JULY 27, 1959

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

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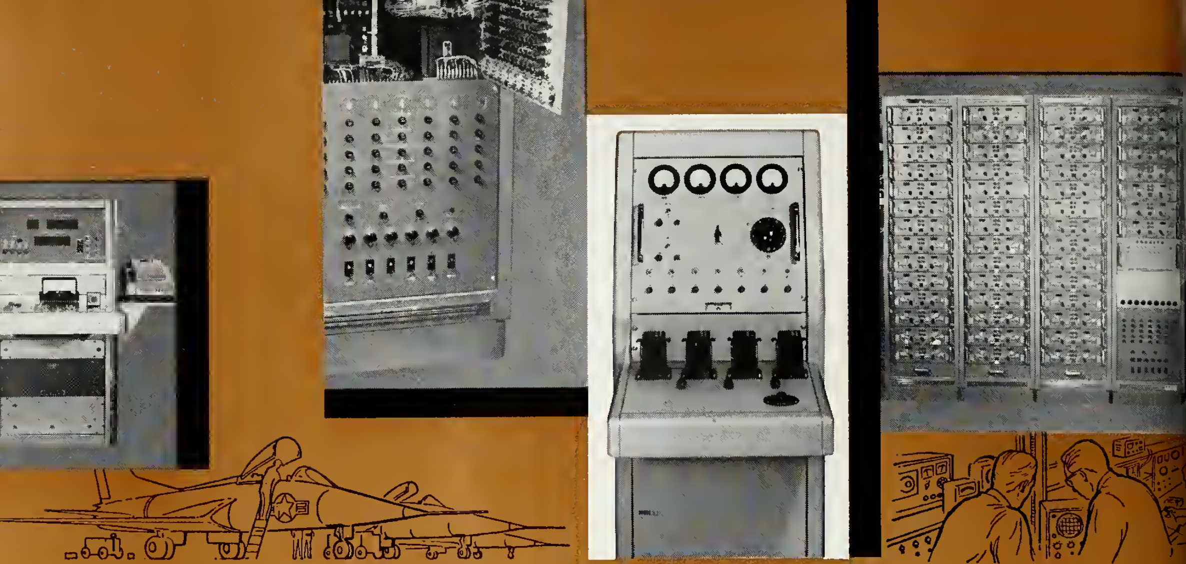

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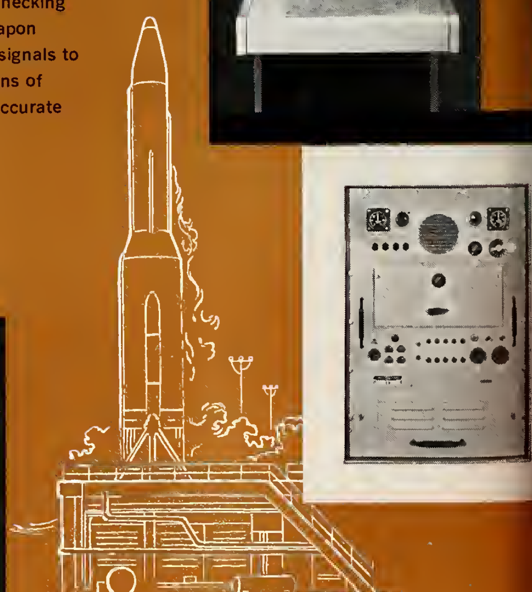

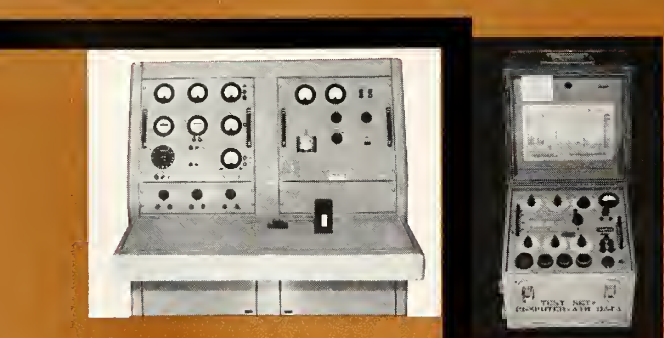

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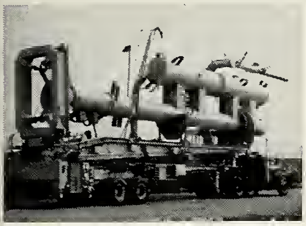
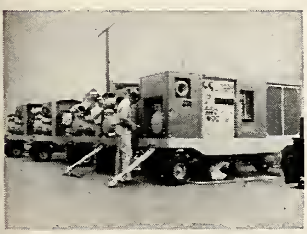
COVER: Multistoried gantry at Cape Canaveral surrounds huge Convair *Atlas* before blast-off. Technicians and engineers are shown pausing in their preparations and inspections.



VEHICLES used by Food Machinery and Chemical Corp. during *Navaho* program were instrumented for shock testing at varying speeds. See story on vehicle requirements, p. 17.

WORLD'S largest solid propellant mixer at Grand Central Rocket Co., Redlands, Calif., has batch capacity of 350 gallons. See survey of outlook for solids, p. 31.



AIR conditioners for Northrop *Snark* missiles are made by Hokanson Co. These are electrically driven, supplying 85 lbs./min., 45°F air. See report on cooling, p. 34.

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

JULY 27 HEADLINES

MISSILE SUPPORT

ASTRODYNAMICS

ASTRONAUTICS ENGINEERING

ASTRIONICS

THE MISSILE WEEK

DEPARTMENTS

USE LOTS OF TAPE?

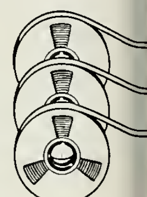
"SCOTCH" BRAND Instrumentation Tapes cut operating costs

Let's develop our own small theory of relativit
For everything's relative, after all—even econom
Clearly, an economy effected now and *correct*
later is no economy at all. In instrumentation tap
there's only one genuine economy—reliable pe
formance. And in performance, the last two wor
for any acute tape-user are "SCOTCH" BRAND.

First to last, "SCOTCH" BRAND Magnetic Tap
offer uniformity and reliability—born of the e
perienced 3M technology that created the first pra
tical magnetic tape and continues to advance t
art of tape-making day by day.

But let's look at economy from another viewpoi
—in terms of some things around the periphery th
might not come so readily to mind—storage, us
waste, and time saved.

What other kind of record is so permanent it ma
last a lifetime, yet requires so little space for sto
age? Three reels of "SCOTCH" BRAND like those at the right "contain" 30 million characters. What other medium serves input, output and memory functions at such high speeds? Accepts both digital and analogue data?



What other kind of record is not *consumed,* even when it is used? "SCOTCH" BRAND Magnetic Tape is run and rerun for analysis, eras
and used again, permits retaping with correction
editing and new data.

Last, but far from least—in these days when tim
is money, what other medium speeds up data acqu
sition, reduction and control programming in
way that keeps critical projects rushing forward
full tilt? Or cuts production lead time and huma
error to a point where a 1000% saving may b
realized?

At any cost, "SCOTCH" BRAND Magnetic Tap
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"SCOTCH" BRAND Tapes offer that greater econom
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Tapes 158 and 159 let you pack more bits per inc
offer extra play reels. "SCOTCH" BRAND Sandwic
Tapes 188 and 189 end rub-off, build-up, cut hea
wear to an absolute minimum, show little wear i
50,000 computer passes. "SCOTCH" BRAND Hig
Output Tape 128 offers top output at low freque
cies, even under ambient temperature extreme
"SCOTCH" BRAND Instrumentation Tapes 108 an
109 offer top performance at lowest cost.

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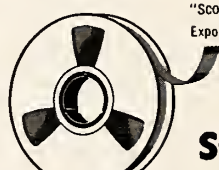


SCOTCH BRAND MAGNETIC TAP

FOR INSTRUMENTATION

MINNESOTA MINING AND MANUFACTURING COMPANY
...WHERE RESEARCH IS THE KEY TO TOMORROW

Washington Countdown

IN THE PENTAGON

The budget squeeze for FY 1961 . . .
is already on for military and space planners. The Administration has passed the word that budgets are tentatively to be cut 10%. This would mean an across-the-board slash of more than $4 billion in the face of rising costs.

• • •

Problems with Convair's *Atlas* . . .
are believed to have been licked with the successful firing of a production model from Cape Canaveral July 21 and recovery for the first time of an *Atlas* nose-cone. But the first operational firing from Vandenberg AFB is still not expected before September. The Air Force wants to fire a few more of the big birds from Canaveral to make sure the cause of recent failures has been licked for good.

• • •

No new development . . .
resulting from production is believed to have caused the series of *Atlas* failures. Officials believe the cause was built into earlier models but failed to show up until recently.

• • •

A new hand is at the controls . . .
of the Pentagon's influentially-placed Ballistic Missile Committee. Deputy Defense Director Thomas Gates has taken over the committee's chairmanship. Ex-Missile Czar William Holaday formerly held the post.

• • •

Some code names . . .
for current ARPA projects to keep in mind:

. . . *Suzano*—A study program for a space platform to provide an advance base for space missions.

. . . *Principia*—An R&D program aimed at obtaining a solid propellant with a 10 to 20% greater specific impulse than any now known.

. . . *Pontus*—An R&D program aimed at obtaining a major improvement in structural and power conversion materials.

. . . *Tribe*—An R&D program aimed at obtaining a family of advanced military space vehicles.

. . . *Longsight*—Continuing studies of possible advanced projects including "unorthodox and creative" proposals.

ON CAPITOL HILL

The Hébert Subcommittee staff . . .
is still digging through a mountain of questionnaires from ex-military officers employed by defense contractors. Meantime, the subcommittee is expected to turn during the week of July 27 to looking into defense contractor associations.

• • •

First Air Force, then Navy . . .
is the order in which top military missile men are expected to testify at the House Space Committee inquiry into recent **Convair** *Atlas* and **Lockheed** *Polaris* failures. The hearings were called to find out whether the U.S. missile program is slipping.

AT NASA

Recent launching failures . . .
have hurt NASA's space research program. NASA did not plan for so many failures in its budget estimates. Now there is a lack of vehicles for some back-up shots.

• • •

NASA plans to bombard . . .
space with five satellites between now and the end of August. The space agency's accelerated launch schedule includes the last *Vanguard,* an *Explorer* balloon experiment, *Thor Ables III & IV,* and *Atlas Able IV.*

AROUND TOWN

Some of the reports . . .
that are being passed as the "latest" in the nation's capital:

. . . **Martin** *Matadors*—nuclear warhead-packing airbreathers—are being installed on Okinawa.

. . . It's possible that Russia may have a missile-launching nuclear submarine about the same time or not much later than the *Polaris* submarine will be operational.

. . . Russia has a good chance to have more than a dozen operational ICBM's in the hands of troops before *Atlas* is operational.

Industry Countdown

STRUCTURES

Major review of Air Force . . .

weapon system management is under way. Big question before Air Staff is whether AF has delegated too much authority to prime weapons system contractors. Officials are looking into criticism leveled at the failure to develop in advance major components and subsystems which delay delivery of weapon.

• • •

Stronger bid for missile . . .

business can be expected from **Ryan Aeronautical** with forthcoming corporate shift. Key change: Edward G. Uhl, who has resigned as vice president of **The Martin Co.,** probably will be joining Ryan shortly as senior vice president. His resignation has been kept quiet up until now. Uhl has been succeeded as Martin-Orlando general manager by G. T. Willey.

• • •

Unless major engineering . . .

problem is licked, hardened ICBM bases will be much more costly than anticipated. Each missile launching pad will require a horizontal underground tunnel 100 feet in length to furnish orientation line for inertial guidance checkout. Elevator systems alone as yet cannot provide the critical tolerances required for positioning the bird in exactly the same space position when lowered and raised. Base line is needed for perfect guidance checkout before firing.

• • •

More construction . . .

problems are posed in ICBM installations by requirement of each missile unit for fixed reference target to align the bird. Material must have equal coefficient of expansion. Reference target cannot settle, must be perfectly rigid and still withstand climatic changes.

• • •

Even wood is finding missile . . .

applications. Some dummy mockups of **Lockheed** *Polaris* are of redwood and are being used to check handling and launching "pop up" gear. One advantage—the dummies float.

• • •

Look for Navy to . . .

start stressing new tactical requirements for *Bullpup*. Missile will be operational with Atlantic fleet this month. Already operational with Pacific fleet squadrons, the air-to-surface weapon is being designed for a 5-year service life.

• • •

'Cold and slow' missile . . .

proposal of **Radiation Inc.** is attracting interest for its biological warfare possibilities. In sharp contrast to the fast and hot missiles being stressed today, this 10-foot "Sprayer" missile would use a slow-burning propellant—probably black powder—to travel at the speed of an old-time Piper Cub. From a low altitude it would spray wide areas of dense undergrowth inaccessible to aircraft and where helicopter operation would be too costly. Fuselage probably would be of cheap material like hard cardboard. Government medical services are looking into this one . . . Radiation also has proposal for moon base environmental simulator that would sustain crew of three for about a month.

PROPULSION

Hydrogen-oxygen rocket . . .

test stand at **Pratt & Whitney's** Florida facility is getting a good workout with full-scale 15,000 pound-thrust *Centaur* engine. Engine is being tested in horizontal facility before being moved to vertical site. Company reports good results—which might mean engine will be available before the vehicle which is expected in 1961.

• • •

One to watch . . .

U.S. Rubber Co. is now actively researching synthetic rubber and plastic-based solid fuels at a new laboratory in Naugatuck, Conn. The work is company-funded . . . Missile activity is picking up in Connecticut (see p. 14).

• • •

Gabriel Co. is building . . .

$1 million propellant plant at Mesa, Ariz., to load thrustors and other devices for its subsidiary, **Talco Engineering,** maker of ejection seats and cable cutters. New Rocket Power Division will be headed by Charles E. Bartley, founder of **Grand Central Rocket Co.**

ELECTRONICS

Courier delayed-relay . . .

communications satellite work is moving ahead. ARPA has let contracts totalling almost $9 million to **Philco** (communications package); **ITT** (ground-based communications) and **Radiation Inc.** (ground-based antennas).

• • •

Gyroless gyro development . . .

of **Martin-Orlando** should stand industry on its ears when it is announced. Most of the system is proprietary, but this much is revealed: Martin has fired a small tactical missile twice successfully—without gyroscopes. System is good for short distances. Works on principle of mass suspension with the missile itself providing necessary rotation.

RAF *Thor* Base on 15-minute Alert

Western World's first ballistic missile site has had 400 simulated countdowns; double key arrangement gives Britain and U.S. joint nuclear control

by Clarke Newlon

FELTWELL BALLISTIC MISSILE BASE, ENGLAND—From a standing start, the Royal Air Force crews of this first operational ballistic missile base in the Free World today can fire its 15 nuclear-armed warheads at predetermined targets in just under 15 minutes.

More than 400 simulated countdowns of the **Douglas**-built *Thor* IRBM have brought the crews to this peak of efficiency, manned 24 hours a day, seven days a week as part of the deterrent force.

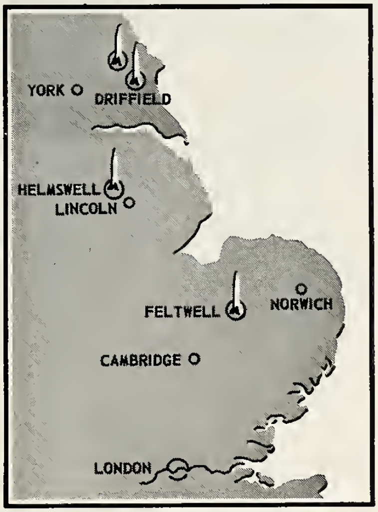
Feltwell became operational early in July. Farther to the north, along the east coast of Britain, Helmswell is expected to be operational in September, Driffield by December and a fourth unnamed base well before July, 1960, thus completing England's intermediate ballistic missile program.

Each base is of squadron strength—15 missiles. And each base consists of a main site and four satellite sites, each with three missiles. The maintenance and housekeeping facilities and personnel are at the main site. Feltwell has about 1000 RAF personnel who are responsible for command, operations, intelligence, communications, base support, safety and administration. Some 00 U.S. personnel, both military and civilian, have the responsibility for nuclear warhead storage, maintenance, technical supply and training. The main site and each satellite are separated by about 20 miles.

• **Vetoes and keys**—For the first time, officers of the RAF and USAF have a full explanation of both the "double veto" over the atomic bomb carried in aircraft from English bases and the similar "two key" arrangement for firing control of the *Thor*

The double veto as regards aircraft means that the British government must agree before nuclear bombs are actually carried in USAF aircraft from her bases; that also, Her Majesty's Government must concur before any nuclear bombs are dropped from planes which take off from her bases.

In the case of the double key for the *Thor* missiles, a comparable arrangement has been worked out. The commander at each site has one key. This must be turned to start the 15-minute countdown. The American officer at the site in charge of the atomic store has a second key. When the countdown has reached the point of minus three minutes, he must turn a second key before it can proceed further. And each U.S. site officer has a direct line to the Strategic Air Command Headquarters in Omaha which he can reach in 30 seconds.



BASE AT Feltwell is now operational. Three more will be added within a year.

Neither the double veto nor the double key precludes a delegation of authority by either side in a time of alert, when warnings were clear that an enemy was mobilizing for possible attack.

General Lauris Norstad, commander of SHAPE, incidentally, recently told newsmen that this double veto-double key arrangement which exists between Britain and France and which is being worked out with Italy, Turkey and Greece, is precisely the same agreement offered to France—and refused by Gen. De Gaulle.

• **The drill**—At Feltwell, the pilot *Thor* base, five crews of 16 men and two angry-looking guard dogs operate each site on an around-the-clock basis. The crews consist of one officer and six non-coms as launch crews; one U.S. officer with the second key, five police guards (and the two dogs); one fireman driver, one cook and one motor transport man.

Missiles for Feltwell are flown into nearby Lakenheath Airdrome, trucked over to the Receipt, Inspection and Maintenance (RIM) building at Feltwell where they are subjected to a complete checkout, and then sent to the sites. There the *Thor*s are normally positioned horizontally under hangars on tracks. The three missiles are located 700 feet apart with the control van being roughly the fourth corner of the square. From this van, in a practice alert as they would in an actual firing, the countdown for all three missiles is controlled through five phases, as follows:

First: an automatic checkout of all equipment.

Second: retract cover hangar and raise missile.

Third: initial and slow propellant fueling.

Fourth: final and rapid fueling.

Fifth: missile disconnects from ground supply, own power takes over, engines ignite, missile fires.

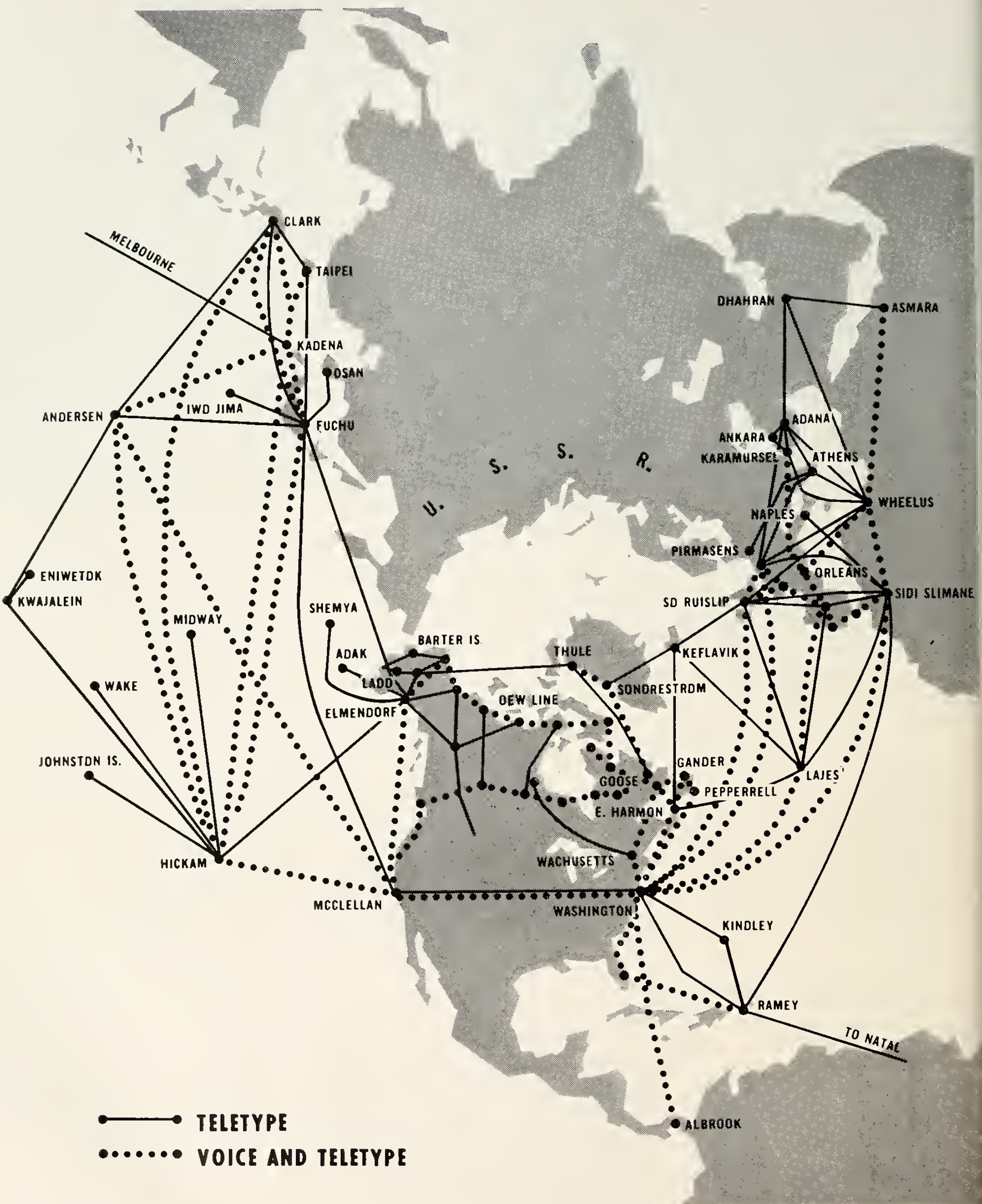
Throughout this operation there are points at which the countdown can be held for times ranging from minutes to several hours, thus cutting down the reaction time during an alert. Through tying in with the NATO warning system, the RAF feels it would have 40 minutes warning time for a bomber attack, probably about seven minutes for a missile attack. The *Thor* countdown can be stopped at firing time minus three minutes if required.

• **U.S. aid**—While the *Thor* bases are almost completely an RAF operation, the U.S. lends a big helping hand. In addition to the U.S. Air Force personnel aiding training and maintenance, Maj. Gen. William H. Blanchard, commander of SAC's Third Air Division in England, estimated that approximately 1000 installation and checkout technicians from **Douglas, A. C. Spark Plug, Rocketdyne, General Electric** and other American companies were working on or near the missile bases, most of them living in trailers.

