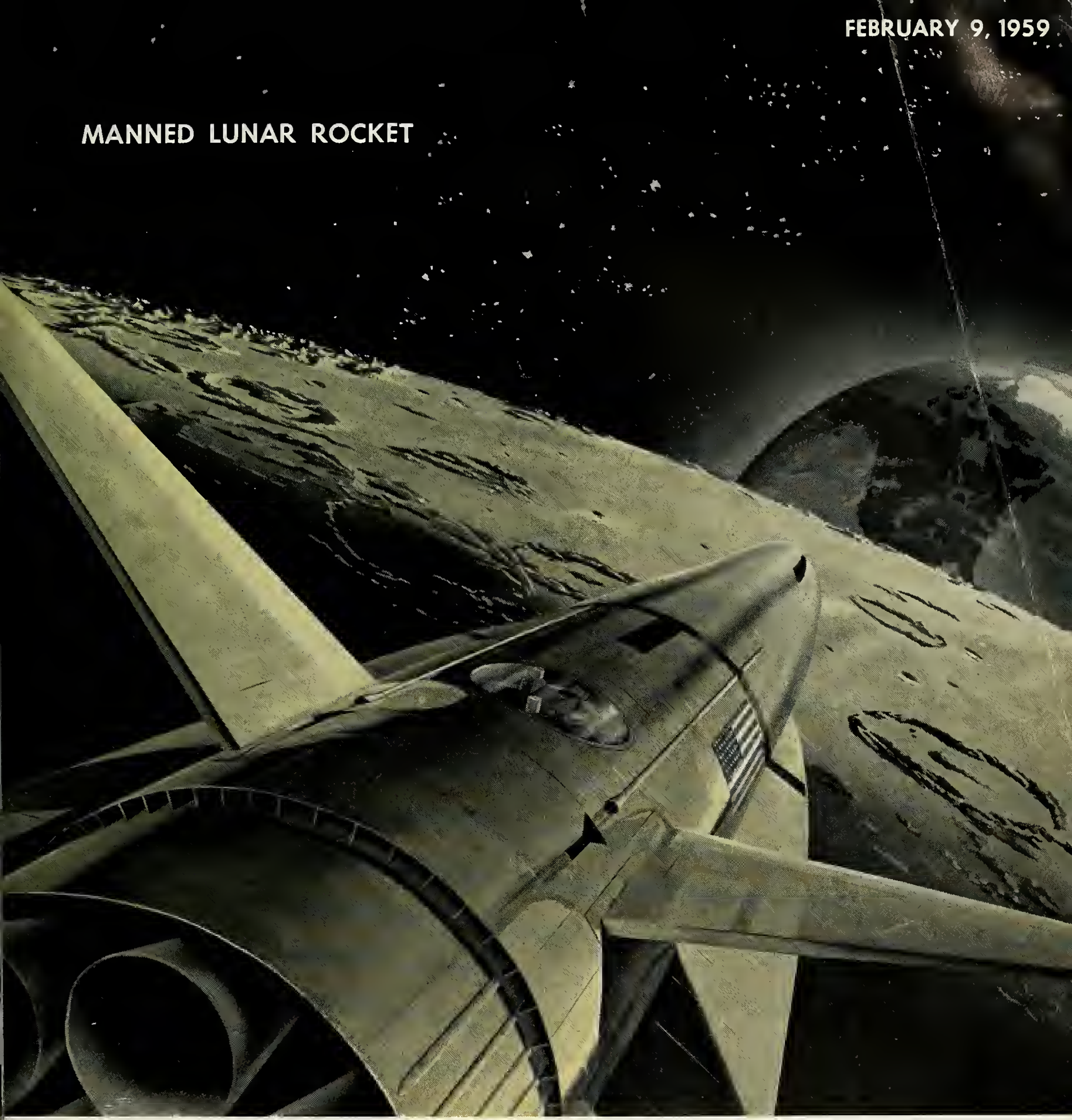
FEBRUARY 9, 1959

MANNED LUNAR ROCKET



missiles and rockets

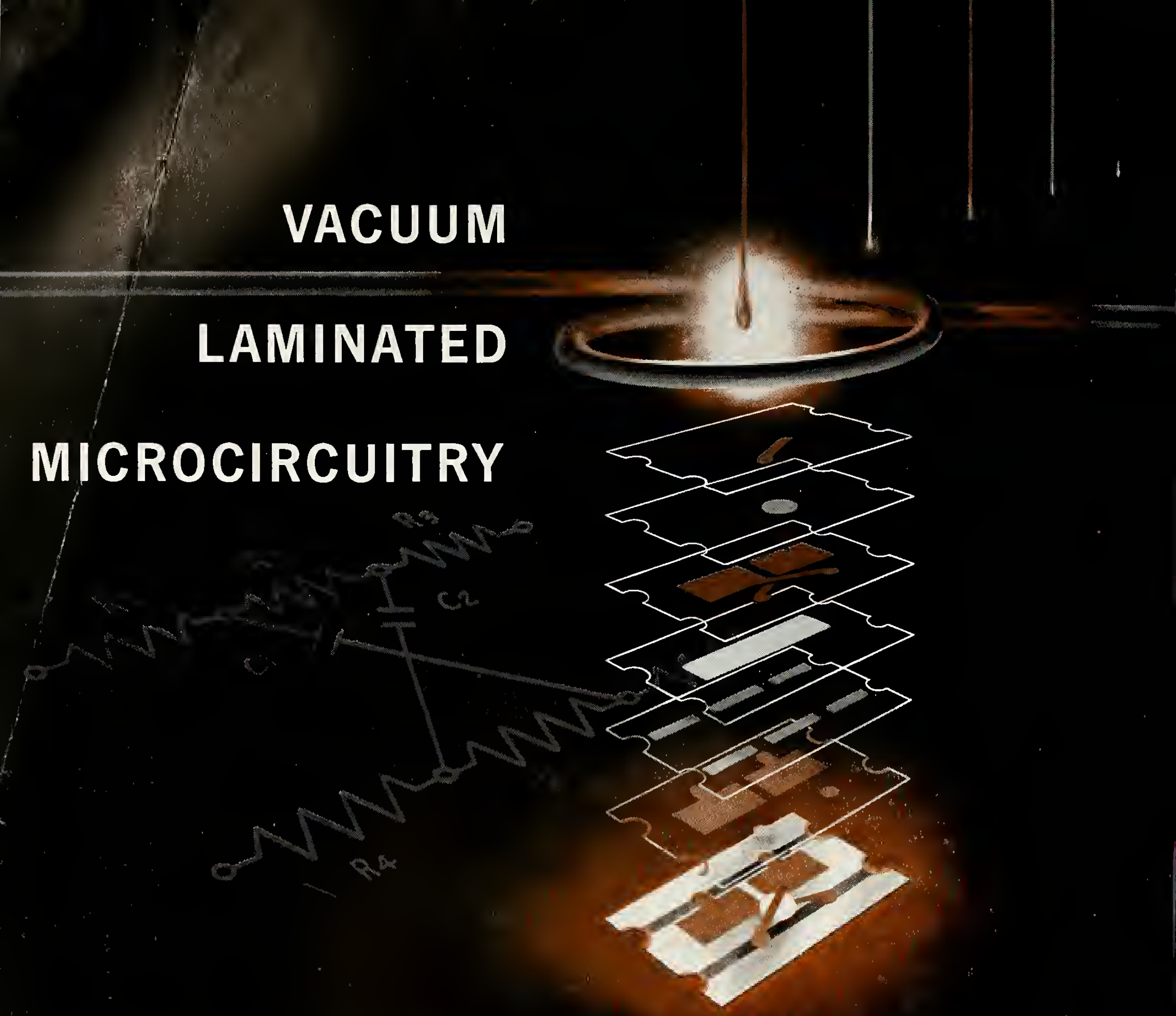
MAGAZINE OF WORLD ASTRONAUTICS

Annual

ELECTRONICS AND GUIDANCE ISSUE

AN AMERICAN AVIATION PUBLICATION

VACUUM LAMINATED MICROCIRCUITRY



Setting the pace in the field of evaporated film technology, Servomechanisms, Inc.'s Research Laboratory is developing a whole new concept of component and subsystem design under sponsorship by the U.S. Air Force, the Army Signal Corps and the Office of Naval Research.

As a result of new materials research by SMI, thin-film Magnetic, Conducting and Dielectric elements which exhibit highly controllable electrical and physical characteristics are being produced now by high vacuum thermal evaporation techniques utilizing electron bombardment.

These micro-miniaturized elements improve system and component reliability while providing a significant reduction in size and weight. This, plus the ability to withstand extreme environmental exposure, makes them invaluable in the design of digital computers, electronic communications equipment, missile controls and digital transducers for space vehicles, satellites and other advanced systems.

New system analysis and design has progressed in step with these advances in materials and techniques. SMI's Research Laboratory would welcome the opportunity to discuss and propose solutions to your microcircuitry and advanced systems problems.

SMI SERVOMECHANISMS INC.

