.

This is why you read about claims burst strengths up to 300,000 psi on one hand, but on the other, you've to read about repeatable flight rdware in excess of 200,000 psi.

Some of the characteristics of notch isitivity discovered to date are sursing. For example, it bears no obus relationship to:

• **Elongation**—Notch sensitivity, nerally speaking, is independent of per cent of elongation—except in very low percentage range (just a v percent), where most materials are y notch sensitive.

• **Yield-tensile strength ratio**—This the ratio of min-yield strength to imate tensile strength. With some cket motor case alloys it is a high ure; with others, quite low. This ead between first plastic deformaa and failure seems to bear no conent relationship to notch sensitivity. a material is notch ductile, it will eve stress concentrations. If it isn't, von't.

Those physical properties which ear to affect notch sensitivity inde:

• **Ductility**—The greater the ductility, the less the notch sensitivity, but also, unfortunately, the lower the material's minimum yield strength.

• **Decarburization**—Convention frowns on decarburization during heat treatment, since it usually defeats the purpose of the alloying effort. Recent work, however, shows that for high-strength motor cases a modicum of decarburization (to a depth not exceeding four per cent of wall thickness) reduces notch sensitivity—particularly to surface flaws.

• **Grain direction**—Often, but not always, notch sensitivity is worse in the transverse grain direction.

• **Temperature**—Generally, the higher the environmental temperature the lower the notch sensitivity. Thus, some of the reported 240,000 psi min-yield motor cases have been hydro-tested at a temperature of over 300°F. At this temperature the material is notch ductile, whereas at room temperature it is notch sensitive.

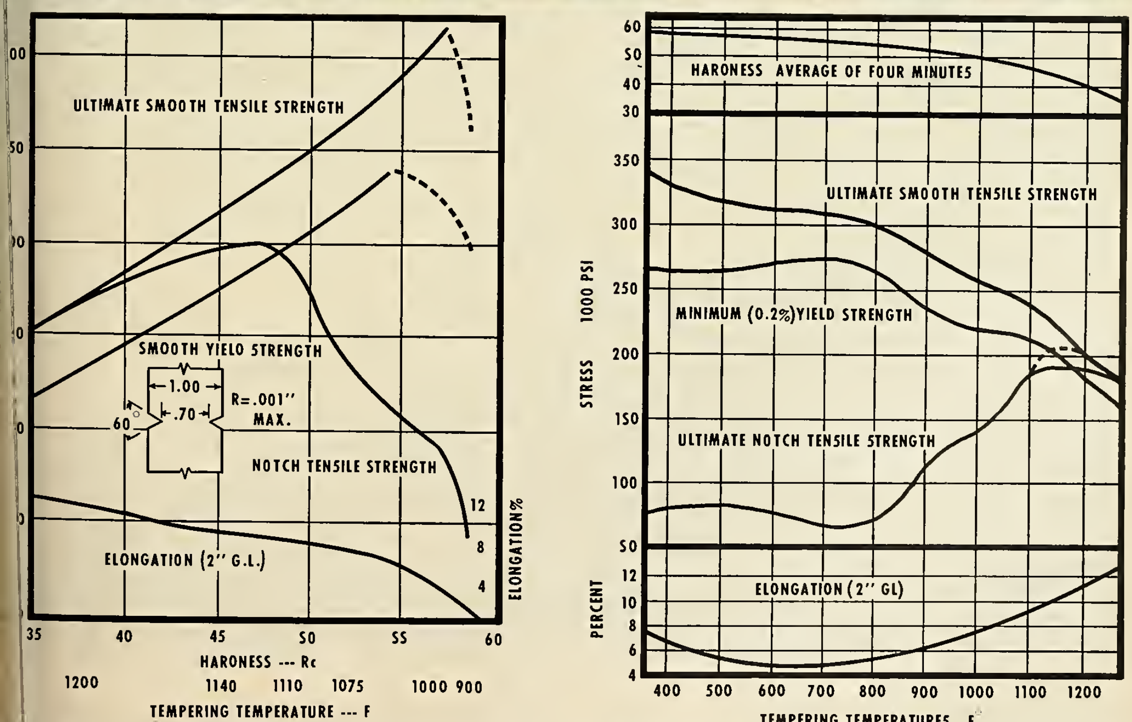
• **Wall thickness**—Very thin sheets (wall thickness below 0.010″) show a much lower notch sensitivity than thicker sheets of the same material. Why? No one knows. It is only an empirical conclusion, as a result of tests.

• **Alloy concentrations**—Notch sensitivity is usually less with alloys that have a lower carbon concentration (0.35-to-0.45% C), such as SAE 4340 types of steels.

All of this technical talk may sound like so much who-struck-John, but it is deadly serious business—one that has cost the American tax-payer literally hundreds of millions of dollars. It can't help but be a major factor in the *Polaris'* and *Minuteman* programs.

• **Size**—Higher strengths have been repeatedly achieved in small-scale model motor cases, say, six inches in diameter. However, results in these small test cases do not scale up to the larger size with any usable degree of reliability.

This is a highly competitive market and the company that first cracks the "notch barrier" effectively, repetitively and reliably and achieves a 1,000,000-inch strength-to-weight ratio in a high modulus (metal—and almost certainly steel) motor case stands to profit much thereby—to say nothing of what it will mean to the country's missile and space flight programs.



R LEMS of notch sensitivity in large solid rocket motor ase were largely unsuspected until a few months ago. Left is -2 0.063 sheet (1750°F, quarter hour (Argon), oil tempera- ure, hour air) at room temperature tests. Right is Vascojet 1000 .063 sheet (850°F (Argon), ½ hour; air triple temper, 3 hour total) at room temperature tests. (Graphs courtesy Lewis Lab, NASA.)

AIRBORNE! FIRST LOW-COST SPACE AGE AIRCRA

USAF-NORTHROP T-38 TALON ANSWERS AIR TRAINING COMMAND NEED FOR A SAFE, ECONOMICAL TRAINER FOR SPACE AGE AIRMEN

Pioneering Monkeys and Mice

Two monkeys came back strong from *Jupiter* flight, though one dies later; *Discoverer III* tests will be US' most elaborate effort

by James Baar

WASHINGTON—This year may be remembered as the year of the space animals. The U.S. Army entry: Rhesus Monkey Able and Spider Monkey Baker. The U.S. Air Force entry: Four black mice.

Other future entries: A variety of animals including larger primates.

The Army's monkeys lodged in the nose cone of a Chrysler *Jupiter* scored ahead of the Air Force when bad weather and technical difficulties delayed launching of *Discoverer III*.

Able died four days later when Army surgeons attempted to remove an electrode placed in her body before the historic launching. However, Army officials said death was caused by convulsive heart movement during the operation and was not a result of the space flight.

Until Able and Baker soared down the Atlantic Missile Range May 28, Russia held most of the records in the space animal derby.

Russia's *Sputnik II* carried the dog, Laika, into a 140-1038 mile orbit Nov. 3, 1957. Laika survived more than a week.

The Russians also have announced successful recovery of two small dogs after they traveled 281 miles straight up in a rocket.

The Army last December sent a monkey named Old Reliable down the Atlantic Missile Range in a *Jupiter*. He never was recovered, but telemete ed data showed that he survived re-entry.

The *Discoverer III* satellite—the most advanced U.S. biomedical space experiment to date—was originally scheduled for May 21 at the Pacific Missile Test Range. The shot was postponed because of bad weather. Technical difficulties forced postponement again May 23 and again May 25.

The Air Force provided the same type missile for *Discoverer III* as it had for the first two *Discoverers:* A Douglas *Thor* topped with a Lockheed-Bell second stage.

Other key *Discoverer III* statistics—all similar to *Discoverer II:*

- A 1600-pound second stage that goes into orbit.
- A 440-pound payload including a 195-pound re-entry vehicle.
- Equipment designed to stabilize and adjust the attitude of the satellite in orbit.
- A recovery system designed to eject the re-entry vehicle at a determined point so that C-119's co be waiting to snag it after it re-ente the atmosphere.

But the all-important difference the presence of the four mice. T recovery would mean the first succ ful return of an animal after it orb the earth.

The mice were placed in a Gen Electric life capsule equipped with conditioning and food.

The pop bottle-size air conditic was designed to keep the tempera at about 75 and eliminate muggir The food—a mixture of orange ju oatmeal and gelatin—fits into a cer feeding station. Instruments mor the mice's reactions.

Results from the Able-Baker laun ing are still being analyzed—part larly the effects on the flight on n spores, sea urchin eggs, human bl onion tissue, seeds and fruit fly pu that were carried in the *Jupiter* cone.

The sea urchin egg experiment cluded fertilized eggs, unfertilized and eggs that were fertilized during 1700-mile flight. Scientists sought check the reaction of both weight ness and cosmic rays on fertilizat

Scientists have expressed con erable doubt that some species customed to a 1 g environment carry out their life cycles in a diffe one.

First results showed that se pound Able and one-pound Baker perienced no "undue alterations" their basal physiology.

This was particularly encoura since the two monkeys experience to 15 g's during takeoff and 38 for less than a second during re-e The most that the first man in spa expected to experience is 12.

Army and Navy scientists stre the risk in extrapolating data f animals to men. But the indica were that men would be able to d well as monkeys.

THIS MOUSE was one of a group of 60 candidates for *Discoverer III* ride.

MONKEY ABLE, who survived space flight but died later in operation.

HELIARC welding the exterior of a double-walled thrust chamber for Rocketdyne's *Redstone* engine.

Welding *Redstone*

Extreme care exercised at Reynolds plant precludes faulty welds

SHEFFIELD, ALA.—Weld strength played an important part in the reliability—about 99%—of the y's *Redstone*.

More than 1000 feet of welds go the construction of the aluminum g used for the *Jupiter-C* rocket the *Redstone* ballistic missile. The gs are fabricated at the Reynolds ls Company missile plant at ield, Alabama. Performance rec- show that because of precision ing, constant research, and in- ve inspection, no *Redstone* or *er-C* has failed due to faulty welds.

luminum outer wall of the 75,000 hrust *Redstone* engine's heat ex- ger is manually Heliarc welded an HW-9 torch. The finishing on the engine's critical thrust ber are also made manually with liarc WH-12 torch. The engine's ide tank, constructed of 17-7 ph ess steel, is joined by a Heliarc 13 torch mounted on an Oxweld 7 carriage.

Provides versatility—The main n for the use of inert-gas shielded- elding on the *Redstone* engine is ersatility, according to Linde cts. It can be used on many dif- metals and thicknesses, deliver- e same results on each.

l Heliarc welds undergo strict inspection before the engine is bled and tested on a static test After final factory approval, the is ready for shipment to ler Corporation in Detroit.

insure quality, Reynolds em- an inspector for every four tech- s who work on the casings. The num sheet and incoming parts ecked for blemishes and tested electronic devices to detect po- weak spots which might fail t. Samples of each lot are with- from chemical analysis and a te record is made of every part d to go into the missile. The sheet is then covered with protective paper tape to reduce the chance of being scratched during fabrication.

• **Fast speeds**—Each 20-foot sheet of type 5086 alloy is trimmed to size to form a shell meeting a .015-inch O.D. tolerance. After the sheets are rolled into a cylinder, the edges are cleaned, scraped and Sigma welded (inert-gas consumable-electrode) at speeds up to 100 inches per minute.

This longitudinal weld is made on an automatic Sigma SWM-3 machine, equipped with an HW-16 torch which is mounted on a Linde OM-48 side-beam carriage and controlled by a Linde SCC-1 control. The shell is then trimmed in length to a .020-inch tolerance and aluminum "Z" rings are spot-welded inside to support the shell.

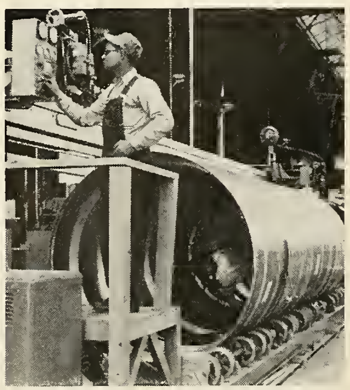
Eight shells of varying lengths are joined to form the center section, or fuel tank, of the *Redstone*. These shells contain the bulkheads of the tank. The shells are assembled on another automatic Sigma SWM-3 machine and girth welded at speeds up to 55 inches per minute.

Power settings are usually 160-250 amp., 20-22 volts. Average welding time is only 4 to 10 minutes, but preparation takes the major part of time due to the extreme care required. First, the weld area is scrubbed with trichlorethylene, then the edges of the sheet are scraped with a special power scraper to remove oxide. Several power interlocks are provided to prevent machines with heavy electrical-current drains from starting during the critical weld cycle.

Prior to welding, a sample weld is x-rayed and checked for physical properties. After welding, each weld is x-rayed to doublecheck weld quality. When the center section meets radiographic and dimensional inspection, a series of aluminum pipes—which carry liquid oxygen, alcohol, or other fuel—are welded in place. The completed section is then ready for hydrostatic test, calibration, chemical cleaning, final assembly and finishing.