Of the personnel trained and being trained for the four RAF missile squad-

(*continued on page* 39)

SAC's 'Trigger' Doubled f



MAP OF the Air Force's communications network graphically demonstrates how the system brackets the Soviet heartland.

ssile Age

AF's vital communications network eventually will include satellites

by James Baar

WASHINGTON—A red phone sits in maha . . .

A baby-blue phone sits in Washgton . . .

The defense of the Free World ings on them. They are the key links the Air Force's 1.3-million mile mmunications network. Over these ould pass the word to unleash the ead power of SAC.

Today this means the U.S. bomber ets. Tomorrow the ICBM's.

The complications involved in buildg and maintaining such a communitions network are stupendous. And e complexity is growing greater as e ICBM enters the arsenals of the est and the East.

In order to meet the growing challge, the Air Force is adding to its twork another 950,000 miles of comunication channels. Some of it will available in the very near future. l of it is scheduled to be operating thin two years.

Nor will this be the end.

The Air Force is looking for rapid velopment of communications satelles. These will help carry the increasig traffic load and insure still greater liability. They also will provide eans for reaching inaccessible areas such strategically vital zones as the ctic.

• **Heavy duties**—The Air Force mmunications system is designed to eet a number of specific difficult reirements. It must transmit such aphic information as maps and recnnaissance pictures. It must transmit pies of written material such as deled orders. It must transmit vast antities of data such as weather d flight information.

But most important of all to the curity of the Free World is that it nsmit verbal messages without fail the greatest possible speed. This is C's trigger.

To make this trigger work without l the Air Force communications net s been spread around the world from United States like two great arms. e western terminus is Melbourne, stralia. The eastern, Dhahran, Saudi Arabia. Together they form a herculean "U" embracing the Soviet Eurasian heartland.

The entire multi-billion dollar system is designed to provide time. Time to get off the ground before you're hit. Time to determine that you're really under attack. Time to pull the trigger.

The missile is rapidly shrinking this time.

• **Command decision**—Today it would be a matter of hours. The DEW line across the top of North America would flash the warning of a bomber attack. NORAD and SAC would receive it simultaneously. An officer in the underground SAC command post at Omaha would raise the red phone. In less than a minute SAC planes around the earth would be ordered into the air.

As the SAC bombers moved toward their targets, the U.S. high command in Washington would have at least an hour and a half to decide whether World War III were on. But not much more. The bombers would be told to go in—or they would have to return.

Such a decision might well be made with only minutes to spare. Then the President, who alone has the authority to order the use of U.S. nuclear weapons, would give that order. An officer in the Pentagon command post would raise a baby-blue phone and speak the code word for "Go!"

Three years from now there will no longer be hours. There will be only minutes.

BMEWS, the **RCA** ballistic missile early warning system now under construction in Alaska and Greenland, would flash the warning to NORAD and SAC that hundreds of Soviet ICBM's had been launched.

There would then be 15 minutes before the ICBM's struck. All that formerly could be done in several hours would have to be done in this brief span. Plus a new task: Scores of U.S. ICBM crews along with the *Polaris* submarines then on station would be ordered to launch their missiles.

The Navy is developing an entirely new communications system designed to be capable for the first time of contacting submarines at great depth anywhere in the world's oceans. Huge towers are being built for the secret system at Cutler, Maine.

The exact method of tying the *Polaris* network into the rest of the nation's deterrent force is still to be determined at the highest military levels.

• **Meeting the challenge**—The unrelenting requirements for a communications net capable of triggering so vast a force in so short a time are staggering. There can be no delay. And its reliability must be nearly 100%. Ninety-nine percent is not good enough. Such a system would fail 14.4 minutes a day—virtually all the warning time BMEWS will be able to give.

The Air Force has been rapidly revamping its communications system because of this Missile Age challenge.

At present, 948,000 channel miles of the Air Force net are the old high frequency channels. These can be jammed and are highly sensitive to sun spots. And they have had to be duplicated many times in order to ensure the high reliability required.

However, the Air Force already has 325,000 channel miles of network based on the superior tropospheric scatter system. And the 950,000 more miles under construction are of the same type.

The troposcatter system is all but unjammable. It provides an extremely wide band of 132 channels. And it has 99.99% reliability.

The system operates by bouncing powerful signals off the troposphere from one relay station to another. The stations are up to 600 miles apart.

At the same time, many of the hundreds of thousands of channel miles of commercial lines and cables available to the Air Force on a full-time basis are being hardened and routed around target areas.

Finally, the Air Force has available in case of national emergency the use of Army and Navy facilities.

All of it is geared to one overriding goal: A guarantee that if some day someone has to reach for the red and the baby-blue phones the codeword for "Go!" will be heard around the earth.

Third of A Series

Missiles Fill Gap in Connecticut

Nutmeg State reaps better than $500 million a year from missile/space work employing about 100,000 and taking up slack caused by other defense cuts

by William E. Howard

HARTFORD—On July 2, 1957, three months before *Sputnik* galvanized the Free World, a team of eight Connecticut manufacturers approached the Springfield (Mass.) Ordnance District. Objective: a contract to develop and produce an entire missile system.

The mission failed. But the foresighted action nevertheless marked the beginning of a major new industry in the Nutmeg State—nearly every member of the team has since become heavily engaged in missile/space work.

Today, although the state still does not have a prime missile contractor, manufacture of highly specialized missile components and support equipment is a mushrooming business. Humming factories are turning out a big percentage of the bearings, springs, castings, gaskets and cams, as well as the more "exotic" items—like nose cones, mixing equipment for solid fuels and infrared guidance packages —that go into virtually every missile system in the nation's arsenal.

The total number of companies directly engaged in missile work was placed in 1958 by the Connecticut Development Commission at more than 220. These firms employ 83,000 on production lines and another 27,000 scientists and technicians. Some 358 research and development firms employ an additional 12,000—with much of their effort related to the new space technology.

Actually, the CDC figure may be considerably outdated. The Pratt & Whitney Division of United Aircraft, which is in the process of organizing to become a prime systems contractor, now has more than 1400 of its 6600 suppliers in the state. By year's end, P&W expects the Connecticut total to increase to 2000. Avco's Lycoming Division has more than 500 firms in the state which are suppliers or subcontractors. And the Electric Boat Division of General Dynamics, producer of *Polaris* fleet ballistic missile nuclear submarines, had another 123 at last count. Many of these suppliers sell to more than one of the bigger contractors—inside as well as outside the state.

Arriving at a dollar volume for the state's missile industry is virtually impossible, because of the multitude of small contracts and purchases conducted entirely within the industry. But basic contracts indicate that missile manufacturing is running at well over a $500 million annual rate.

• **Missile transition**—Industry experts note that Connecticut is in a period of transition brought on by the phase-in of missiles and a cutback in aircraft production and other military weapons long made here. The spurt in missile component manufacture appears to be offsetting this loss of other defense business.

The Connecticut Labor Department reports that aircraft and parts employment centered in Hartford, Bridgeport and New Haven was 60,000 in May—6000 less than the same month a year ago. However, total manufacturing employment is even with last year—at about 400,000 statewide.

Connecticut, along with other New England states, also has lost much of its textile industry in the migration to the South. As a result, despite the expanding national economy, the state is just about holding its own wh industry is on the increase elsewhe

Accordingly, state officials a lustily beating the drum to attr new industry.

Gov. Abraham Ribicoff journey to the West Coast a month ago a at a luncheon arranged by the Co necticut Development Commission San Francisco for a group of Nort ern California industrialists, he sai "Connecticut has the most to offer a industry planning to establish an E Coast branch."

Apparently in deference to t tussle between New York and Ca fornia lawmakers over geographic placement of defense contrac Ribicoff hastily added:

"I want to make it crystal cle that . . . we are not here on any i dustry raid. We are not asking an one to pack up and move to Conne ticut. However, a community of i

ANECHOIC chamber at CBS Labor tories, Stamford, used for quantitati checks.

XAMPLE of inter-industry cooperation in Connecticut is use of ultrasonic resonance gage developed by Branson Instruments, ıc., of Stamford, to test wall thickness of *Nike-Hercules* nose cones built by Avco's Lycoming Division, Stratford.

ɪrest exists already between our two ates . . ."

• **Alarm at DOD cut**—One Con- ressman, Rep. Frank Kowalski (D- onn.) is frankly alarmed at an ap- ɪrent sharp cut in defense orders ɔing into the state. In his home town Meriden, Kowalski says, there are 500 unemployed defense workers. oreover, he has compiled figures hich show that Connecticut has ipped from $1.2 billion in defense ɔntracts—7.5% of the 1956 defense ıdget—to $897 million, or 4.3%, in 958.

He expects the state's share of the efense dollar this year to be even less -about $500 million.

"This means a shift of 40,000 jobs ıt of the state," Kowalski told M/R. am against this kind of whipsawing, ith the defense industry shifting to alifornia for two years and then ifting back. It is jerking the hell out our economy."

Kowalski says DOD should strive create more stability of the day- -day variety in defense manufacture. nd he adds, "Maybe we need a ecial agency to plan for the *present*."

The lawmaker concedes, however, at missile component manufacture is king up the slack and that the re- ıction in defense contract dollar lume may not tell the whole story. he difficulty is, though, you can't ally determine just where we stand," said.

• **UA missile build-up**—At the ɔment the volume of missile busi- ss shows every indication of con- uing to boom. Here's what is happen- ɪg around Connecticut:

United Aircraft President William P. Gwinn two weeks ago announced that the company will spend $68 million to expand and modernize production and experimental facilities to handle its bigger role in missile/space work. All four operating divisions—P&W, Hamilton Standard, Sikorsky and Norden—are being geared to bid as a prime systems contractor.

Several thousand of UA's more than 45,000 employes are involved in missile manufacturing operations. There are 10,000 in P&W engineering sections.

Heading UA's Missiles & Space Systems Division, which was formed a year ago and is now working up steam, is aircraft propulsion wizard Wright A. (Parky) Parkins. His 200-man engineering division at East Hartford is making weapon and space proposals and has "several" classified contracts under negotiation.

"We are hopeful this will grow into a real program and Connecticut will benefit in a large way," says Parkins. He explains that the overall plan will see P&W, which now builds *Hound Dog* J-52, and *Snark* J-57 engines, providing both liquid and solid rocket propulsion systems; Hamilton-Standard—controls, air conditioners and other accessories; Sikorsky—airframes, and Norden—electronics and guidance.

UA's United Research Corp. at Menlo Park, Calif., is actively pursuing propellant research, on both a long- and short-range basis. Parkins told M/R UCR is setting up a multi-million dollar facility for solids development. The effort is strictly R&D and production will be handled by P&W in Connecticut.

P&W right now is developing rocket cases of titanium and steel in a "cold-flo" turning process. These are second- and third-stage cases for *Minuteman*, *Pershing* and *Polaris* under sub-contracts with Aerojet-General, Thiokol, the Navy's BuOrd, and Hercules Powder.

At Middletown, UA has 1500 employes in the Connecticut Aircraft Nuclear Engine Laboratory. CANEL is a "hot lab" owned by the Air Force and has been in operation since 1950. Various other engineering sections of UA also are working on advanced propulsion systems—ion, plasma, solar—and lead boundary layer devices.

• **Norden consolidation**—Norden-Ketay, acquired by UA a year ago, is in the process of being brought under one roof. Facilities at Stamford, Milford and White Plains, N.Y. may be moved to a new plant at Norwalk, Conn., although no site has been picked yet. The division's 2300 employes are turning out gyros, synchros, analog-to-digital converters, pressure ratio transmitters and indicators, gas pressure systems, servo motors, resolvers and other components. These parts all have been designed specially for *Atlas, Polaris, Thor, Nike, Terrier, Tartar, Redstone, Jupiter, Talos, Bomarc, Regulus, Snark, Hound Dog, Tall Tom* and *Swallow* missiles.

The Hamilton-Standard Division, which was hit by a curtailment in aircraft propeller demand, is making a comeback in the missile controls area and now employs 7000. H-S officials are excited by a new "Min-IR-Cooler" for IR detection and satellite applications which was developed with Arthur D. Little, Cambridge, Mass. The division is producing auxiliary power packs and is on the Boeing team to make environmental controls for the global boost-glide *Dyna-Soar* space vehicle.

Leaning back in a chair in a paneled office once occupied by aircraft pioneer Chance Vought, Parkins observed recently that the Missiles & Space Systems Divisions real job is to "unite and exploit the capabilities already in UA—and we're on the spoor."

MSS, incidentally, is not tied to UA's other operating divisions in putting together a missile/space system. "We're free to go," says Parkins, "anywhere we can find a better mousetrap."

• **Big Avco contract**—Avco's Lycoming Division at Stratford is the production arm of the company's big R&D laboratory at Wilmington, Mass., along Boston's "Golden Industrial Semicircle." It also has outside contracts. Just three weeks ago, Aerojet-General signed the division to a $6 million order for second and third rocket chambers for *Minuteman* and *Polaris*. The unit's 3700 employes also are busy producing *Titan* and *Minuteman* re-entry vehicles, *Nike-Hercules* nose cones and the forward diffuser for the Bendix *Talos* surface-to-air missile.

In 1958, Avco-Lycoming had 1750 suppliers to whom it paid $12.3 million. Some 500 of them were in Connecticut and received $4 million. The company says there will be a "lot more" this year.

It was H. Webster Crum of Avco-Lycoming who spelled out the proposal of the eight Connecticut manufacturers to the Springfield Ordnance District just two years ago. Others joining in the now-famous "Southern New England Missile Resources Group" were American Machine & Foundry, which has a substantial R&D laboratory of 1100 at Greenwich, Conn., Kaman Aircraft—now working on highly classified *Polaris* electronic countermeasures; Electric Boat, Landers Frary & Clark—now making small rockets; Norden-Ketay, Manning Maxwell and Moore Inc., Stratford—researching high pressure/high temperature and controls for chemicals, power and other applications, and Sperry Products, Inc.—electronics and data processing.

• **EB payroll $60 million**—Electric Boat's huge shipyard at Groton is a beehive of activity in the big push to launch fleet ballistic missile submarines to carry the Lockheed *Polaris*. Some 10,000 employes—2000 of them commuters from Rhode Island—are hard at work on the 380-foot, 5600-ton Patrick Henry, sister ship to the first FBM sub, George Washington, which was launched June 9. (M/R June 8, p. 31.)

With a 1958 payroll of $60 million, the yard has contracts to build two more FBM subs, first of a new class. EB has on the ways two other revolutionary nuclear subs. They are the high-speed Triton, which has two reactors for propulsion, and the Tullibee —the nation's first atomic-powered "killer sub" for anti-submarine warfare.

All of the subs are costing around $100 million, and the Navy has provided more than $2 billion so far for the entire FBM program. EB, incidentally, says that through January, 55% of its direct purchase orders under the FBM program went to small business. These suppliers also received 38% of stock inventory dollar volume.

• **Wealth of specialties**—The multitude of small, growing firms which make up the fabric of Connecticut's missile industry produce products which read like a rocket hardware store. At Middletown you will find Safeway Heat Elements making heaters and heating pads; Hart Mfg. at Hartford turns out relays; Hi-G, Windsor Locks, is producing capacitors. Vickers Inc. Marine & Ordnance, a division of Machinery Hydraulics, is a ground handling and launching equipment fabricator.

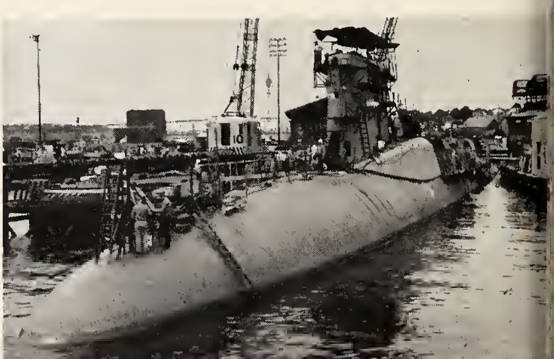
In the Waterbury area, there is the Bristol Co., with 1400 employes producing high-speed relays and choppers at Danbury, Barden Ball Bearing makes miniature instrument bearings for missile applications, and Reeves Soundcraft, telemetry tapes and product control systems.

The Perkins-Elmer Corp., Norwalk, an old established company is in the missile business with tracking theodolites and infrared systems.

To test the wall thickness of Avco Lycoming's *Nike-Hercules* nose cones, Branson Instruments Inc., Stamford, has developed an ultrasonic resonance gage. These cones must be held to a variance factor of ±0.006 in. A new company ready to make itself available to other Connecticut missile men is Propulsion Test Facilities, New Haven, an affiliate of MB Mfg. Co. This firm offers complete environmental test facilities for checking component reliability under simulated space conditions.

The Rogers Corp., Rogers, supplied the duroid in the *Thor-Able* telemetry system, playing a small but important part in the recovery of the test missile's nose cone. The tiny 2-ounce motor which drove the miniature tape recorder in the *Vanguard II* weather satellite was made by the A. W. Haydon Division of Consolidated Electronics Industries Corp., Waterbury.

JET ENGINES for *Hound Dog* and *Snark* are turned out at Pratt & Whitney's Aircraft Division in East Hartford.



OUTFITTING of USS George Washington, first FBM submarine at EB, Groton. Sister ship is under construction.

Vehicle Requirements Are Tricky

A look at some of the myriad problems involved in designing mobile systems and an outline of some of the vehicle combinations that may be chosen.

by John J. MacRostie

SAN JOSE, CALIF.—One of the ıajor problems in the testing and de- loyment of large missiles is transport- ıg them over land.

Difficult obstacles must be over- ɔme. Specialized support vehicles are eeded to overcome them.

The Preliminary Design Depart- ıent of **Food Machinery and Chemical orp.'s Ordnance Division** has con- ucted extensive studies in order to ıeet this challenge. The results show ıe great complexity of the problems ıvolved.

To begin with, in order for a mis- le system to be mobile there must be ıe capability of moving missiles from he launch area to another on short otice even during adverse weather onditions. Careful consideration must e given to the ground over which the quipment must travel.

Here are some of the possible ter- ıin conditions:

• Good, hardtop roads exist be- veen all possible launching sites, and ıere are *no* bridges nor underpasses ith limited clearance.

• Good, hardtop roads exist be- veen all possible launching sites, but ıere *are* bridges or underpasses with earance limits.

• Good, hardtop roads exist over *ırt* of the area, but secondary dirt ɔads must be used in other parts. hese secondary roads are good in dry eather, but will become muddy dur- g prolonged use in rainy weather.

• Both hardtop and dirt roads exist the area but the tactical situation emands that the equipment must various times be moved over open ountry where no roads of any type ist. Under this general terrain situ- ion, the ground may be hard-packed ıd will support the equipment during y weather without excessive sinking, sandy soil may exist causing high olling resistance even during dry wea- ıer, or mud conditions may exist over ost of the terrain during wet weather, creating extreme mobility problems.

• Good roads in the area, but dur- ing the winter (even in the southern U.S.) there may be snow conditions at certain times of the year.

• There are normally good roads available, but, due to man-made or climatic damage, the roads must be detoured in certain areas either via secondary dirt roads or via open field terrain.

• The slopes that exist in the area must be considered. If there is rolling terrain with severe grades, then greater tractive effort is required than would be required in flat areas.

• The final conditions to be con- sidered is the width of the roads, radii of curves, and clearances at intersec- tions. If the roads are narrow and meet at 90° intersections, then long trailers could not turn without going off the road, and if there are deep drainage ditches or other obstructions at these intersections, then, to insure adequate equipment maneuverability, a steerable trailer suspension must be provided.

In establishing an equipment mo- bility concept, each type of terrain mentioned above must be considered to determine whether that particular condition would be encountered in the area of missile system operation.

If it is known that good roads will exist at all times, it is not necessary to provide equipment with a high degree of cross-country capability (which will cost more and be more difficult to maintain than simple highway-trailer type equipment). If, on the other hand, difficult terrain must be traversed, even for short distances, cross-country mo- bility must be incorporated into the design.

However, if a high degree of mobil- ity is required for only short periods, the mechanism may be designed for low-speed operation and relatively short life. Or, if a high degree of cross- country mobility is required for all normal use, then the feature must be incorporated for full-life usage and must be effective in all speed ranges.

• **Combinations**—Many mobile equipment concepts, embodying vary- ing degrees of mobility, are possible. In each case the prime mover—tractor —is a critical item, and its size, power and tractive capability must be con- sidered relative to the weight and roll- ing resistance of the trailed load.

Here is a brief list of some of the possible equipment combinations which apply to 50,000-pound payloads or 100,000-pound payloads:

• A *highway type* semitrailer and a military wheeled prime mover which would utilize standard tire pressure (in excess of 30 psi) for highway use.

• A *wheeled* semitrailer and a trac-

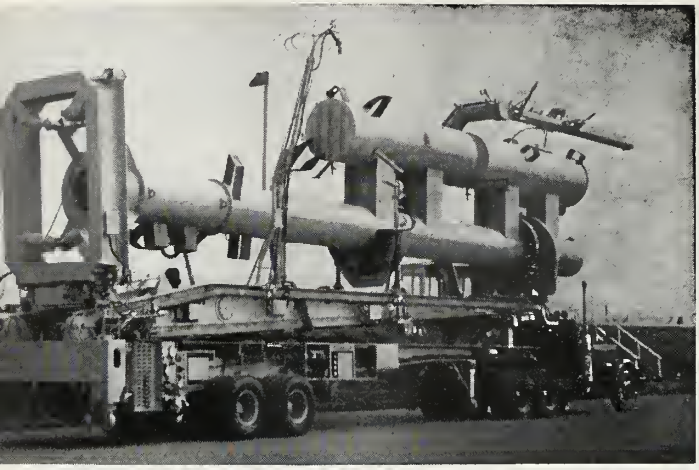
About the Author

John J. MacRostie is manager of the Preliminary Design Engineering Depart- ment of the Ordnance Division of Food Machinery and Chemical Corp. Before this assignment, he was Chief of Pre- liminary Design. In his nine years with FMC, MacRostie was an engineering group leader on the M-59 and T-93 ve- hicle programs and was project engineer in the Navaho missile support equipment program.

The FMC Ordnance Division has for over 17 years devoted much of its design and manufacturing capabilities to provid- ing mobility for U.S. Armed Forces. It has done considerable work in the past four years in the area of wheeled trans- porters for large missile systems.

FMC, under a contract with North American Aviation, designed and manu- factured the transporter erector launcher for the G26 Navaho, and subsequent to that designed the transporter erector launcher for the G38 Navaho and was actively engaged in that program at the conclusion of the overall Navaho pro- gram. In the field of IRBM's, FMC, under contract to Douglas, developed and manu- factured the transporter erector launchers for the Thor system.

wide choice of equipment . . .