GENERAL OFFICES
12500 Aviation Boulevard, Hawthorne, California

SUBSYSTEMS DIVISION
Hawthorne, California

MECHATROL DIVISION
Westbury, L.I., New York

SPECIAL PRODUCTS DIVISION
Hawthorne, California

RESEARCH LABORATORY
Goleta, California

The products of SMI are available in Canada and throughout the world through Servomechanisms (Canada) Limited, Toronto 15, Ontario to the one engineer in ten

who achieves greatest professional satisfaction from missile test and analysis

we invite an investigation

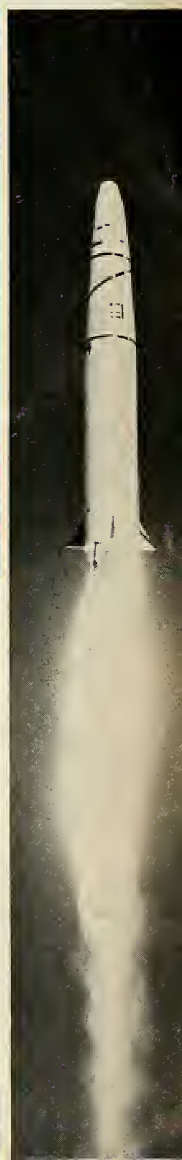
of the opportunities for **on-the-spot participation**

in this country's major missile test and space probe activities

at Cape Canaveral with Pan Am.*

GUIDED MISSILES RANGE DIVISION

PATRICK AIR FORCE BASE, FLORIDA



** The Guided Missiles Range Division of Pan American World Airways has prime responsibility for management, operation and maintenance of the 5000-mile Atlantic Missile Range. This responsibility and the division's dynamic growth create unique opportunities for the high level electronics engineer, physicist or mathematician in the pioneer arts of missile range management, operation, maintenance and test data collection and reduction.*

Please address your resume in confidence to Mr. J. B. Appledorn, Director of Technical Employment, Pan American World Airways, Inc., Patrick Air Force Base, Cocoa, Florida, Dept. B-4.

Circle No. 35 on Subscriber Service Card.

Circle No. 1 on Subscriber Service Card.

missiles and rockets Vol. 5, No. 6, Feb. 9, 1959

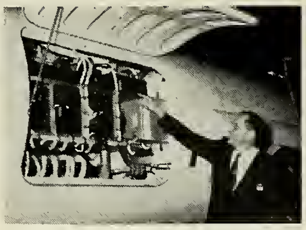
Published every week by American Aviation Publications, Inc., 1001 Vermont Ave., N.W., Washington 5, D.C. Printed at the Telegraph Press, Harrisburg, Pa. Second class postage paid at Washington, D.C., and at additional mailing offices. Copyright 1958, American Aviation Publications, Inc.

Subscription rates: U.S., Canada and Postal Union Nations—1 year, $8.00; 2 years, $12.00; 3 years, $14.00. Foreign—1 year, $20.00; 2 years, $30.00; 3 years, $40.00. Single copy rate—$.75. Subscriptions are solicited only from persons with identifiable commercial or professional interests in missiles and rockets. All subscription orders and changes of address should be referred to: the circulation fulfillment department.

missiles and rockets

MAGAZINE OF WORLD ASTRONAUTICS

COVER: Nortronics conception of manned spacecraft circling the moon.



GUIDANCE for *Thor* pointed out by A-C Spark Plug's Dr. James C. Bell at Douglas plant tour.

EIA'S President David Hull talks frankly on future of electronics.

CHRYSLER showed *Jupiter* assembly line last week. *Redstone* line is in background.

INTERNAL *Thor* model is demonstrated by Donald Douglas, Jr., and AF Lt. Col. Greene at press meeting.


OUR
BUSINESS IS
CONTROLS
FOR
THE FULL
SPECTRUM OF
PROPULSION SYSTEMS

The Age of the Electron

As we experience the first thrills of space exploration and receive new information about the Universe surrounding us, we become conscious of new problems and of new potential solutions that underline the ever-increasing penetration of electronics into all phases of our daily lives, of our industrial endeavors and of our scientific research.

We might trace the range of activities of radio engineers since the establishment of the Institute of Radio Engineers in 1912. Marconi had established radio communication across the Atlantic and even to Hawaii using wavelengths of 1000 to 10,000 meters; but it was evident that shorter waves would lead to much higher radiation efficiencies.

The invention of the electron tube and its perfection by engineers who understood the flow of free electrons in vacuum under the effect of controlling electrodes led to large power generation at medium wavelengths. This made radio available for public entertainment as well as for air navigation and control.

The new classes of klystrons, magnetrons, and, finally, traveling wave tubes constitute ingenious exploitations of the interactions between electrons and electromagnetic fields where the electron inertia as a particle characteristic plays an important role.

In the meantime, the knowledge gained by the study of crystal structure and its application to semiconductors . . . has led to the new field of so-called solid state devices, the equivalent of certain types of electron tubes. The transistor is the most appealing commercial end product since it will permit miniaturization of many electronic circuits and systems for applications where either space or weight or both become critical factors. The instrumentation in satellites can be made not only light but much more reliable because of the rugged characteristics of these tiny wafers of semi-metals.

We are also returning to the study of discharge phenomena, which were first explored about 100 years ago. This time we call the ionized gases plasma and are interested in their properties, in propagation of signals through them, and in aerodynamic motion of bodies through them.

As early as 1902, O. Heaviside in England and H. E. Kennelly at Harvard University had independently put forth the hypothesis that the earth was surrounded by an ionized layer which reflects the long radio waves, the only ones with which experience had been established at that time. Today we have penetrated this ionosphere and have, indeed, preliminary information from much greater distances indicating other layers of intense radiation.

Additional interest in plasma physics is linked to the possibility of controlled nuclear fusion. Approaches to this potentially vitally important subject include studies of plasma generation, control by magnetic fields, acceleration by electric fields, and creation of exceedingly high temperatures so as to approach the state of total ionization which appears to be characteristic of the sun's atmosphere. This new field is designated as magneto-hydrodynamics and is also linked to endeavors to produce ion propulsion which might be of significance for space vehicles in the highly rarified strata of outer space.

We are, indeed, approaching rapidly the age of the electron, utilizing its swarming drift in conductors to signify electric power for useful work, for the control of processes, for the generation of heat; employing electron beams in vacuum to produce and amplify oscillations up to the highest imaginable frequencies for the transmittal of intelligence, for the reception of information, for service in entertainment; exploiting various levels of local ionization in solids not only for similar purposes but also for high speed computation; and now attempting to force submission to our control of completely ionized matter, whatever its original state might be.

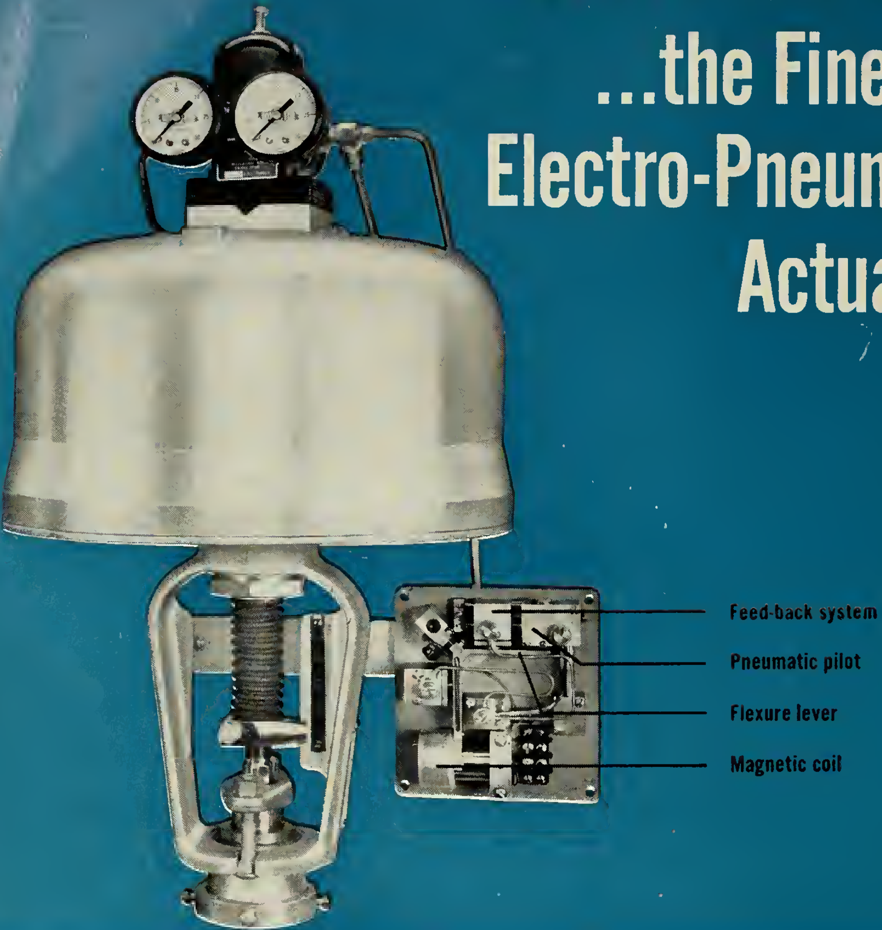
In all of these endeavors we are dealing with the inanimate elements and can be sure of their performance once we have deciphered the laws governing their action. We are yet far, far from similar capabilities with the living aggregates; we know that there, too, ionization and electron transitions are important but we have very little knowledge that would permit control.