When the center and tail sections get final factory approval, the casing is forwarded to Chrysler Corporation in Detroit where the engine and instrumentation system are added to the ballistic shell to form a completed *Jupiter-C* or *Redstone* missile.

SIGMA welding is used by Reynolds Metals to make longitudinal weld on *Redstone's* center section.



ANOTHER Sigma machine makes a girth weld on *Redstone* fuel tank.

BRITISH ASTRONAUTICS

Government evasive on how much will be spent for space flight program; planetary probes and manned flight ruled out already

by G. V. E. Thompson

LONDON—British effort in the field of space research has so far been confined to the vertical sounding of the upper atmosphere with a few *Skylark* rockets, the tracking of U.S. and U.S.S.R. satellites and the analysis of the data obtained. Now government approval has been given for the establishment of a British spaceflight programme.

Government spokesmen have been evasive as to the expenditure involved, saying only that the sum spent would be hundreds of thousands of pounds, rather than millions, and that Parliament would not be committed to large or unlimited sum of money. A steering committee under the chairmanship of Sir Edward Bullard, F.R.S., has been appointed to advise on the allocation of money to the various projects.

At the moment no precise programme has been agreed upon, though it has been decided not to build planetary probes, not to undertake manned flight, and not to include animals in any launchings. Design studies have been put in hand for adaption of the *Blue Streak* and *Black Knight* rockets for launching satellites weighing 1000 lb. into orbits some hundreds of miles above the earth. It is expected that these studies will take about six months; the first satellite vehicle will probably be ready for firing in about two years' time. The likely design is a three-stage vehicle. The first stage would be *Blue Streak* (as yet unfired), the second would be *Black Knight*, and the third would be some solid-fueled rocket.

The R.A.F. teams at present being taught to fire *Thor* rockets will probably be responsible for the launching of the British satellites. It is too early for launching sites to be known—the most likely choice is the Woomera rocket range in Australia. If other Commonwealth countries participate in the programme, Kenya would be very suitable for launching satellites into equatorial orbits, but lacks the necessary ground facilities. The money to be allocated to the programme is not intended to cover the cost of constructing launching sites, but only design of the vehicle, adaption of military rockets and development of satellite instrumentation.

The greatest effort will be in the field of instrumentation; the series of experiments at satellite altitudes which scientists consider desirable would take over 40 years to carry out, even for a country with a space research budget as large as those of U.S.A. or U.S.S.R. Britain cannot hope to cover all that might be done, so a selection will have to be made.

The initial experiments will be an extension of the present *Skylark* sounding rocket programme, and will include use of an improved *Langmuir* probe for measuring atmospheric composition and temperature, magnetic field measurements, mass spectrometry, and meteorological studies. Ultra-violet and X-ray astronomy are other potential lines of research.

The instrumentation will be available before the launching vehicles, so advantage will be taken of the U.S. offer to COSPAR to fly other countries' equipment in American satellites. Professor H. S. W. Massey, Chairman of the British National Committee on Space Research, is shortly to lead a team of experts who will visit Washington to discover how much help can be expected, when, and on what basis. Following questions in Parliament, the possibility of joint action with the U.S.S.R. is also to be studied.

• **Transatlantic radio via moon**—Britain and the U.S. have cooperated in carrying out tests of the moon as a mirror for transatlantic radio communication. The experiments have been successful and have commercial and military potentialities.

Studies of radar echoes from the moon have been made since 1946, and Dr. John Evans of the Jodrell Bank radio telescope research station in Cheshire, England, advanced the theory that these echoes returned from quite a small area of the moon's disk. The absence of scattering indicated that it should be possible to bounce back signals carrying messages wit[h] loss of intelligibility. This was de[mon]strated last year at Jodrell Bank [...] signals transmitted and received a[t the] same spot.

Pye Telecommunications Ltd[.,] Cambridge, England, became inter[ested] and provided a standard 1 kw., [...] mc transmitter for the transatl[antic] experiments, in which the 25[0-ft.] diameter Jodrell Bank radio teles[cope] sent messages to the moon. The [re]flected signal was received at the 84-ft. diameter dish of the U.S. [...] at Sagamore Hill, Hamilton, M[ass.,] which has only just become op[era]tional and can only receive at pre[sent]. A message in Morse sent from Eng[land] read: "We will have no trouble [...] fishing boats on this circuit," allu[ding] to the Russian trawlers suspe[cted] recently of tampering with Atl[antic] cables. This was followed by [...] transmissions.

Pye's are to produce a [...] diameter radio telescope with [...] power and higher frequency for fu[rther] experiments. These will include si[...] tests with the planet Venus (which [will] be at its nearest to the earth in [Sep]tember), and later with large inf[...] artificial satellites. Use of the m[oon] is limited to the time when it [is in] view of both transmitter and rece[iver]. However, the method is not aff[ected] by ionospheric disturbances.

• **Cryogenic propellants**—The r[...] engineer's approach to the handlin[g of] cryogenic liquids used as propel[lants] (ammonia, methane, hydrogen, ox[ygen], oxygen difluoride, and fluorine) [is] discussed by D. Hurden of the [de] Havilland Engine Co. Ltd. in a p[aper] read in London at a joint meetin[g of] the Institute of Refrigeration and [the] Low Temperature Group of the P[hysi]cal Society. Particular reference [is] made to the *Snarler* and *Scre[amer]* rocket engines developed by [Arm]strong-Siddeley Motors Ltd. for r[ocket] aircraft (later abandoned). For mis[siles], delivery to launching sites by insu[lated] pipeline from central storage are[as is] preferred to the road tankers [used] with the rocket aircraft. If nitr[ogen] gas is used to pressurize liquid ox[ygen] tanks, to prevent it dissolving in [and] contaminating the LOX, the two [can] be separated by a hollow piston; [dia]phragms of goatskin or kangaroo [skin] have been suggested, but the qu[ality] of the material is variable.

The *Screamer* LOX pump wa[s de]signed to deliver 25 lb./sec. at 80[0 ...]. It ran at 20,000 rpm. and abso[rbed] about 120 H.P. It was mainly [con]structed in stainless steel, the ox[ygen] seal being an optically flat stai[nless] steel ring soldered to a bellows [and] bearing on a rotating sintered br[onze] disk.

FBM Sub Provides New Market

With 45 missile-launching boats possible, lion's share of some $4.5 billion should go for support equipment

by Donald E. Perry

ROTON, CONN.—More than $2 n has already been provided for *'olaris* Fleet Ballistic Missile pro- r and the next five years may see er $4.5 billion expended for this ent weapon system.

mazingly enough, the lion's share funds will go for support equip- in this gigantic program which be marked by the launching of rst of possibly 45 fleet ballistic e submarines this week at Electric Division of General Dynamics here.

he $100 million George Wash- (380' and 5400 tons), which will s first Lockheed *Polaris* missile year, slides down the launching une 9. Five more boats now under uction will follow the GW once three months.

timately, within the next five the Navy figures that some 45 submarines will be an adequate er to keep at sea constantly and ation, allowing for their upkeep rew training.

Funding swells—Whether the will get that many FBM sub- es or not is another matter, but ogram has vital implications for and shipbuilding suppliers who urnish the tons of support equip- Let's look at it:

ngress appropriated funds for the ree FBM submarines even before easibility of launching ballistic s from beneath the ocean had demonstrated in full-scale tests. eorge Washington is expected to next year.

t in the meantime, further Con- nal and administrative faith in gram has been shown by plac- submarines under construction very early development of the This in turn has pushed the t of money appropriated for hardware beyond the amounts d in development.

s will give the nation, by the next year, three *Polaris* submarines with nine expected to be under construction. Cost? Well, $2.063 billion has been provided to date for the FBM program, bringing into being a vast program which includes:

Fifth of a Series on Missile Support

- The USS Compass Island, a navigation development ship which has been testing instrumentation for more than two years.
- Another ship, the USS Observation Island, which soon will conduct a missile firing at sea; and other auxiliary support vessels.
- Six FBM submarines, with keels for three more subs to be laid this year, bringing total construction to nine.
- A tender especially converted to maintain *Polaris* submarines on station outside the continental United States.

The money which has been appropriated through FY 1959 will buy missiles for the first five boats and will continue the missile's flight development and testing program.

• **Six in '60?**—How about FY 1960? The Navy is requesting $611.7 million for continuation of the program and there appears a distinct possibility

WORKMEN put the finishing touches on the George Washington, the nation's first FBM submarine to be launched at Electric Boat Co. June 9.

that a *Polaris*-minded Congress may authorize additional millions for possibly six more submarines.

This was brought out in hearings before a Congressional appropriations subcommittee earlier this year when Rear Adm. W. F. Raborn, director Special Projects office, Bureau of Ordnance, was questioned on the add-on cost of a six-boat program for FY 1960. For the six submarines a $600-million figure was given along with $51 million for additional support.

FY 1960 funds for the *Polaris* program will do several things:

1. Permit construction of a second FBM tender designed from the keel up for its missile role, rather than conversion of some existing ship.

2. Provide advance procurement of long leadtime components for three FBM submarines, bringing the total number of boats to 12.

3. Provide additional *Polaris* tactical missiles.

4. Continue an extensive flight test and evaluation program, and maintain R&D effort on reliability.

Here's how the amounts break down:

Operation and maintenance, $19,-275,000 (This would provide continuous support of test vessels and facilities, give upkeep and repair capability; give ship and ashore type training equipment; provide some $1.3 million in communication equipment and another $3 million in a "service-wide operations" activity).

Shipbuilding and conversion, $54,-042,000 (New tender construction would be $61 million, principally from previously appropriated funds); long time lead items for three boats; basic reactor components, cores, and the ships' SINS inertial navigation equipment.

Procurement of ordnance and ammunition, $314 million (of this $84.5 million would go for tactical missiles; $107.2 million for missile components for development test; $13.4 million for operation of flight test program; $77.2 million for production facilities and other missile system support; and $31.6 million for training, logistics and weapon system support).

• **Participation**—And how are suppliers participating in the FBM program? Electric Boat Co. points out that through January 55% of direct purchase orders under the FBM program went to small business firms. In the same period, small business got 38% of the dollar volume of stock inventory and 58% went into plant maintenance.

Actually, however, EB has only added perhaps 50 more suppliers under the FBM program. It acts more as an assembly participant in the gigantic jigsaw program with many items regarded as GFE (government-furnished equipment) under separate contracts by BuShips, BuOrd and Special Projects Office.

While Congress has almost overwhelmingly endorsed the *Polaris* FBM program, obsolescence of the FBM submarine frequently comes up for discussion.

Admiral Raborn points out that a weapon system does not become obsolete so long as it remains an "efficient instrument for the performance of its mission, in comparison with other weapon systems and in the face of existing defenses."

• **Growth potential**—He points out that the useful life of a submarine is 15 to 20 years, that the Navy is building a 1965 submarine and missile today and that everything that is going in is based on a potential and growth capability.

You have only to look down one of the 16 missile launching tubes of the George Washington to confirm this. While Navy will not give out any statistics on *Polaris*, it is generally conceded by the missile trade press that it has a length of about 26.5 feet and about a 5' diameter. The Navy is still reluctant to talk about the size of George Washington's launching tubes (even though they were designed on practically 50-year-old standards of torpedo tubes). However, it is safe to assume that they could accommodate a future solid-propellant missile approximately 7 ft. in diameter and more than 40 foot long.

This will extend the range of *Polaris* to an ICBM category without any major revision of the FBM submarine, thus giving it a global coverage capability of 100% rather than an 80-90% of potential enemy targets as previously speculated.

• **Old & new**—It is no secret that the missile launching tubes operate on the tried and proven principle of torpedo tubes—air expulsion. Electric Boat Co. design engineers are inclined to gloss over their design achievement for the tubes and EB's FBM Project Engineer, William G. Atkinson even refers to them as "simpler than torpedo tubes." He adds that they are bigger and easier to service and maintain.

But back of this came good shipbuilding engineering. Included was a special air-ejection system for the missile. Another air compressor has been added to the submarine's system to handle missile launchings which probably will be made at 4500 psi.

With 16 missile tubes lined up [illegible] of the conning tower sail in pairs [illegible] eight, CG principles and additional [illegible] sign parameters for water pumping [illegible] trim compensation were major [illegible] sideration. The George Washing[illegible] a sister ship to the Skipjack—wo[illegible] fastest submarine—differs only in [illegible] addition of a 130-foot missile sec[illegible] aft of the conning tower sail. Th[illegible] are no provisions for reloading [illegible] missile tubes from the submarine.

After the firing tube hatch c[illegible] has been opened M/R has learne[illegible] plastic diaphragm directly above [illegible] missile reportedly keeps the missile [illegible] Air pressure within the tube equal[illegible] outside water pressure. The missil[illegible] fired through the diaphragm, an[illegible] special water compensation system [illegible] to be installed to accommodate [illegible] great change in weight.