HEAVY equipment used by FMC's Ordnance Division was instrumented for shock testing during the company's work under the *Navaho* program.

tor; using large-diameter, off the road low-pressure (under 15 psi) tires on both the tractor and trailer.

• A wheeled semitrailer with a *tracked* prime mover. In this case, the tracked vehicle ground pressure would be less than 10 psi, and the trailer tire pressure would be under 15 psi.

• A wheeled semitrailer with *power-driven* wheels combined with either a wheeled or tracked prime mover which would supply power to all of the wheels. The trailer wheel drive would be used for *all* speed ranges, and the tire pressures again would be under 15 psi.

• A wheeled semitrailer similar to the above, but with power applied to the trailer wheels *only at speeds below 5 mph* to provide traction for difficult terrain. Above that speed, the wheels would be free-wheeling.

• A *track* type prime mover and a *tracked* semitrailer with power at the trailer track through all speed ranges.

• A tracked semitrailer similar to the above, but with power at the trailer track at speeds only below 5 mph.

Let us now consider the reasons that would cause us to use the various combinations.

• Standard highway tires (pressure over 30 psi) have large carrying capacities for a relatively small size. The small size is an advantage in keeping the vehicle width and height to a minimum, but if the vehicle is to go off the highway, small, high-pressure tires will be a severe disadvantage due to their small area of ground contact. For special usage, it is helpful to reduce tire pressure in the highway type tires —but tests have shown that for a specific tire diameter and load condition, reducing the pressure beyond a certain point will actually increase the rolling resistance in soft ground.

• Large-diameter, low-pressure tires offer low rolling resistance across soft terrain and thus afford good cross-country mobility. Their large size, however, means that the equipment must be considerably wider and higher. The wheels must be placed far apart to permit sufficient room between the tires to accommodate the payload—in this case, the missile. For large tires approximately 7 to 10 feet in diameter, stability considerations generally preclude placing the entire payload above the tires—hence the vehicle must accept increased width.

• **Aircraft problems**—This width factor is particularly critical when air transportability is required. The largest cargo aircraft today will accept a load 144" wide—and load height is also a design factor.

To overcome this limitation, thought must be given to the possibility of disassembling equipment (in a short period of time and with simple tools) to reduce over-all package dimensions.

• **Track suspension?**—A tracked trailer might be used for this application. Although it is not a common trailer design concept, this type of vehicle has been manufactured in the past for the U.S. Army. It has several advantages, primarily in the area of low ground pressure for soft soil, sand, or mud.

A tracked suspension is available for static loads up to 120,000-pound load capacity (M-48 tank), and this capacity could be increased. The tracks could be placed entirely under the payload, since a 60-inch-high deck would clear the entire suspension, thus pe mitting a narrower overall vehic width.

One objection to the track suspe sion is that compared to wheeled v hicles, it has a rather high rolling r sistance on hard-surface roads. He again the probable terrain must b considered.

In line with the tracked trailer ide tracked prime movers must also b considered. A tracked vehicle will ou perform a wheeled vehicle of the sam weight and power over difficult te rain; if maximum drawbar pull pe pound of dead weight of prime move is required, tracked vehicles should b selected. Alternatively, if most of th trip is to be made at high speed (abov 30 mph) and on hard-surface roa wheeled vehicles should be considere

• **Choice of drive**—Once a suspe sion has been selected, we must co sider the drive mechanism. If th equipment is to traverse cross-countr terrain, power should be provided t all wheels of the prime mover an trailer. Without power to all wheel even large-diameter, low-pressure tir will provide only limited performanc on soft ground, sand, or mud. Withi the powered-wheel concept, there a two primary approaches:

• Power to the trailer wheels fo all speed ranges.

• Power to the trailer wheels onl for low speed (under 5 mph).

Before a drive method can b chosen, operational requirements o the trailer drive must be determine Either the trailer drive will functio through all speed ranges from 1 to 4 mph, or it will be used only for low speed, high-tractive-effort travel (b low 5 mph).

In the latter case, it is assume that: if the terrain is such that th tractor can pull the trailer at spee above 5 mph, it doesn't need the hel of the trailer wheel drive; terrain co ditions requiring tractor drive at spee under 5 mph will be limited; and tim delay due to lower speed will not b a large portion of overall transpo time.

The reason for offering this lov speed alternate is that, for speeds fro 1 to 5 mph, no complex gear shiftin is required, since either an electric o hydraulic motor can regulate speed ir ternally in those ranges and still giv good output efficiency. A greater rang of self-regulation is possible, but ur less the motor size is increased to giv reasonable torque at high speed, som performance will be sacrificed at th high and low extremes of speed, if 40-to-1 speed relation is required.

There are three basic methods o providing power to the trailer wheel

1. Mechanical drive to a standar

ruck-type axle, with power supplied y either a separate engine on the railer or a mechanical drive shaft rom the prime mover.

2. Electric motor drive for each wheel, with power provided by a generator mounted on the prime mover.

3. Hydraulic or air motor drive for each wheel, with power provided by hydraulic pump mounted on the rime mover.

• **Mechanical**—The mechanical rive has several disadvantages: The rive-shaft from the prime mover to the actor would require a very complex ower take-off coupling on the prime over, the drive shaft would be excessively long for the trailer length that required for this program, and the lative angle between the prime mover nd the trailer would be restrictive, verely limiting the maneuverability of e equipment. A separate engine on e trailer is rather redundant, since ime movers with adequate surplus ower for this requirement are availble. The problem is not power but nverting to useful tractive effort.

• **Electric**—An electric-motor drive r each wheel is now becoming quite mmon, at least in prototype equipent, and the state of the art is suffiently advanced to make this method actical. One disadvantage of the elec c drive is the weight problem, since e generator and drive motors are rel vely heavy items. On the other nd, performance of electric drives is cellent, affording a good range of rque-versus-speed performance, with e proper "gear range" being selected tomatically, and thus reducing the ver-skill requirement. Dynamic braki reduces wear on friction-brake lins and offers greater braking ability r prolonged periods of time during ended down-hill operation.

• **Hydraulic**—A hydraulic-motor ive for each wheel will offer performce somewhat similar to the electrictor drive, at least for low-speed option. In this system, vehicle speed is proportionate to pump output ume, and vehicle torque or pulling ver is proportionate to pump output ssure. At high speed, the volume of flow for large equipment would reqre large-capacity pumps, valves, and ing. Therefore, there is a flow rate ond which it would *not* be econically feasible to operate, and this v rate would dictate the maximum icle speed.

If used in the speed range which is conomically feasible, the hydraulic dve may prove to be a lightweight syem with performance comparable to an electric drive.

• **Prime movers**—So far, we have di ussed some of the factors to be cosidered in arriving at an overall concept for the transporter-erector-launcher for a large mobile missile system. Now let us look at the problem of selecting a prime mover or tractor that will propel the unit.

The results of an FMC survey of prime movers resulted in the data presented on p. 20. Time did not permit an examination of all vehicles which may be available, but the broad cross section obtained was sufficient to establish a working base considering performance, physical characteristics, availability and cost.

Let us examine a hypothetical case involving a missile that weighs 75,000 pounds—midway between the 50,000 and 100,000-pound load discussed previously. These basic calculations will aid in selection of a prime mover:

G = Incline of Grade, in per cent
X = Coefficient of Rolling Friction
R_r = Rolling Resistance, in pounds
θ = Horizontal Incline of Road, in degrees
W = Vehicle Weight, in pounds
U = Tire-adhesion Coefficient
R_g = Grade Resistance, in pounds
R_a = Air Resistance, in pounds
D = Drawbar Pull, in pounds

The following weight assumptions are made for this calculation:

Item	Weight
Missile	75,000 lbs.
Transporter-Erector-Launcher	45,000 lbs.
Sub total	120,000 lbs.

It is desirable in the case of a semitrailer to distribute the 120,000 lbs. so that approximately 1/3 is on the tractor's 5th wheel and 2/3 is on the trailer wheels. The semitrailer approach is favored for cross-country operation, since some of the towed weight can be put on the tractor to add to its draw bar capability.

Load Distribution

Item	Weight
Tractor 5th wheel load	40,000 lb.
Trailer running gear load	80,000 lb.

From the chart on p. 20 it can be seen that there are several tractors in the proper size area. (Assuming a 5000-pound overload is permissible, then a tractor with 35,000 pound rating is usable.)

Total Highway Load

Item	Weight
Missile & trailer	120,000 lb.
Tractor (Caterpillar DW-20)	29,000 lb.
Total	149,000 lb.

The vehicle required gradability performance must now be predicted. Below are some standards that can be applied:

Description	Grades "G" Maximum
Super Highway	6%
Mountain Highway	12%
Desired for our system	20%

(The 20% maximum grade was selected for our system as the unfavorable field condition most likely to be encountered if some reasonable planning can be followed in selection of terrain.)

The resistance due to grade can now be computed using $R_g = \frac{WG}{100}$ which is the simplified form of $R_g = W \sin \theta$ and is sufficiently accurate for grades less than 20%.

For total load of tractor plus tractor plus missile

$$R_g = \frac{WG}{100} = \frac{149{,}000 \times 20}{100} = 29{,}800 \text{ lb.}$$

For towed load, which will give drawbar pull requirement due to grade,

$$R_g = \frac{WG}{100} = \frac{80{,}000 \times 20}{100} = 16{,}000 \text{ lb.}$$

To the above must be added the rolling resistance due to soil or road conditions. Assuming a tire pressure of approximately 25 psi

SUMMARY OF PRINCIPAL STATE HIGHWAY VEHICLE RESTRICTIONS

DESCRIPTION	CALIFORNIA	MAXIMUM	MINIMUM	PREVALENT
WIDTH	8′ 4″	8′ 6″	8′ 0″	8′ 0″
HEIGHT	13′ 6″	N. R.	12′ 6″	12′ 6″
LENGTH				
Single Unit	35′ 0″	N. R.	35′ 0″	35′ 0″
Tractor and Trailer	60′ 0″	N. R.	45′ 0″	50′ 0″
MAXIMUM AXLE LOAD (LB.)				
Single	18,000	22,400	18,000	18,000
Tandem	32,000	40,680	26,080	32,000
MAXIMUM GROSS WEIGHT (LB.)				
3 Axle T. S. T.	76,800	86,400	45,000	73,200
4 or 5 Axle T. S. T.	76,800	86,400	56,000	73,200
Highest Weight Possible	76,880	88,000	55,980	73,200

T. S. T. = Tractor, Semitrailer
N. R. = No Restriction
Reference: American Trucking Association, Inc., November 1958
California Trucking Association, Inc., September 1957
S.A.E. Handbook, 1957, Page 1029

some non-engineering problems . . .

Surface Description	Coefficicent X lb/lb vehicle wt.
Highway	.017
Road hard gravel	.025
Off highway medium	.040
Off highway soft or sand	.200

From the above, the total rolling resistance can be computed. $R_r = WX$. For the tractor plus trailer plus missile: R_r = 149,000 x .200 = 29,800 lb. For the trailed load: R_r = 80,000 x .200 = 16,000 lb.

The factor which is of interest at this time is the draw bar requirement placed upon the tractor due to the trailed load. It is a summation of the grade resistance R_g and the rolling resistance R_r.
$R = R_g$ plus R_r = 16,000 plus 16,000 = 32,000 lbs.

It can be seen from the chart below that the Catcrpillar DW-20 has a draw bar capability of 35,300 pounds. This is more than we require, but the figure is for *ideal* tractive conditions and it must be recalled that we used the ground condition of soft soil or sand. Let us now compute the draw bar capability using data from the following chart.

Tire Adhesion coefficient U

Surface description	U (static)	U (sliding)
Highway paved	.85	.70
Road hard gravel	.60	.60
Off highway medium	.60	.50
Off highway soft	.40	.20

For the Caterpillar DW-20, assume that 20,000 pounds of the tractor weight and 40,000 pounds of the trailed weight is on the rear driving wheels. Then the tractive ability on off-highway soft conditions is

$P = 60{,}000\ U_{st} = 60{,}000 \times .40 =$ 24,000 lbs. for static friction

$P = 60{,}000\ U_{sl} = 60{,}000 \times .20 =$ 12,000 lbs. for sliding friction

Since the tractive ability of 24,000 lb. for even the most advantageous static friction condition is less than the draw bar requirement of 32,000 lb. this tractor will not be able to pull the load up a 20% grade in soft dirt. In this case, power would have to be supplied to the trailer wheels if tl terrain is to be traversed using th particular tractor.

The foregoing discussion presen merely a few of the problems in pr viding mobility for larger missile sy tems. These problems, however, ca be solved with equipment and desigı that are well within the present sta of the art.

Aside from the engineering prol lems, there are several other problen listed below:

- Snow and ice conditions will l encountered at certain times of tl year.
- Elevation above sea level wi proportionately reduce the engir horsepower output of naturally-aspirate engines. Turbocharged engines hav been evaluated, since their horsepow output is not appreciably reduced t the higher elevations.
- Minimum road widths, radii, an clearances at intersections must t studied. Maximum wheelbase wa found to be approximately 60′ 0″. T insure adequate equipment maneuve ability above this dimension, steerab trailer rear suspension was provide
- Maximum speed on the pave highway was established at 40 mpl

(Continued on Page 40)

Comparison of Vehicles

VEHICLE TYPE	MANUFACTURER AND MODEL	H.P.	DRIVE	VEHICLE WEIGHT (LB.)	TIRE SIZE	SPEED (M.P.H.)	DRAWBAR (LB.)	PAYLOAD (LB.)	HITCH	REMARKS
2 x 2	CURTISS-WRIGHT J	375	Converter	44,000	33.5 x 33	5.7 min. 34.4 max.	47,500 max. 3,300 min.	35,000	Kingpin	
	CATERPILLAR DW21	320	Gear	26,000	29.5 x 29	3.2 min. 28.0 max.	34,100 max. 3,900 min.	20,000	Kingpin	
	OTAC GOER	330	Electric	20,000	......	4.0 min. 30.0 max.	....	15,000	Kingpin	Drawbar can be i creased by motori ing trailer.
	GENERAL ELECTRIC 765	600	Electric	55,000	44.5 x 41	0.0 35.0 max.	60,000 max. 6,000 min.	60,000	Kingpin	Max. D.B. can b doubled by motori ing trailer.
	MICHIGAN 310	375	Converter	30,000	33.5 x 33	3.9 min. 31.2 max.	60,000 max. 2,000 min.	33,000	Kingpin	
4 x 2	MRS 250	600	Gear	61,600	14.0 x 25 (F) 33.5 x 33 (R)	2.5 min. 34.0 max.	64,500 max. 5,000 min.	Towed	Drawbar	
	K-W DART 70S	430	Converter	44,500	18.0 x 33 Duals (R)	7.8 min. 32.0 max.	49,000 max. 4,450 min.	100,000	Fifth Wheel	600 hp Option
	CATERPILLAR DW20	320	Gear	29,000	14.0 x 24 (F) 29.5 x 29 (R)	2.6 min. 29.0 max.	35,300 max. 3,100 min.	35,000	Kingpin or Drawbar	
	GENERAL ELECTRIC 765	600	Electric	60,000	16.0 x 24 (F) 44.5 x 41 (R)	0.0 35.0 max.	60,000 max. 6,000 min.	80,000	Kingpin or Drawbar	Max. D.B. can b doubled by motori ing trailer.
4 x 4	MRS 200-4	335	Gear	45,500	20.5 x 25 (F) 29.5 x 25 (R)	2.4 min. 35.1 max.	38,200 max. 2,900 min.	Towed	Drawbar	
	MICHIGAN 480	600	Converter	85,000	33.5 x 33	3.6 min. 28.6 max.	....	41,000	Optional	
	COLEMAN D400	450	Converter	60,000	24.0 x 25	1.0 min. 30.5 max.	45,000 max.	Towed	Drawbar	
TRUCK	OTAC M123 6x6	256	Gear	30,400	14.0 x 20 Rear Duals	.... 42.0 max.	40,000 max.	30,000	Fifth Wheel	
TRACKED VEHICLE	M45	500	Gear	60,000	Track	5.5 min. 30.0 max.	26,000 max. .... min.	30,000	Fifth Wheel	
	T99E1	440	Converter	30,000	Track	2.5 min. 35.0 max.	54,000 max. .... min.	30,000	Fifth Wheel	
	M8A2	363	Converter	44,500	Track	..... 41.0 max.	51,600 max.	Towed	Drawbar	

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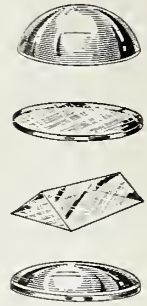
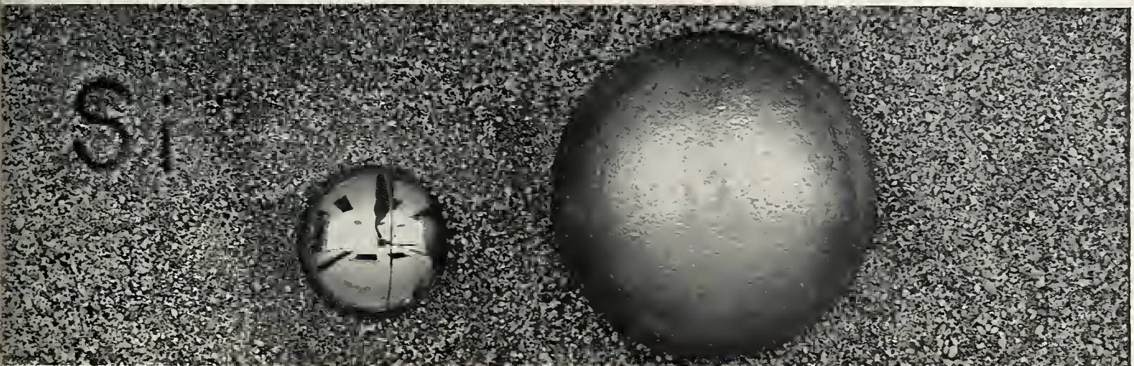
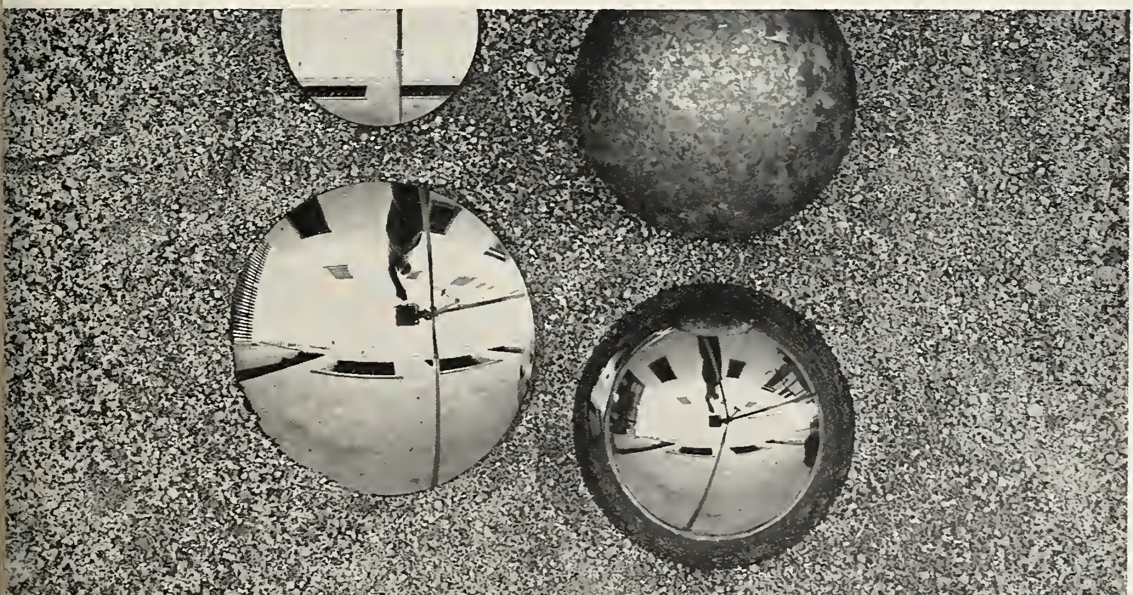




SOPHISTICATED SILICON IN A VARIETY OF SHAPES



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The Search for Space Vehicle Power

Government and industry strive to find sources of electrical power that will allow man and his vehicles to undertake prolonged space missions

by Paul Means

WASHINGTON—Generation of electrical power during space flight is one of the vital obstacles to be overcome before man or his vehicles venture very far into space.

Manned space expeditions will either have to take along enough stored power, or generate enough power in flight to provide for communications, navigation attitude and flight control, fire control, and environmental control.

And electrical power needs will increase sharply in advanced space vehicles motivated by electric propulsion. According to studies by the Air Research and Development Command of the U.S. Air Force, power requirements for an electrically propelled manned deep space expedition could be as high as 30 megawatts.

Satellites are presently powered by chemical batteries, some rechargeable by solar cells. But the weight factor of chemical batteries and the inability of solar batteries to give large amounts of power instantaneously are drawbacks to their sole use in advanced vehicles and missions.

To meet the power needs of future space vehicles, industry, the services, and the National Aeronautics and Space Administration are experimenting with many different types of power supplies and converters. These include: advanced electric generators and chemical batteries, solar cells, thermionic converters, thermopile generators, thermoelectric generators, fuel cells, atomic power units (both isotopes and reactors) and magnetohydrodynamics.

• **Future needs**—How much electrical power will be required to run the equipment aboard space vehicles and missions planned for the next ten years?

According to an ARDC study, the secondary power needs of equipment aboard space vehicles now in the planning stage could vary from as little as two or three watts for certain reconnaissance equipment to upwards of 100 kilowatts for electric propulsion devices.

Specific secondary power requirements, according to ARDC, would amount to about one kilowatt for satellites in 300-mile orbits, hard impacts on the moon, and unmanned flights to the moon and back.

A soft landing or a manned flight to the moon and back would take about 1.6 kilowatts of secondary power, as would semi-hard or soft landings on Mars or Venus. About five kilowatts is needed to power the equipment aboard a stationary equatorial satellite, unmanned trips to Mars and Venus and return, and manned trips to the moon. Soft landings on Mars and Venus and back would require about 10 kilowatts.

Secondary power requirements increase many times if electric propulsion equipment is utilized to correct the trajectories of long duration space flights and to correct orbits of long duration earth satellites.

ARDC figures indicate that approximately 80 kilowatts of electrical pow[er] will be required to obtain one pou[nd] of thrust from an ion propulsion devi[ce] with a specific impulse of 3000 se[c]onds. If the specific impulse is increase[d] to 20,000 seconds, the power requir[ed] jumps to 550 kilowatts per pound [of] thrust.

Since a secondary power generati[ng] plant could not meet these demands, [it] is suggested that a slight increase wou[ld] be made in the capacity of the genera[t]ing equipment for the electric propu[l]sion system in order that it may al[so] serve as a source of secondary pow[er] for the vehicle.