DR. ERNST WEBER
President, Polytechnic Institute of Brooklyn;
President, Institute of Radio Engineers


solving critical control problems for space-age progress
WHITTAKER GYRO
BRUBAKER ELECTRONICS
DATA INSTRUMENTS
ENGINEERING SERVICES
WHITTAKER CONTROLS
NUCLEAR INSTRUMENTS
TELECOMPUTING CORPORATION
915 NORTH CITRUS AVENUE
LOS ANGELES 38, CALIFORNIA

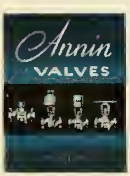
 Circle No. 39 on Subscriber Service Card.

Now! From Annin ...the Finest in Electro-Pneumatic Actuators



Annin's Model 30,000 transducer, coupled with the Annin Domotor, gives you greater range of adjustment, unequalled stability, and exceptional dynamic characteristics

The Model 30,000 has been developed to provide process engineers with a practical transducing element for converting a small electrical signal to an accurate and stable pneumatic output pressure. It embodies only four basic sub-assemblies, which minimize motion and wear, simplify adjustment and installation. The Model 30,000 features full-scale zero adjustment and a wide range of span settings for split range and sequencing applications. Absence of complex components, together with minimum installation,contribute to low maintenance. Linearity and accuracy reach a new high in electro-pneumatic transducing with the Model 30,000. *Technical data on request*



Send for your copy
of Annin's new Catalog 1500-D

Annin VALVES

THE ANNIN COMPANY Division of The Annin Corporation
1040 S. Vail Ave., Montebello, California

Circle No. 15 on Subscriber Service Card.

INCONEL*
FAMILY

PRECISION FORGINGS PRODUCED BY

CANADIAN STEEL IMPROVEMENT

FOR HIGH TEMPERATURE

AERONAUTICAL APPLICATIONS

- **guaranteed grain size control**
- **precision tolerances maintained**
- **consistent quality assured**
- **reduced machining costs**
- **excellent stress-rupture properties**

Modern high speed flight has cleared the sound barrier . . . penetrated the thermal thicket. Advanced turbojets, rockets and ramjets are producing unbelievable bursts of power.

The problem: HEAT . . . heat so intense that most metals can't withstand prolonged stress.

The solution: INCONEL family . . . because Inconel wrought alloys can withstand extreme stresses in high temperature aeronautical applications.

Canadian Steel Improvement Limited has pioneered many new developments in precision-forged Inconel parts for modern aircraft. By producing Inconel parts to extremely close tolerances with an excellent surface finish, machining time is greatly reduced.

The result: Precision-forged blades and close-to-form discs of the finest possible quality at the lowest possible cost consistent with maximum stress-rupture properties for high temperature service in modern high thrust gas turbine engines.

For complete information about Inconel parts for aeronautical applications, consult Canadian Steel Improvement Limited, 289 Horner Avenue, Toronto 14, Canada or their representative,

C. F. Russell Company, Inc.
Bay Shore, N.Y.
Newington, Conn.
Arcadia, Calif.
Alexandria, Ky.
Catonsville, Md.
Alamonte Springs, Fla.

**T.M. Registered The International Nickel Company*

CSI

CANADIAN STEEL IMPROVEMENT LIMITED

289 Horner Avenue, Toronto, Canada

Circle No. 2 on Subscriber Service Card.

NEW LOX TANKING COMPUTER SYSTEM

WITH 1/10% OVERALL ACCURACY

OTHER RECENT CONTROL PROJECTS BY LEONARD INCLUDE:

- PROPELLANT UTILIZATION COMPUTER
- TANKING COMPUTER CALIBRATOR
- LOX TANK LEVEL TRANSDUCER
- MACH NUMBER DEVIATION COMPUTER
- INDICATED AIR SPEED TRANSDUCER
- DRAG-RISE DETERMINATION SYSTEM
- INDICATED ALTITUDE TRANSDUCER
- PRESSURE RATIO COMPUTER

Please discuss your system requirements with our engineers.

LEONARD PASADENA

Wallace O. Leonard, Inc.
373 SOUTH FAIR OAKS AVENUE
PASADENA, CALIFORNIA
TELEPHONE SYCAMORE 2-7131
TWX-PASA CAL 7321

Circle No. 3 on Subscriber Service Card.

washington countdown

Conflicting reports . . . on U.S./USSR ballistic missile strength keep coming from Defense Secretary McElroy. Item: McElroy told reporters there would be only "one or two missiles" difference in U.S. and Russian stocks of war-ready ICBM's by the year's end. Item: He and Gen. Nathan F. Twining reportedly told the Senate Foreign Relations Committee behind closed doors this:

By 1962 . . . Russian strength (with U.S. numbers in parentheses) will be: ICBM's 1,000 (300); IRBM's 2,000 (135); bombers, 1,200 (1,750); Navy bombers, unknown (500); IRBM submarine-launched missiles, unknown (100).

By January, 1960 . . . Twining and McElroy told the Committee, Russians will outnumber US in ICBM's 300 to 10; and will have 750 IRBM's to our 75.

More money for research . . . was the plea made before Congress last week by Lt. Gen. Samuel E. Anderson, ARDC chief, who said $534 million had been chopped from his budget by the Administration. Anderson claimed it is needed in the vital areas of basic and applied research.

10 to 15 years . . . is NASA Deputy Administrator Dr. Hugh L. Dryden's estimate of how long it will take the United States to put a man on the moon. Members of the House Space Committee were surprised, since the summary of expert opinion in a recent Committee report indicated that this was possible within a decade. Rep. James G. Fulton (R-Pa.) replied that if it takes as long as Dryden thinks, "there'll be a man there saying 'nyet' when he arrives."

***Regulus II* termination . . .** was not just an economy move, according to Congressional testimony by Adm. Arleigh A. Burke. Rapid progress on *Polaris* was another reason. Answers came as Senators asked why cancellation after $290 million had been spent and there had been 23 successful flights. Was it prudent to cancel? In answer, the CNO said, "That's a good question, but it was prudent."

Further testimony . . . revealed what was termed "some minor sacrifice in range" of the first *Polaris* missiles. What was not explained was that this applies only to test vehicles and that *Polaris* missiles deployed to submarines in 1960 will have the designed range of 1500 miles. These operational missiles are designated A1-P. They will follow the current AX series and an A1-X series which will incorporate the guidance system. First full-scale test shots of the A1-P will be early in 1960.

***Polaris* follow-on . . .** program has not been announced but a number of possibilities are being considered. Navy said range could be doubled by lengthening the missile by 30 inches. Allegany Ballistics Laboratory is working on a double base propellant, while another area getting attention is an improved control system to eliminate gimballing.

What's cooking? . . . in the space kitchen was one question Senate Democratic leader Lyndon Johnson tried to get answered by ARPA and NASA officials appearing before his space committee. Later, after trying for an hour to get a clear definition of duties and responsibilities, he said: "What I want to know is, who is chief cook in the space kitchen?" The question was tossed to Roy Johnson, Dr. Herbert F. York and DOD Missile Chief William M. Holaday. The collective answer—"Dwight D. Eisenhower."

Failure of *Discoverer* firing . . . at Vandenberg is being laid to premature firing of the second-stage engine which permitted acid to foul the entire launch vehicle. Because Mikoyan was in country, crew was under severe high-level pressure not to fire and fail—thus jittery. More recent *Titan* firing at Canaveral was scrubbed when go-no-go black box cut off engine in late stages of countdown.

Reliable information . . . indicates that the Russians do what they say they do, NASA's T. Keith Glennan told Congress last week, and there is no reason to doubt their claims about *Lunik* or any other scientific advance.

industry countdown

Radar beacons for *Titan* . . .
will be produced by ACF Industries, Avion Division, under latest contract for $200,000. Beacons are used to complement the ground radar during test flights of the ICBM and tracking of the nose cones.

Proposed merger . . .
of Sylvania Electric Products, Inc. into General Telephone Corp. will become effective about March 5, provided shareholders approve the plan at a Feb. 11 meeting.

Boeing is building . . .
an arc-discharge type tunnel that will test models at approximately 18,000 mph. Expected to be used in the *Dyna-Soar* program, test section of the tunnel will have a 40 inch diameter model positioning area. Tunnel—the eighth at Boeing—will be in operation by the end of the year.

***Discoverer* second stage skin . . .**
is made of a new high strength-to-weight ratio magnesium alloy by Dow Chemical. Three thin-wall tanks for the propulsion system are fabricated to a tolerance of ± .002 inch. Magnesium was selected for the *Discoverer* upper stage for combatting the expected high aerodynamic heating, wide temperature variation when the vehicle passes in and out of the earth's shadow, and for resistance of compressive buckling.