One example of support equipm[illegible] for the tubes are heat transfer [illegible] developed by Tranter Manufactu[illegible] Inc. of Lansing, Mich. Each *Po*[illegible] firing tube will have the units—w[illegible] consist of embossed sheets of m[illegible] welded together to form channels [illegible] the passage of hot or cold wate[illegible] maintain the solid fuel at the spec[illegible] temperature at the time of firing. T[illegible] perature will be maintained withi[illegible] range of plus or minus three degree[illegible]

• **Seats open**—One source says [illegible] submarine missile men are taking [illegible] new tubes in stride. In both the forw[illegible] and aft missile compartments on [illegible] three decks are card tables of [illegible] cribbage variety, nestled between [illegible] tubes. Cribbage has been a fav[illegible] submarine game for many years, [illegible] submarine missile men apparently [illegible] take advantage of the new-found sp[illegible]

Atlas Parts Test Stand Produced by Rocketdyne

CANOGA PARK, CALIF.—A port[illegible] Components Test Stand for all ele[illegible] pneumatic and hydraulic parts of [illegible] *Atlas* ICBM has been delivered [illegible] Vandenberg AFB by its designer, [illegible] ketdyne Division of North Amer[illegible] Aviation, Inc.

The three-ton unit, first of se[illegible] to be constructed, will make it pos[illegible] to check out *Atlas* parts at SAC sq[illegible] ron level. Incoming spares or co[illegible] nents removed for service or r[illegible] can be field-checked prior to inst[illegible] tion in the missile.

Under design and fabrication [illegible] the past year to meet requests of [illegible] vair, Rocketdyne and *Atlas* sup[illegible] engineers, the test equipment will [illegible] dle all parts that are field repair[illegible] including Convair-developed co[illegible] nents.

A Mammoth Gantry for *Saturn*

Structure will cost $9.5 million with test tower, opening new dimension in missile support equipment

HUNTSVILLE—America's biggest
vehicle—the 1.3-million-pound-
t *Saturn*—will be assembled in
nation's largest gantry, a 305-foot
ter which will tower into the sky
igh as a 28-story building or a
of four *Atlases*.

onstruction of the huge mobile
gantry is scheduled to begin
ly. It will signal a new era in the
of missile support equipment for
r space vehicles yet to come.

he Army Corps of Engineers,
n designed the structure with the
y Ordnance Missile Command and
ice H. Connell & Associates,
ni A&E firm, says bids will be
tised soon. Construction may be
or at Cape Canaveral.

stimated cost of the gantry and
t test tower will be $9.5 million.
static test stand towers are 135
t high, by comparison, and cost
nd $1 million apiece.

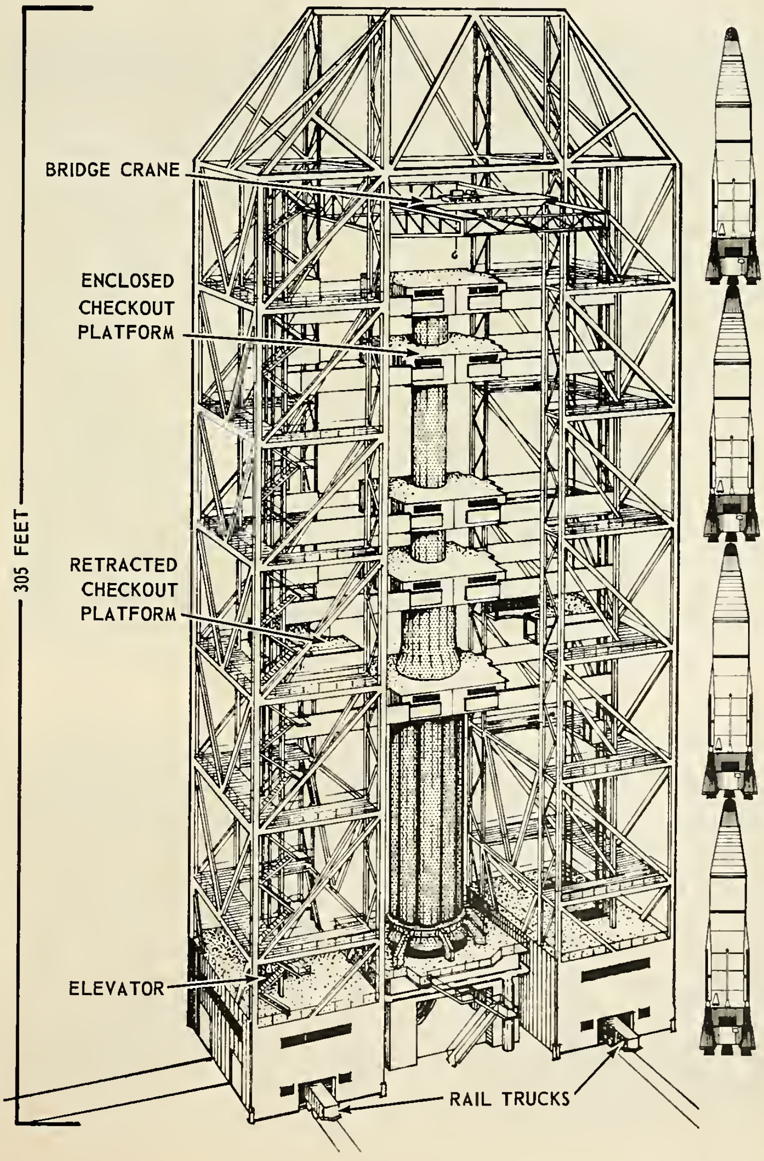
he gantry to accommodate the
tage ARPA-ABMA *Saturn*, which
l ave a cluster of eight H-1 Rocket-
n *Jupiter* rockets as a booster
, May 25, page 36), will be a
etely self-sufficient unit. It will
n "on-board" diesel electric gen-
s sufficient to power all equip-
and propel the structure along
ets of railroad tracks at 40 feet
inute.

ecifications call for one freight
wo passenger elevators. Bridge
, vertically positionable from 43
25 feet high, will be capable of
ng out to a point 20 feet beyond
ructure. There will be six en-
checkout platforms located at
of stage interconnection, control
uidance sections, payload and
stage fueling and servicing.

nge of platform vertical adjust-
vill be 175 feet, extending from
vation of 50 feet above the
ing pad upwards to 225 feet.
service platform is halved for
ire about the rocket vehicle,
will be about 200 feet high. The
platforms are retractable into
ver legs, facilitating the handling
ckout equipment.

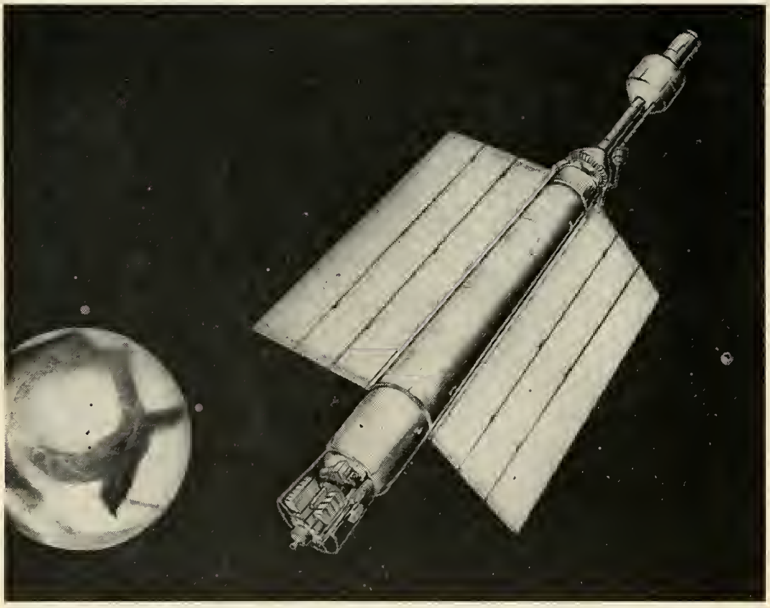
borate facilities have been incorporated to provide for fire and lightning protection, personnel safety, heating and air conditioning.

Static firing of *Saturn's* booster-cluster is expected here some time this fall. Flight testing may come at the Cape next year. If the big gantry is built here, Corps of Engineers officials say it will be transported to the Cape as nearly intact as possible.

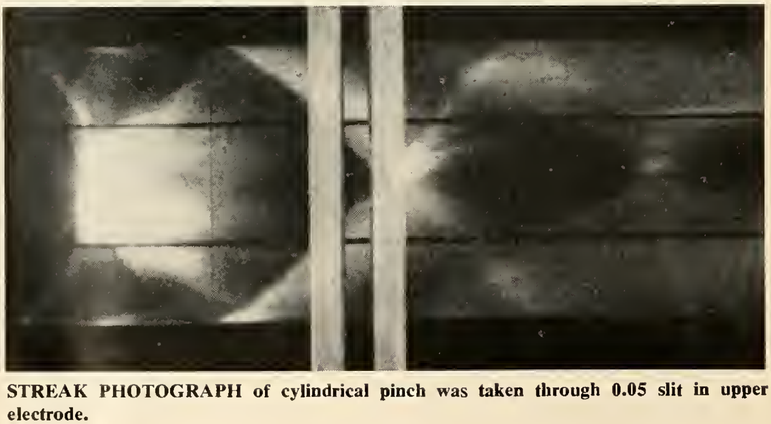


Plasma Engine Delivers Nearly 2-lbs.

Republic's experimental 'magnetic pinch' engine produces over 4000-lbs. at peak with 1700 sec. I_{sp}



PROPOSED MARS vehicle's folding "wings" would be heat radiators. The nuclear reactor would be housed in the nose with plasma engine in tail.



STREAK PHOTOGRAPH of cylindrical pinch was taken through 0.05 slit in upper electrode.

by Hal Gettings

FARMINGDALE, N.Y.—A unique plication by Republic Aviation C of ion (or, more properly, "plasn propulsion promises to provide a p tical interplanetary space vehicle gine within a relatively short time.

The device is capable of thrusts above those obtained by present perimental ion propulsion systems. "magnetic pinch" engine produces p thrusts of more than 4000 pounds a specific impulse of over 1700 onds. Average thrust runs 1-2 lbs. systems to date have produced thr of only fractional pounds.

Most of Republic's work has b done in company-sponsored resea The firm will release no figures or investment to date, but it is estim that Republic has spent somewher the neighborhood of a million dol on the program in the last two year

The company recently received contracts totaling $193,000 to tinue the work: one, with AF O of Scientific Research for analysis pinch effect gas dynamics; the o with Office of Naval Research for peated pinch cycling techniques.

• **Will provide 800 kw**—Repub design for an interplanetary en calls for a nuclear power source w provides 800 kw of electrical po Present plans include a nuclear actor-turbo generator combinat With the rapid strides being mad thermoelectricity however, a di conversion system may be avail when needed. Weight of the engine power plant will total somew around 12,000 pounds. The additio propellant, structure, guidance, metering, etc., will bring total pay weight to around 27,000 pounds— within the capability of super liquid boosters now under developm

The advantage of the Republic

ne is that it is easier to get suffi- ent mass movement from the mag- tic pinch than from conventional ion chniques. A patented "curved nozzle" ilizes the pinch to form a shock wave iston" which produces the high- locity axial thrust. A further ad- ntage is that the pulsing technique bjects the engine itself to only micro- cond-duration high temperatures. The erall heating effect is small and no oling is necessary except for long- ration flights.

The plasma engine uses a heavy gas ch as liquid oxygen or nitrogen and rns it into plasma—a fourth state of atter evolving from gases in which e molecules are broken into electrons d positive ions. This provides tre- endous power for a comparatively all amount of fuel.

• **Utilizes intermingled particles**— cret of the plasma engine is a ethod of compressing and accelerat- g a fluid in a cylindrical magnetic ld and shooting plasma out the rear tremendous velocities. Unlike the oposed ion engine which accelerates ns and negative particles in separate eams, the plasma engine utilizes the ermingled particles in a single jet rust. It can also operate on fuels ore readily available than those re- ired for the ion engine, and attain eater thrust.

The basic principle of the plasma nch is illustrated in Figure 1. A 6000- lt charge from a capacitor is dis- arged into a gas confined in a cyl- ider, the ends of which are electrodes. rrent then flows in the outside cir- mference, or "skin," of the resulting ized gas (plasma). The magnetic ld set up by the flowing current ex- s an inward force on the plasma ylinder" causing it to constrict to a n tube at the axis of the electrodes, ing it the action of a piston. This gnetic piston causes a shock wave ich raises the temperature and pres- e of the gas. If a hole were cut in center of the right-hand electrode, resulting energy could be released ough it to provide a high-velocity j

This principle is utilized in the public engine and greatly enhanced forming the electrodes into a curved zle. The piston action is very simi- to that described for the basic en- e in Figure 2. The pinch effect ves the gas towards the center and hock wave is generated ahead of the on. The curvature of the electrodes ces the wave into an axial direction.