The ARDC study gave particul[ar] notice to the "specific power" requir[ed] to perform various missions. An ou[t]put of 7 kilowatt hours per pound [of] secondary power generating equipme[nt] is acceptable for most of the missio[ns] during the next few years, but lat[er] missions will require from 50 to 2[5]... kilowatt hours per pound of seconda[ry] power generating equipment. Syste[m] weight in mechanical systems shou[ld] decrease during the same period fro[m] 300 pounds per kilowatt to from 50 t[o] 100 pounds per kilowatt.

• **20 KVA capacity**—The stud[y] indicates that an advanced space v[e]hicle of the 1965 era will need a ce[n]tral power source with an entire sy[s]tem capacity of at least 20 KVA.

In a study of the requirements o[f] an electrical system for Air For[ce] weapons systems to be operational [in] 10 to 15 years, a total environment w[as] determined (see table). This enviro[n]...

ADVANCED VEHICLE POWER REQUIREMENTS
(both secondary & primary)

Mission Profile	Electrical Kilowatts
Earth Satellites	1-50
Unmanned Planetary Probes	10-500
Manned Reconnaissance Vehicles (No Landings)	500-5000
Manned Expeditions	5000-30,000

Prepared by AR[DC]

Specific Secondary Power Requirements

MISSION DESCRIPTIONS	Secondary Power: Continuous Output	Secondary Power: Specific Power (KWH/LB)
SATELLITES (ORBIT AT 300 MI) HARD IMPACT ON MOON AROUND MOON AND RETURN	1KW	7
SEMI-HARD OR SOFT LANDING ON MARS OR VENUS SOFT LANDING ON MOON AROUND MOON AND RETURN (MANNED) CONTROLLABLE ORBIT SATELLITE (APPROX. 22,000 MILES ALTITUDE)	1.6KW	50
ORBIT OVER ONE EQUATORIAL POINT (APPROX. 22,000 MILES ALTITUDE) SPACE STATION MANNED (APPROX. 22,000 MILES ALTITUDE)	5KW	100
SOFT LANDING ON MOON AND RETURN (MANNED) AROUND MARS OR VENUS AND RETURN (UNMANNED) SOFT LANDING ON MARS OR VENUS AND RETURN (UNMANNED & MANNED)	10KW	250

Prepared by ARDC

ent imposes the most severe condi-ons that all of the vehicles studied ould have to withstand.

Though some of the criteria would be less extreme for certain space re-irements, the ARDC study recom-ends that all materials, components, d other hardware be tested in these tal environment extremes and not be nsidered acceptable unless they with-nd all of the extremes.

In evaluating the different compo-nts that may generate the necessary wer for future space vehicles, the mary and most important criterion weight. Depending on the type of ssion, the ability to produce large ounts of power instantaneously may an important criterion. Also, the tal amount of power needed in the hicle may decide which type of com-nent will be used.

As Dr. S. Fred Singer, Professor Physics at the University of Mary-d pointed out in an article in M/R December, 1956, different power pplies require different amounts of erhead, e.g. the initial weight invest-nt for a nuclear or fusion power pply is very large so that the supply come economical only if the power uirements are fairly high.

Following is a survey of the vari-components that may be used as wer sources in space vehicles, their imum applications, and their present te of the art.

• **Chemical batteries**—Non-charge-e chemical batteries have applications short space flights. They are always dy for use, require no preparation, lve no gas, pose no radiation haz-, and have a reasonably long shelf li.

Mercury batteries are presently d in satellites and will be for many rs to come. One advantage is that ir voltage does not drop off until r the end of its useful life.

However, as the included chart pre-ed by ARDC indicates, chemical teries are not competitive with other es of power systems if the flight is last longer than ten days. For dura-s of over ten days, the specific ght of the chemical systems in-ases very rapidly but the specific ght of the solar and nuclear sys-s increase only slightly.

Rechargeable chemical batteries, luding fuel cell batteries, could be d in conjunction with other power eration devices, such as electric and rmoelectric generators, solar, or lear power.

• **Solar cells**—Solar cells are being tinually improved and show many ce applications. In the photovoltaic s (solar battery) presently in use, ton energy from the sun disturbs solid state equilibrium of the cell

Energy Output of a Power Supply Divided by its Weight

	Watt-hour/lb	Power Range (Watts)
Dry battery	14	<10
Activated battery types	25	<10
Re-chargeable nickel-cadmium battery	12	<10
Fuel cell battery	60	>100
Radioactive battery	10^4	<10
Nuclear reactor power supply	5×10^9 (max)	>100
Fusion power supply	5×10^{10} (max)	>100
Solar battery	infinite	<100

Prepared by Dr. S. Fred Singer

material, and an electric potential is generated which will cause a current to flow in an external circuit.

The solar energy input at the top of the atmosphere is 1400 watts per square meter (130 watts per square foot) and the measured efficiencies of present silicon junction photocells is about 10 percent. This gives an electrical power output of about 100 watts per square yard of battery.

Larger amounts of solar power can be produced if a number of cells are connected in series-parallel combinations. The two present disadvantages of such a system are present component weights, which would require 1000 pounds per kilowatt, and the old Christmas tree bulb problem. That is, if one of the cells is destroyed by meteoric impact, the total output of the series is destroyed.

Studies are also being made to determine the practicability of using concentrated solar energy as the heat source for a closed thermodynamic cycle. Using liquid or gas as the working fluid, the system uses a parabolic reflector to concentrate the sun's energy on the boiler of the system. The heated fluid from the boiler is expanded through a turbine which drives the alternator and the compressor or pump, and then waste heat is rejected in the radiator prior to sumping the fluid back to the boiler. Such a system would have an overall efficiency of 10%.

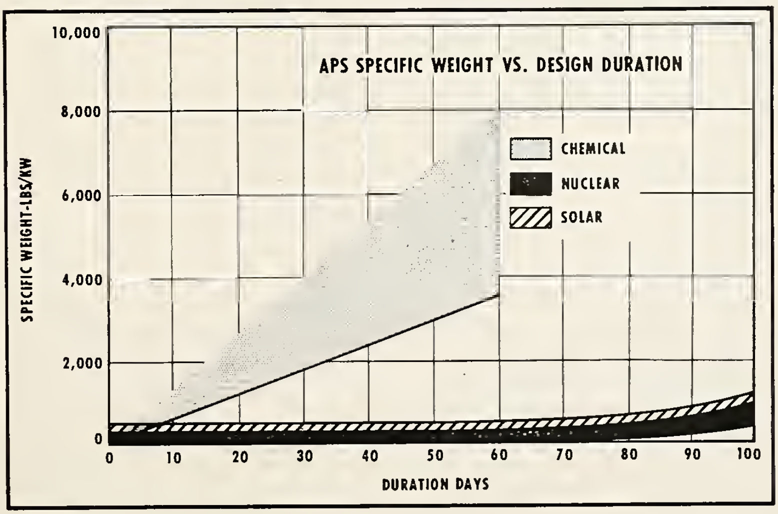
ARDC studies indicate that it would take about 80 square feet of concentrator projected area per kilowatt of generated electrical power. But the weight of the radiator make such a system impracticable until newer fluids and newer materials resulting in higher operating temperatures are found.

Before solar energy becomes a major power source for space vehicles, a heat storage unit must be devised which would not be subject to degeneration on re-cycling.

• **Electrical generators**—The Thompson Products Division of **Thompson Ramo Wooldridge Inc.**, has recently published a paper on the problems to be overcome in developing electrical generating equipment for space systems. Such generators, whether electrostatic, or electromagnetic, according to the Thompson report, will probably have to use direct radiation cooling, either directly from the motor frame to the ultimate heat sink of space at a temperature of about 40 F or from the motor frame to the vehicle skin which radiates to space.

According to the Thompson report, the alternator showing the greatest promise is the inductor-type having no rotating windings, no brushes, and capable of withstanding a high temperature environment without cooling, exposure to working fluids, and capable of high rotating speeds.

The type of generator used may depend on the type of propulsion system used. Ion types of propulsion, requiring high voltages and low currents, which is characteristic of the electrostatic generator. Plasma propulsion



QUANTITATIVE DEFINITION OF HYPER ENVIRONMENTS FOR ELECTRICAL SYSTEMS

Environments	Values
CONVENTIONAL	Existing Documents (MIL-E-5272, MIL-E-4970)
OZONE	11 parts/million at 13 mi to 21 mi
HIGH TEMP—AERODYNAMIC	0 to 47 mi 125°F to 932°F +
SHORT TERM RE-ENTRY ENVIRONMENT	60g deceleration and 932°F +
LONG TERM RE-ENTRY ENVIRONMENT	8g and 932°F
HIGH VACUUM	Approximately 0 pressure and 0 density
HIGH TEMPERATURE	5 Min to go from —68°F to 932°F, held at 932°F for 10 min, reduce to 752°F, hold for 1 hour, reduce to 702°F, hold 4 hours.
SOLAR RADIATION	1 to 100,000°A (Maximum Intensity at 4500-5000°A) as radiated by a "black body" of 6000 to 6500°K.
MECHANICAL VIBRATION	5 to 55 cps at 3/8 in. double amplitude
ACOUSTICAL VIBRATION	190 db, 30 to 10,000 cps
SHOCK	50 to 200g for 11±1 m.s.
ACCELERATION	8g for 1 min to 60g
ZERO GRAVITY	0g
EXPLOSIVE ATMOSPHERES	High Energy Fuels and Fluids
IONIZED GASES	Number of Electrons 1.5 x 10^4/cm^3 at 38 mi to 1.5 x 10^6/cm^3 at 159 mi
DISASSOCIATED GASES	Atomic oxygen particles 1 x 10^{12}/cm^3 at 56.5 mi to 5 x 10^{12}/cm^3 at 75.5 mi Range 50% to 100% atomic Atomic Nitrogen Particles 1.4 x 10^{12}/cm^3 at 56.5 mi to 1.2 x 10^8/cm^3 at 113.5 mi
AURORAE	565 to 285 mi 10^8 electrons/cm^2/sec at 100,000 ev 285 to 565 mi 10 to 100 kev X-rays with intensities of 1000-100,000 Photons/cm^2/sec
SOLID PARTICLES	.2 Microns to 8 cm Particles
MAGNETIC FIELD	2.5 Mev Protons above 250,000' to 500,000 feet (10^8 Protons/cm^2/sec)
EXPLOSIVE DECOMPRESSION	8,000' to vacuum instantaneously (10.2 psi) 932° to 1.9 x 10-12 psi
TEMPERATURE SHOCK	—65°F to 932° in approximately 2 min
PRESSURE SHOCK	S.L. to vacuum in 3 to 5 min
NUCLEAR RADIATION	Dose Rate — Integrated
NEUTRON	2 x 10^{14} neutrons/cm^2/sec — 7.5 x 10^{17}/neutrons/cm^2
GAMMA	4.5 x 10^9 roentgen/hour — 2 x 10^{11} roentgen

Prepared by ARDC

systems, on the other hand, require low voltages and high currents, characteristic of electromagnetic generators.

The Thompson study points out that both types of generators have disadvantages to be overcome, and that the existing state of the art "falls far short of meeting the requirements of electrical generation in space systems."

The bulk of available equipment according to the Thompson study, has been built to specification MIL-G-6099, which requires only that units operate at barometric pressures ranging from 30" of mercury to 3½" of mercury, with the aid of 120C cooling air at sea level and 40C cooling air at 50,000.

Furthermore, present generators require too much cooling air, and are too bulky.

In order to meet these problems, the Air Force is sponsoring a program, sometimes called "Hotelec", to achieve a 600 F capability for the components normally associated with an electrical generation system.

Thompson has announced the development of an electrical insulation for motors, generators, and transformer solenoids suitable for 1000° F applications.

• **Thermoelectric generators**—The recent announcement by the Atomic Energy Commission that they had achieved practical power generation from the SNAP III thermoelectric generator demonstrated the feasibility of using thermoelectricity as a power source for satellites and space craft using nuclear energy and solar radiation. (See M/R, Page 29, June 22.) A thermoelectric converter or generator is essentially a number of thermocouples which are series parallel connected to obtain the voltage and current desired.

In a space vehicle, cold junction temperatures would be maintained by radiating heat from the cold junctions into space. The system is highly reliable because there are no moving parts. As in the case of the photovoltaic cell, this system requires series connection to obtain high voltages.

Because the converter is almost entirely an integral part of the reactor, it is unlikely that any part of the electrical circuitry would be damaged by meteorites. Although the specific weight of this system is presently rather high —about 1500 pounds per kilowatt— very large reductions are theoretically possible.

The **Westinghouse Corp.** recently completed a 100-watt unit for ARDC, called the TAP-100, which uses gas for fuel and is claimed to have an efficiency of about 8 percent. The thermoelectr material is a combination of sem conductors in cascade. An advanc version will use a nuclear isotope f source of heat.

• **Thermionic converter**—This com ponent utilizes the same principle use in the familiar vacuum tube. He boils off electrons from the cathod which then move to the anode settin up a potential difference between th plate.

This potential is dependent on th difference of the work function of th materials utilized for the cathode an anode. The greater the work functio of the cathode, and the smaller th work function of the anode, the great the potential will be.

According to the ARDC study, e perimental devices have attained ove all efficiencies of over 8 percent, wi 30% theoretically possible.

Ultimately, the weight of this sy tem, according to ARDC, may be th least of all those considered. Both th thermionic and thermoelectric con verters can be used with solar energ for the heat source, although the in creased probability of meteorite dam age reduces the attractiveness of th type of installation.

• **Fuel cells—The General Electri Company** recently announced the d velopment of a practical fuel cell generating directly from hydrogen and oxygen in the air. Future progress could produce a chemical re-chargeable battery having great potential as a source of space vehicle power.

Basically the fuel cell converts the chemical energy of recombination of hydrogen and oxygen directly into electrical form. The output therefore consists of electrical energy and water. The water could then be circulated to a nuclear power source to be decomposed again into hydrogen and oxygen.

According to the ARDC study, storing of gaseous hydrogen at 6000 psi inside a tank of liquid oxygen at 500 psi (both at 150°K) could produce from the fuel cell as much as 100 to 120 watt hours per pound. A better approach, the ARDC study reports, could be the liquid storage of both hydrogen and oxygen with an output of 105 to 815 watt hours per pound depending upon duration of mission and year of mission (and current state of the art). The problem with this method is that hydrogen must be stored at –400° to 475° F and at that temperature its critical pressure is only 188.2 psi, too low for use in the high pressure cell without compression or super heating.

According to the ARDC study, the Redox (reduction-oxidation) cell offers great advantages over the hydrogen-oxygen cell in that it eliminates gaseous electrodes and can use cheap, crude fuels, such as kerosene, alcohol, etc. This cell promises from 266 to 860 watt hours per pound, and in cases where atmospheric "air" will always be available, it could produce up to 1200 watt hours per pound.

Limitations of fuel cells is their necessity to carry all the necessary fuel for the entire mission. One answer is to have a nuclear installation convert the water back into water and hydrogen in a closed cycle. ARDC estimates that a solar regeneration reactor could handle fuel for 10 watts per pound.

The thermal or nuclear regenerative fuel cell is in the early stages of R & D, and problems yet to be solved include the control of the rates and flow of both hydrogen and oxygen in the proper ratio to meet the required load, decomposition of the catalyzing electrodes in the electrolyte, fuel storage, and system weight reduction.

• **Magnetobydrodynamics** — Scientists are presently interested in the probability of generating an electric potential by passing a conduction fluid, a gas such as mercury at 2000° K through a magnetic field. According to the ARDC study, this principal seems to offer a specific power in the range of 100 to 1000 kilowatt pounds per hour. Work on this process is in the very early stages of research and development.

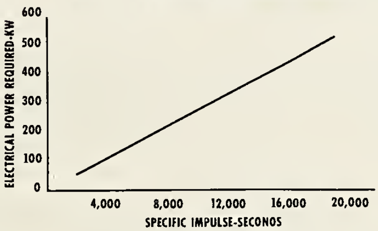
• **Atomic batteries**—Undergoing R&D at the present time, atomic batteries have only specialized applications for space flight in that they deliver only microwatts or possible milliwatts of power.

• **Nuclear reactors**—Probably the greatest supplier of both primary and secondary power for future space vehicles will be nuclear power from both isotopes and reactors.

In applications requiring more than 100 to 1000 watts, nuclear power is practically without competition. It also can be used to generate electrical power through the use of either static or mechanical power conversion devices as was the case with solar power.

Essentially the nuclear reactor acts as a heat source, approximately one billion B.T.U.'s are produced for every ounce of uranium which is fissioned. The engine itself can be run hot, limited only by the strength of materials at high temperatures.

ION PROPULSION
POWER VS. IMPULSE FOR 1 POUND OF THRUST



The two major problems with a nuclear power source is heat dispersal and radiation. In his article, Dr. Singer proposed that nearly all of the heat could be radiated away into space, keeping the exhaust temperature in the vicinity of the freezing point of water if the satellite is built large enough with a large radiating surface. Dr. Singer states that the area in square yards is given approximately by expressing the energy to be radiated in kilowatts.

The shielding problem reduces the attractiveness of the nuclear system for manned flights with low secondary power requirements. But shielding increases only slightly with increased output and at high power levels is only a small fraction of the total weight.

One solution to the radiation problem for space flights not requiring large accelerations has been proposed by Dr. Singer. His idea is that the reactor power supply on take-off could be integral with the space vehicle but would be shut off, all of the power being furnished by batteries.

On reaching orbit or whenever the propulsion system is off and the acceleration becomes zero, the reactor would be removed to a safe distance from the space vehicle, with only a cable connecting the two. Then the reactor can be turned on by remote control and electricity piped into the space vehicle. Similarly, for landing, the reactor would be shut off first before it is brought close to the vehicle.

Steel Melting Processs Avoids Contamination

PITTSBURGH—Firth Sterling Inc. has developed an arc melting process for purifying steel that avoids contamination with refractory compounds.

The process, invented by Firth Sterling's R. K. Hopkins, involves melting an electrode under a controlled slag at a controlled rate in a water-cooled mold.

The molten slag protects the metal from the atmosphere. In addition, Firth Sterling reports, the composition of the slag is such that it neither adds undesirable elements to the metal nor removes desirable elements. Furthermore, the slag provides an ideal ionized path for the support and stabilization of the arc.

When melting titanium-bearing minerals, or any materials having elements that react with the oxygen or nitrogen of the air, the slag blanket is very effective in removing the resulting refractory compounds. Air melted material, which ordinarily is used for electrode stock in consumable electrode processes, invariably carries non-metallic inclusions, the company noted.

The inclusions are broken up and dispersed but are not eliminated in vacuum arc melting. In the Hopkins process, Firth Sterling said, the inclusions float to the surface of the molten metal and then are absorbed by the slag blanket.

An improvement in macro and microstructure is realized, the company declared, particularly in large ingots. Firth Sterling says it is making further improvements in melting to produce fine grained ingots, and the fine grain, with proper forging and rolling technique, can be maintained through to the finished product.

The company said the steels and alloys produced by the Hopkins process are A-286, 16-25-6, Discaloy, Waspaloy, Inco 901, PWA 1002, SAE 9310, SAE 4340, SAE 3312, tool steel and high-speed steel.

Hope Sustains Monopropellant Work

Despite their many disadvantages, the odd fuels continue to attract government and private researchers who hope for a 'near-miracle' to boost their I_{sp}

by **S. David Pursglove**

WASHINGTON—How do monopropellants figure in the nation's missile plans? Where will these handy, one-squirt propellants be used in our defense and space sciences programs?

The answer, in a nutshell, appears to be, "they won't."

They won't figure in our plans, they won't be used in our rockets. That sums up Washington's best-informed opinion on the current state of monopropellants. That's the answer, stripped of platitudes, euphemisms, and apologies from officials of the three services, the National Aeronautics and Space Administration, a handful of propellant firms, and government-contract study organizations.

Why, then, are almost all of these people engaged, to some degree, in monopropellant research?

• **A someday thing**—The answer to that question is the same answer that could be used in reply to the question, "Why research at all?" for hundreds of years, past and future—hope.

One official sums up the typical government feeling: "Even though the specific impulse of all practical monopropellants is very low, and probably will remain low, the government recognizes their advantages and hopes that some near-miracle will bring about a marked increase in specific impulse."

He cautions that none of his people who are authorities on propellants knows of any breakthrough in the offing. "For this reason," he says, "government interest is flagging considerably, but there always will be a small spark of interest."

"Small spark" is just about all the government interest amounts to right now. We queried a top Air Force official about monos, and he had this to say: "Sure, I can talk to you about them—there's nothing worth keeping secret. Seriously, though, I can't discuss the amounts of money we're spending on research contracts because that would reveal the level of our effort."

How Do Monopropellants Compare?

Specific impulse of monopropellants under study versus I_{sp} some typical bipropellants

Propellant	Appx. I_{sp} (sec)
Monopropellants	
nitromethane	190-230
ethylene oxide	160-190
hydrazine	160-190
hydrogen peroxide	160-190
Bipropellants	
analine-nitric acid	220
JP-4-nitric acid	200-230
hydrazine-nitric acid	230-260
gasoline-LOX	240
RP-1-LOX	300
hydrazine-LOX	315
hydrogen-ozone	400
hydrogen-fluorine	410

By the time we had talked with him and several others, it was apparent that the Air Force level of effort is extremely low. (The Navy's is a little higher.) But, on every hand—here too—we ran into this "We'll maintain a spark of interest" attitude.

Why any interest in monopropellants at all? Why should the fact that official U.S. interest in monopropellants is lagging even be worth a news story?

The answer lies in accepted descriptions of "monopropellants." There are no widely accepted, simple, compact definitions of monopropellants—it is more what they *aren't* than what they *are*. For example, one author distinguishes between the two major classes this way: A bipropellant is a system of a fuel and an oxidizer, whereas when the fuel and oxidizer are wrapped up in a single molecule, the propellant is a monopropellant. This is true—but does not cover all cases. However, a monopropellant does involve just one homogeneous solid mixture or compound, or just one homogenous liquid, although the homogeneity may be the result of thoroug[h] mixing of several ingredients.

Examples of true monopropellan[ts] include the solid nitrocellulose (a sing[le] molecule capable of sustaining its ow[n] combustion), and the liquids nitro[-] methane (a single molecule) and nitro[-] propane-nitric acid (a homogeneou[s] mixture of a fuel in an oxidizer.)

• **Advantages**—Now, what is s[o] great about this? In the case of sol[id] propellants, not much. But, in the cas[e] of liquids, the monopropellant requir[es] only one storage tank, one pumpin[g] system, one filling hose, one fillin[g] operation, one tank within the missil[e,] one pump within the missile, one rou[te] to the combustion chamber. On th[e] other hand, a propellant system of [a] fuel and an oxidizer—kerosene-LOX[,] etc.—requires *two* of everything.