Explosive forming . . .
is still an art and not a science, warns the Propellex Chemical Div. of Chromalloy. Yet, this revolutionary forming method, under investigation by many companies, is expected to have widespread application in the missile industry. One "apparently" outstanding advantage of the explosive forming technique is the induced plasticity resulting in a 30% increase in material strength. Secret of the technique is the geometry of the explosive charge.

***Eagle* guidance system . . .**
consisting of an airborne radar, digital computer, and operator displays, is being sub-contracted by Bendix Aviation Corp. Sanders Associates, Inc., credited with development work on guidance systems for *Sparrow*, *Terrier* and *Hawk* systems, will design and develop part of the *Eagle's* command system.

Last *Regulus I* . . .
Number 514 in a line dating back to 1950, has been delivered from the Dallas plant of Chance Vought Aircraft to Pt. Mugu. Navy made 850 flights during the missile's test program—some as many as 18 flights before destruction.

Chance Vought wins . . .
contract to develop a system of standards in the fields of quality control and reliability for the *Polaris* after a competitive study by Bureau of Ordnance at numerous major aircraft firms. C-V will publish standards outlining the minimum quality control and reliability system requirements for each of the contractors on the *Polaris* program.

***Thor* weapon system . . .**
Contractor Technical Compliance Inspection (CTCI) is underway at Douglas Aircraft Company's Sacramento facility. It is the first such inspection to be performed on a ballistic missile.

***Hound Dog* and *Quail* . . .**
facilities construction at 11 U.S. and one Puerto Rican air base is expected to cost approximately $9 million—appropriations to be made during the current fiscal year. Bases and costs are: Eglin AFB, $650,000; Loring AFB, $1 million; Dow AFB, $800,000; Griffiss AFB, $800,000; Seymour-Johnson AFB, $650,000; Blytheville AFB, $650,000; WPAFB, $800,000; Robbins AFB, $700,000; Wurtsmith AFB, $800,000; Altus AFB, $750,-000; Minot AFB, $800,000 and Ramey AFB, Puerto Rico, $550,000.

Instrument planning contract . . .
for PMR has gone to Aeronutronics Systems, Inc., a subsidiary of Ford Motor Co. Runner-up for the six month study was a team led by the Canoga Division of Underwood Typewriter. Others associated with Aeronutronics are Cook Research Labs, Dunlap Associates, Eastman Kodak, and Page Communication Engineers.

No *Snark* cancellation . . .
or interruption of production is contemplated AF says. Secretary McElroy indicated in testimony before Congress that the Northrop program would be cancelled. Present contract for $114.5 million reportedly would carry production through 1960.

service now available locally...

from your Fabricator of Industrial Formica laminated plastics

Now you get fabricated parts faster, direct from your own local Fabricator of Industrial Formica laminated plastics.

This new nationwide network of regional fabricators represents over 50 times the productive capacity ever offered for this purpose. It saves days and weeks on delivery by giving you a thoroughly competent fabricator practically in your own backyard.

The new service recognizes the need of industry for a dependable, big volume source of fabricated parts. Formica is proud to be the first to make available field fabrication facilities with these four key advantages:

1. **Faster, direct service.** Truckload or tote-boxful, you'll get parts faster direct from your regional Fabricator of Industrial Formica laminated plastics.
2. **High quality production** of Formica laminated plastic parts by plastics fabricating specialists.
3. **Application engineering service** from Formica's home and district offices, as well as through field fabricators.
4. **Widest grade selection.** Streamliner inventories maintained of 42 standard grades; most can be shipped within 48 hours. Ample research facilities for new grade development.

For further information on how the new Formica field fabricator program will speed up your production schedules, get your free copy of "Man of Many Parts." Write Formica Corporation, subsidiary of American Cyanamid, 4533 Spring Grove Ave., Cincinnati 32, Ohio.

FIF

ALBUQUERQUE, N. M.
Plasticrafts, Inc.

ARLINGTON, VA.
Milton H. Brooks & Son

ATLANTA, GA.
Southeastern Plastics Sales Co.

BRISTOL, VA.
Williams Co.

BUFFALO, N. Y.
Curbell, Inc.

CHICAGO, ILL.
Colonial Kolonite Co.
Tingstol Co.

CINCINNATI, OHIO
Aqua Sportsman Inc.
Durham Mfg. Co.

CLEVELAND, OHIO
Jaco Products Co.

COLORADO SPRINGS, COLO.
Empire Plastics

COLUMBUS, OHIO
Dayton Plastics, Inc.

DAYTON, OHIO
Dayton Plastics, Inc.

DENVER, COLO.
Plasticrafts, Inc.

EAST RUTHERFORD, N. J.
Insulating Fabricators, Inc.

EL CAJON, CALIF.
Dutton Mfg. Co.

FORT WORTH, TEXAS
Plastelite Engineering Co.
Service Engineers, Inc.
Standard Parts & Equip. Corp.

GIBSONVILLE, N. C.
Engineered Plastics, Inc.

GRAND RAPIDS, MICH.
Novel Products

HOUSTON, TEXAS
Houston Gasket & Packing
F. H. Maloney Co.
Replacement Parts Co.

HUNTINGTON, W. VA.
O'Neill Industrial Plastics, Inc.

INDIANAPOLIS, IND.
Automatic Machinery Co., Inc.

JACKSONVILLE, FLA.
St. John's Fdry. & Mch. Co., Inc.

KANSAS CITY, MO.
Brooks Beatty Co.

LOS ANGELES, CALIF.
Conroy & Knowlton, Inc.
Leed Insulator Corp.
Tri-State Supply Co.

LOUISVILLE, KY.
C. Lee Cook Co.

MEMPHIS, TENN.
Norrell, Inc.

MIAMI, FLA.
Commercial Plastic & Sup. Corp. of Fla.

MILWAUKEE, WISC.
General Plastics, Inc.

NASHVILLE, TENN.
Plastic Fabricator Co.

NEW ORLEANS, LA.
Prager, Inc.

NEW YORK, N. Y.
Commercial Plastics & Sup. Co.
Frank Products
Thomas J. Long, Inc.

OZONE PARK, N. Y.
Comco Plastics

PHILADELPHIA, PA.
Laminated Materials

PITTSBURGH, PA.
Earl B. Beach Co.

POMONA, CALIF.
Plastic Stamping, Inc.

ROCHESTER, N. Y.
General Circuits, Inc.

ST. LOUIS, MO.
Harris Mfg. Co.

ST. PAUL, MINN.
Plastics, Inc.

SAN DIEGO, CALIF.
Ridout & Co.

SAN FRANCISCO, CALIF.
Laminated Fabricators
Tri-State Supply Corp.

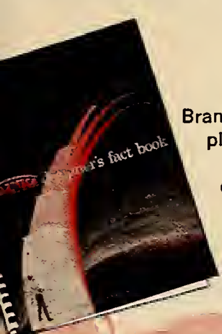
SEATTLE, WASH.
Tri-State Supply Corp.

TAMPA, FLA.
Manatee Corp.

UNIONVILLE, CONN.
Fabricon Corp.

WATERTOWN, MASS.
Insulating Fabricators of N. E.

WEST ALLIS, WISC.
Colonial Kolonite Co.



new fact book . . . free!

Brand new concept in the presentation of laminated plastic properties and application data. Valuable aid to designers, production engineers, purchasing agents. Send today for your free copy.

A product of CYANAMID

Laminated plastic sheets, tubes, rods, molded parts. Field fabricator service.

FI-2006

Circle No. 26 on Subscriber Service Card.

SHOOT FAST... SHOOT SHARP

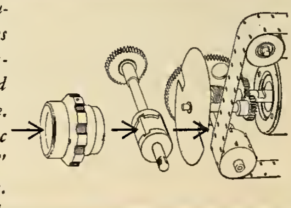
with the light, rugged Photo-Sonics 16mm-1B $1300

at 1000 pictures per second you see all *the action...in laboratory experiments, missile recording, documentary footage, auto safety studies, time-motion studies, rocket engine testing, aircraft flight testing, and industrial analysis.*

This rocket-age sharpshooter takes full-frame, extremely high-resolution pictures under the most unfavorable environmental conditions. It is light, compact, and made for operational convenience. Start and stop it for runs of less than magazine capacity if you wish ... change exposure time simply by "dialing" different shutter openings (9°, 18°, 36°, 72°), giving a range of selective and precise exposures from 1/60 second to 1/40,000 second ... change film capacity quickly and easily by attaching one of the interchangeable magazines (100, 200, 400 or 1200 ft.). Range of frame rates with one motor—12 to 1,000 frames per second. Standard package includes 16 mm Photo-Sonics 1B camera, heater, two timing lights, three sets of motor reduction gears, 100-ft. magazine and carrying case. Many accessories and complete range of lenses are available. Ask Traid for the full story on this remarkable camera; or ask about other 16mm and 35mm rotating prism cameras with frame rates up to 4,000 pictures per second, and featuring the same high resolution prism and disc shutter combination.