The compressed and accelerated then leaves the nozzle-electrode at h velocity. The exhaust nozzle is igned to convert a substantial ount of thermal energy existing in exhaust to kinetic energy. At the

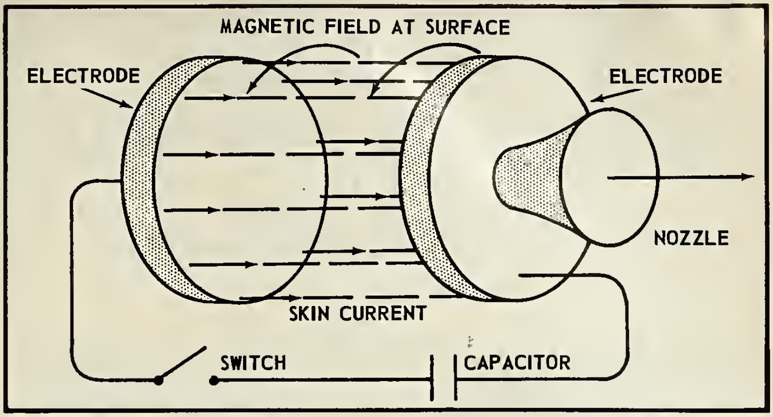
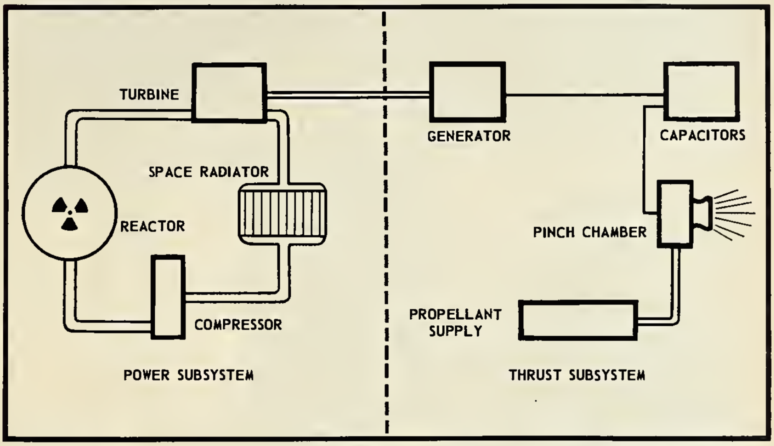


FIG. 1—Schematic drawing of basic engine shows skin currents and magnetic field set up by the high-voltage discharge into the gas between the electrodes.



POWER PACKAGE for Mars vehicle. Units shown would weigh 14,000 pounds. Development of direct thermoelectric source would eliminate turbine and compressor.

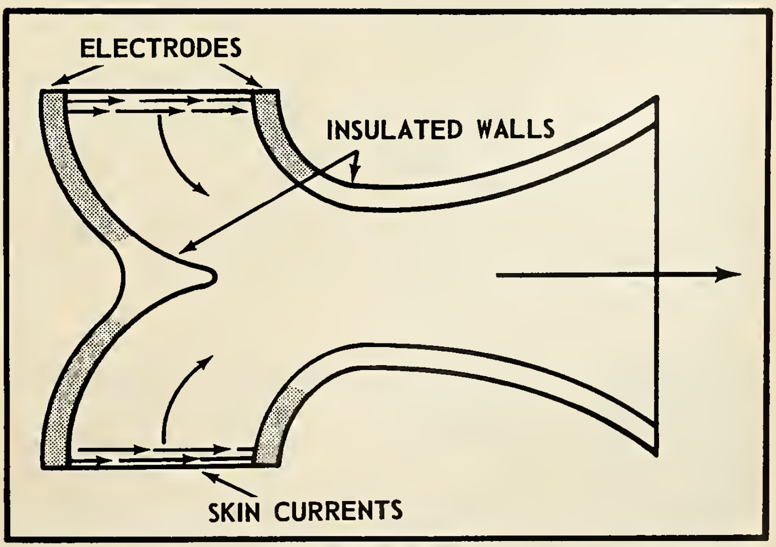


FIG. 2—Republic's patented "curved nozzle." Magnetic pinch produces shock wave in throat which expels high-velocity mass to develop thrust.

nozzle throat the energy produced approximately 50% kinetic and 50 thermal. Expansion in the nozzle cc verts a significant percentage of tl thermal to thrust-producing kine energy.

The thrust produced exists for period of a few microseconds. T cycle is then repeated an undisclos number of times per second. Resear work is going forward on optim cycling techniques and periods.

• **Prototype built**—An experimen prototype of the engine has been bu and operated over a period of seve months. First test results showed thrust over twice as great as earl calculations had indicated.

There are many unknowns in tl new field, however, and some of t analysis must be based on assumptio Many areas, too, have moved ahe of existing instrumentation techniqu and the velocities, temperatures, et must often be measured with less th perfect precision.

Exhaust velocities from the engi range around 150,000 fps. Temperatu are in the neighborhood of 20,0C 25,000°K. As mentioned before, ho ever, since the high temperatures ex for only microseconds at a time, t cumulative heating effect is small.

The plasma engine can find ma applications in various space vehicl One specific use would be for positi and attitude control of satellites. Su an application would require only small version of 1/100 to 1/10 pou thrust. It could use a solar cell pow source for ionization current.

• **For Mars mission?**—Since t plasma propulsion system is a lo thrust low-propellant consuming engi it is primarily suited for low-accelea tion long-range missions in relative force-free fields. It would, therefo fit well, for example, in an interplar tary vehicle such as the Mars reco naissance ship illustrated. The "wing of such a craft would be necessary contain the radiators for bleeding the heat generated by the nucle power source.

The Mars vehicle would be c signed to take departure from a 10 km earth orbit and culminate in a 5 km Mars orbit. Travel time wou require approximately eight months

Republic recently announced a $ million space research and develo ment program and construction of $14 million engineering research cent has begun. The company plans to cc tinue its own research on plasma p pulsion along with the work present under contract. The program will carried on by a staff of 50 scienti and engineers under the direction A. E. Kunen who has directed t plasma research from the start.

ADMIRAL CORP. nuclear engineer remotely handles components in the company's 20 kilocurie cobalt 60 radiation chamber.

Radiation Effects: What's Being Done?

by Charles D. LaFond

CHICAGO—Nuclear radiation envi-nents born of our scientific and ineering advances in recent years essarily have altered requirements test methods for electronic com-ents.

The problem was recognized early, both the military and industry been testing a multitude of de- and components with particle and radiation at varying energy levels. goal of course is to acquire enough wledge to evolve new or modified ronic components that will func- reliably under otherwise damaging tion.

uch radiation can occur from a ear explosion or in the field of a ear reactor. The design engineer is oled primarily with the latter. The or is a problem only when insuffi- shielding is provided. This occurs a weight limitation prevents the of suitable shielding. And space air-supported vehicles in our pres- oncept inherently demand this lim- n.

he proposed nuclear-powered ram- *luto*, the boost-glide *Dyna-Soar*, other possible orbiting satellites by their nature, require electronic onents capable of surviving in onments of sustained high nuclear tion.

he Nuclear Physics Department of ral Corporation, located here, has a strong arm in the continuous Force program investigating the se effects of unconventional en-ments. The program has been sup- since January, 1955, by a series search contracts from the Elec- Components Laboratory of Wright Air Development Center. Admiral currently is working under a $2-million contract to study contemporary and future requirements for electronic components.

• **How it happens**—The two damaging constituents of nuclear radiation are neutrons and gamma rays. In all tests, the energy spectrum of each must be known since variations can have damaging effects ranging from normal extremes to complete failure.

In addition, two other damaging conditions must be considered: large amounts of ozone are produced in the local atmosphere by highly ionizing gamma radiation; and increased temperatures in components will result from gamma radiation absorption. The ozone problem will be serious only during long sustained flight.

Admiral research has indicated that about 0.01 watt/grain is dissipated in components (subjected to radiation in the CP-5 research reactor at Argonne National Laboratory), and that the resulting heat rise will effect a derating in performance or require supplemental cooling equipment.

One of the most confusing problems Admiral has faced is the current use of different dose units in technical literature describing magnitudes in particular environments. (Example; Roentgen Equivalent Physical (rep) or Mammal (rem).)

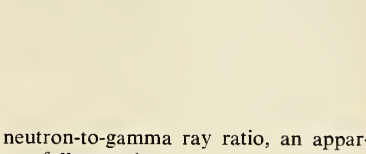
The problem is readily evident. A neutron dose rate of 10^4 fast neutrons/cm^2/sec equals 1 rep/hr. Also, 7 x 10^5 gammas/cm^2/sec of 1 mev energy equals 1 rep/hr. But it has been proved in the laboratory that radiation-induced damage to a resistor by an equivalent rep dose of neutrons far exceeds that of a rep dose of gamma rays. Without the knowledge of the neutron-to-gamma ray ratio, an apparent fallacy exists.

Research to date has provided other highly significant general conclusions:

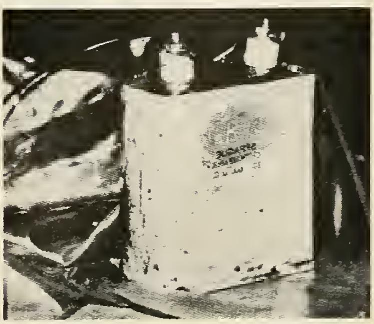
• Thermal characteristics of proposed nuclear-powered space-aero vehicles will severely limit capabilities of electronic components.

• The provision of sufficient gamma ray shielding in these vehicles is doubtful and the magnitude of gamma heating will vary directly with reactor power and shielding.

• New techniques may have to be developed to transmit or receive from these vehicles. As a result of attenuation and share rotation suffered by an



RADIATION-INDUCED damage to image orthicon tube by 18-hr. exposure to the CP-5 nuclear environment.



RADIATION damage received by oil-filled capacitor. Distortion and swelling is caused by gas evolution in the hydro carbon insulation oil. Again cause was CP-5 environment.

electromagnetic wave propagated through the ionized medium, complete reflection from the ionized boundary layer can occur. This same ionization also tends to limit impedance levels within the various circuit devices. The situation worsens with increased reactor power, but is dependent also on the presence of an atmosphere.

• The neutron-gamma ray dose received by any component is a function of both the neutron and gamma ray dose rates at the component position and of the total time of irradiation.

• Although some conventional electronic components operate reliably in radiation of moderate severity, future high-power weapon systems will necessitate radically new components. More work must be accomplished on electronic components development if they are to be suitable for contemporary nuclear-powered vehicles.

Typical relative environments to which space-aero vehicles in sustained flight will be subjected are shown in the table below. (More precise data are available but these are still classified for security reasons.)

• **Component damage**—A summary of some of the more pronounced effects of nuclear radiation will indicate the seriousness of the problem. In many instances, damage is very severe.

Irradiation of components in the Argonne CP-5 reactor represented dosages comparable to those which would be expected in contemporary nuclear-powered vehicles. The time period was approximately 3000 hours maximum.

Electron tubes demonstrate rather marked effects: most glass envelopes shatter; all glass envelopes darken. Borosilicate-type hard glasses are most susceptible to these shattering effects, attributed to neutron bombardment; discoloration results from gamma rays.

In general, all photo-sensitive components are sensitive to gamma rays, but gas-filled tubes and ionization devices are not. The most notable result observed with electronic tube devices was the rapidity of failure once the radiation damage began—often occurring within a few minutes.

Results of in-pile tests of semiconductor devices are sometimes conflicting. Damage also seems to vary more with manufacturing methods than with the properties of the solid-state components under test.

During bombardment of semi-conductor diodes, it was found that the forward currents decreased and backward currents increased. Oddly, post-exposure tests indicated partial recovery. In the transistors tested, gain was found to decrease under irradiation. But there were exceptions, since some devices showed a gain increase followed by a greater decrease later.

With respect to radiation resistance, silicon generally proved less susceptible, but again there were instances when the reverse was true.

In general, vacuum tubes have shown greater resistance than semiconductor diodes; the diodes have done better than transistors.

Crystal units tested indicated appreciable damage to component parts under gamma-neutron irradiation. Quartz structures darkened and fiber board and glass-to-metals seals in particular proved unsuitable.

Various types of capacitors were tested using mica, glass, ceramic, oil impregnated paper, and plastic. Both capacitance and dissipation factor were observed under irradiation.

Swelling and distortion were very apparent in oil-filled capacitors, resulting from a characteristic gas evolution. In general, capacitance decreased, dissipation factor increased. All of the other types of capacitors showed only slight capacitance change with somewhat more sensitivity in dissipation factor.