The monopropellant saves conside[r]able weight within a rocket. Equall[y] important, it saves storage space an[d] cuts down handling problems [at] launching sites. This is important whe[n] it comes to shipboard missiles, and ex[-] plains why the Navy is devoting mor[e] attention to monopropellants than [is] the Air Force which can operate fro[m] fixed, land-based sites.

It may also provide a clue to th[e] Army's thinking about mobility, or t[o] the Army's missile plans. Monopro[-] pellants, logically enough, would be o[f] great value to a mobile army. How[-] ever, the Army went on the recor[d] with M/R this way: "The Army ha[s] a very small interest in monopro[-] pellants—the interest is mainly in th[e] Air Force and Navy."

Nonetheless, all missile-oriente[d] agencies have a continuing interest i[n] monopropellants for another use. Thes[e] handy propellants are used to operat[e] auxiliary power systems; most ofte[n] they decompose to provide expandin[g] gases which operate turbine pumps o[r] generators. The monopropellant allow[s] engineers to hold APU size and weigh[t] to a minimum.

• **And disadvantages**—If monopropellants have so many advantages, why aren't they widely used—why so little interest?

This is the easiest question to answer in the entire missile business: the disadvantages outweigh the advantages. Those disadvantages fall into two major categories:

(1) The monopropellants just aren't powerful enough.

(2) They are too hard to handle; detonate too easily.

None of the near-practical monopropellants can hold a candle to most of our widely used bipropellants (see box).

The handling problems are explained by a paradox in the requirements for a monopropellant: It must be stable enough to store, yet be highly combustible without an added oxidizer. So far, most monopropellants have sacrificed handling safety for combustibility.

• **Three classes**—In general, there are three types of monopropellants, classified according to the way they function:

• Single molecules containing both the fuel and oxidizer. Popularly, this is visualized as a molecule "with the fuel at one end and the oxidizer at the other."

• Compounds (as opposed to mixtures) which undergo exothermic decomposition as a result of molecular structure. These single substances decompose to release heat because the arrangement of atoms is not stable

• Mixtures of fuels and oxidizers.

Monopropellants and Industry

These firms have monopropellant interests

*Aerojet General • Air Products Corp. • Allied Chemical • American Rocket Co. • *Atlantic Research Corp. • Becco Chemical Div., FM&C • Dynamic Devices, Inc. • Fulton-Irgon Corp. • *Hughes Tool • Olin-Mathieson Chemical • *Pennsalt Chemical • *Phillips Petroleum • *Rohm and Haas Chemical • *Rocketdyne • Shell Chemical • Special Products Lab., FM&C • *Stauffer Chemical • *Thiokol Chemical • Topper Manufacturing*

*Known to be doing considerable work in monopropellants

Here the paradox of requirements discussed above really comes into its own. Naturally the fuel-oxidizer must be a combustible mixture, but on the other hand, it must be possible to mix, store and handle it without danger of combustion.

• **Some examples**—One of the most famous monopropellants of the first class above is nitroglycerine. It is too unstable for use as a liquid monopropellant, since the reaction from the liquid state is detonation rather than combustion. However, just as clay or sawdust slow down nitroglycerine in dynamite, so do certain plastics and rubbers slow it down to make it an effective ingredient of some solid propellants.

Hydrogen peroxide, usually thought of as an oxidizer in a bipropellant system, is a monopropellant when its decomposition is catalyzed. The catalysts usually are permanganates, often calcium permanganate as used by Germany in World War II.

A more recent monopropellant under serious consideration is ethylene oxide. This is an important industrial chemical, the starting point or major intermediate in many commercial processes. Therefore, when new ethylene oxide plants, or expansions of existing plants, are announced, there is no reason to believe they are to supply the missile industry.

This, by the way, is true also of nearly every chemical propellant. Some of the major industrial chemicals that mislead followers of the missile industry into believing the quantity and variety of propellants are expanding, are nitric acid, liquid oxygen, hydrogen peroxide, and ammonia.

Ethylene oxide is produced in the laboratory and in some plants by reaction of ethylene chlorhydrin with an alkali. Most plants, however, produce it by direct oxidation of ethylene. This process route will keep the petroleum industry interested in missiles even after kerosene and other petroleum fuels are no longer used. Ethylene oxide has one drawback. Its low boiling point of 51°F means that it must be refrigerated for use as a liquid.

The most widely discussed monopropellant is nitromethane. It detonates very easily, and is quite hard to handle. A saving grace is that the nitromethane molecule exhibits a semi-polar double bond. The double character contributes the kind of instability necessary in a monopropellant; the semipolarity aspect makes it miscible with other polar compounds, including water and alcohols.

Diethyleneglycol dinitrate (DEGN), like nitromethane, is a nitrated hydrocarbon. However, the DEGN molecule is more complex. It is made by the direct nitration (with nitric acid) of diethyleneglycol vapors. Like nitroglycerin, to which it is close kin, DEGN is a very unstable liquid, but can be controlled as an ingredient of solid propellants.

• **Government approaches**—Here is a summary of what the various government agencies are doing in monopropellants, or say about them:

The AIR FORCE is still interested in monos because of their obvious advantages, but interest is at a low ebb because of the higher specific impulse of other, easier-to-handle propellants. AF is looking at hydrogen peroxide, propyl nitrate, and ethylene oxide. Nitromethane is about out of the pic-

Project MAST Being Stockpiled

ATRAN guidance systems produced for the Air Force's *Mace* system are being warehoused by Goodyear Aircraft along with support equipment. Unique world-wide military electronic supply program is dubbed "MAST," for Missile-Automatic-Supply-Technique. It brings "push-button" notice when parts are needed anywhere on globe.

rundown of company effort . . .

ture because of handling difficulties.

Fiscal Year 1959 contractors are **Pennsalt Chemical, Hughes Tool,** and **Phillips Petroleum.** On June 1, the AF announced invitations to bid on research in high-energy monopropellants, including solids and storable liquids. Conventional storables will occupy Air Force interest for the next five years. By then there might be a breakthrough in monos. Biggest monopropellant interest right now is amines.

The ARMY has little interest in monopropellants, and is willing to let the Air Force and Navy blaze the trail. However, **Rohm and Haas Chemical** is doing monopropellant work for the Army at Redstone Arsenal.

NASA has little interest because much of its work on chemical fuels is actually done by the services. However, NASA personnel formerly with other agencies have carried with them a strong interest in monos, and the space agency is conducting some work in the field.

The NAVY's Bureau of Aeronautics has a keen interest in monopropellants. Naval Ordnance Laboratory is doing some work, and Naval Research Laboratory "has a couple of old projects kicking around." The Navy sponsored a monopropellant symposium in New York May 5-6. An official of a government contract study organization says the Navy is by far the most interested Federal agency.

The Navy talks a lot about having made a breakthrough—a monoprop that has a high specific impulse and is safe to handle—but, since no details are available and since Navy scientists can only allude to "our secret discovery," many chemists ignore the talk.

Commerce Department's OFFICE OF TECHNICAL SERVICES prepares continuing bibliographies of work in government laboratories or in private labs under government contract. Although there have been many reports on propellants in recent years, there have been none exclusively on monoprops.

• **Industry effort**—Here is a rundown of what some of the companies are doing:

Thiokol Chemical is doing a lot of research, but is not running any engines on monopropellants. The firm is looking at high-energy, stabilized monopropellants that are safer and more powerful than nithromethane. One engineer describes them as having "bastardized molecules." By this, he says, Thiokol is synthesizing hopefully ideal monos. Chemists at Denville (N.J.) start by describing the desirable characteristics of a monopropellant, then try to build the molecule.

A Thiokol spokesman says the known compounds are no longer useful—they have been surpassed by missile needs. The chemist then has two choices: Look for other compounds; synthesize.

Rocketdyne "is very definitely in monopropellants," says a spokesman, but the company is not able to describe its work in detail.

Astrodyne has no interest in monopropellants as they are usually thought of—as liquids—since the company is limited to solids. However, Astrodyne is interested in the solid equivalent of monos: homogeneous solids.

Phillips Petroleum is very active in monopropellant research for the Air Force. The firm's special interest is in high-energy monoprops.

Aerojet-General is doing "practically nothing" in monopropellants right now, a spokesman says, but does support a continuing program on the chemistry of nitro-compounds for possible monopropellant use. In the past, Aerojet has looked at nitromethane, but decided its detonability and generally dangerous handling properties could not be overcome. The company still is interested in ethylene oxide and propylnitrate for a gas generator.

If Aerojet chemists develop an acceptable monopropellant, it might be either a liquid or a solid, but probably will be a straight organic compound—nothing fancy.

Atlantic Research recently developed a heterogeneous liquid monopropellant, Arcogel. **Thompson Products** holds exclusive licenses on both the gel propellant and burner system. Thompson plans gas generating and propulsion applications.

Stauffer Chemical is one of the firms most interested in monopropellants. Stauffer was host at the New York symposium sponsored by Navy BuAir.

Wyandotte Chemical is working with ethylene oxide and other monopropellants. The company's other monoprop intcrests cannot be identified, but some work is being done for BuAir. Industry sources believe this is under a contract that calls for development of a monopropellant with an I_{sp} exceeding 250 seconds.

Air Reduction Company has done some almost basic research that was applied to monopropellants. Combustion and Fuels Technology engineer G. A. Mead wrote on "Compression Sensitivity of Monopropellants" in the American Rocket Society Journal, June, 1959. However, his work was done in 1958.

Among other recent papers of interest is "Improvements in the Operating Characteristics of n-Propyl Nitrate," W. H. Lawrence and W. P. Knight, Aerojet-General, in ARS Journal, January, 1959. They summarize Aerojet-General's work on a gas generator designed to use propyl nitrate.

The Navy's "breakthrough" monopropellant is described by J. D. Clark, Naval Air Rocket Test Station, in Astronautics, September, 1958 (p. 34).

Aerojet Courts Goodwill of Its Workers' Wives

SACRAMENTO—Planned tours of the rocket plants here are being conducted by **Aerojet-General Corporation** in an effort to reduce dissatisfaction among wives of employes who work long hours. The evening tours attracted over 500 wives during the first month of the schedule.

The highlight of each tour is the firing of a liquid rocket engine in the test area, which the wives watch from the observation post. The company reports that the tours have resulted in increased apprcciation by wives of the need for long hours put in by company personnel.

Storable Oxidizer Has High Oxygen Content

NEW YORK—Hummel Chemical Co. reports that its propellant oxidizer Tentranitromethane, $C(NO_2)_4$ is a stable, storable liquid with an active oxygen content only a little lcss than liquid oxygen.

In a new technical data sheet, Hummel says TNM has 1.07 G/CC of active oxygen, compared with 1.14 for LOX. However, TNM has a density of 1.64 G/CC, almost 50% higher than LOX's 1.14.

TNM can be stored for long periods below 40° C in mild steel drums or tanks, Hummel says. The oxidizer is stable up to 100° C. It melts at 12.5–13.7° C and boils at 125.7° C. Hummel reports pure TNM is relatively insentitive to impact or adiabatic compression, but the sensitivity is greatly increascd in mixtures with hydrocarbons or entrapped air. TNM is available in commercial quantities.

The Role of Solids Is Growing

Survey shows they are involved in virtually all weapon systems and the problems connected with their use—including I_{sp}—are finding solutions

by **Frank G. McGuire**

Grand Central and Aerojet officials were interviewed in connection with this survey because their work is typical. As the story indicates, other companies are involved.

LOS ANGELES—"Given the same levelopment time and research funds iat liquid propellants have had, solid ropellants should someday be able to o almost any job the liquids can do," ays Dr. Cledo Brunetti, Vice President nd General Manager of **Grand Central Rocket Company.**

"For immediate and any conceivble future military applications, solids vill play a very significant part, and e further intend to strengthen their ole in this area. As far as space appliations, I think there will be a subantial amount of solid rocket motors sed," says Dr. E. R. Roberts, Manger of **Aerojet-General's Solid Rocket Research and Development Division.**

These are the general reactions of vo companies with heavy business instments in solid propellant rocketry. espite the 100-seconds-higher specific npulse that solids still must concede liquids, there are no plans afoot to scuttle" the solid-propellant business. n the contrary, Grand Central has vested $3 million since September in ew facilities to carry out the aim of s vice-president and general manager.

There are solutions now in existnce, or in sight, for many of the oblems that have plagued solid proellants in the past. Nozzle-cooling is rtually solved, combustion instability as been eliminated, reliability is over 9%, grain size is practically unlimited, nd temperature ranges have been eatly expanded, these authorities say.

• **A place for both**—It is conceded at solids still must make considerable ogress before displacing liquids in ose applications where high specific npulse is the prime requirement for mission. The general picture is, hower, that for military purposes, nearly l new systems now under developent call for solids (*Minuteman, Polis, Pershing,* et. al.). It is therefore ry difficult to say "it is all liquids" "it is all solids" when looking at the future of propulsion for the next decade or so.

Until recently, there was still a fairly clear-cut division where the large units needing high I_{sp} were liquids, and the small tactical rockets, which needed instant readiness characteristics, were solids. We have now reached the point where it is possible to produce huge solid-propellant rocket motors and still retain the advantages of reliability and instant readiness. By steadily increasing specific impulse levels, the solid-propellant people hope to eliminate all the disadvantages of solids, relative to the liquid systems.

• **Shifting border**—There is considerable optimism that this will be done, and it appears that the borderline between the two systems is shifting back and forth with the intermingling and overlapping of the respective systems and their missions. So it is now necessary, not only to determine whether solids or liquids should be chosen, but also exactly what propellants can be tailored to the job.

There are few large firms in the field of solid propellants that do not also have an investment in liquids to some extent. Aerojet-General is definitely in all type of propulsion. Grand Central's parent companies, **Tennessee Gas** and **Food Machinery & Chemical,** are both in the liquid-propellant field, and Thiokol has its liquid-oriented **Reaction Motors Division. Astrodyne,** jointly owned by **North American** and **Phillips Petroleum,** has strong ties through both Phillips and NAA's **Rocketdyne Division.**

It can be seen that none of these firms can afford to ignore the advantages of liquids, and must therefore "keep both feet on the ground." when evaluating various systems. All are in business to stay. As Grand Central's Dr. Brunetti puts it: "We expect to be in the solid propellant business for a long, long time and we are tied to the economics of it."

• **Performance**—The highest level of specific impulse reached to date is above 250 seconds, well over what was thought to be the solid-propellant "bar-

MIXING blades in Grand Central's 350-gallon mixer, ground to extremely close tolerances and constantly X-rayed for signs of weakness.

rier" of 240 seconds. New propellants and techniques are incrementally raising this level. The goal set by ARPA for the immediate future is 280 seconds, and this is expected to be reached in substantially less than five years. Specific impulse of 300 seconds is hoped for in a few additional years, and this would involve as yet unexplored techniques of separating the extremely energetic ingredients, one from the other, in solid-propellant systems.

Specific impulse importance varies with the stage under discussion. On the *Minuteman*, for example, the exchange ratio of range to specific impulse is more important on the first stage than on succeeding stages, merely because of the greater amount of propellant involved. It is therefore desirable to have higher I_{sp} in the first stages because of the more favorable exchange ratio. On the other hand, the exchange ratio for burnout weight (the penalty in reduced-range paid if the burnout weight of any given stage is increased) makes it important to reduce burnout weight in succeeding stages. Mass fraction is expected to increase from the present level (around .93) to .96 in a short time.

The increases in performance expected of solid-propellant rockets generally varies with the timetable given. There is a lag time estimated at from two to four years between laboratory achievement and production-motor achievement of specific impulse levels. However, according to Aerojet's Dr. Roberts: "It is evident that we are going into larger and larger sizes, but it might not be so evident that the physical properties will be a more significant parameter than the specific impulse, the burning rate, or any other parameter, which in the past used to be the primary concern."

• **Propellants**—Raising the I_{sp} levels will undoubtedly depend primarily on propellants and their processing. In this respect, the greatest advances in propellants in the past year have been in physical properties, temperature ranges, etc., and the best propellant for maintaining ability to withstand thermal stresses in case-bonded motors appears to be nitropolyurethane. With certain additives, it appears to have an all-around bright future.

Aerojet's work with the nitropolyurethanes stems from research sponsored by the Office of Naval Research. The polyurethane propellants being studies at AGC result from basic work done by the **Jet Propulsion Laboratories** in Pasadena. Most of Grand Central's work in composite propellants has been on ammonium perchlorates with rubber binders. (A composite propellant is one which has a crystalline oxidizer with a rubbery fuel binder. Instead of the two high-energy components, nitroglycerine and nitrocellulose, which characterize the double-base propellants, it has discrete particles of oxidizer embodied in a rubbery binder.)

Further work at GCR is aimed at four fundamentally different types of rubber binders of a high-energy nature. It is from this work that GCR expects to get ten to fifteen seconds more I_{sp} than from regular rubber binders. (Also, through some "rather interesting" approaches to design, GCR hopes to drastically improve mass ratio.)

Both Aerojet and Grand Central Rocket Co. have been working on new processing methods for solid propellants. One more advanced than most is the continuous mixing process, which allows propellant-mixing right at a launching site, if necessary. The capacity of the system depends on the type of propellant being mixed. Aerojet says it has demonstrated a pilot-plant operation of the continuous mix process. Grand Central has also been at work on the technique for some time, and pioneered the method.

In addition to the continuous mixing process, the development that has pointed the way to the huge solid-propellant motors is the technique of producing fuel systems which can be made to solidify without evolving heat.

Development of various techniques has allowed production of large propellant grains that do not create sufficient heat to warm the grain. Hence it is possible now to create grains of almost unlimited size, and cure (or solidify) them without fear of a combustion disaster.

In addition to work with nitropolyurethanes, polyurethanes, modified nitropolymers, and hydrides, AGC is looking forward to adaptation of the high-energy components of liquids into solids, a field in which Grand Central is also strongly interested. As things now stand, it is not possible to calculate a system using solid propellants which would give the same order of specific impulses as a liquid system, regardless of the solid propellant used in the calculations.

• **Combustion stability**—Once a plague on the solid-propellant field, combustion instability is said to be nonexistent in modern propellants. One of the best cures for the problem was addition of metals to the propellant to raise the specific impulse level. Th metals, the most common of which aluminum, also solved the combusti instability problem through happy c incidence. Quality control has a helped. According to Grand Centr once a motor and propellant are c signed, tested and kept under tig quality control, the problem of unstal burning, once eliminated from ea test models, is permanently absent.

• **Temperature range**—"More th half our problems are associated w the requirement that we operate witl -65° to 165°F, and this requirement expanding," says a harassed solid-pı pellant engineer. "We are being ask to meet temperatures of 250°F, and very special applications, up to 400°F

In the low I_{sp} areas, from 200 230 sec., great temperature ran have been met. Examples are t *Sidewinder, Zuni, Asroc, 2.75* rock etc. In the *2.75*, the propellant op ates the same from -30°F to 130° and through chemistry doing the j performance-wise in the missile, o 150 pounds of fire-control and oth electronic equipment has been elin nated from aircraft.

• **Nozzle cooling**—The evolution nozzle cooling has reached the poi where Grand Central Rocket conside it "quite obsolete" to route fuel oxidizer through the nozzle walls f cooling, when there is a lightweig plastic nozzle available for liquids well as solids. (With the exception the extremely large liquid engine Among the methods used in conjur tion with the plastic nozzle are fil cooling, ablation, transpiration a auxiliary propellant charges.

Film cooling, in which a film material is introduced between t flame and the nozzle, utilizes a m terial which is solid in storage, b which liquifies under high temperatu and flows across the surface to cooled. The nozzle developed **Douglas** for use with the GCR *Nik Zeus* motor is an end-grain refrasil, essentially a fibreglass material wi a high-grade resin.

A combination system using t self-cooling nozzle with some auxilia film cooling does not appreciably dow grade the I_{sp}, and represents one the methods which prevent heat fro getting to the nozzle in the first plac The problem is not one of cooling heat-sink nozzle would do that), b one of cooling lightly and efficiently.

• **Reliability**—"To state it fund mentally, when you are using a soli propellant motor, you are using t product of a chemical plant which still back at the factory. When you' using a liquid rocket, you are dumpi raw materials into the missile, whi then must act as a chemical plant metering, mixing and controlling the fuel and oxidizer. There are a lot more things that can go wrong when your chemical plant is airborne, then when it is sitting on the ground and you control the product." This is the case for reliability as the solid-propellant-rocket manufacturer sees it.

If a solid-propellant system is properly designed, thoroughly tested and tightly controlled for quality, there is no resaon why 99% reliability cannot be attained, they say, and point to the outstanding records already established. The *Viper* rocket, produced for sled use by GCR, has demonstrated reliability in excess of 99% in a long series of runs. (In discussing reliability, sources made it clear that they were not including JATO units, and other low-performance solid-propellant motors in the reliability factor.)

The Air Force clustered 21 of the *Viper* motors on a sled four times and 39 motors once during the first week of June, to drive test sleds at high Mach numbers. About 700 of the *Viper* motors have been fired. They are not the "workhorse" type rocket, but are a recently developed. high-performance motor having a performance index of over 160 . . . considered very high.

In the clusters fired at Edwards, Holloman and other bases, reliability is vital, because of the expense of sleds, their special design, etc. Of 162 rockets ordered by Edwards AFB since last February, not one has failed to fire. They get GI handling, and are production rockets, not specially "mothered" laboratory models.

• **Casings**—Thin-walled motor casings, another shining goal of solid-propellant men, has reached the state where Grand Central Rocket is working with casings having thicknesses of less than 100 mils, and Aerojet's Aerowrap process, involving spiral wrapping of the steel casing, has produced .015" walls.

Although Aerojet says it is not now employing the Aerowrap process, the company is believed to have produced a considerable number of casings by the method with wall thicknesses of less than .050". Design strength of the casings was said to be 250,000 psi yield strength, but actually is 265,000 psi, and "ultimate failure has been occurring between 300,000 and 330,000 psi." Once the desired thickness is determined, the spiral wrapping of steel is begun and the necessary amount of layers added until the thickness is as specified.

• **Hybrids**—In the midst of the solid/liquid melee stands the poor relative of both: the hybrid rocket. Grand Central Rocket Co., noting that the most vulnerable parameter of solid-propellant rockets is thrust-level control, is strongly considering the hybrids. The firm "has some ideas" about the system and may come up with a unit having liquid oxidizer and solid fuel (which would also serve to pressurize the liquid propellant tank). The system is expected to provide a three-to-one thrust-control capability which would be adequate for many applications.

No hybrid systems are being considered by Aerojet, which feels that a hybrid system "buys the disadvantages of both liquids and solids." No other techniques for thrust-level control are being pursued at AGC except complete termination of combustion.