The 16mm-1B is only one of Traid's many on-the-shelf data recorders to fill your photo instrumentation needs. Traid distributes one of the most extensive lines of 16mm, 35mm and 70mm cameras and accessories in the U.S., with both rotating prism and intermittent type movements, time-lapse, standard speed, and high-speed picture-taking rates. Talk to Traid first for a better, faster answer to your photographic problems.

Prism and rotating disc shutter turn in synchronism with continuously moving film. Prism provides image compensation; disc shutter produces high resolution and even exposure over full frame. Combination of prism and disc shutter eliminates "image smear" common with other prism cameras. Film at aperture is flat, not curved.



To: Mark MacIntosh, Traid Corporation
17136 Ventura Boulevard, Encino, California

Dear Mac:
OK—Send me more dope on the Photo-Sonics 1B high-speed camera.

Name ______________________ *Dept.* __________

Company ______________________________

Address ______________________________

____

Shot at 1000 frames per second, 36° shutter, 1/10,000 second exposure

TRAID

Traid Corporation • 17136 Ventura Boulevard, Encino, California

DOD Chiefs Back Budget; Regret Cuts

Sentiment heavy in Congress for restoring many budgetary cuts. ARPA's Johnson says both his agency and NASA need $300 million additional.

ARDC had $534 million cut from its request. Senator Anderson wants more development funds for nuclear aircraft. Missile strength figures debated.

WASHINGTON—A seven-billion-dollar question faces Congress as it goes into the second month of its new session.

Chiefs of the Army, Navy and Air Force, testified before the Senate Preparedness Investigating Subcommittee that individual budgets submitted by them to the Secretary of Defense were cut a total of $7.1 billion. Under oath, they said the $40.9 billion budget submitted by the Administration was adequate. But each expressed reservations in regard to his own service.

Questioning by members of the Subcommittee headed by Senate Democratic Leader Lyndon Johnson (Tex.) generally followed party lines. The Democratic majority, spearheaded by Johnson and Sen. Stuart Symington (Mo.), drew from the witnesses their reluctant approval of the overall budget. Republican minority members obtained statements substantiating the claim that the overall budget is sufficient.

• **ICBM lead**—First to appear was Secretary of Defense Neil H. McElroy, flanked by Chirman of the Joint Chiefs of Staff Gen. Nathan E. Twining. McElroy, in line with earlier statements, said this country did not intend to attempt to match Russia missile for missile in the ICBM field, but the total deterrent forces—bombers, missile-launching submarines, foreign-based IRBM's, and forthcoming ICBM's—are adequate, and there are no serious gaps in the national defense for the time covered by the budget submitted.

Symington asked the defense chief how it could be that less money was being asked now than was sought last year, yet it had been stated there was an emphasis on missiles? McElroy said that this was true because obsolete items had been eliminated, items which have been completed or are nearing the end of development and test stage would require less money, and spending generally would be more efficient.

• **JCOS**—Appearing before the subcommittee in the afternoon were the uniformed service chiefs.

Chief of Naval Operations Adm. Arleigh A. Burke testified that his budget board originally submitted to him a request for $17-18 billion dollars. This was pared to $14 billion, which was the budget sent to the Department of Defense. Final budget figure for the Navy was $11.5 billion.

Gen. Thomas D. White, Chief of Staff of the Air Force, said that a request for $20.6 billion was reduced to $18.6 in the final budget.

Gen. Maxwell D. Taylor, Army Chief of Staff, said his budget planners handed him a proposed $13.6 billion budget which he cut to $12.5 billion before sending it to DOD where it was finalized at $9.9 billion.

Gen. Randolph McC. Pate, Commandant of the Marine Corps, whose budget is covered by the Navy's, was the only service chief to say he was satisfied with the weapons he has and is getting. However, he said that while he did not argue with the cut, personally he would have done it in another way.

• **Reservations**—Sharp questioning from Democratic Senators brought out the specific reservations of the military chiefs.

Modernization of the Fleet was Burke's major concern. This, he said, should have been begun 15 years ago. He testified that the present budget provides for modernization of about 2% of the Fleet, of which 81% is wearing out or approaching obsolescence.

The reduction in requested funds, according to Burke, resulted in the termination of the *Regulus II* program which he said "still is the best air-breathing missile we have." The Rocket Assisted Torpedo *(RAT)* also was a casualty but will be replaced with forthcoming more efficient weapons. Overall missile procurement will be reduced as a result of the cut, he said.

Pate admitted the cut in Navy funds will mean a reduction in landing teams.

White said his principal reservations concerning the AF budget dealt with financial ability to replace B-47's with B-52's and B-58's. The B-58 recently was used in test firing of an air-launched ballistic missile. White also regretted lack of acceleration of the nuclear-powered aircraft. It failed to get priority, he explained, because the scientific community says it is not completely feasible at this time. His other reservations dealt with such matters as personnel problems and housing.

Sen. Clinton P. Anderson (D-N.M.), newly-elected Chairman of the Joint

Atlas Production

FIRST production line photograph of *Atlas* ICBM at Convair shows vehicles to be fired in the test program and similar missiles for operational use.

Congressional Atomic Committee, said he will push for an additional $280 million to step up development of nuclear and atomic-powered planes. With this money, it could be done in four years, he said.

• **No padding**—All the service chiefs declared their higher budgets had not been padded in any way and represented actual needs of their forces. Taylor was the only witness to say in so many words that his budget "is not adequate within the confines of the Army."

Taylor, like Burke, was worried about modernization, which he said would not be permissible under the present budget. He said he had submitted a reasonable program for development of the battlefield mobility concept and modern weapons, but that the $9.9 billion budget will do little more than provide for replacement of equipment wearing out.

Taylor further stated he had great reservations in the effect the reduced budget might have on the *Nike-Zeus* program and on other Army surface-to-air missiles.

Chairman Johnson throughout the questioning urged witnesses to give their personal and honest opinions as to adequacy of the budget. All insisted that the memorandum recently sent to Secretary McElroy by Budget Director Maurice Stans had nothing to do with their approval of the overall budget. However, each followed the provisions of the memorandum and pointed out that the budget had been determined from the overall viewpoint and that they were not asking for more money.

Johnson's viewpoint was apparent from his repeated urging that they say exactly what they thought as experts and as those responsible for the nation's defense. He summed it up by saying:

"It is beyond me how your three inadequacies can make a single adequacy."

Later, he told Taylor:

"By approval with reservation you really mean the Secretary of Defense makes the decision whether a defense program is adequate and you all agree not to fight it, isn't that what you mean?"

"We offer our superiors our best advice and he makes the decision," Taylor replied.

Johnson later said the military chiefs had testified "like good soldiers."

• **Retaliation**—Another witness, Maj. Gen. Bernard Schriever, head of AF Ballistic Missiles Division, said production of ICBM's should be stepped up, although the *Atlas* program is on schedule as set up in 1955.

"In this ballistic missile age, we should do everything we can to reduce the risk to our retaliatory capability and more ICBM's will do this," he said. "And we certainly can build more if we want to put the weight behind it."

Gen. Thomas S. Power, head of the Strategic Air Command, which McElroy described as the nation's main retaliatory force, told the Senators there is no airborne alert in this country though he was ready to put one up any time he was told to do so. He said SAC presently is planning wider dispersal, tightening its precautions against sabotage, hardening bases and trying to improve communications to insure retaliatory capability after an enemy attack. He admitted that while the warning system against manned aircraft is good there is no warning system against missile attack.

Number one priority at SAC, he said, is the B-52G bomber-*Hound Dog* missile, and the KC135 tanker package to extend SAC's range.

• **ARPA**—DOD's Advanced Research Projects Agency got a thorough going-over. Witnesses appearing, following a morning session with National Aeronautics and Space Administration officials, included Roy Johnson, ARPA director; William Holaday, Director of Guided Missiles; Dr. Herbert York, newly-appointed Director of Defense Research and Engineering; and Dr. Wernher von Braun, of the Army Ballistic Missiles Agency.

Johnson was the only witness to say specifically how much more money he needed, though von Braun told the Senators more money is needed especially in research and to buy vehicles for test purposes.

Commenting that "I may be out of a job," Johnson said ARPA needs a supplemental appropriation of $40 million for the clustered 1.5-million-pound-thrust vehicle. Including this, Johnson estimated that the space program would require for ARPA and NASA an additional $150 million in fiscal 1959 and a similar amount in 1960. This money would be utilized in stepping up the booster program, development of better tracking and high-energy upper stages.

Von Braun told the subcommittee this country is five years behind the Russians in rocketry. He said the gap could be closed in a year if the Reds stood still, but there was no sign they would do that.

More money is needed, he said, not for greater numbers of missiles but for research and for test vehicles in early phases. He predicted this would speed the time when space vehicles can be produced with twice the thrust of present Russian hardware.

• **Disagreement**—ARPA's Johnson and NASA Director T. Keith Glennan, Jr., disagreed as to whether or not President Eisenhower is willing to spend enough money for space research and technology in fiscal 1960.