			Sustained Flight		Boost-Glide	Satellite
			Contemporary	Future	Future	Future
Temperature			-65 to +200C	-65 to +500C	-65 to +1000C	-65 to +500C
Pressure			0.04 In. Hg.	0.04 In. Hg.	0.04 In. Hg.	0.04 In. Hg.
Moisture (100% R. H.)			10C	10C	10C	10C
Vibration	Cycles/Sec		10 - 2000	10 - 3000	10 - 3000	10 - 3000
	G		15	40	40	40
Shock	Time (MSEC)		11 + 1	11 + 1	11 + 1	11 + 1
	G		50	50	50	50
Air-Induced Vibration	Cycles/Sec		150 - 9600	150 - 9600	150 - 19200	150 - 9600
	Pressure*		160	165	165	165
Acceleration	Time (MSEC)		10	10	10	10
	G		50	50	50	50
Nuclear Radiation	Dose Rate	Neutrons	10^9	10^{16}	10^{18}	10^9
		Gammas	10^{11}	10^{18}	10^{20}	10^{11}
	Total Dose	Neutrons	3.6×10^{15}	3.6×10^{22}	3.6×10^{24}	3.6×10^{16}
		Gammas	3.6×10^{17}	3.6×10^{24}	3.6×10^{26}	3.6×10^{18}
	Time (Hours)		10^3	10^3	10^3	10^4
Operating Life (Hours)			2×10^3	10^4	10^4	10^5

TYPICAL relative environments to which space vehicles will be subjected.

Different types of resistors w irradiated and, as might be expect wirewound types showed the least s sitivity. In general, resistance chang either because of damage to the c ducting material or the insulation. also is believed that parallel cond tion paths from the radiation-induc ion fields may have lessened res ance. This varied with reactor inten for all types of resistors.

With respect to wire and insulati results of irradiation are fairly const —insulation material deteriorates lo before any appreciable change in metal conductor occurs. As the rad tion field is increased there is a c responding decrease in insulation sistance, probably associated with c rier production in the material.

• **Contemporary and future co ponents**—As indicated above, many our present components are not se ously affected by expected radiati from contemporary nuclear-powe vehicles. But, as indicated in Table the environments of the future we ons systems have factors of from to 10^9 probable dose rates above t of existing facilities. Similarly, therm environments will double in range. do not now possess components capa of functioning reliably in such tremes.

The combinations of extreme vironments will cause even grea complications. The big problem is limited size of existing nuclear react which will not permit the simulati of synergetic environmental con tions. A partial answer would be velopment of small environmen chambers which might be placed side an existing irradiation facility.

• **Future design**—What can be d to provide more suitable compone for such damaging environments? miral, as a result of its research, lieves there are several practical proaches:

(1) Minimize damage by selecti of component materials with high sistance to gamma-neutron bomba ment: high-purity mica, ceramics, ra ation-insensitive glass (under devel ment), and the use of inorganic rat than organic materials.

(2) Higher temperature operati This is based on the concept that crystalline and vitreous structu damage by radiation can be voided an annealing process. The ideal c would exist when the rate of radiati induced damage equals the rate annealing of damage areas.

(3) The best approach proba will be development of wholly n solid-state components which will designed for use in these difficult vironments.

Miniaturization—A Swelling Tide

Chain reaction of new breakthroughs could lead to microscopically small parts before trend runs its course

y Heyward E. Canney, Jr.

SHINGTON—A bold new engineer-
cipline fostered by the advent of
ex weapon systems and high-
e rocketry, miniaturization is al-
a cornerstone of guided missile
ace-flight technology.
e small artifact has been known
ntiquity in art, jewelry, and the
y of documentary pinhead in-
ons, but it can hardly have been
ective undertaking for more than
de or so. There was no need for
re the complexity of rapid war-
diotelemetry and automatic com-
And before modern quality con-
d reliability concepts, it was not
feasible.
t only has miniaturization made
e products available to the pri-
tizen, it has so condensed tech-
systems that large numbers of
nits have created new systems
y. New capacity, in turn, has
new vistas, generated new goals
then demanded still further min-
tion.
ividual components shrink
y in size with each new break-
in concept, materials, design,
brication—and then swarm on
ne again in more-dizzying pro-
At the present rate, there is a
enuine prospect that individual
as we come closer to compre-
the basic behavior of matter
may become invisible to the
eye.

• **hat is it?**—Miniaturization is an
ring discipline devoted to re-
the size of a useful artifact to
one or more functions which
e in scope or efficiency specifi-
ecause of the miniaturization. It
is applied to individual parts to
total size of an assembly, com-
or system fabricated from such
Although the discipline now includes mechanical idioms, its untimate implications involve matter and energy of a fineness which begs the distinction between electricity and mechanics.

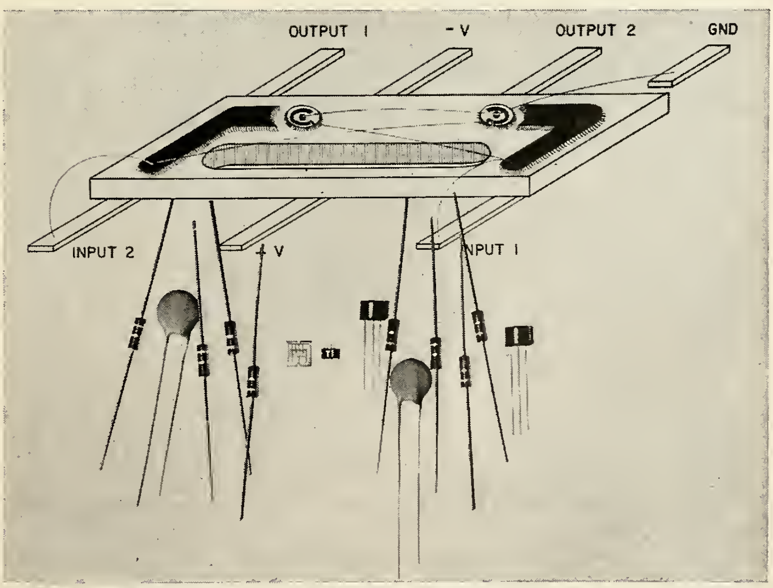
Miniaturization aims to increase performance and/or portability, or to prevent non-portable devices from growing to unmanageable size. The result is properly a tool or technical instrument generally involved with handling information in some form.

It is achieved through scaling down dimensions, using new materials for lightness in basic or aggregate structure, involuting and telescoping structural configuration for reduced space envelope, and adopting new concepts of interplay between matter and energy.

It is aided by new philosophies of fabrication which may not be intrinsically miniature themselves but which enhance the general undertaking—such as (in electronics) the use of printed circuitry, modularization, and intrinsic agencies for drawing all or part of a device's operating energy from the environment.

• **Methods and factors**—The most direct method is scaling down, which can be done when function does not directly depend on size, or compensations must be made. Resistors, for example, must adopt a new active element of greater resistivity beyond a certain point. A voltmeter ¼" in diameter has dubious utility, though one doubtless could be built.

Redundancy is made possible, but must be used intelligently to avoid



TEXAS INSTRUMENTS' silicon solid-circuit multivibrator unit (at top) measures less than 1/4x1/8x1/32 inches but has equivalent of conventional components shown.

bogging down through mechanical and electrical loss accumulations. And one should be willing to include a non-miniaturized part where its performance is clearly better.

Lightness of material of carefully chosen properties is utilized, though resistance to environment, vibration, acceleration, impact, and internally-generated heat must be considered.

Redesign of intimate and general structure is very important: individual parts may be placed closer together; structural support may be involuted; parts may share interface, be placed inside each other, or be made both functional and structural at the same time.

Mechanical linkages and power trains may be shortened, rotating parts substituted for sliding ones, and so on. Primary power agencies may be arranged to eliminate intermediate step-up or step-down. This makes for compactness or high component density, and hence greater weight, which must also be reckoned with in the end result. Problems of heat dissipation, magnetic isolation, and access for service also arise.

Techniques of fabrication include printed wiring and circuitry, which permit automated dip-soldering and flatness for dense stacking, and sometimes the use of stampings and extrusions. Micromodularization, made possible in part by deposit of filmy circuit elements on wafers which are then stacked and potted, promotes shortness of leads, positive connections, low loss, and structural integrity.

Deposited elements spring from a still more basic practice of producing elements from solid-state materials such as semiconductors, or magnetostrictive or piezoelectric substances from an essentially chemical origin, and stretching into thin ribbons.

Construction may be adapted to accommodate twistors, cryotrons, MASERS and ferrites, which may demand exotic provisions of environment such as extremely low temperature.

Finally, systems may be reduced by relying on extract of power from gravity, buoyancy, friction, fluid intake for chemical action, radiations, static- and piezo-electricity, and magnetism. In a few cases all power may be so derived (though this is often risky) and in others, minute amounts of energy for reference or control will suffice. In handling data, one may convert the form of coding and telemeter for reduction elsewhere.

• **Why miniaturize?**—The impulse springs partly from the way Man looks at his relationship to the total environment, and in part from certain basic realities of interplay between matter and energy.

In looking at the environment, one compares goals with resources. The Russians surveyed an essentially mediocre average of craftsmanship in a vast labor force, built things to relatively relaxed tolerances, and got crude and heavy results. These doubtless included nuclear warheads, which needed large rockets for delivery, and which were crude and heavy for the same reason. The word "crude", here, hardly means oxcart crudity. A MIG is a lot of airplane, and a very crude 10-megaton ICBM warhead detonating on target will be distinctly noticeable.

The comparison is with "sophistication"—the lavish resources of American money and craftmanship combined with a yen for convenience resulting from disinterest in world conquest. Convenience, among other things, meant reducing both non-portable and portable systems to economical and manageable size. Before we realized it, we were involved in a chain reaction of alternate conveniences of miniaturization and acceptance of greater and greater challenge opened up by complexity. We considered our resources and decided on many peaceful conquests rather than one warlike conquest.

In the process, we happily discovered that the richness of our approach revealed the above-mentioned physical relationships of interplay between matter and energy. We discovered, for example, that with increasing RF frequency, electron-tube geometry—based on the concepts of the time—required reduction in tube size in obedience to such requirements as inter-electrode capacity. Power levels eventually dwindled to useless amounts, except in the laboratory, and electrical forcing in practical equipment only burned out the tube. Physical laws are implacable, and the only thing left was to start with a new approach. We eventually came up with transistors, and it wasn't long before everything was being miniaturized.

Conceptual daring paid off handsomely. Proliferation of parts created complex systems, which permitted the audacious approach of "doing big jobs conveniently." It turned out we also did them better, faster, and more cheaply.

• **Advantages**—Aside from the general desirability of convenience, there were direct benefits in technical performance. Parallel duplication improved reliability . . . and you can afford duplication if what you ar plicating is small and light. Also, things can be done with the same ability when parts are small, since tems can get more complex.

Portability is advantageous in planes and missiles because it incr capacity and performance per weight and volume. As for non-p bility, if you are erecting an ambi digital computer, it is a real bene contain it in a room rather th whole building.

Space and weight reductions a obvious boon to satellite and launching systems, because it's ch to use a smaller rocket to loft the load. In mass production, small are generally cheaper per unit, an payload itself also costs less. In lites and probes this is no trifle.

Removal or reduction in nun of moving parts increases reliat Micromodules, which permit stan ization and potting, have impr structural strength and environm protection. Shortening leads and ages reduces power loss and pe smaller power sources, again red size and weight. Printed or depo wiring and circuitry permit auton production, which saves money.

Component density permits l duplication in parallel to increase all capacity, or deal as a team specific functions to promote reliat In many cases, sensing elements reduced area have improved sign noise ratios.

• **Trends and prospects**—Emp cally higher component density is way. Until the recent breakthr about 60,000 parts per cubic foot the limit. About 300,000 looms fo reasonably near future, and som perts forecast densities between 5, 000 and 34,000,000 if whole sys can be fabricated solely of mo like the Texas Instrument multiv tor, the Westinghouse module, others. The Air Force is already ously studying a new realm of "m tronics" . . . involving volumetric aturizations of 1000:1.

Wider operational tem ture ranges are in prospect, thank only to extensive encapsulation but to the closer packing resulting standardization of modules. Auton production, increasing use of m modules, and automatic testing of systems and systems seem likely, the assembly jig is constantly conn to testing instruments, so that te can proceed as the systems are a bled. Testing itself will be more ous, and greater confidence may i diately be placed in the received e ment.

Data itself will be subject to so

d new themes of coding, and com- ive devices will have ingenious iques of storage, access, process eadout. There may also be some icant developments in transmission ta through novel types of phasing, plexing, and compound pulsing.

odules will tend to have highly ic functions, but also be capable ried applications. Incredibly high- automatic GO/NO-GO sequence- olled checkout equipment will ap- Design will provide for rapid ement of critical components for diate initiation or resumption of e, with repair done elsewhere by l facilities.

xtremely small size will permit not new degrees, but also new dimen- of redundancy. Supercritical cir- may be triplicated into strategic subcircuits (von Neumann "ma- organs") to optimally reinstate ons whose failure would be catas- ic.

n the far horizon lies the vista of niniaturization, which will pro- materials and devices capitalizing ernal fields, molecular spin reso- and electrostatic charges. Power ation or extraction agencies will inutely integrated and dispersed. this degree of smallness, the no- of following classical schematic is and notation boggles the mind. reaches an operational threshold substances, with trivial changes m and loading, can act as almost reviously-known circuit part. That ey may amplify, detect, rectify, , resist, have capacity, or respond tely to a magnetic, mechanical, or radiative stimulus.

agination flags when one ponders ossible nature of completely in- circuitry, or the equipment to e it—and can only entertain vague inkling of three-dimen- scanning for impression of e-down images . . . creating mo- circuit components by locally- lled stresses in specially-prepared ate "raw" material.

t we can go only so far. Even- the Principle of Indeterminacy in, as the sensing agencies for eedback loop become as small at they are measuring. This is sly a vast distance into the fu- Whenever it comes, miniaturiza- vill then presumably have to in the towel. But maybe it won't Arrival at that state of fineness mean that artifact has finally l parity with biological detail . . . an may have then available some providing him with a direct e link between his mind and the l Universe.