• **Costs**—One of the hottest topics tossed about during M/R's interviews was the subject of costs. The major points of difference that solid-propellant men have with their liquid-propellant counterparts are: "It is not necessarily what system will put the biggest payload on the moon?", but the question is "What will it cost?" The other point is "It's not the propellant cost we have to worry about, it's system cost—or mission cost."

J. J. Crowley, Vice President—Project Management and Marketing for Grand Central Rocket Co., feels there is reasonable doubt that the amount of cost per pound for payload on the moon is clearly an advantage of the liquids. His company feels that the best way to determine which system to employ in any space application is to conduct an operations research study, to show the total cost of delivering whatever payloads are called for. This would cover every cost connected with the program, including development and ground support facilities.

TEST FIRING by Aerojet of large solid-propellant rocket engine for guided missile launchings. The company is working on the solid propellants for the Navy's *Polaris.*

Similarly, D. F. Sprenger, Associate Manager of Aerojet's Solid Rocket Research & Development Division (and head man on their *Minuteman* work), feels that a good example of low-cost space research with solids is the *Scout* program, the first major application of solids to this type of work. "Possibly a year from now, we will be able to more accurately assess just where solids fit in, but it looks to us right now as if it is a very low-cost method."

The actual development cost of a million-pound-thrust solid-propellant motor is "considerably lower" than the cost of a million-pound liquid engine, and Grand Central Rocket would "gladly" take a contract to build a 20-million-pound-thrust solid rocket, because of the relative ease with which it could be done, compared to a liquid engine with the same order of thrust.

"And in the future, it will be the development cost that really matters," says Dr. Brunetti, "because many of these things we are working on will never, in the true sense of the word, be 'produced.' We may make 200 development units of a very large rocket, then actually produce only 300 'production' units."

• **Problems remaining**—In the final analysis, there are several areas in which solids are making strong efforts to whittle down large advantages enjoyed by liquids. The areas of specific impulse, thrust-level control, acceleration control and similar characteristics, are among the most vital.

Asked what was the next hurdle they would like to see cleared in solid propellant technology, Aerojet spokesmen cited the need to find a method for coating hydrides, or the protection of high-energy materials so that they can be incorporated into solid propellants without prematurely reacting. This accomplishment would move the technology to the next major "plateau" of specific impulse. Grand Central's answer, while granting the need for a method of coating hydrides, was to raise specific impulse without compromising the temperature range of a missile, and actually to expand it.

Beyond these problems lie others, but the future looks promising. In the words of one company official: "What solid propellant rocketry would like to have is a solid form of high-density hydrogen."

Cooling Gear Gets New Emphasis

Experts say heating problems in missiles and support equipment will grow and design must be done early—first of a two-part survey

by Hal Gettings and Charles D. LaFond

WASHINGTON—Vital to the achievement of optimum performance is electronics cooling, a major link in assuring high reliability in missile electronic systems and components. A multimillion-dollar business, it is all too often a stepchild in early equipment and system design. An M/R staff survey into this very important area of missile and ground-support equipment design brought two similar responses from each of the companies queried:

1) As a result of increased component density in micro-miniaturized circuit design, increased power requirements per unit volume, and aerodynamic (environmental) heating will continue increasingly to cause system degradation in missile and ground-support electronic systems.

2) To combat this, systems should include at an early stage of design and throughout development the services of competent cooling-system design engineers.

We have long since passed the time when free convection would satisfy the requirements for cooling electronic equipment in the majority of existing and proposed future high-performance electronic systems. Unique operational requirements have resulted in unusual designs in cooling systems. To meet requirements, compact electronics cooling packages have been designed, utilizing liquid-to-air, oil-to-air, air-to-air heat exchangers plus the use of electric-driven fans and flow control valves in the electrical controls and switches.

New and better means to provide individual component cooling are currently being developed, including new applications of the Peltier effect for controlling temperatures in transistors (to be covered in part 2 of this survey).

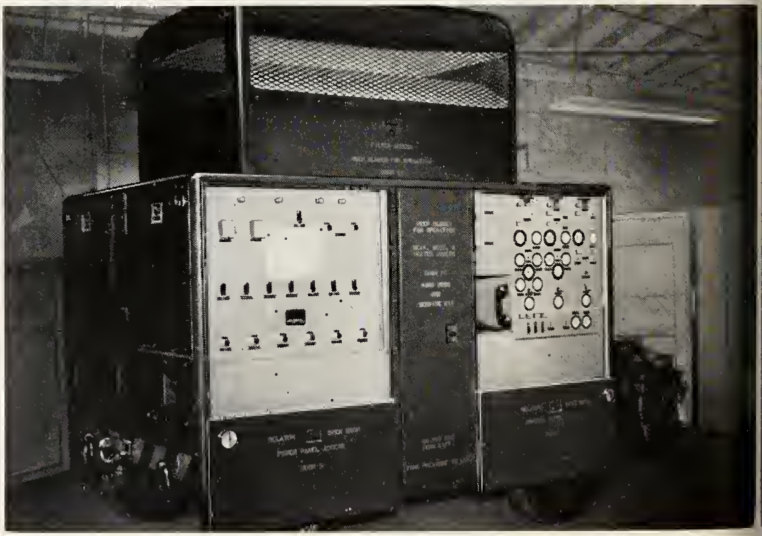
Electronic cooling packages can be grouped into two principal types: missile support equipment and missile carried equipment. While performing the same functions, it is obvious that cooling system configurations for the two types are considerably different. They range from the massive air-conditioning systems required for computer centers down to very small units for cooling infrared detectors.

As an example of the former, for the NORC computer center at Dahlgren Naval Proving Grounds, 50 tons of cooling equipment are contained in the computer system itself while 40 tons are required to cool the room in which NORC is installed. On the other end of the scale is the recently announced 8-ounce "min-IR-cooler" developed by **Arthur D. Little, Inc.,** of Cambridge, Mass., and currently being manufacturer by **United Aircraft Corp.'s** Hamilton Standard Division as an IR detector-cell cooler.

The systems and components produced by **United Aircraft Products, Inc.,** of Dayton, Ohio, as summarized in Table 1, indicate roughly how diversified electronics cooling can be. The table shows only part of the picture, since the UAP also produces the various valves, hand pumps and other components and accessories to complement its systems.

• **Missile support**—Missile support cooling equipment, either ground installed or airborne, is designed to reject heat from the fluid which is cooling the missile components during preflight checkout operation to the ambient heat sink—that is, the atmosphere or the ocean. Thus the fluid on the heat-sink side is usually air or water. On the heat-source side (missile), the fluids generally used are air, water, water-glycol, high-temperature synthetic oil, and inert gases.

• Checkout cooling—The extent to which air conditioning of systems can be carried probably is best demonstrated by those produced by **C. G. Hokanson, Inc.,** of Los Angeles. To provide reliability for missile systems during checkout, the company has developed a



TRAILER-mounted air conditioning production unit made by Hokanson for *Thor* missile bases. The "snorkel" was designed to place the air intake above the LOX level.

whole line of specialized equipment, providing "tailored atmospheres" for many different missiles systems and aircraft.

In all of these systems, temperatures are held within very close tolerances. A pioneer in this field, the company completed the largest single air conditioning installation in the West for rocket test facilities at China Lake Pilot Plant, Naval Ordnance Test Station, Inyokern, Calif. Among many of its major cooling systems built since that time, Hokanson test and production units are currently employed in the **Douglas** *Thor*, **Martin** *Titan*, **Northrop** *Snark* and **Lockheed** *Polaris*.

For *Thor* during final checkout, the Hokanson system essentially consists of three different operational units. They are all integrated and combined into one single mobile chassis.

- The measurement unit provides continuous heating and cooling during storage, standby, and countdown.
- The guidance portion of the system provides both heating and cooling but only during countdown.
- The third portion of the system is for the engine which provides heat during the countdown only.

Air connections to the missile are provided with four 150 ft.-long lines, including three inlets and one return.

In the measurement-cooling system, temperature is controlled by means of a thermistor sensor in the missile. The temperature control point is 90°F ±20. The unit can provide 15,000 BTU/hour cooling capacity and 25,600 BTU/hour heating. This portion of the system employs an air-to-air heat exchanger to lower refrigerant-compressor operating time.

In the guidance-cooling portion of the system, fresh air can be delivered through the ducting at a rate of 800 cubic feet/minute against a static pressure of 13.5 inches of water. Again temperature is controlled by a thermistor sensor in the missile. An air blower supply is energized when the missile temperature reaches 80°F. The refrigerant cooling unit is energized when the missile temperature drops to 45°F. A warning system is actuated when missile temperature falls outside of the range of from 33°F to 124°F. Cooling capacity of this portion of the system is 36,000 BTU/hour.

In the engine-cooling portion of this system, fresh air input is at the rate of 1,000 cubic feet/minute against 13.5 in. of water. Control and regulation of temperature is initiated at the air conditioner with a range of from 40° to 200°F. Blower start and stop on lower speeds are actuated from the missile automatically. Again, a warning signal is produced if missile temperature goes below 5°F. This portion of the system can provide 225,000 BTU/hour heating capacity.

Heat for the air conditioning system is provided by a small electric fluid emersion heater which is divided into three-25kw stages. The fluid consists of a 50-50 mixture of ethylene glycol and distilled water. This is circulated to all three parts of the system by means of two pumps. More accurate temperature control is obtained through forced circulation by the dual pumps.

Reliability of the system is good. Specifications for the measurement unit provided for a 500-hour non-stop operating time, 100 hours at high speed and 300 hours at low speed in the engine unit, and 200 hours in the guidance section. The system is capable of 10,000 hours operation before the need for scheduled overhaul and its built-in test equipment permits monitoring of components not in continuous operation.

- **Missile cooling**—Because of the singularly unique operational requirements of the various systems, the environmental conditioning equipment carried in short-time flight has assumed practically every thermodynamic configuration possible. These requirements include flight time, whether in terms of minutes or hours, and an enormous, repetitive checkout period.

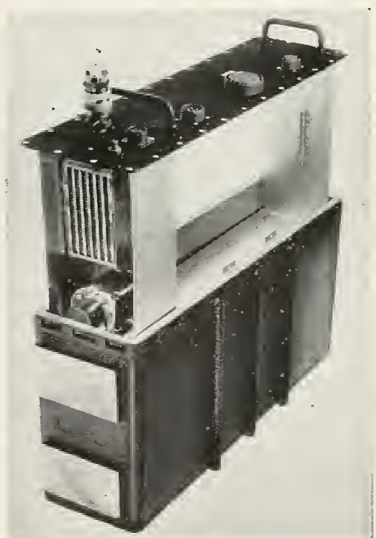
Installations have been designed by **Garrett Corporation's AiResearch Manufacturing Division,** a well-known leader in the field, utilizing only the thermal mass of the pre-cooled structure. Most installations however, said a company engineer, require the missile to carry an expendable evaporant in order to adequately cool the equipment. AiResearch ranks pure water, pure ammonia, and a solution of water and ammonia and water-glycol in that order as the most advantageous evaporants to use.

Water has the lowest thermal pressure and a good heat evaporation. Ammonia has low heat sink but high pressure. However, its storage and use is disagreeable to animal life.

Most problems which dictate unusual solution are high voltages in a small package requiring a high dielectric strength cooling medium and cooling specifications requiring close temperature control in order to minimize instrument drift. AiResearch said it

Table 1. Summary of Electronics Cooling Systems and Components Produced by United Aircraft Products, Inc.

		MISSILE TYPE								PROPULSION						GUIDANCE				
		Surface-surface	Air-surface	Air-air	Surface-air	ICBM	IRBM	Drone	Tactical	Liq. fuel rocket	Solid fuel rocket	Booster	Ram jet	Turbo prop	Gas turbine	Radar	Inertial	Infrared	Radio	Ground Support
SYSTEMS	MECHANICAL REFRIGERATION				X	X						X	X			X			X	
	EXPENDABLE REFRIGERATION	X			X	X														
	CRYOGENIC					X				X								X		X
	HEAT TRANSPORT							X												X
	CONSOLE COOLING	X		X	X		X		X	X	X					X	X			
	EVAPORATIVE	X			X			X						X					X	
HEAT EXCHANGERS	LIQUID/AIR	X	X		X			X		X		X	X			X	X		X	
	AMMONIA/GLYCOL	X																		
	LIQUID/GAS												X							
	EVAPORATIVE		X																	
	LIQUID/LIQUID	X	X		X							X			X		X			X
	LIQUID AMMONIA/LIQ. OXYGEN					X				X						X				
	HOT GAS/NITROGEN TETROXIDE				X															
	AMMONIA/AIR				X								X			X				
	COLD PLATE (CONDUCTIVE)	X		X							X					X	X			



AIRBORNE pressurized cooling package by AiResearch. It uses water-glycol.

three approaches to radiation . . .

has maintained temperatures within ±1°F for electronic equipment dissipating from 10 watts to 10kw.

One unique feature of missile-carried equipment is that environmental conditioning equipment usually performs double duty as a cooling or heating system while providing structural mounting for the components being conditioned. For example, several AiResearch systems have taken the form of breadboards, container walls and other unique configurations. For this reason, they have vigorously attempted to educate electronic firms into consulting environmental-control firms at an early development stage in order that the environmental system may be feasibly designed into the package itself.

A typical example of an environmental conditioning system for electronic equipment involved a low total-head dissipation aboard a high-altitude missile.

AiResearch selected an open-cycle cooling unit because it is much lighter and less complex in operation than closed cycle systems. Net heat rejection was 85 w and it used an ammonia (NH_3) evaporant to cool nitrogen circulating over heat-generating electronic components. The system included an NH_3 storage tank, pre-cooler superheater, associative components. Specifications are shown in Table 2.

Table 2. AiResearch performance specifications for missile-borne cooling system

Heat Transfer Data	Hot Side	Cold Side
FLUID	NITROGEN	NH_3
FLOW RATE	3.22 LB/MIN	0.016 LB/MIN
TEMP. IN	57.7°C	-32°C
TEMP. OUT	53.7°C	-35°C
PRESSURE IN	14.7 PSIA	17 PSIA
PRESSURE DROP		2 PSI
PROOF PRESSURE		800 PSI
Fan Data		
TYPE	VANEAXIAL	
TEMP. IN	53.4°C	
PRESSURE IN	14.7 PSIA	
PRESSURE RISE	1.7 IN. H_2O	
POWER SOURCE	3 PHASE, 400 CPS, 115V	
POWER REQ.	40 WATTS	
Valve Data		
TYPE	PORTIONAL-INTEGRATION MODULATION	
CONTROL	FIXED ±2°C	
MAX. TEMP.	800 PSI	

• Radiation cooling—In the missile-cooling applications above, energy transfer to the heat sink was by means of convection or conduction. This is quite satisfactory in flights of short duration. But, in space vehicles this transfer to the heat sink must be by means of radiation since the lack of an atmosphere removes the mechanism for convection and conduction.

Thompson Products Div. of **Thompson Ramo-Wooldridge, Inc.,** Cleveland, in a report titled "Electrical Generating Equipment for Space Systems" has indicated that there are three possible (and practical) means of providing for this heat radiation cooling: employ a radiator designed to collect heat from the vehicle and its equipment and radiate its energy into space; employ the outer surface of the vehicle as a radiator; or, use a combination radiator and radiating vehicle skin.

Key to direct radiation cooling, according to Thompson, is the provision of equipment designed to withstand high operating temperatures. Their reason: thermodynamically, the higher the operating temperature of the equipment the greater the amount of heat transfer. Biggest advantage in radiation cooling would be the great savings in weight.

Space Technology Laboratories, Inc., of Los Angeles, recently revealed the development of new coatings for satellite skins that are capable of controlling internal temperatures in flight. Developed by Rudolf X. Meyer, a scientist in the company's Physical Research Laboratory, the coatings change color with temperature change such that they become light with an increase in heat and darken with heat loss. Thus they compensate for the temperature change by reflecting or absorbing heat radiation as required.

Meyer has found nearly 35 substances, either paint-like or plastic that have this "chameleon" ability. In using polymer compounds, he said use is made of the reversible transition from the "sol" state to the "gel" state as the temperature increases.

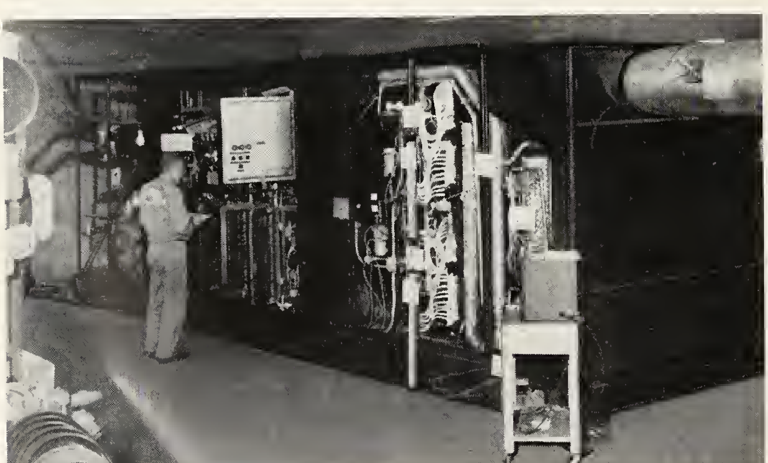
• **Heat exchangers**—An innovation in heat exchanger equipment is the heat transfer surface called "Inner-fin" developed and patented by **Dunham-Bush** of West Hartford, Conn., which is achieving marked success. The Inner-fin coils have proven to be one answer to the space and weight problem so significant in adapting cooling equipment to the relatively confined spaces associated with electronic equipment in missiles and aircraft.

The company has indicated that the use of their special coils has reduced necessary size by as much as 60%, still maintaining the same air and liquid pressure drops through the coil as obtained in standard finned tubes.

The exchangers are of all aluminum dip-brazed construction. Units finding direct application in the missile and aircraft business have been ethylene glycol-to-air, and oil-to-air heat exchangers. The Inner-fin construction has also been applied to Freon-to-Freon and air-to-air heat exchangers for airborne conditioning system components and ground support electronics cooling respectively.

Basic principal in the patented Inner-fin is the arrangement of longitudinal fins inside a tube in conjunction with outer fins. A small inner tube is mechanically expanded which locks the longitudinal Inner-fins in close contact with the inner wall of the outside tube and the outer wall of the inside tube. This type of construction provides greater surface area and smaller hydraulic radius. Thus the transfer of heat is more rapid. The longitudinal arrangements of the Inner-fin keep pressure drop at a minimum.

(Part 2 next week: Cooling missile components)



COMBINED air conditioning and water chilling units designed and built by Hokanson Co. in support of *Titan* program. It yields unprecedented amount of dry air.

Eyelets vs. Plated-thru Holes

A report on a comprehensive test in which all located failures were in eyeletted phenolic boards —last of two articles on printed circuitry

by Bernard C. Alzua, Jr.
Motorola, Inc.

PHOENIX—The most costly and me-consuming operation in the as-mbly of an electronic unit or chassis the hand wiring of the circuit. It is so the source of frequent errors, ecessitating costly inspection proce-ures.

The development of circuit boards d printed wiring has done much to leviate this situation. In fact, the high olume production techniques of cir-it boards for radio and television assis is no longer a "state-of-the-art" ethod but more a mechanical process hich turns out quantities of 5000 to),000 units a day.

The use of circuit boards for mili-ry applications in missile and air-aft equipment, however, presents a fferent set of requirements. Here the ctors of reliability and quality con-l are paramount, and costs are sub-rvient to reliable performance. It is th these high-quality, high-reliability pes of boards that this article is con-rned.

• **Reliability factors**—The cost of nted wiring is high, especially when iability is a "must." The cost of the ost expensive board, however, is atively little when compared to the st of a reject board that is completely embled and contains 75 or more ounted components.

To the Army Ordnance Missile mmand, Huntsville, reliability means "the positive assurance that the weapon will function effectively whenever required." The military demands that reliability be achieved during the R&D phase of each weapon system through quality-assurance and quality-control programs.

Accordingly, exhaustive flight testing is the rule in current programs. For example, an average of 230 individual measurements are obtained during each flight of the *Redstone* missile.

• **The controversy**—One of the most important debates relating to reliability of circuit boards is over the use of eyelets or plated-thru holes. At **Motorola's Western Military Electronics Center** in Phoenix, our Reliability and Components Group has been conducting a lengthy and comprehensive evaluation of the relative merits of each.

In the past few years, many users of printed boards have had so much trouble with plated-thru holes that they want no part of them in the future. We have found grounds to indicate that the trouble is not so much with the basic technique as it is with such deficiencies as poor quality holes, contamination and insufficient copper in the holes. It will be shown that we have, indeed, used the technique of plated-thru holes in several high-reliability applications with outstanding success.

A missile, rocket, or aircraft has numerous printed wiring boards—indicating that hundreds and thousands of eyeletted or plated-thru holes would be involved. Without attempting to be complete, the following report on comparative tests presents the most significant results obtained thus far.

Before these tests were made, several versions of wall thickness of plated holes were made and analyzed. Failures were located and their causes traced. We finally struck upon what we feel is an optimum thickness, and this was used in the test program.

• **Test program**—The objectives of the performance tests were:

1) to determine the relative ability of properly installed and soldered eyelets and of properly plated holes to maintain electrical continuity through epoxy glass boards; and

2) to evaluate, in the same manner, properly installed and soldered eyelets in XXXP phenolic printed wiring boards.

• **Environmental tests**—Briefly, eighteen epoxy glass eyeletted printed boards and three epoxy glass plated-thru hole boards (each board having a total of 100 holes) were subjected to the following environmental procedures:

1) thermal cycling, 15 cycles from -65°C to 125°C in air;

2) vibration, 10g 20—2000 cps and at their resonant frequencies for one hour, while carrying 30 ma-dc;

3) humidity exposure 91% RH 70°C, for ten days while carrying 30 ma-dc; and

4) immersion-vibration cycling, three cycles, each compromising three days of water immersion at 70°C followed by the vibration cycle.

Three standard eyelets were chosen for the tests because they fell within the average and standard hole sizes. Type 1, Circon #CE-34 was tooled to obtain serrated flanges on both sides. Type 2, American Brass #E-3700, was tooled to obtain funnel flanges on both sides. Type 3, United Shoe #S-5862, was tooled to obtain a rolled flange on one end and serrated flanges on the other.

Three hundred plated holes, gold finish, were compared with the same quantity of each of the eyelets just mentioned.

An equal number of phenolic boards was eyeletted and all of the boards included in this test were soldered and fitted with leads in the following manner. Approximately one-quarter (25)

The author is manager of the nted Circuit Facility at the otorola Western Military Electronics nter, Phoenix, Ariz. A mechanical gineer, he has an extensive back-ound in photography and photo-phic methods. Formal training: Uni-sity of Arizona, the Kodak Institute, tgers University.

cracks between flange and solder . . .

of the holes in each board were prepared with each of the following variables:

1) Holes were filled with 60/40 solder from both sides.

2) Holes were filled with solder from one side using the blind technique.