'No," was Johnson's answer after two hours of questioning before the Senate space inquiry.

"Yes," was the cautious answer given by Glennan, who qualified this by saying that his agency would ask for more money in the near future if it were needed.

The best estimate is that ARPA and NASA will get the $300 million Johnson is asking for. Whether the Administration will freeze the funds is another matter.

Glennan's testimony contradicted Johnson's.

In answer to a question by Sen. John C. Stennis (D-Miss.), Glennan said that NASA had enough money at the "present stage of our development," but that "this field is going to move . . . fast, and if we need more money, we will be back."

The NASA Administrator modified this statement slightly in an appearance before the House Space Committee by saying that he doubted whether more money would speed the program, though it might provide greater assurance of meeting goals.

• **Red lead denied**—Glennan admitted that Russia was 18 months to two years ahead of us in rocket power, that their guidance was apparently better and that the Russians might put a man in space this year—thus beating us by two years.

He denied that Russia had the all-over space lead.

The nation is being "deluded," according to Glennan, into thinking that the space program should be pinned to the development of high-powered rocket boosters.

The important thing, Glennan stated, is how much information "we get back out of space." He said there is no sign of any great difference between the information received by the scientists of either nation. In fact, Glennan reported, the quality of the Russian information received from space might be less than our own in some instances.

The House Space Committee criticized Glennan for taking a "penny-pinching" approach to the international space race on the one hand, and calling for Americans to "roll up our sleeves" and get on with the job or "spend our money buying telescopes" to watch Russians space advances on the other.

Complication for Solids: Thrust-Direction Control

Ballistic missiles will require thrust vector control, thrust termination, thrust modulation

by Norman L. Baker

NEW YORK—The long-range second-generation solid propellant propulsion systems, in development or on the drawing boards, are beginning to complicate what until now has been the simplest rocket propulsion system. Until the advent of the large-grain ballistic missiles, *Polaris, Minuteman,* and *Pershing,* problems of thrust and directional control of rockets were essentially the headache of the liquid engine systems.

Tactical solid rockets, the limited range weapons, have used relatively simple control principles. Some of the solid rockets (*X-17, Honest John*) have their ballistic trajectory fixed at the time of launching, stabilized by roll about the longitudinal axis and fixed aerodynamic surfaces. Other solid systems (*Lacrosse, Hawk*) are capable of varying to a limited degree their direction of travel and distance traveled by command changes of aerodynamic control surfaces.

Most solid systems to date have operated within the atmosphere, where aerodynamic surfaces can hold the missile on a prescribed course once the longitudinal axis is positioned relative to the direction of travel. Current solid systems that have been used beyond the atmosphere (*Jupiter-C* final stages, *Vanguard* third stage) have been spin-stabilized before ignition to assure attitude control during powered flight with thrust cutoff velocity left to the pre-calculated performance of the solid grain.

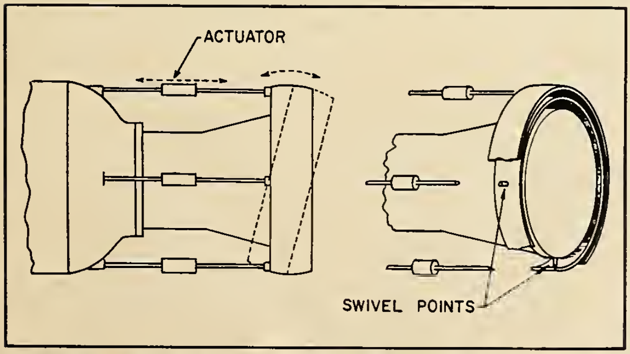
Changing the direction of travel of a solid propellant system has been limited to atmospheric missiles equipped with airfoil control surfaces which are effective during powered flight but diminish in value after burnout.

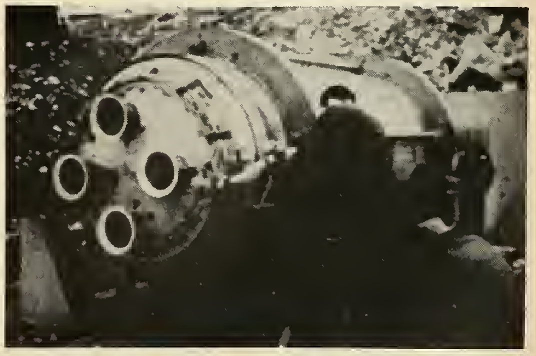
• **New controls needed**—The solid propellant control systems mentioned have been restricted to short-range missiles with a very small circular error probability. When the range is extended beyond 200 miles the precise attainment of roll control during powered flight, burnout velocity, and proper attitude (pitch and yaw) at burnout is of major importance if the payload is to impact or intercept a predetermined position. Except for a few rather short-range missiles (*Hawk, Falcon, Sidewinder,* etc.) most of the solid systems are simple free-flight vehicles that do not contain a guidance system and hence do not require a stabilized reference axis.

Now the precise control requirement, reaching a rewarding stage of development in liquid systems, is under investigation for the second-generation solids.

Dr. H. W. Ritchey, Vice President and Technical Director of Thiokol Chemical Corp., speaking at the 27th Annual Meeting of the Institute of Aeronautical Sciences here last week, discussed the control problems confronting solid propellant system designers. He listed three types of thrust control:

1). Thrust vector control. Control of the direction, which involves generating vectors along two axes perpendicular to the main line of thrust. Also, a torque can be generated around the main axis for roll control.





JETEVATORS ON EACH of the four nozzles in AX *Polaris* series are formed from two gimballed rings to deflect thrust.

2). Thrust termination.

3). Thrust modulation, involving adjustment of the amount of thrust at the command of some operational control.

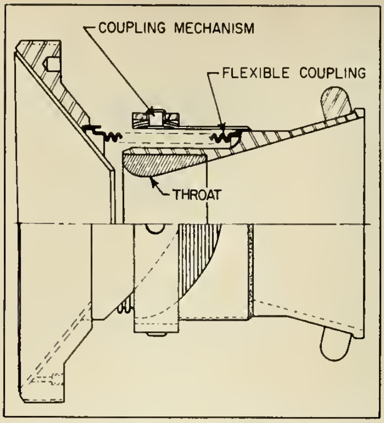
Thrust Vector Control

In addition to thrust vector control of the general direction and flight attitude of the principal vehicle, Ritchey said, moderate forces may be needed to correct for mechanical misalignment or gusts during periods of takeoff when external aerodynamic forces are not adequate to achieve control. Thrust vector control may also be needed at very high altitudes where atmospheric density is not sufficient to generate external aerodynamic forces.

A third need for such control may develop, the Thiokol official pointed out, in certain applications where the vehicle itself encounters flight regimes of aerodynamic instability. Some of these applications may require very high side vectors as well as very rapid speeds of actuation.

• **An old technique**—Thrust vector control was first obtained by use of vanes in the exhaust stream. Dr. Robert H. Goddard's rockets and the famed *V-2* used this method. Conventional application may require four jet vanes sometimes coupled with external control surfaces, if any.

Vanes in the exhaust stream have the advantage of providing roll control torques as well as side vectors when applied to a single nozzle. However, according to Ritchey, there are two principal disadvantages: (1) The attainment of large side vectors requires large vane surfaces and vane cross-sections, which introduce drag loss in the jet, and (2) Constant immersion of the jet vanes in the very high-velocity and high- temperature exhaust jet raises a difficult materials problem.



LATEST METHOD is gimballed nozzle attached to the combustion chamber by a flexible coupling.

• **The jetevator**—Very few materials are available that will permit long exposure to the hot gases of the rocket combustion; the desire for large side vectors has shifted thrust vector control investigations to applications of the jetevator. Ritchey says this device is a central zone of a sphere, usually mounted on gimbals, which dips into the exhaust jet in the direction desired to provide the necessary thrust vector.

In contrast to the jet vane, the jetevator is immersed in the exhaust jet only for the time the control forces are needed. However, it induces relatively high drag loss during the period it is used, and it cannot provide roll control unless the rocket engine is fitted with multiple nozzles.

The AX series of *Polaris* test vehicles, resembling closely the operational system, is reportedly using this method of control. Photos of static test firings reveal a form of gimballed jetevators on each of four nozzles.