Beryllium Structure Made

BALTIMORE—The Martin Company has successfully fabricated structurally sound beryllium sheet material which has been used to construct the world's first beryllium structure.

Use of beryllium in frame structures will make it possible to solve many of the aerodynamic and structural heating problems associated with space flight and re-entry of the earth's atmosphere at speeds up to 18,000 miles per hour.

Martin engineers believe the achievement brings interplanetary travel within the realm of practical engineering design because frame material research has not, to date, kept pace with the rapidly advancing state of the art of propulsion research.

The project was accomplished under an Air Force contract placed with Martin in the summer of 1957. Development and fabrication was performed in conjunction with Nuclear Metals, Inc., Concord, Mass.

• **Other approaches**—The Martin approach to beryllium is just one of many avenues now being explored. Manufacturing Methods Division of Air Materiel Command is developing test criteria to evaluate the Martin program as well as work being done by Brush Beryllium Corp. under AMC contract.

The sheet program is only one of many now under way. Others include: a contract with Beryllium Corp., Reading, Pa., to determine the feasibility of making beryllium castings and to develop methods for producing shaped castings; Northrop Corp. is attempting to develop a process for producing extrusions of adequate aircraft quality; Ladish Company, Cudahy, Wis., is working to develop forging techniques to permit the production of beryllium parts and to develop necessary engineering data; Kettering Laboratory, University of Cincinnati, is trying to develop sufficient industrial, medical, toxicological and industrial hygiene engineering information to safeguard industrial personnel working with beryllium.

Still other contracts include: Brush Beryllium to improve the ductility of beryllium sheet by addition of alloys; Avco to develop techniques for joining beryllium; Nuclear Metals Division to fusion weld beryllium; Lockheed Aircraft to study the effects of notches and cracks on the structural quality of beryllium; and Armour Research to make casting studies.

• **Merits**—The Avco research possibly deals with nose cone technology. It is interesting that in recent testimony before the House Appropriations Subcommittee, Lt. Gen. Roscoe Wilson, AF deputy chief of staff for development, commented that a beryllium nose cone would weigh about 13 pounds while a comparable copper cone weighs approximately 100 pounds.

Beryllium is lighter than magnesium, has a melting point twice that of aluminum and a stiffness factor exceeding that of stainless steel. All desirable attributes for missiles and space vehicles.

The combined properties of beryllium are superior to all other structural materials from the standpoint of strength, stiffness, heat absorption, and lightness in weight, Martin engineers said. Its use in frame manufacturing will enable designers of space vehicles to effect vital savings in weight, fuel loads, and vehicle size.

In addition, beryllium structures may not require complicated cooling systems to compensate for structural heating caused by friction at the time of high speed re-entry. Instead, they said that ordinary insulation may be sufficient for structures made of beryllium.

Ballistic missiles can utilize beryllium in nose cone construction to take advantage of the material's great heat storage capacity. Beryllium can absorb two-and-a-quarter times more heat than any other structural material under conditions of a given rise in temperature.

• **Barriers cleared**—Until now all characteristic forms of beryllium—castings, forgings, rolled sheet, etc.—have exhibited non-uniform properties and brittleness akin to glass. This stumbling block has been largely removed with the development of sheet material possessing homogeneous properties suitable for structural fabrication.

Brittleness in beryllium forms has been due primarily to planes of weakness in the metal's metallic crystal. Martin and Nuclear Metals, Inc., took an unusual approach in solving this problem by attempting to control both the crystal size and orientation during basic sheet fabrication. Test results on both the material and the completed structure indicate that excellent properties have been achieved, the engineers said.

Other limitations for beryllium usage, however, still remain. In the first place, forming or bending the sheet can be performed only within a finely defined band of hot forming temperatures. It can presently be joined only with fasteners, and cannot be fusion welded.

As for extrusions, forgings, and rolled sheet forms, Martin tests indicate that all continue to yield crystal orientations resulting in the familiar brittleness.

—— reviews ——

SPACE DICTIONARY OF GUIDED MI[S] AND FLIGHT, **Grayson Merrill (E[d]), Van Nostrand Company Inc., Prin[ceton], N.J., 688 pp., $17.50.**

The rapid advance in missile rocket technology has produced a dered, somewhat unwieldy new nology. Fusing terms from the varie diverse scientific field represente rocketry has brought about a compl jargon completely understood by Heat, as a term, for example, mean thing to the physicist, another t chemist, and something else again veterinarian.

This dictionary is a good attem bring some order out of the chaos explain most of the commonly used in the guided missile and space fields today.

Terms defined include current an torical guided missiles and space their systems for guidance and co propulsion, armament and launchin components that make up these sys and all related terms from aerodyn astrodynamics, electronics, astronom physics. Included are terms for typ antennas, circuits, radar systems anc pellants, as well as laws, relation equations, space environments and cepts which govern utilization in de

Illustrations help define difficult and a comprehensive cross-referenc tem is provided. Aiding Mr. Merr the preparation of this lexicon were expert missilemen and missile linc C. W. Besserer of STL; Kraf Ehricke of Convair, and Ballard B. of the Aberdeen Proving Grounds.

CONCISE DICTIONARY OF SCI[ENCE], **Frank Gaynor (Ed), The Philoso[phical] Library, Inc., 546 pp., $10.00.**

The terminology confusion ramp the missile and rocket industry is tive of the fusion of old sciences, ar vent of many new sciences. This under one cover, attempts to provid cise definitions of terms and concept taining to all fields of science.

Included is a coverage of many newer sciences such as virology, e ology, cytogenetics, radio-chemistry, energy and solid-state physics, etc. by a science writer of merit, the dicti is a valuable addition to any librar

ROCKET ENCYCLOPEDIA ILLUSTR[ATED], **John W. Herrick (Ed), Aero Publ[ishers], Inc., Los Angeles, Calif., 607 pp.**

An attempt to marshal most presently known rocket facts and th into one compact volume. Profuse pictures, charts, and drawings, the makes an ideal text for the specia the field who wants to keep abre the other phases of rocketry.

This is one of the first attem publish an encyclopedic presentatio Theodore von Karmann writes the duction.

moscow briefs

by Dr. Albert Parry

pressure of 5 million atmospheres chieved by a group of Soviet ex- enters acting on the initiative and ctions of Academician Y. B. vich. In reporting this accomplish- *Komsomolskaya Pravda* admits 'this monstrous pressure" lasted moment, yet the fact that it was d at all, even for such a short on, is truly a great triumph of science. The pressure was the of the clash of two plates, one of was accelerated "to the speed of *k*."

riting in *Literaturnaya Gazeta* of successes with *Sputniki* and T. Trifonova makes an admis- are for Russian propagandists: who does not know that on the o these triumphs there had been difficulties, bitter failures . . . s of despair . . ." This is a direct diction of the frequent assertions onid Sedov and other Russian experts that their *Sputniki* were ed on the very first tries, with tely no failures ever marring 's rocketry progress.

"Steam Moves a Rocket" is the title of a brief article in *Sovetskaya Aviatsia*, which comments on the latest researches and experiments of using "ordinary water vapor instead of products of burning fuel for rockets." The article is accompanied by a diagram evidently adapted from a West German source, as the Russian author remarks that "West German military experts, feverishly working on their job of equipping the re-emerging Wehrmacht, predict a bright future for this inexpensive motive power" in rocketry.

The diagram and text in the Moscow publication describe the steam rocket engine as a vessel made of steel, by its appearance resembling a large balloon with compressed air. It has a widening nozzle with a faucet that can be turned on and off. The steel container is filled with water to three-quarters of its capacity.

The water is heated to a high temperature with the aid of oil burners or electricity. In this water-heating process the pressure in the chamber rises to 40 or 50 atmospheres. At this point the faucet is turned open, and the hot water rushes into the nozzle. As the water flows out it evaporates with tremendous force. The speed of the vapor stream is considerable. Thus comes the jet power to move the rocket.

It is true, the Soviet commentator adds, that this rocket energy lasts less than one minute, since the vapor pressure in the steel container falls rapidly. But with a steel container holding 500 kilograms of heated water, the very first 10 seconds will give the rocket a respectable momentum. The entire weight of such a steam-powered rocket engine, together with its water, does not exceed 800 kilograms.

A new type of star accumulations or galactics was announced in Moscow as a recent discovery by the staff of the Burakan Astrophysical Laboratory in Soviet Armenia headed by the famous astronomer Victor Ambartsumian. He named them "Non-Stationary" or "Azure Blue." A considerable part of them is gas, out of which apparently new stars are now being formed. Because of this initial stage of star formation, physical processes occur in these "Azure Blue Galactics" far more intensively than in all of the already known constellations.

Professor Ambartsumian says that a thorough study of the Azure Blue Galactics should show new physical phenomena and qualities of matter.

AF Contractors' Backlog Now Totals $7.191 Billion

Backlogs of principal Air Force contractors as of March 1, 1959, totalled $7.191 billion. Twenty-four companies are involved representing approximately 75 percent of Air Force procurement funds. Breakdown in millions, including both missiles and aircraft and covering engines and electronics equipment: A-C Spark Plug, $43.8; Aerojet General, $33.1; Allison Division, General Motors, $96.1; American Bosch ARMA, $53.7; Avco, $24.2; Bendix Aviation, $32.8; Boeing Aircraft, Seattle, $839.5, Wichita, $592.8; Burroughs, Detroit, $80, Paoli, Pa., $11; Convair, Fort Worth, $554.3; Astronautics Division, San Diego, $108.6, San Diego, $371.3.

Douglas Aircraft, Long Beach, $286.6, Tulsa, $27.7; Ford Motor, Aircraft Engine Division, Chicago, $26.9; General Electric, Evendale, Ohio, $179, Philadelphia, $53.3, Syracuse, $158.2, Gas Turbine Division, Utica, $73.9; Hughes Aircraft, Culver City, $232.7, Tucson, $137.6; International Business Machines: Kingston, N.Y., $216.5, Owego, N.Y., $64.2.

Lockheed Aircraft, Burbank, $191.7, Marietta, Ga., $224.5, Sunnyvale, Calif., $13.8; Martin Co.: Baltimore, $110.4, Denver, $58.2; McDonnell Aircraft, St. Louis, $448.1; North American Aviation, $458.1; Northrop Aircraft, Inc., Hawthorne, Calif., $209.9; Pratt & Whitney, Hartford, $566.1; Radio Corp. of America, Camden, N.J., $214.2; Republic Aviation, Farmingdale, N.Y., $239.0; Sperry Gyroscope Co., Division of Sperry Rand, Long Island, $88.7; Western Electric, $79.5.

The Senate Space Committee has okayed a $485.3 million authorization bill for NASA. This is $4.7 million more than approved by the House for space R&D and hardware.

Zeus' Breakthrough

Breakthrough is claimed in the solid propellant motor for *Nike-Zeus* antimissile missile with the development of extremely thin casing walls, a new high-energy propellant and plastic nozzle. Joint effort of Douglas Aircraft and Grand Central Rocket Co. produced a full-scale tactical motor designed for *Nike-Zeus* sustainer which performed perfectly with the series of new improvements.

Sensor to control missile fueling is being placed in production by Pioneer-Central Division of Bendix Aviation. The company says the instrument to detect any change from liquid to gas or vice-versa will be used in *Titan* support and an evaluation order has been received from Convair for use on *Atlas* fueling system.

Air Force Office of Scientific Research is planning to build late this year a hypersonic wind tunnel at the University of California. Tunnel will be used to pursue investigation of re-entry problems, ion propulsion R&D and high-temperature research.

Follow-on $15 million contract for additional production of the 20-foot truck-launched *Lacrosse* surface-to-surface missile has been awarded Martin-Orlando by the Army. This makes $25 million contracted for the artillery-type weapon since January. Two battalions are to be equipped with *Lacrosse* at Ft. Sill, Okla., before the end of this month.

Sound Assaulted

New assault on the effects of sound energy—believed to be the cause of many missile and rocket failures—will be attempted with a new acoustic high-energy generator which theoretically could shred a human brain in 30 seconds. The $100,000 generator produced by Transducers Inc. will be used for testing components by the Autonetics Division of North American Aviation. Reportedly the device can actually simulate the sounds encountered under normal service operating conditions. Horn section is exponential acoustic impedance matching device with more than 100 50-watt high and low frequency drivers. Transducers for high and low frequency drivers are powered by 3500 watt amplifiers, each capable of peaking at 10,000 watts.