3) Component leads were inserted and soldered from both sides.

4) Component leads were inserted and soldered from one side.

• **Comparative results**—The comparisons that can be made from our test results obtained to date are shown in Figs. 1 through 6.

From Fig. 2 it can be seen that the most significant number of failures occurred in funnel-flange eyelets installed in phenolic boards.

All located failures were on eyeletted phenolic boards. Microscopic examinations showed that cracks had developed between the eyelet flange and the adjacent solder. Similar cracks have developed on many other eyelets in both XXXP and epoxy glass boards which have not yet failed.

All failures of eyelets in epoxy glass boards were classified as unlocated because, though definite circuit interruptions had occurred during vibration, the continuity was restored when vibration ceased.

Specimens prepared with blind soldering techniques had more failures than those that were soldered from both sides.

At present, we have found that G-10 and G-11 laminate series have been the most satisfactory to use on military type printed boards, particularily if the application involves a missile or aircraft device.

As far as printed-board materials for the future are concerned, I believe that the industry will gradually go in the direction of boards that can withstand higher temperatures and shock.

Of the several methods to produce a printed wiring board, we have found the copper-clad and etching method to be the most reliable. Remember that I am considering military-type boards only.

Some other methods involved have shown signs of potential breakdown either in a cold-copper joint, or erratic adhesion to the laminate and other fabrication defects.

To produce a high-quality military-type printed-wiring board is definitely a "state-of-the-art" program and shall continue to be so as long as reliability is the key to the success of missile/aircraft vehicles.

TEST RESULTS

Light areas show unlocated failures; shaded areas show located failures.

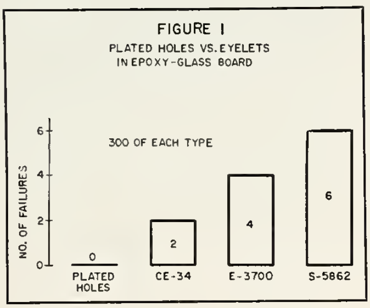


FIGURE 1
PLATED HOLES VS. EYELETS IN EPOXY-GLASS BOARD

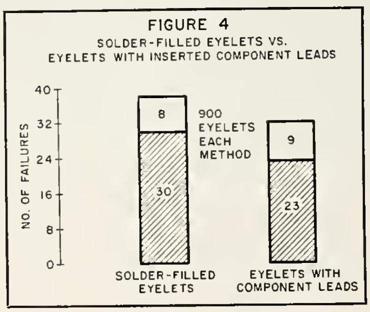


FIGURE 4
SOLDER-FILLED EYELETS VS. EYELETS WITH INSERTED COMPONENT LEADS

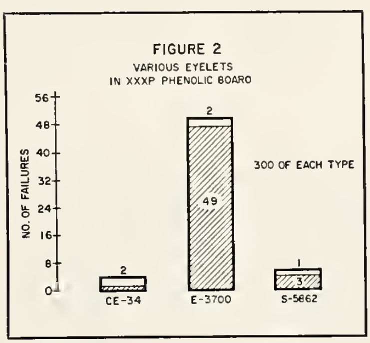


FIGURE 2
VARIOUS EYELETS IN XXXP PHENOLIC BOARD

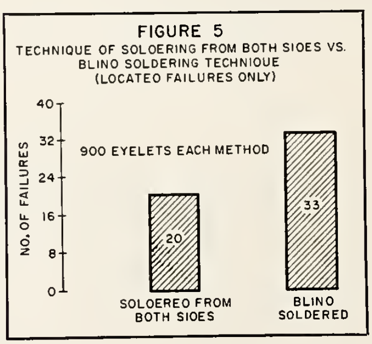


FIGURE 5
TECHNIQUE OF SOLDERING FROM BOTH SIDES VS. BLIND SOLDERING TECHNIQUE (LOCATED FAILURES ONLY)

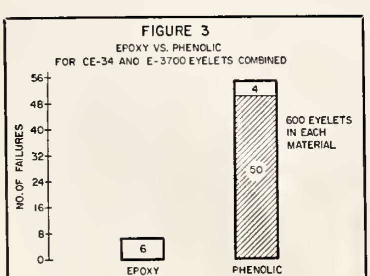


FIGURE 3
EPOXY VS. PHENOLIC FOR CE-34 AND E-3700 EYELETS COMBINED

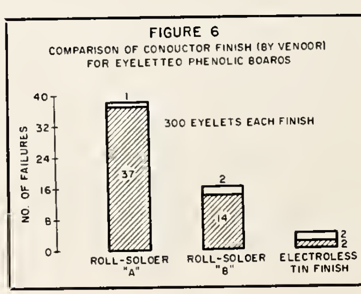


FIGURE 6
COMPARISON OF CONDUCTOR FINISH (BY VENDOR) FOR EYELETTED PHENOLIC BOARDS

ITT Monitor Guards Launch Communications

CHICAGO—An automatic monitor to watch over and switch communication lines in case of trouble has been developed by **International Telephone and Telegraph Corp.** for the *Atlas* project. Designed primarily to assure uninterrupted voice communications during missile launches, "Commswitch" has possible future applications in such areas as teleprinter circuits, telemetry, and stock tickers.

In its present application, the unit "listens" to a phone conversation and automatically switches to an alternate line in case of excessive noise, change in transmission characteristics, distortion, or line break. Maximum operating distance—either on landline or equivalent microwave relay—is 60 miles.

Circuit Elements Mounted in Module

MENLO PARK, CALIF.—A new "window frame" technique for mounting transistor circuit elements in a compact module has been devised by **Stanford Research Institute.**

Two sets of eight elements are mounted back to back in the hinged frame and one connector serves all 16 circuits.

RAF Thor Base

(continued from page 11)

rons, Nos. 1 and 2 got individual training in the United States and crew training actually on the job in England. Nos. 3 and 4 got or are getting individual training at the U.S. plants and crew training at Vandenberg AFB, Calif. All of the crews will rotate back to Vandenberg for practice firing training.

In discussing the entire RAF missile training program for the *Thor*, Duncan Sandys, British Minister of Defense, said that he was immensely impressed by the speed with which it has been carried on and he paid especial tribute to the USAF and to the Douglas training program. He thought the *Thor* tests carried out in the States proved that it was becoming more reliable every day and that we were rapidly approaching the day when it would be regarded as a normal operational weapon, much as today's bombers are regarded.

Sandys referred to the missile, incidentally, as a successor to the manned bomber, although his RAF leaders feel —as do most USAF generals—that it now only complements the manned aircraft and will do so for a long time.

• **Made in Britain**—As a follow-on to the *Thor*, Defense Minister Sandys said the RAF has coming up the *Blue Streak*, a 2000-plus-mile missile, 10 feet in diameter and about 60 feet long, roughly the size of the *Thor* but more powerful. It will also be used for scientific experiments, Sandys said, adding that the Woomera Test Range had been extended to test it. Making the one-stage *Blue Streak* are **de Havilland Propellers Ltd.** and **Rolls Royce,** with **de Havilland Aircraft** and **Sperry Gyroscope Ltd.** as associated contractors.

Air Vice Marshal Gus Walker, the RAF's new chief of information, came up with a new definition of an effective deterrent force for a group of American newsmen recently. He said:

"When Russia sets up a war game against the West, plays it and *loses*—then you have an effective deterrent."

The World War II RAF hero also noted the part the British Bomber Command plays in this deterrent force. It is "several times" as large as the SAC contingent stationed in England, he said, can carry either British or American nuclear bombs and—due to its forward location—would be the first manned force to strike the Soviet Union in case of war.

Vehicle Requirements

(*continued from page* 20)

with a nonstop range of approximately 250 miles. The range and speed both decrease as the travel conditions become unfavorable with increases in grade and/or rolling resistance. The range may be readily increased, if desired, by increasing the fuel capacity.

• Consideration was given to the various U.S. state highway regulations, since the vehicles will travel on the highways. For the heavier missiles, it will be necessary to upgrade, by special permit, the highway size and weight restrictions. Farm and construction equipment criteria will be used. The study will include separate delivery of the missile and booster to reduce G.V.W. and size.

• The chart on p. 19 is a summary depicting the principal state highway restrictions currently in effect. The summary is severely condensed, since the individual state highway regulations would fill several publications.

• Eight feet is the maximum prevalent vehicle highway width allowed today. With special permit, excess width allowance is granted by the various states to farm, earthmoving, and construction vehicles. In general, 12 feet is the maximum width allowable for mobile equipment subject to rail shipment, due to the restrictions of tunnel and multiple, parallel-track side clearances. Certain of the FMC concepts have exceeded the 12-foot width to obtain other design advantages.

• Height limitations vary from 12′6″ to 13′6″ in the various state highway laws. The height limitations are established from subway and underpass dimensions, public utility lines, traffic signal, electrolier, etc., clearances. Careful consideration has been given to the extreme length required for the transporter.

• **Shock effects**—The final problem that we will consider is the effect on the missile of shock imparted from the road as the wheels pass over various bumps or obstacles. At our high-speed test track and cross-country test course of FMC's Ordnance plant, we have performed tests to determine the shocks imparted to missiles under various transport situations.

During the *Navaho* program, the equipment shown in photo (p. 18) was instrumented for shock testing and tests were performed for highway transport. At speeds up to 15 miles per hour on our paved test track, the maximum shock load was .230; however, this was under the equivalent of good highway conditions.

We recently completed test for a 14,000 lbs. missile load equivalent being carried on a tracked vehicle. Under normally severe cross-country conditions it was found that a maximum of 3 g loads are to be encountered. Under severe tests which went beyond the realm of reasonable usage, shocks of 5.8 g were encountered for periods up to 20 mili seconds.

In summary, it can be seen that there are many factors to be considered if a large mobile missile system is to be designed. A careful study must be completed to predict operational requirements before military characteristics can be written for transport equipment. Predicting overly severe conditions will lead to overdesign—with increased cost and weight. On the other hand, if too optimistic views are entertained, the system will fall short on performance when severe conditions are encountered.

It can be readily seen that one important factor is relating the missile's physical characteristics to operational requirements for mobility. If the missile and its components cannot withstand the expected shock loads, then despite the mobility that is inherent in the equipment, the system will not function when required at a critical time.

soviet affairs . . .

By DR. ALBERT PARRY

The Red version of Project *Mercury* . . .

how well has it fared compared with the choice and training of our seven astronauts? The Soviets say and publish very little on their part in this momentous race. They talk instead about the training and flights of their twelve dogs and one rabbit.

Yet, Soviet spacemen-in-training do exist . . .

We hear that Moscow did sometime ago select five men for such conditioning. One of the five has since been killed in an accident, the nature of which had not been revealed. All five were World War II flyers, decorated for their feats in air combat. This much was told by Soviet space-medicine experts to our Brigadier General Don Flickinger, medical assistant to the commander of the U.S. Air Force's Air Research and Development Command, on the general's recent trip to Moscow.

Older than Project *Mercury* airmen . . .

Russia's would-be-spacemen were perhaps not as carefully selected as our seven candidates. General Flickinger concluded this, in part, from a certain surprise evidenced by the Soviet space-medicine men to whom he talked: they voiced their interest in the fact that the seven U.S. astronauts had particularly high IQ's. Was this a requirement? they asked. No, our general replied, it just happened that the American candidates who passed the stiff requirements of psycho-physical fitness have those high IQ's as well.

As to the Soviet yardsticks . . .

for their spacemen, it may be argued that if the Soviets had similar tough standards of psycho-physical fitness for their candidates, the latter might have also possessed keen intelligence and the Moscow doctors would not have been surprised by our men's IQ's.

On the other hand, we may speculate that the Soviet spacemen are not only flyers but have also been specifically trained in various advanced astro-sciences. This would make them almost invariably older than our men, and thus spared anything like our exacting standards of psycho-physical fitness applicable to younger men only. Yet, the older Soviet spacemen may be every inch of their brain as intelligent as our younger ones. The Moscow doctor's interest in our men's IQ's may be due to the fact that in Russia generally, IQ tests are seldom, if ever, used.

Soviet interest in *Mercury* is high . . .

This is seen particularly from the recent article in *Sovetskaya Aviatsia* on American methods of selecting and training of "cosmonauts," written by Dr. V. Borisov, a space-medicine expert.

An American film shown in Moscow recently was judged as of great value to Dr. Borisov and his fellow space-medicine men. This was the movie brought by U.S. delegates to the May 25-June 1 conference of the International Aeronautical Federation held in the Soviet capital. Dr. Borisov wrote that during the period of weightlessness, shown in the film clearly by the floating of a few unattached objects in the plane's cabin, the American flyers who were being tested "worked on a special installation with a large number of buttons and levers"—and the Soviet viewers obviously admired our flyers' movements "which were quick and well coordinated."

Particular impression in Moscow was made . . .

by these U.S. ways to overcome weightlessness: Item One—training an astronaut to float in the cabin during his weightlessness. This floating, Dr. Borisov observed, was done "dexterously," the floater's cycle of movements "greatly resembling the ordinary movements of a swimmer." Item Two—the use of special shoes with magnetic soles. Item Three—combatting the difficulty of drinking liquids while weightless. Dr. Borisov wrote approvingly of special vessels from which U.S. astronauts squeezed water directly into their mouths.

— review —

Forty-two years ago the Bolshevik leaders of the Soviet Union faced a hostile world with an air force limited to some 300 obsolescent foreign planes, a few Ilya Muromet bombers and a lack of spare parts.

Today the Soviet Air Force—with its bombers, its tactical fighters, its troop-carrying jets, its ICBM's and IRBM's—is the terror of the earth.

The detailed story of how this has come about is the core of *The Soviet Air and Rocket Forces* (Praeger, $7.50), an excellent new symposium edited by British Aerospace Expert Asher Lee.

But Lee, a former British intelligence officer and wing commander, and his fellow writers also do much more. Along with one of the best histories of modern Soviet air power to date, they also provide a provocative series of chapters which explore the Russian military mind and its effect on air strategy and tactics. In the end, a remarkably clear picture of the future of Soviet air power emerges.

Undoubtedly one of the most important conclusions that can be drawn is that if Lee and his associates are correct the United States will be most foolish indeed to write off the threat of Soviet manned bombers at least anytime in the next decade.

The book brushes aside Soviet Premier Khrushchev's statements that the bomber belongs in a museum as so much propaganda.

At the same time, Lee & Co. raise an even more ominous threat: The missile-launching Soviet submarine.

Soviet work on launching long-range missiles from submarines is, unlike the U.S. *Polaris* program, no comparatively recent development. Instead, it dates back to work by German scientists at Peenemunde in 1945.

So far, Russia has been developing two series of submarine missiles: the *Golem* and *Komet*, designed for firing from submerged submarines.

Lee and Robert Stockwell state in a chapter on Soviet missiles that the Soviet Union today probably has only a few dozen submarines capable of firing long-range missiles with any accuracy. However, they add: "With each year that passes the long range attacking power of Soviet submarines will become more important to overall Soviet strategy."

Finally, another warning from this many facted book is based on Russia's growing fleet of jet transports. These would be capable of rapidly transporting large numbers of Red Army units to distant points for seizing key positions—vital in a future atomic war.

—moscow briefs—

by Dr. Albert Parry

In summarizing the NATO's plans for rocket bases, two Soviet officers write in *Krasnaya Zvezda*, the daily organ of the USSR's Ministry of Defense, that "by the end of this year the United States proposes to implement 35 rocket bases in the countries of the NATO"; also that at the present time there are stationed in Europe 30 NATO divisions armed with missiles, which number by 1963 is to be increased to 100 divisions. The authors of the *Krasnaya Zvezda* article, Colonel V. Nagrebetsky and Lt. Colonel A. Kashcheyev, express their alarm and indignation over the increase of rocket armaments in Great Britain, Italy, Greece, and Turkey. They refer also to the American "pressure" on Norway to accept nuclear warheads for her missile weapons. In addition, they dwell on U.S. efforts to expand "the building of American rocket-nuclear bases and storehouses" in Canada, and to change the role of Canadian infantry in Europe by arming these troops with rocket-nuclear weapons "so as to enhance the attacking capacity" of Canada's foot-soldiers.

In another issue *Krasnaya Zvezda* reports that West Gemans are planning to have nine nuclear-rocket divisions, with 26 missile-launching sites and 288 rocket weapons "which will be delivered from the United States." *Krasnaya Zvezda* also estimates that nearly 1000 West Germans are now being trained in the United States to handle "military rockets with atomic warheads," and that some 2000 such West German officers and soldiers, completing their missile training in America, have already returned home, ready for their new duties.

The "militarization of the 49th state" is described in compact but ample detail by Lt. Colonel P. Kondrat'yev in *Sovetskaya Aviatsia* in a special article devoted to Alaska. He calls the newly admitted state "the springboard of American aggression in the Arctic . . . aimed to attack the Soviet Union and other Socialist countries." In his listing of U.S. bases and arms in Alaska he mentions the presence of the *Falcon* as a notable operational Air Force air-to-air missile.

• **Rocket lit. watched**—U.S. and other Western literature on rocketry is being carefully watched in Moscow by the staff of *Izdatel'stvo Inostrannoi Literatury* or the Foreign Literature Publishing House, which, as every other publishing establishment in Russia, is of course owned and run by the Soviet government. Books and articles deemed to be most important are selected for translation into Russian for early Soviet publication. An outstanding project is a nine-volume series to which the Moscow editors gave the inclusive title of *Foundations of Designing Missiles*. The first of the nine books came out in 1958; the second has just been published in Moscow.

This volume II is made up of translations from the English of articles by several authors, under three categories: "Research of Operations," "Warheads," and "Launching of Missiles." It has drawn a detailed review in *Sovetskaya Aviatsia* by Lt. Colonel V. Tyurnin of the Soviet engineering troops, who is also a candidate of the technical sciences and holds a teaching post as *dotsent* in one of the academies. He pays particular attention to the book's data on ground-to-air missiles; also praises the "original and very simple method of defining areas of possible attacks by missiles" as explained in the volume.

But a greater part of the review is belligerently negative. Lt. Colonel Tyurnin criticizes the "low scientific level" of the book, its "inexact expressions and vague definitions," its generalizing about missile warheads without giving more precise details about them, its paucity of information on resistance of materals used in missile making. The Soviet reviewer complains: "The small amount of valuable data contained in the book is dissolved in the many pages of little or no worth." He also rebukes the Soviet translators and editors for preserving intact the original author's Western political view of the Cold War. The *Sovetskaya Aviatsia* writer warns the Moscow editors and publishers of Western literature to cut and prune while translating, in sum, to be more "discerning."

• **Future sciences**—Astrogeology, astrogeography, and astroclimatology are the sciences of the future, the foundations for which are being laid by Soviet savants right now, according to I. Zabelin, a candidate of the geographic sciences writing in *Komsomolskaya Pravda*. The three new branches of human knowledge are concerned with novel methods of probing into our planet's structure and climate by comparing them with those of the Moon, Mars, Venus and other planets. The writer names B. L. Lichkov and G. N. Katterfel'd of Leningrad and M. V. Stavos of Dnepropetrovsk as three of the Soviet scientists in the forefront of these new interests and techniques.

NAA Help Wanted Ad Probed by Congress

A **North American Aviation** newspaper advertisement seeking a "military advisor to advise-counsel-report to high level management on military matters as they apply to long-range planning . . ." was poorly worded, a company official conceded to House investigators last week. The ad in the May 7 Wall Street Journal also said applicants should be "personable with high degree of speaking and writing ability" and have an Air Force colonel or Navy captain background, preferably with Joint Chiefs of Staff experience.

W. H. Yahn, vice president and general manager—NAA Columbus Division, in response to questioning told the Hébert Armed Services Investigations Subcommittee Joint Chiefs experience was sought because the company wanted a man who "plans ahead" and who could anticipate military needs by 5 to 10 years. The ad drew 70 responses, Yahn testified, adding that three men were under consideration. In an exchange with subcommittee counsel John Courtney, Yahn said the cost of the ad was charged to company profits instead of allowable overhead on government contracts, and was probably an error. If that was true, said Courtney, NAA appeared to be promoting its own business with government funds.

Another witness, Gen. Omar Bradley, chairman of the board of the **Bulova Watch Co.** and head of the company's R&D laboratories, said no one in or out of the service had ever attempted to pressure him when he was a five-star general. Noting that several other witnesses had testified in the same vein, Rep. Porter Hardy (D-Va.) commented the investigation may be a "tempest in a teapot." But Chairman F. Edward Hébert (D-La.) said it was still the subcommittee's duty to air fully charges that firms were employing ex-military men to influence defense contract awards.

Ablating *Atlas* Recovered

The *Atlas* re-entry vehicle recovered July 21 after a 5000-mile flight down the Atlantic Missile Range was the biggest yet flown by the U.S., according to the **General Electric Co.**

Vehicle was more than 12 feet long, an elongated cone with a rounded nose constructed of ablation materials. A spokesman of GE's Missile and Space Vehicle Department in Philadelphia said the vehicle came through the test in "good shape." The cone carrying data equipment in the warhead compartment is described as one of a series of experimental models leading to a second generation ablating type ICBM operational re-entry vehicle. Recovery system, including after re-entry parachute deployment, balloon support after impact and radio-flashing light-dye marker locating devices was by **Cook Electric Co.,** Chicago.

Sylvania Data Facility Size Doubles in Year

Sylvania Electric Products Inc. is adding another 67,000 square feet to its Data Systems plant, Needham, Mass., where it is developing data processing systems for BMEWS and MOBIDIC. The new addition, to be completed by Sept. 1, will bring the plant size to 212,000 square feet—more than double the original size when Sylvania moved in 12 months ago . . . **Kurz & Root,** Appleton, Wis., producers of electrical missile support equipment are opening a manufacturing facility in Burbank, Calif. . . . A new firm—**Production Machinery Inc.**—has been organized at Des Planes, Ill., to import and market West German metalworking machinery. . . . **Applied Electronics Corp.** of New Jersey has moved into a 4000 square foot plant in Metuchen, N.J. . . . and last week, **Reeves Soundcraft** stock moved up to the New York Stock Exchange for trading . . .

Purchase of **Applied Science Corporation of Princeton,** N.J., for $3.8 million has been contracted by **Electro-Mechanical Research Inc.,** Sarasota, Fla. The agreement is still subject to stockholder approval. Both firms are in telemetry field.

Corvus Is Launched Successfully

POINT MUGU, CALIF.—*Corvus,* an air-to-surface missile for use by carrier-based Navy aircraft, has been flown successfully for the first time at the Pacific Missile Range test center.

The Navy, in announcing the July 18 firing, ended almost two years of speculation with the announcement that *Corvus* has a pre-packaged liquid engine. However, the propellant ingredients were not disclosed. Before the announcement, it had been generally believed that *Corvus* has a solid propellant system.

Temco Aircraft Corp. of Dallas, Tex., has the contract for development. **Thiokol** is providing propulsion. *Corvus'* guidance system will home on enemy radar. **Texas Instruments** and **W. L. Maxson** are working on electronic components.