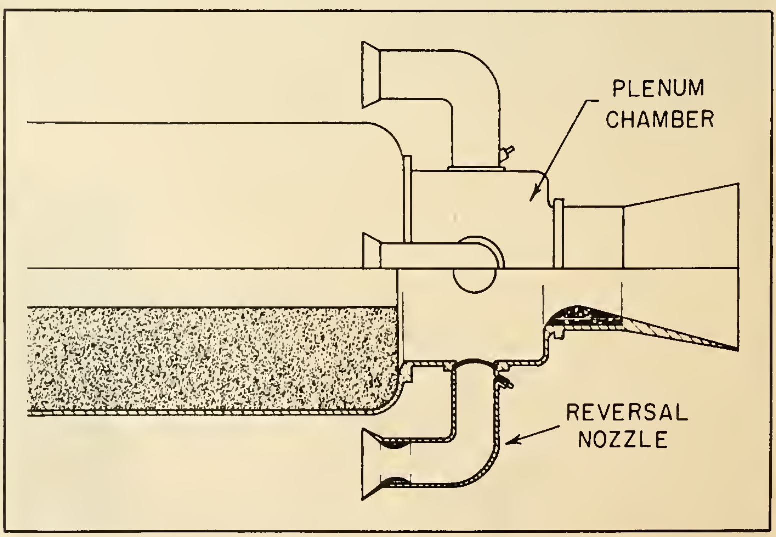
• **Nozzles favored**—The third device discussed by Ritchey is the flexible or gimballed nozzle, taking a page from liquid engine development. In the solid motor, the nozzle is connected by flexible coupling to the combustion chamber and is mounted on gimbals so that the exhaust jet can be diverted in any direction. Ritchey believes that from the standpoint of drag loss, this device should be the most efficient of the three. However, it brings in the mechanical problem of requiring seals against hot, high-pressure gas. And roll control can be obtained only from multiple nozzles.

Thrust Termination

Thrust termination of long-range ballistics requires command halting of thrust on attaining the proper velocity to provide the required range.

Thrust termination may be gained by generating an exhaust jet opposite the direction of the main propulsion stream. Ritchey said a reverse thrust equal to or slightly larger than the main forward thrust currently is being accomplished by generating a reverse jet through reversal ducts flowing into a plenum chamber at the aft end of the motor.

The first twenty-two *Polaris* test vehicles used this control system. The motor was a modified *Sergeant* with



FIRST 22 TEST vehicles in the *Polaris* series, using *Sergeant* motors, had four thrust reversal nozzles under lower skirt.

gases flowing into a plenum chamber and out through four nozzles aft, and four nozzles facing forward for reverse thrust. This system was affectionately tabbed "the octopus with the bends."

On the *Polaris* AX series, aft nozzles provide thrust, roll and vector control with forward end ducts (four equally spaced) supplying thrust termination and stage separation. On the staged *Polaris* the end ducts must be placed at an angle to the main axis so that the payload is not subjected to the head and shock of the reverse jet.

• **Some hazards**—Ritchey explained that both of these devices require some arrangement for rapid opening of the activation ports. He warned that the flight patterns of certain types of vehicles might be seriously disturbed unless all the ports are opened at exactly the same time and with exactly the same mass flow.

• **Dousing the fire**—Ritchey introduced another method of termination which involves quenching of propellant burning. He said this can be done by setting up a shock expansion wave inside the engine. A new nozzle throat area is opened which is larger than the initial throat area. This sets up a shock expansion wave inside the combustion chamber that extinguishes burning.

During transit of the expansion wave in the combustion chamber, this intermediate combustion zone expands and cools the surface of the propellant below combustion temperature, causing complete extinction of the flame. Under atmospheric conditions, the rocket can be expected to reignite after several seconds, but at high altitudes the intermediate combustion zone is so diffuse and the reaction so slow that combustion energy is not generated close enough to the surface to cause reignition.

Thrust Modulation

Dr. Ritchey explained that since thrust, as a first approximation, is proportional to the operating pressure of the engine, varying this pressure would seem to be the most direct approach to controlling the amount of thrust. He said it is necessary to open only very small ports of additional exhaust area to get a wide variation in pressure and thrust.

A scheme for modulating the thrust could use an externally-supported pintle arrangement, according to Ritchey, for varying the balanced auxiliary jets that are used for thrust modulation. Thus penalties for drag or other inefficiencies of expansion in the supplementary jet would have very small overall effect on the efficiency of the rocket.

R&D on Nuclear Missile Propulsion Decreases

WASHINGTON—The Atomic Energy Commission has released figures that show research and development on nuclear propulsion systems for missiles has dropped off in the past year. The $12.568 million spent for R&D in FY 1957 had dropped to $12.005 million in FY 1958.

Manned aircraft propulsion systems also experienced a reduction in R&D expenditures from $68.875 million to $62.222 million for the same period. Emphasis on the missile phase of nuclear propulsion experiments was placed on critical assembly measurements, propellant experiments, and studies of advanced missile concepts. General support work continued on advanced moderators, coolants, and structural materials.

Expenditures for satellite power sources, however, increased from $1.5 million in FY 1957 to $3.4 million in FY 1958, a 127% jump. The report, which specified the power sources were for use in "planetary satellites," did not give any further data on these units, but they are most likely of the type recently revealed at the White House.

The United States spent $107 million more for nuclear weapons research and fabrication in FY 1958 than in the preceding year. Weapons development and fabrication in FY 1957 amounted to $337.2 million, compared to an increase in FY 1958 to $443.9 million, a jump of 32%.

As of June 30, 1958, the AEC investment in plant and equipment for the production and storage of weapons showed a total of $781.8 million, and an additional $52.8 million in weapons test facilities.

Over the past eight years, the AEC's cost of operations in weapons development and fabrication rose from $163.6 million in FY 1951 to its present level of $443.9 million.

Capital Banquet Marks *Explorer I* Anniversary

WASHINGTON—*Explorer I* had its first birthday on January 31st and more than 700 people gathered at a banquet here to commemorate the event. The banquet was preceded by the presentation of a replica of the *Jupiter-C* launching vehicle for permanent display at the Smithsonian Institution.

Secretary of the Army Wilber M. Brucker, master of ceremonies at the banquet, introduced five speakers who each made a brief speech. They were Maj. Gen. J. B. Medaris of AOMC, Dr. Werhner von Braun of ABMA, Dr. William H. Pickering of JPL, Dr. James A. Van Allen of the State University of Iowa, and Dr. Maurice Dubin of the Cambridge Research Center.

Seventeen companies received awards from the Department of the Army and the George Washington Chapter of the Association of the United States Army for their participation in the *Explorer* program. They included Brown Engineering of Huntsville, Chrysler Corporation, Consultants and Designers of Arlington, Va., Cooper Development Corporation of Monrovia, Calif., Curtiss-Wright Corporation, Ford Instrument Company of Long Island City, General Electric Company, Globe Industries of Dayton, Ohio, Grand Central Rocket Company, Hallamore Electronics Company of Anaheim, Calif., Lodge and Shipley Corporation of Cincinnati, Rocketdyne division of North American Aviation, Osbrink Manufacturing Company of Los Angeles, Radiaphone Corporation of Monrovia, Calif., Reynolds Metals, Sprague Electric Company and the Waster King Corporation of Los Angeles.

Cosmic Rays Originate Outside Our Galaxy?

NEW YORK—Cosmic rays originate outside our galaxy, according to an M. I. T. physicist.

Dr. Bruno Rossi said recently he had drawn this conclusion from the fact that some primary cosmic ray particles have energies as high as 10 billion billion electron volts. This is about a billion times as great as the energy given to a particle in one of the largest man-made accelerators.

Speaking at the American Physical Society meeting, Rossi said a particle could not accelerate to this energy by traveling through all the magnetic fields of our galaxy. Furthermore, he said, particles of such tremendous energies come from all directions and not just from the plane of the galaxy.

Rossi said cosmic ray particles would create no hazard in space travel because there are so few of them.

In another paper at the meeting, Dr. S. Fred Singer of the University of Maryland said that some of the particles in the Van Allen doughnut-shaped radiation belts about the earth are from cosmic rays. The others, Singer said, are particles shot out from the sun.

Singer said the Van Allen particles are either protons or electrons trapped in the earth's magnetic field. Rossi said the cosmic ray particles are mostly protons.

Continued Growth in Military Electronics

Armed Services seeking those companies with electronics capabilities to serve as missile/astronautics prime contractors

by Raymond M. Nolan

WASHINGTON—A significant feature of the military electronics business today is that the armed services are awarding more and more prime contracts to companies with strong electronics capability. Latest indication of this is the award of the *Eagle* prime contract to Bendix Systems Division, Ann Arbor, Mich. Bendix thus joins a growing list of electronics companies charged with systems management of some of the biggest programs.

Among other such firms are Sperry with the *Sergeant*, Philco with the *Sidewinder*, Minneapolis-Honeywell with the *Wagtail*, and Sylvania with *Plato* (although the fate of *Plato* now seems to be somewhat unpromising).

The broad category of military electronics sales is estimated by Electronic Industries Association to represent 52% of total industry sales during calendar 1958. This was an increase of $200 million over calendar 1957 and adds up to a grand total of $4.1 billion (See EIA graph).

• **Sharp rise**—The missile electronics figures show an even more dramatic increase. During FY 1955, the total was $306 million. This climbed to $1.268 billion during FY 1958 and is expected to reach $1.5 and then $2 billion in 1959 and 1960.

This increase in spending results mainly from the shift in emphasis from earlier unguided or simply-guided missiles to more complex ones with more sophisticated guidance and control gear. In fact, more than 90% of the procurement dollars for missiles in 1959 are for weapons which were not produced in operational quantities during FY 1955. Long-range missiles will take more than half of the procurement funds during FY 1959.