HM11XA is first die-castable alloy (1% thorium, 1% manganese and the balance magnesium) to be developed for service above 500°F, according to Dow Chemical. The company reports the new alloy, which has density of 0.064 pounds per cubic inch, also retains good mechanical properties through 800°F.

BMEWS Facility

Domed facility 15 stories high to checkout BMEWS radar and computers is being built near Moorestown, N.J., within sight of the New Jersey Turnpike by RCA, prime contractor for the missile warning system. Tower supporting antenna and radome will be constructed on pylons descending independently through the base building and anchored in an octagonal slab 5 feet wide and 8-feet thick. This is to meet extreme accuracy requirements of tracking equipment which must remain unaffected by wind, snow, ice or shifting of the building.

Flight testing is under way of Electronic Specialty Co.'s low-cost P proximity fuse. All weather evaluation is being conducted under $93,000 contract with AF Special Weapons Center, Kirtland AFB, N.M. The company estimates armed services will spend million in next five years on electronic proximity fusing.

Ivar C. Petersen, formerly director of technical services for Aerospace Industries Association, has gone to Boeing. After leaving AIA he was involved in unsuccessful attempt to form a ground support association.

EIA estimates authorizations through FY 1970 for the space market will total over $14 billion with electronics getting 33% or $4.8 billion. NASA funding, EIA says, may hit $2 billion a year by 1970.

Astrodyne Development

Astrodyne Inc. reports development for Navy of low-cost, lightweight insulator for solid-fueled rocket motors. Composed of rubber and asbestos, material has resulted in successful firings with significant thrust levels durations of over 3½ minutes. Exterior casing temperature was held to 2 for that period while motor was exhausting 5500°F flame.

Canada's Department of Defense Production has awarded a ceramic engineering study contract to Titania Electric Corp. of Canada, a subsidiary of Gulton Industries Inc., Metuchen, N.J. Study will be directed at electronic nuclear applications.

Schlumberger Ltd., which has acquired an 80% stock interest in Computer Systems Inc., New York, plans to invest $3 million in expanding CS. . . . Hycon Eastern Inc., Cambridge, Mass., has switched its name to Hermes Electronics Co.

propulsion engineering

New liquid hydrogen plant . . .

at Palm Beach, Fla., is huge—one of the largest industrial gas plants ever built. The facility, which Lt. Gen. Bernard A. Schriever says turns out the "purest hydrogen ever made" has a compressor building six stories high and a quarter of a mile long. Data for the rest of the plant, operated by Air Products, is classified. Schriever told the Institute of Aeronautical Science and the Air Force Academy Cadet Engineering Society meeting at Colorado Springs that the plant is turning out liquid hydrogen in "large tonnage" quantities, thanks to a scientific breakthrough.

This "breakthrough" is not really new . . .

and has been reported twice in this column—March 30, April 6. It is the National Bureau of Standards process for converting unstable orthohydrogen to stable para-hydrogen. Liquid hydrogen ortho molecules naturally want to convert to the para form. The conversion releases considerable heat which constantly vaporizes the liquid hydrogen. This is why liquid hydrogen is so difficult to store and generally calls for recycling refrigerating equipment. The NBS found a way—based on hydrous ferric oxide as a catalyst—to speed up the natural conversion. The technique results in 95% conversion. Since the para-hydrogen is stable, no further heat is evolved and it's possible to store liquid hydrogen in much the same way LOX is stored.

ARDC and Air Materiel Command took over the Bureau of Standards technique and awarded contracts for development of practical, large-scale equipment to Air Products and Stearns-Roger Mfg. Co., Bakersfield, Calif. Each company built small development facilities, and Air Products designed and built the Florida plant.

Development time was remarkably short. The NBS Cryogenic Engineering Laboratory, Boulder, Colo., announced its conversion process only last year, and the Air Products plant was turning out liquid hydrogen last month.

Liquid hydrogen—LOX . . .

propellant system offers 40% more thrust than best present propellants. H_2O_2 will be used in Convair *Centaur* second stage, which has a Pratt & Whitney engine.

Ozone-hydrogen is next . . .

on the list of propellants. Work is progressing in this field, much of it under the direction of Dr. A. V. Grosse, Temple University Research Institute, Philadelphia. Grosse and A. G. Streng recently determined the density of solid ozone, the first time this has been done. Their value, at 77.4°K, is 1.728 grams/cubic centimeter. The liquid density at the same temperature (77.4°K is the melting point-freezing point of O_3) is 1.614 g/cm³. Thus, expansion on melting is 7.1%.

Density of solid ozone had not been measured before because of "its ability to detonate at the slightest provocation," Streng and Grosse report in the *Journal of the American Chemical Society*. Their biggest problem was in devising adequate safety measures. Once the pure ozone was frozen into cylinders, it was fairly easy, they say, to measure the length and compute the density.

High-intensity arcs and plasma jets . . .

test Carborundum Company's high-temperature ceramics. C. E. Shulze of Carborundum's Research and Development Division, Niagara Falls, N.Y., says the free-burning high intensity arc and the plasma jet (Propulsion Engineering, March 30) have been extremely helpful in development of ceramic composition for high-temperature use.

Specimen surface temperatures above 5000°F are reached in only about 30 seconds of testing, Shulze told the Philadelphia meeting of the Electrochemical Society. Test samples are cylinders one-half inch in diameter. They are subjected not only to high temperatures, but also to subsonic and supersonic jet velocities.

missile business . . .

By WILLIAM E. HOWARD

Along Wall Street and its backwaters, financial men appear to be getting more and more wary of the "glamor" stocks—fast-moving shares of missile/aircraft, space and electronics companies. Ask almost any stock broker what he thinks of the missile industry issues, and more than likely the answer will come back: "overpriced, I guess, maybe . . . maybe not."

How can any stock selling at 70 to 80 times earnings . . .

be worth it? Just a few years ago many brokers were loath to recommend stocks selling at 30 times earnings. Is the stock market now moving into an entirely new era? Or will there be a sharp downturn and a reversion to the old standards? You can get as many different answers to these questions as you can find experts.

Monopsomy is a word bandied about . . .

of late in the money marts. One broker defines it as describing an economic condition where there are many sellers—and one buyer. The missile industry and the Government. On one hand monopsomy may hold a degree of security in that weapon contracts are large and payment is certain. But, on the other hand, contracts are subject to cancellation and the Renegotiation Act and the profits can be small. Competition is keen.

Accordingly, the watchword of many investment dealers on missile stocks is caution. They say a "shake out" of the industry is bound to come—a "shake out" in which some big companies now in the field may wind up small as far as missiles are concerned. While some experts concede upward revision may be in order for the earnings-price ratio, they point out that stock prices have been helped to new highs by a relative scarcity of stock compared to public demand.

Predicting the "market could break anytime" . . .

the vice president of a mutual fund management firm said recently his investment trusts are cashing in their profits and investing in blue chips. "In our opinion (missile stock) prices have reached levels completely unrealistic to their true worth because of wild speculation by the public," said William S. Palmer of Templeton Debbrow & Vance.

Could the public be right . . .

are worries unjustified? Taking a long look into the future, Walter K. Gutman of Shields & Co. investment house, says it is possible that modern technology can bring about a "complete economic solution" for all the people of the world by 2000 or shortly after. The 1929 crash was a disaster in his opinion which has become a "neurotic fixation with us." At that time, Gutman says, the market was saying something big and may be saying something equally big today—because the huge industrial output and profits 1929 speculators dreamed about have come to pass "and even more than they dreamed."

In a few years today's prices . . .

may seem "very conservative," says the optimistic stock broker. "The stock market is far from ahead of our true industrial potential." And Gutman believes this will be borne out after 1960.

And he sounds another cheery note . . .

"Perhaps there will be several sorts of disaster between now and the year 2000—but if these disasters do not occur . . . if year by year we find the vision becoming more real . . . then we will have to recognize that the stock market of 1957-59 was seeing truly—not giddily.

"It was not drunk, just enthusiastic."

William A. M. Burden, New York financier and aviation consultant, has been elected chairman of the board of trustees of the Institute for Defense Analyses.


BURDEN

The Institute is a non-profit corporation formed in 1956 at the request of the White House [illegible]nalyze and evaluate the nation's de[illegible]e systems and provide other technical [illegible]ices to the Executive Office of the [illegible]ident, the Secretary of Defense and [illegible]t Chiefs of Staff.

Burden recently won unanimous ap[illegible]al from the Senate Space Committee [illegible]it on the National Aeronautics & [illegible]e Council. He is also a director of [illegible]Council on Foreign Relations, a di[illegible]r of the Hanover Bank, Cerro de [illegible]o Corp. and other companies.

[illegible]aro Mfg. Co. Inc.'s new division, [illegible]owave Power Laboratory, will be [illegible]ed by **Jack G. Smith,** vice president-[illegible]neering. This division will exploit [illegible]epts and applications of very high [illegible]owave power outside the radar and [illegible]munications fields.

William A. Mussen, former chairman of Southwest Research Institute's Electrical Engineering Department, was named chief development engineer for the Singer-Bridgeport facility of the Singer Military Products Division, and will be in charge of military [illegible]n and development projects. At [illegible]hwest Research, Mussen maintained [illegible]nical and administrative control over [illegible]rical engineering activities from 1955 [illegible]ugh 1959.


MUSSEN

Fred W. Trebes has been appointed general manager of Hydromatics, Inc's. Pacific Division. Trebes was engineering group leader on control valves for the Rocketdyne Division of North American Aviation, Inc. He was formerly in power plant engineering for North[illegible] Aircraft, and later for Douglas Air[illegible]a[illegible].

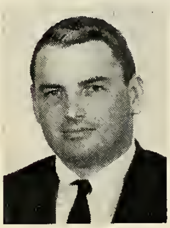

TREBES

Dr. Winfield W. Salisbury, who has [illegible] appointed technical director of the [illegible]ion, is known for his pioneering efforts in high power RF sources starting with cyclotron development at University of California in 1937. **Dr. Fred L. Whipple,** Director, Astrophysical Observatory, Smithsonian Institution, will act as consultant.

The staff will be expanded to 150, of which 50 will be physicists and engineers. Several new facilities will be required.

Two men have been appointed to management positions for the Missile Development Laboratory of Minneapolis-Honeywell Regulator Co., as part of a staff expansion program. **Kenneth H. DeRoche,** 34, of the sales engineering and administration departments, has been named contract manager.

Samuel H. Cantwell, 30, named manager of administration, has been employed by the company's Aeronautical Division for five years in the personnel and contract management departments. He is a graduate of Harvard University.


CANTWELL

Harold S. Geneen has resigned as executive vice president of the Raytheon Manufacturing Company to become president of the International Telephone and Telegraph Corp. Geneen joined Raytheon in 1956 from the Jones and Laughlin Steel Corp., where he had been vice president and controller. Prior to that he served for four years with the Bell and Howell Co.

Thomas H. Evans has become controller of Servomechanisms, Inc. He had been serving the accounting firm of Ernst & Ernst as consultant analyzing Servomechanisms, operational requirements. He will now be responsible for the company's dealing with governmental agencies on financial affairs.


EVANS

William L. Reynolds recently submitted his resignation to Electronic Industries Association to accept the position of general attorney of Litton Industries, Inc. Before joining EIA in 1953 as staff attorney, Reynolds was an associate in the Washington law firm of Covington & Burling. He was named assistant general counsel of EIA in 1956 and elected by the Board of Directors in 1957 to succeed **Glen McDaniel** as general counsel of the Association.

Edmund G. Shower was appointed to the new position of production engineering manager for the Sperry Semiconductor Division, Sperry Rand Corp. He will direct the development, design and construction of new facilities and equipment for volume production of silicon transistors, diodes, and rectifiers.


SHOWER

The Senate has confirmed the nominations of **William A. M. Burden** of New York (see above) and **Dr. John T. Rettaliata** of Illinois to be members of the National Aeronautics and Space Council. Both were endorsed unanimously by the Senate Space Committee.

William F. Hafstrom was appointed assistant to Bendix Aviation Corp. vice president and group executive **E. K. Foster.** In his new capacity, Hafstrom will work directly with the management officials of Bendix Radio Div., York Div. and Cincinnati Div., the three divisions for which the vice president is responsible.

It has been announced that a long-time employe of Avco's Crosley Division, **A. J. Verax,** has become manager of its Cincinnati plant. Verax was Crosley's director of purchasing. **R. B. Megrue,** who has divided his efforts as plant manager between Crosley's Evendale and Cincinnati facilities, now will devote his full attention to the Evendale plant. Verax joined the Crosley Division in 1946 and since that time has been associated with the Division's Purchasing Department. He first was employed as a follow-up man, then successively became a buyer, project leader, manager of defense procurement, senior buyer, purchasing agent for commercial products, and, in July of last year, director of purchasing.