The test vehicle was fired from a Navy A-40 Skyhawk jet fighter over a sea test corridor just west of here against an undisclosed target. *Corvus* is designed for attacking heavily defended areas, including surface ships.

Hearings Start on Nuclear Plane

by Erica M. Karr

WASHINGTON—Political, economic, military and technical questions are all wrapped up in development of the nuclear-powered aircraft, the Joint Atomic Energy Committee was told when it reviewed at public hearings, as M/R went to press, the 13-year old ANP program. This was the first public hearing after almost 50 executive sessions in the last 12 years.

The political question simply stated is: "What would be the effect of a Russian flight of a nuclear-powered aircraft on world politics?" Russia's big 6-or-8-engined Bounder, which has been seen flying, is—or could be—a prototype for a nuclear-powered aircraft.

Economic questions are also relatively simple. Estimates by Dr. Herbert York, Director of Research and Engineering at the Pentagon, indicate that it may cost as much as $10 billion to develop a weapon system. Congress and the American people will have to decide whether the investment is worth making. So far, over the last 13 years about $1 billion has gone into development of the nuclear power plant.

• **Varied potential**—From a military standpoint, what would the investment buy? Its potential for many uses has been discussed frequently. Basically, however, the Air Force—which has supported the program over the years—conceives of CAMAL (continuous air alert and missile launch and low-level penetration) as providing the post-attack reconnaissance capability not available from any other type of equipment. Without it, the claim is made, the U.S. would be blind once an all-out attack were launched.

Other potential uses include continuous air alert (obviously outside the borders of Russia) to gather information to be used by *Polaris* submarines, *Minuteman*, *Atlas* and *Titan* bases after an attack is launched, or as a virtually invulnerable mobile missile warehouse/launcher. The Air Force feels such an airplane has as much ability to hide in the vast expanse of air as a *Polaris* submarine has to hide in the ocean.

• **Hold-ups**—What are the technical questions holding up the program at this time? Perhaps the most important one is the engine. The Air Force position is that the direct cycle reactor under development at **General Electric** is far enough advanced at this time to warrant building two prototype aircraft so that problems of logistics, ground handling, crews, ground and air safety can be proved out while the engine is perfected or improved. This is under the current AF doctrine of concurrency; The Air Force estimates that if a flight test vehicle program is initiated now, actual flight reactor tests could get under way within 3½ to 4 years.

Actually, the current reactor is a relatively crude one with its metallic core. A later reactor at GE would have a ceramic core follow. The other engine (indirect cycle) at **Pratt & Whitney** is merely described as a more advanced concept. The Navy wants a turboprop engine. AF is talking in terms of a turbojet.

The Pratt & Whitney engine is two to three years behind the engine a[t] GE. Here the question is: Does th[e] U.S. want to buy time or does it wan[t] to wait for the engine?

Air Secretary James Douglas an[d] Air Force Chief of Staff Thomas D[.] White are urging the fly-early program[.] They argue that the U.S. must start t[o] fund the flight program now if an oper[-]ational aircraft is to be available whe[n] it is needed.

"You don't start with your fina[l] product," said one official in the pro[-]gram. "You start with your curren[t] capability."

GE Sees Promise in 'Tunnel Diode'

SCHENECTADY—A significant new development in semiconductor devices—the "tunnel diode"—shows promise of outstripping its older brother, the transistor, in many applications. **General Electric,** at work over a year in a concentrated research program, has just announced that limited quantities of experimental samples will be available within a few months.

According to Dr. Guy Suits, GE v-p and director of research, the tunnel diode offers considerable advantage over transistors in several areas. First, energy motion within the device takes place at the speed of light in contrast to the relatively slow speed of electrical charge carriers in transistors. The resultant high-frequency response will allow switching speeds 10-100 time[s] faster than transistors. Also, oscilla[-]tion frequencies higher than 2000 m[c] have already been obtained; 10,000 m[c] are expected in the near future.

The tunnel diode—which operate[s] on a different principle and is smalle[r] than a transistor—is little affected b[y] environmental conditions. It operate[s] at 650°F and is more resistant t[o] nuclear radiation by a factor of 100[0] to one.

Dr. Suits predicts that before lon[g] the device should find its way int[o] many applications including high-spee[d] computers, television and communica[-]tion equipment, nuclear controls, satel[-]lites and space vehicles.

COMPLETE transmitter, no larger than a half-dollar, contains one variable and tw[o] fixed ceramic capacitors, a coil, and tunnel diode (in "can" at center of device)

propulsion engineering

Petroleum industry arguments . . .

which urge long-range plans to continue use of petroleum-derived fuels instead of jumping into synthesized "pure" compounds emphasize the high performance of available liquid hydrocarbons, their low cost and abundance. The whole industry's argument is summed up by M. E. Conn and W. G. Dukek, **Esso Research and Engineering Co.** Their argument makes sense. It is unfortunate that they represent a major petroleum company, as this might be viewed as detracting from the impartiality of their comments. However, regardless of their industry affiliation, what they say will find ready agreement among chemists, missile designers, military planners, and economists.

Only the coal industry can object . . .

to the Conn-Dukek proposal to meet our future missile fuel needs by deriving hydrocarbon fuels from petroleum streams. This eliminates coal tar starting materials and intermediates that are being examined as sources for the so-called "pure chemical" fuels. The end results often will be the same: Commercially acceptable chemical compounds which could have been derived either from coal or petroleum. The difference is that by processing petroleum streams, chemists eliminate many steps and cut costs. Besides, the petroleum fractions already are passing through refineries, and some of them even are wastes.

Strongest point in the argument . . .

is that there really is a difference between theoretical performance and attainable performance of fuels. Some inorganic propellant systems offer higher theoretical impulse and heat content than the polycyclic naphthenes that Conn and Dukek discussed at the recent Society of Automotive Engineers meeting in New York. However, they point out, the attainable performance depends on many other factors: thermal stability, vapor pressure, combustion characteristics, viscosity-temperature relationship, density, specific heat. Also, ease and safety of handling are important factors to consider in choosing a fuel. Conn and Dukek say—and, by their own means, prove—that liquid hydrogen is all-around best, hydrocarbons are in second place, next down the scale is hydrazine. Metal slurries and metal hydrides are tied for the bottom of the list.

Logistics arguments . . .

are just as impressive as are the arguments relating to performance, handling ease, etc. Conn and Dukek say these arguments are even more important. They point out that the Air Force believes that within five or ten years its requirement for high performance fuels for air-breathing supersonic missions alone may reach 100 million gallons/yr. We'll need 25 million gallons of liquid rocket fuel just for testing and development by 1965. The advent of multi-million pound thrust engines, using fuel at 10,000 lb/sec., could more than quadruple the needs. The Esso R&E scientists believe that only the nation's huge petroleum refineries can guarantee a steady supply of fuel at low cost.

The picture is not complete . . .

without a look at the major disadvantage—if the word applies—of the polycyclic naphthenes. Since these are actually petroleum fractions cut out of refinery streams, and not compounds synthesized especially for the purpose, the petroleum industry cannot guarantee absolute uniformity or constant quality. However, test procedures are available to match the fuel to the engine or mission. Besides, Conn and Dukek point out: "Even the basically superior uniformity of pure compounds may be difficult to realize in practice." If enough meaningful specifications are developed and applied to manufacturing operations, they believe the batch-to-batch uniformity or petroleum fraction fuel can be controlled to a sufficient degree.

west coast industry . . .

By FRED S. HUNTER

Douglas Aircraft Co.'s ALBM (air-launched ballistic missile) contract is a study contract, but there is little doubt it will develop into a research and development contract before too long. Personnel assignments made to the project make it plain Douglas is confident R&D funding will follow without mishap. J. A. Gorgenson, heading up the program, has been appointed weapon systems manager, reporting directly to Leo A. Carter, vice president and general manager of the Santa Monica division. Both Gorgenson and Victor E. Crosley, assistant weapon systems manager, were brought over to Santa Monica from the El Segundo division originally to participate in preparation of the proposal which won the study contract for Douglas.

Strong projecting engineering group . . .

also has been established by R. L. Johnson, Santa Monica division missiles and space systems chief engineer. J. C. Solvason, former project engineer on the *Sparrow* series, is chief ALBM project engineer. His aides: H. E. Bauer, a former *Thor* project engineer, on missile aspects; S. L. Gehring, with *Sparrow* II and *Thor* experience, on missile support equipment; C. E. Starns, who also has a *Sparrow* background, aircraft support.

One of Hughes Aircraft's most popular . . .

vice presidents, Clarence Shoop, is demonstrating a remarkable capacity for assuming added responsibilities. Shoop began his career with Hughes in 1947, mainly in the flying end. One of his early jobs was chief pilot. As Hughes Aircraft expanded into electronic activities, he became director of aircraft operations and flight test. Subsequently, he was put in charge of product reliability and elected a vice president, but still retaining flight test. The other day, when R. M. Russell resigned as vice president-sales and manager of the international division, Shoop took on the international division and on top of his other duties became responsible for Hughes Aircraft's activities outside the U.S. And in addition to wearing three hats at Hughes, he is air chief of staff for the California Air National Guard, an administrative job carrying the rank of major general.

For the sake of secrecy the U.S. may test . . .

some of its missiles at the Woomera test range in Australia. We've had a team of experts there looking the place over. Situated in the Great Desert of Western Australia, the Woomera range was recently extended to a length of 1250 miles, and next year Britain will use it to test its 1500-mile *Blue Streak*. Cape Canaveral is close to a populated area and on flat ground. Vandenberg and Point **Arguello** are better, but the other day a cabin cruiser with a dead engine drifted within the three-mile limit off Arguello without being detected. A railroad cuts through Vandenberg and various roads bisect the region.

Only real secrecy the U.S. has ever . . .

achieved in rocket firings was with three Project *Argus* nuclear rockets fired from a Navy ship and exploded more than 300 miles above the South Atlantic last summer. Partial secrecy was managed in firing hydrogen devices above Johnston Island in the Pacific, but the flash was visible in Honolulu. In contrast, Russia's launching areas for long-range missiles are at Kyzyl Kum, near the Aral Sea, and at Kapustin Yar, 60 miles south of Stalingrad. Known impact areas are those east and north of Yakutsk in northeastern Siberia and in the Anadyr region even farther east.

They let no grass grow under their feet . . .

at **Lockheed.** No sooner had Lockheed acquired the **Puget Sound Bridge & Dredging Co.** than its missiles and space division brought the new Seattle subsidiary into a joint venture bid for the design of ground facilities for the *Minuteman.*

contracts

ARPA

$4,046,119—**International Telephone & Telegraph Co.**, for ground-based communication stations for Project *Courier*.

$3,614,515—**Philco Corp.**, for Project *Courier* communications equipment.

$1,283,740—**Radiation, Inc.**, for Project *Courier* ground-based antennas.

NAVY

$23,500,000—**Pratt & Whitney Div. United Aircraft Corp.**, for continued work on the J-52 turbojet engine used in planes and missiles.

$4,500,000—**Northern Ordnance Inc.**, Minneapolis, for engineering and production of *Tartar* surface-to-air missile launching systems.

$2,400,000—**Beech Aircraft Corp.**, Wichita, Kan., for design, development, fabrication and production of a missile target system, including one prototype target.

$2,000,000—**Packard Bell Electronic Corp.**, for design and production of the ancillary test console subsystem, a portion of the *Polaris* automatic checkout and readiness equipment (subcontract from **Lockheed Missile and Space Div.**).

$300,000—**Arnoux Corp.**, Los Angeles, for design, fabrication and installation of telemetry data, receiving and recording station to be installed at Point Mugu.

$200,000—**Aeronutronic Systems, Inc.**, Glendale, Calif., for additional Pacific missile range instrumentation study.

AIR FORCE

$42,101,389—**Federal Electric Corp.**, Paramus, N.J., for operation and maintenance of the Distant Early Warning Line.

$1,706,469—**Convair Astronautics Div., General Dynamics Corp.**, San Diego, for installation of a new improved *Azusa Mark II* missile tracking system.

$794,200—**Lumen, Inc.**, Joliet, Ill., for miscellaneous projectors, instruction books and progress reports (missile support equipment).

$600,000—**Coleman Engineering Co., Inc.**, Torrance, Calif., for design and construction of missile ground handling equipment (two contracts, one for lift and transportation trailers and workstands for *Hound Dog* air-to-surface missile and the other for a missile nose cone transportation trailer for **Avco Corp.**).

$328,630—**Alabama Bridge & Iron Co.**, Talladega, Ala., for trailer and lift for aircraft and missile engines.

$192,500—**Food Machinery & Chemical Corp., Westvaco Chlor-Alkali Div.**, N.Y., for 110,000 lbs. of unsymmetrical dimethyl hydrazine for evaluation studies as a rocket fuel.

$158,743—**Recordak Corp.**, N.Y., for printer-process viewers, microfilm type (missile support equipment).

$107,640—**Consolidated Systems Corp.**, subsidiary of **Consolidated Electro-dynamics Corp.**, Monrovia, Calif., for high-speed digital data recording system.

$82,491—**Bell & Howell Co.**, Chicago, for 320 amplifiers with cover for use in 16 mm motion picture sound projectors (missile support equipment).

$80,284—**Leeds & Northrup Co.**, Philadelphia, for precision potentiometers and accessories (in addition to a previous award of $233,000.).

$43,430—**Pilotless Aircraft Div., Boeing Airplane Co.**, Seattle for technical data for *IM99A* missile components.

$29,911—**The Houston Fearless Corp.**, Los Angeles, for replacement parts for A-9 and A-11 processing machines (missile support equipment).

ARMY

$7,132,408—**Blaw-Knox Co., Power Piping Div.**, Pittsburgh, for *SM-65* launcher facilities, Fairchild AFB, Spokane, Wash.

$1,900,000—**Martin Co.**, Orlando, for electronic equipment used in air defense coordination systems.

$1,891,532—**Western Electric Co., Inc.**, N.Y., for *Nike* spare parts and components (six contracts).

$1,447,333—**C. H. Leavell & Co.**, El Paso, Tex., for construction of guided missile maintenance shop at Pueblo Ordnance Dept., Pueblo, Colo.

$1,064,969—**Fred R. Comb Co.**, Minneapolis, for construction of SAC missile facilities located at Minot AFB.

$958,942—**Technical Construction Inc.**, Mobile, Ala., for phase II equipment for preflight evaluation laboratory at Redstone Arsenal.

$400,000—**Parabam, Inc.**, Hawthorne, Calif., for production of astrodome type shelters for the protection of missile tracking instruments.

$397,566—**Norris-Thermador Corp.**, Los Angeles, for T-238 rocket motor assembly.

$384,911—**Emerson Electric Co.**, St. Louis, for facilities for production equipment of *Little John* program.

$242,896—**Whaley Co., Inc.**, Birmingham, Ala., for construction of propellant development facilities at Redstone Arsenal, Huntsville.

$199,523—**Redding & Co., Inc.**, Baltimore, for construction of special AAA *Nike* missile field maintenance shop at Fort George C. Meade.

$188,037—**Emerson Electric Manufacturing Co.**, St. Louis, for pre-production engineering studies for rockets.

$141,245—**Orlando Welding & Piping Contractors of Orlando**, Fla., for construction of guided missile liquid fuel facilities at Cape Canaveral Missile Test Annex, Patrick AFB.

$129,224—**Douglas Aircraft Co., Inc., Charlotte Ordnance Missile Plant**, Charlotte, N.C., for *Nike* spare parts and components.

$100,000—**The Siegler Corp.**, for the manufacture of special electronic test gear for the *Sergeant* missile (subcontract from **Sperry Utah Engineering Co.**, subsidiary of **Sperry-Rand Corp.**).

$99,650—**Atlantic Research Corp.**, Alexandria, Va., for solid-propellant rocket sustainer motor for automet test vehicle.

$93,428—**Western Electric Co., Inc.**, N.Y., for semiconductor diode devices.

$92,004—**Teletronics Laboratory, Inc.**, Westbury, L.I., N.Y., for various type oscilloscopes.

$65,000—**Bowmar Instrument Corp.**, Ft. Wayne, Ind., for the manufacture of a miniature servo-package to be used in the guidance system of the *Pershing* missile.

$54,502—**The Hickok Electrical Instrument Co.**, Cleveland, for signal generators.

$54,179—**Southwestern Industrial Electronics Co., Div. of Dresser Industries, Inc.**, Houston, for design of servo amplifiers for Redstone Arsenal.

$51,188—**Gilfillan Brothers, Inc.**, Los Angeles, for research work for twelve months to survey guided missile design practices including technical reports.

$49,435—**Ampex Corp.**, Los Angeles, for video tape recorder and head assemblies.

$39,873—**Midwest Research Institute**, Kansas City, Mo., for research and development on loading missiles due to atmospheric turbulence and wind shear.

$28,780—**National Research Associates, Inc.**, College Park, Md., for design, construction and demonstration of an operating mock-up of a minimum ground pressure vehicle.

$27,516—**Heiland Div., Minneapolis Honeywell Regulator Co.**, Denver, for six direct writing oscillographs.

when and where

JULY

The Denver Research Institute of th[e] University of Denver, 6th Annua[l] Symposium on Computers and Dat[a] Processing, Stanley Hotel, Estes Park, Colo., July 30-31.

AUGUST

Institution of Investigation of Biologica[l] Sciences, Sponsor: Air Force Offic[e] of Scientific Research, Aeromedica[l] Div., World Health Organization, Montevideo, Uruguay, Aug. 2-7.

Association of the U.S. Army, Annua[l] Meeting, Sheraton-Park Hotel, Washington, D.C., Aug. 3-5.

American Astronautical Society, Secon[d] Annual Western Regional Meeting, Ambassador Hotel, Los Angeles, Aug. 4-5.

William Frederick Durand Centennia[l] Conference, The Problems of Hypersonic and Space Flight, Stanfor[d] University, Stanford, Calif., Aug. 5-7.

Institute of Radio Engineer's Professiona[l] Group on Ultrasonics Engineering, First National Ultrasonics Symposium, Stanford University, Stanford, Calif., Aug. 17.

Institute of Radio Engineers, Wester[n] Electronic Show and Conventior[n], Cow Palace, San Francisco, Au[g.] 18-21.

AFOSR/Propulsion Research Division Directorate of Aeronautical Science[s], Office of Naval Research, Office o[f] Ordnance Research & National Aeronautics and Space Administration, Symposium on "The Dynamics o[f] Ionized Cases," Northwestern University, Evanston, Ill., Aug. 24-25.

American Rocket Society, Gas Dynamic[s] Symposium, Northwestern University, Evanston, Ill., Aug. 24-26.

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

Army-Navy Instrumentation Program, Annual Meeting, Symposium and Industry Briefing, Statler Hilton Hote[l], Dallas, Tex., Aug. 31-Sept. 2.

International Astronautical Federation, 10th Annual Congress, Churc[h] House, Westminster, London, Au[g.] 31-Sept. 5.

SEPTEMBER

Air Force Office of Scientific Researc[h] and General Electric Company'[s] Missile and Space Vehicle Department, Conference on Physical Chem[istry]

istry in Aerodynamics and Space Flight, University of Pennsylvania, Philadelphia, Sept. 1-2.

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

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

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

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

astrument Society of America, 14th Annual Conference and Exhibit, Chicago Amphitheatre, Chicago, Sept. 20-25.

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

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

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NATO's Strength Backs West Berlin

While the ministers of the world's major powers debate the future of Berlin, a problem which is unavoidably bound to the future of all of Europe, General Lauris Norstad goes quietly and almost relentlessly about his job of strengthening the NATO forces which keep the Geneva meetings a debate and not an ultimatum.

The sword and the shield of NATO have become so legendary in the ten years of their existence that it now seems almost impossible to separate them from the national forces of the NATO nations. France, Britain and the United States are the Western occupying powers which guarantee the freedom of West Berlin. West Berlin, strictly speaking, is not part of NATO, even though West Germany is. Nevertheless, NATO is on record as supporting the position of the occupying powers and—while an attack on West Berlin nationals per se *would not* be an attack on NATO, an attack on any of the troops of the three Western powers in West Berlin *would be*. So, inevitably, NATO links itself to the freedom of West Berlin and publicly recognizes that encroachment there is no different than encroachment on any other free territory in Europe.

This fact rarely if ever comes out in the discussions which are held between the ministers of the East and the West, but it certainly cannot be far from the minds of Soviet leaders that in the Berlin situation Russia faces not just the three occupying powers but 15 allied nations and probably the greatest military force the Free World has ever seen in peacetime.

The sword forces of NATO are the great retaliatory forces—the big bombers of SAC and Britain's Bomber Command, plus the atomic Navy forces in the Atlantic. Just added—and NATO-committed—are the four squadrons of *Thor* intermediate range ballistic missiles now operational or becoming so in England, an addition of 60 atomic warheads aimed at 60 predetermined targets (see page 11). Joining them within a year or so will be two squadrons of *Jupiter* IRBM's stationed in Italy. And a little later two more *Jupiter* squadrons—one each in Greece and Turkey, most likely. These latter four will be under General Norstad's actual command as Supreme Allied Commander Europe and will comprise the first actual NATO atomic force. (Other nuclear forces, while supporting NATO, are under the command of their national leaders.)

The shield forces of NATO are 22 divisions of ground forces strung from Turkey in the south to Norway in the north, with the heavy concentration in the center. Many of these ground units are equipped with nuclear missiles and rockets, more are becoming so. They are supported, again from Turkey to Norway, by fighter planes many of which also carry atomic weapons.

The NATO goal for this shield force is 30 divisions; while not more important than the retaliatory forces, it certainly is no less. These 22 divisions, as one official expressed it, give NATO political and military flexibility. It is the force the people of the NATO countries can see and know about, watch flying overhead or wheeling through maneuvers. It is their visible protection against limited aggression. Like the sword force, its ability to react must be immediate and effective. And it is NATO doctrine that any unit should have a nuclear delivery capability if that is necessary to the unit's mission.

"This shield force of 22 divisions," the official said, "represents the difference between all or nothing—the difference between all-out war and knuckling under to Soviet demands otherwise."

The forces of the three Western Powers—France, Britain and the U.S.—in West Berlin are negligible, and it is the shield force of NATO which gives strength to the arguments of the Western Ministers in Geneva.

This shield force General Norstad continues to build up with inflexible will. A unit of the Italian army recently was equipped with the nuclear-armed *Honest John* rocket and has been trained by its U.S. allies to use it expertly. The Greek Air Force has been practicing for months in the delivery of atomic bombs by fighter planes and will be nuclear-equipped as soon as bi-country agreements can be worked out. Similar negotiations are underway with Turkey. New weapons supplant old as fast as they can be procured.

No one talks about NATO in the Berlin situation. It is just there, providing a great measure of the strength from which the ministers of the West maneuver.

Clarke Newlon