VERAX

Robert E. Gross, chairman of the board of Lockheed Aircraft Corp., and **Donald H. Douglas,** chairman of the board of Douglas Aircraft Co., were co-winners of the California Industrialist of the Year Award, presented by the California Museum of Science and Industry.

Gross was recognized for leading Lockheed's development of the new jet prop Electra and achieving success in a space program including system management of *Polaris* and the *Discoverer* series.

Douglas was honored for directing development of the DC8 jet passenger transport and the *Thor* IRBM.

—letters

LITES Suggested

To the Editor:

In a recent article by Major William C. Mannix, USAF, and an editorial—both in the April 27th issue of M/R, an appeal was made to the "scientific community" for some method of standardizing velocity terms and units.

Major Mannix suggests the use of the word "Optik" until something better could be applied. He also requested the reader to let him know if a better word could be applied for the unit.

My suggestion, strictly from a layman's point of view and without taxing a scientific mind is the word LITES—which is derived from Light In Thousandths of Energy Seconds—or 1 LITE equals 186 mps.

Major Mannix is to be highly complimented on his article—a text well within the reach of the average mind. Too many "brains" today try to talk as far above the average citizen as the intersteller space that they are speaking of.

A special bit of praise should also go to the Missiles and Rockets editorial staff for a magazine unexcelled in its field.

F. A. Fleckenstein,
Engineering Analyst,
Cleveland Ordnance Plant,
Cadillac Motor Car Division

Moon Trolley

To the Editor:

Undoubtedly the task of keeping up with all the latest developments in missile and space projects keeps you extremely busy, but you may find that the following epochal communication will be of interest to scientists and engineers engaged in research and development on the ways and means of space travel. Our group, which is occupied with less esoteric problems, reads your magazine avidly and, indeed, considers it a "must" to be well-informed in the field. However, we feel that coverage of events will be incomplete without the addition of the plan outlined below.

After deciding during one of our recent coffee breaks to solve some pressing problems confronting the world today, we have come up with a practical, relatively inexpensive means of shuttling men and materials to the moon and back. Once instituted, our plan will enable diversion of the astronomical sums of money now being spent for rocket ships into other channels.

Since the moon always presents the same face to the earth a cable, securely anchored to the moon's surface, could be stretched to within 20 miles of the earth's surface. The earth end of the cable will simply be left hanging, free to circle the earth as it is pulled around by the moon. The moon's orbit is not quite circular, therefore the distance from the surface of the earth to the free end of the cable will vary somewhat and should be sufficiently great to prevent the cable from scraping on mountains.

Most of the cable's mass will lie wit in the earth's gravitational influence a will therefore try to fall to earth; ho ever, since its earthward movement constrained by being anchored to t moon, the net result will be to keep t cable taut. The farther away from t earth and moon the cable is, the less w be the gravitational attraction on t cable. Therefore, the cable possesses ma but relatively little weight along mo of its length. This property will help prevent the cable from failing in tensio

Next, we attach a cable car to t cable, and use the car to climb the cab until it reaches the gravitational influen of the other body, either moon or ear depending upon direction of travel, which point the car will start to desce the cable. The car will be kept at a re sonable speed by braking during desce to the surface of the attracting body.

Shuttle rocket planes will be used ferry men and materials to the cable c at the earth's end to which a passeng terminal and observation platform wou be attached for convenience of waiti passengers.

We have not worked out minor d tails such as size of cable necessary, lowable car speeds, etc., but perhaps som of our mathematically-inclined frien may be interested in working out the problems.

Obviously this solution will not wo for travel between planets because of t variations in orbits, but we expect to wo on that problem in future coffee breal

Francis A. Handville
Raymond F. Pohl
Picatinny Arsenal
Dover, New Jersey

P.S. The coffee contains nothing mo than cream and/or sugar.

Hardeman Participating

To the Editor:

Paul Hardeman, Inc., is proud of i participation in the design and constru tion of missile test and launching faciliti To date we have participated in over major projects of this nature. We a particularly enthusiastic about our late participation in the *Titan* program throu the start of construction of the first ni operational complexes at Lowry Air For Base, Colorado.

We were distressed, therefore, to fi our name missing from the list of o joint venture partners on page 45 of t May 11 issue of MISSILES AND ROCKET The correct information is as follows:

Morrison-Knudsen Company; Pa Hardeman, Inc.; F. E. Young Constructi Co.; Johnson, Drake & Piper, Inc.; Ols Construction Co. have been awarded contract for the construction of W 107A-2 technical facilities, Lowry A Force Base, Denver.

Morrison-Knudsen Company is t sponsor of the joint venture and Pa Hardeman, Inc., and personnel will be a substantial share of the responsibility.

Patrick R. Black,
Vice President, Engineeri

We regret the omission . . . Ed.

WASHINGTON—The Department of fense has announced that it awarded otal of $213,400,000 in contracts **Lockheed Aircraft Corp.,** for work military satellites. The amounts had been disclosed previously. $96,-,000 applies to Project *Sentry*, an erimental satellite designed to size enemy installations with camera ipment. $106,000,000 was awarded to April 30 for experimental *Dis-erer* satellites, closely tied in with *Sentry*. $10,800,000 is allocated to ject *Midas*, the experimental satel- being designed to warn against my missile attacks.

NASA

4,805—**Avion Div. of ACF Industries, Inc.,** Parmus, N.J., for production of transistorized electronic devices for the Project *Mercury* capsule (subcontract by Collins Radio Co.).

NAVY

557,000—**Aratz Contracting Co.,** San Francisco, for guided missile support facilities at the Naval Ammunition Depot, Concord, Calif.

50,000—**Perkin-Elmer Corporation,** Norwalk, Conn., for design and construction of a 36" aperture telescope to be used in high-altitude photography of planets and celestial bodies (subcontract by Princeton University).

6,631—**Thompson Ramo Wooldridge Inc.,** Cleveland, for labor, facilities and material to manufacture *Sidewinder* 1-0 motor tubes.

AIR FORCE

2,500,000—**The Crosley Div. of Avco Corp.,** for radar equipment. Many items to be sub-contracted o other companies.

1,000,000—**Western Electric Co., Defense Projects Div.,** for design and installation of a communications network in support of AF facilities in the Aleutians. **Bell Telephone Laboratories** will participate with 50% of the work being subcontracted.

2,00,000—**Vitro Engineering Co.,** for operation and maintenance of power facilities on SAGE-*Bomarc* bases.

2,00,000—**Astrodyne, Inc.,** McGregor, Tex., for research, development and testing of large-scale rocket motors and new high-energy solid propellants. Included is 188,000 for the manufacture of *Megaboom* solid propellant rocket motors for Holloman AFB.

$400,000—**The Siegler Corp., Hallamore Electronics Div.,** Denver, for development and installation of photo optical, film camera and closed circuit TV systems used with the *Titan* missile. **The Martin Co.** is the prime contractor.

$251,300—**Philco Corp.,** Philadelphia, for technical services (two contracts).

$100,000—**The Johns Hopkins University,** Baltimore, for research on design, development and operation of instrumentation to make auroral spectral measurements from rockets, balloons or satellites.

$93,000—**Electronic Specialty Co.,** Los Angeles, for testing of its new low-cost Panda proximity fuse.

$53,500—**The University of Michigan,** Ann Arbor, for research and study of rocket measurements of aerodynamic quantities.

$52,000—**Stanford University**—Stanford, Calif., for research and investigation of the current flow of plasmas.

$50,000—**Stanford Research Institute,** Menlo Park, Calif., for research on phenomena related to high-speed impact of particles with gases.

$31,187—**Oklahoma State University of Agriculture & Applied Science, Research Foundation,** Stillwater, for design, development and construction of meteoritic microphone detectors of various sensitivities for use in satellites.

$25,450—**Massachusetts Institute of Technology,** for research and development for determination of heats of formation, heats of fusion and heat capacities of compounds of magnesium with Group IVb elements.

The Budd Company, Philadelphia, has announced that they have been awarded a contract by the **Utah Div. of Thiokol Chemical Corp.,** for construction of solid-propellant rocket engine cases for the *Minuteman* ICBM (amount not disclosed).

ARMY

$15,181,000—**The Martin Co.,** Baltimore, for additional production of *Lacrosse* artillery missiles. (Total amount contracted for this weapon $25,181,000.)

$3,024,735—**Ray M. Lee Company,** Atlanta, for building construction at Redstone Arsenal.

$2,757,897—**Blount Brothers Construction Co.,** Montgomery, Ala., for construction of *Bomarc* facilities including all related work at Raco Auxiliary Field, Raco, Mich.

$2,669,250—**Blow Knox Company,** Pittsburgh, Pa., for 20 sets of propellant loading skid assemblies.

$2,320,567—**California Institute of Technology,** Pasadena, for research and development on the *Sergeant* missile program. Work to be done at the Jet Propulsion Laboratory in Pasadena.

$2,000,000—**Raytheon Mfg. Co.,** Waltham, Mass., for engineering services on the *Hawk* missile. This prime contractor invites sub-contractors in NE for drafting services, specs writing and technical manual preparation.

$807,642—**Ashburn & Gray, Inc.,** Huntsville, Ala., for site preparation for missile systems test facility for solid propellants at Redstone Arsenal.

$238,962—**C. H. Leavell & Co.,** El Paso, Tex., for modifications and additions to existing launching areas at White Sands Missile Range.

$99,638—**M. Steinthal & Co., Inc., Aeronautical Equipment Research Corp., Div.,** N. Y., for design, development, fabrication and test parachute recovery system for the *Redstone* booster.

$43,712—**Yale University,** New Haven, Conn., for research study of theoretical nuclear physics.

$39,557—**Harvey Aluminum, Inc.,** Torrance, Calif., for production engineering.

$37,250—**Beckman/Berkley Div.,** Richmond, Calif., for computer analog.

$34,000—**C. H. Wheeler Mfg. Co.,** Philadelphia, for two items of single stage, double suction volume, horizontal split case pumps.

$32,952—**Potter Aeronautical Corp.,** Union, N.J., for six items of turbine type flow-meters.

$32,920—**Redel Engineering Corp.,** Pasadena, for generators and amplifiers.

$32,175—**Olin Mathieson Chemical Corp.,** East Alton, Ill., for research and development of missile components by use of explosive media.

$27,965—**Consolidated Electrodynamics Corp.,** Pasadena, Calif., for two 36-channel oscillographs.

Lycoming Div., Avco Corp., has been awarded a contract for development and delivery of AC-DC power systems incorporating a mechanical constant speed drive for the AN/-USD-4 *Swallow* surveillance drone. **Republic Aviation Corp.,** Farmingdale, L.I., is the prime contractor. (Amount not disclosed.)

when and where

JUNE

American Rocket Society, Semiannual Meeting, El Cortez Hotel, San Diego, June 8-11.

American Society of Mechanical Engineers, Semiannual Meeting, Chase-Park Hotel, St. Louis, June 14-18.

United Nations Educational, Scientific and Cultural Organization, UNESCO House, Paris, June 15-20.

Michigan Aeronautics and Space Association, Industry Missile and Space Conference, Sheraton-Cadillac Hotel, Detroit, June 16-17.

Cornell University Industry Engineering Seminars, Cornell University, Ithaca, N.Y., June 16-19.

Institute of the Aeronautical Sciences, National Summer Meeting, Ambassador Hotel, Los Angeles, June 16-19.

Institute for Practical Research on Operations, The University of Connecticut, Storrs, June 21-July 3.

American Institute of Electric Engineers, Air Transportation Conference, Olympic Hotel, Seattle, June 24-26.

Nuclear Industry Division, Instrument Society of America, Second National Symposium, Idaho Falls, Idaho, June 24-26.

Institute of Radio Engineers' Professional Group on Military Electronics, Third National Convention on Military Electronics, Sheraton-Park Hotel, Washington, D.C., June 29-July. 1.

Pennsylvania State University, Summer Seminar on Plastics—Its Mechanical Properties, Design and Applications, University Park, Pa., June 29-July 3.

JULY

Tenth Annual Basic Statistical Quality Institute, University of Connecticut, Storrs, July 12-24.

Radio Technical Commission for Aeronautics and Los Angeles Section of the Institute of Radio Engineers, Third Biennial Joint Meeting, Ambassador Hotel, Los Angeles, July 16-17.

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

Institution of Investigation of Biological Sciences, sponsored by Air Force Office of Scientific Research-Aeronautical Div., World Health Organization and United Nations Educational, Scientific and Cultural Organization, Montevideo, Uruguay, Aug. 2-7.

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

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

Institute of Radio Engineers, Western Electronics Show & Convention, Cow Palace, San Francisco, Aug. 18-21.

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

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

SEPTEMBER

Air 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.

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

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

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

Industrial 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.

American Rocket Society, Solid Propellants Conference, Princeton University, Princeton, N.J., Sept. 24-25.

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

OCTOBER

Electronics Industries Association Conference, University of Pennsylvania, University Park, Oct. 6-7.

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