In relation to the total defense budget, military electronics has risen steadily. Major procurement and production expenditures rose from 19% during FY 1955 to 29% in FY 1958. The percentage in relation to the total DOD budget including all categories has risen in the same period from 7% to 10%.

Air Force

In the split of missile electronics money, the USAF is far in front.

Two parallel programs are in existance for the *Atlas* and *Titan*. Originally, the *Atlas* was to use GE radio-inertial guidance and the *Titan* was to use Arma pure inertial guidance. However, it has been announced that *Titan* guidance will be used in the *Atlas* and that the first series of *Titans* will use a radio-inertial system developed by Bell Labs.

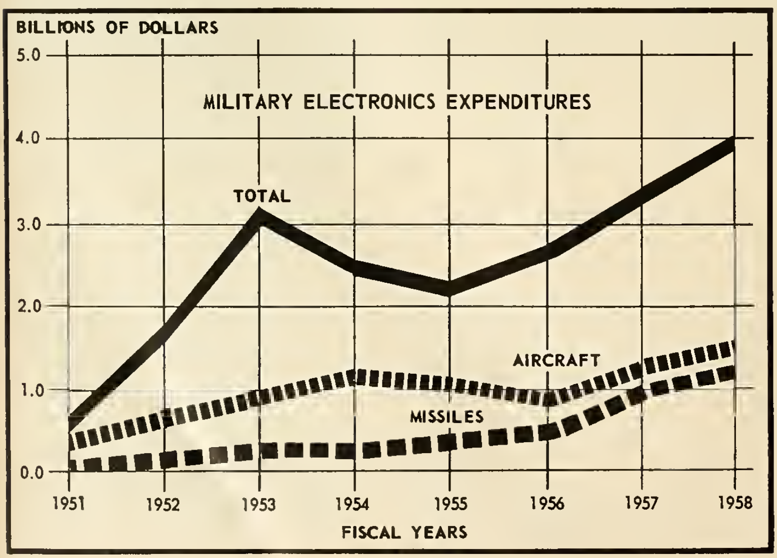
As for AF IRBM's, the *Thor* uses inertial guidance developed by AC Spark Plug and the Army-developed *Jupiter* has inertial guidance built by Ford Instrument Company. AC Spark Plug in another program makes the inertial guidance for the *Mace*. No word is out yet on who will build the guidance for the *Bold Orion*, the air-launched IRBM now under development by the Air Force.

The *Bomarc* program, which might easily become one of the largest in the budget, uses radar homing guidance manufactured by Westinghouse. Northrop manufactures the stellar-inertial guidance used on its *Snark*, but here the money figure is not too impressive because of the cloudy future of the *Snark* (although the Air Force awarded $50 million in contracts for *Snark* production last fall).

In the air-to-air category, the series of *Falcons* use either radar or IR, depending on their GAR number. Even-numbered GAR's use radar and odd-numbered GAR's use IR. The present *Genie* is unguided but there are reports that a guided version is under development. The *Sidewinders* that the USAF is buying also use IR. The old standby *Matador* uses radar guidance with a few modifications.

For its missiles of the future, the Air Force is staying with complex guidance systems. The *Minuteman* reportedly will use inertial guidance manufactured by Autonetics. The *Hound Dog*, with guidance also manufactured by Autonetics, is said to use a form of Doppler-corrected inertial system. No information has been released on the type of guidance used by the *Green Quail* and the *Wagtail* although the latter, since it is manufactured by Minneapolis-Honeywell, can be presumed to use some system incorporating gyros.

Sperry Gyro built the inertial sys-



INDUSTRY SALES BREAKDOWN

CATEGORY	1957	1958	PERCENT CHANGE	
Consumer Products	$1.7 billion	$1.6 billion	—	6%
Military Products	$3.9 "	$4.1 "	+	5%
Industrial Products	$1.3 "	$1.38 "	+	1%
Replacement Parts, Tubes, Semiconductors	$ .9 "	$ .86 "	—	4%
TOTAL INDUSTRY SALES	$7.8 "	$7.94 "	+	2%

GOVERNMENT SALES

8UDGET CATEGORY	FY 1951	FY 1952	FY 1953	FY 1954	FY 1955	FY 1956	FY 1957	FY 1958
Aircraft	$314	$ 632	$ 968	$1,085	$1,046	$ 999	$1,083	$1,446
Ships & Harbor Craft	34	56	106	97	90	79	81	99
Combat Vehicles	39	210	396	141	52	4	7	1.7
Support Vehicles	2	28	13	9	16	6	3	4.3
Missiles	11	91	159	159	306	628	1,108	1,268
Electronics & Comm.	193	597	1,001	827	636	771	880	875
Research & Development	136	209	253	248	244	267	303	3.8
Miscellaneous	18	106	146	100	64	48	41	38
TOTAL	$747	$1,929	$3,042	$2,666	$2,454	$2,802	$3,506	$4,050

em installed in the *X-15*. But no guidance manufacturer has been named or the *Dyna-Soar* because of the team competition now going on between Boeing and Martin.

Army

The biggest money item in the Army missile electronics budget could be the *Jupiter*—but it has long since passed to the Air Force for primary money. This leaves the Army with the old *Redstone* as its biggest missile.

The *Redstone* uses essentially the same pure inertial system, manufactured by Ford Instrument, as does the *Jupiter*. But the *Jupiter* has an extra accelerometer and a slightly different computer arrangement because it has a swiveling engine instead of control fins like those on the *Redstone*.

Bendix is just beginning to swing into production on the inertial system for the *Pershing*. It will resemble that of the *Jupiter* but will be considerably smaller. Another inertial system, manufactured by Sperry and Minneapolis-Honeywell,. is in use on the *Sergeant*.

The *Corporal*, because of its production status, represents a good share of Army electronics money. Its command guidance is built by the Gilfillan Company. The surface-to-air *Hawk* uses radar homing developed and built by its prime contractor, Raytheon. The *Lacrosse*, an artillery missile, has terminal guidance manufactured by Federal Telephone Labs.

In the *Nike* family, Western Electric has a clear field, building command guidance for the *Ajax*, the *Hercules* and the *Zeus*. Sylvania has the contract for *Plato*, the system which would use the *Nike-Zeus*, but there are reports that *Plato* may be on the way out.

Right now, the Army doesn't own an anti-tank missile. But three foreign birds are competing for the job—the German *Kobra*, the Vickers *Vigilante* and the French *SS-11*. All are wire guided with built-in electronics packages.

Navy

The biggest missile item that the Navy owns is, of course, the *Polaris* and it is on *Polaris* guidance that most Navy missiles electronics money is being spent. Because the *Polaris* will need some of its guidance system outside the missile, the money is split. GE makes the in-bird equipment and Sperry Gyro the SINS (Shipboard Inertial Navigation System) necessary for launching accuracy.

In the air-to-air category are the *Sidewinder*, with IR guidance; the *Sparrow III*, using the radar homing system built by Raytheon, and the *Bullpup*, with its Martin-manufactured radio command guidance. A group of air-to-air missiles are now on the way, but the only one whose guidance type has been revealed is the *Diamondback*, an IR type reported to be the successor to the *Sidewinder*.

The *Terrier* and *Tartar* as well as the *Talos* use beam-rider guidance manufactured by several different companies. All also use a type of homing direction, said to be passive for the *Talos* and active for the *Terrier* and the *Tartar*.

For the future, the Navy has several air-to-surface birds developing, such as the *Corvus*, *Crossbow*, *Eagle* (one of its uses), *Hopi* and *Raven*. No details of the guidance system of any of these have been released although it is rumored that Texas Instruments is building the system for the *Corvus* and it can be presumed that Bendix will provide guidance for the *Eagle*.

• **More to come**—This review did not even consider electronics fields which most certainly will take more and more of the missile dollar in years to come. One example is ground control and check-out. One knowledgeable missileman recently said that anyone who thinks of the missile as the bullet should consider the relative price of the gun to shoot it. This gives some idea of the role which ground support will assume in the future.

Turning back to research and development, it is almost impossible to conceive how much money has been and will be spent on electronic instrumentation necessary in design phases of missile programs.

Finally, there is the money which will be spent by the National Aeronautics and Space Administration. No figures are yet available but the R&D programs which must precede any of NASA's programs will take on added importance even though production money, because of the small number of units, will never be great.

Hercules Powder Says R&D Limiting Profits

New York—Hercules Powder Co., which established a chemical propulsion division in 1958, says the cost of research and development, and the uncertain duration of government contracts, will limit profits in this field.

Nevertheless, Hercules said in a recent report to stockholders, "in the national interest this work must be carried out, and with its long experience in the production of solid propellants, Hercules is a logical participant in the program."

Hercules, which has headquarters at Wilmington, Del., reported its 1958 net sales and operating revenue totaled $236,513,000, a decline of 4% from the 1957 all-time high. Earnings were $2.04 a share on common stock, 5% lower than in 1957.

Astronautics Tests

Jan. 30—The first in a series of *Nike-Hercules* cold weather tests was initiated. Successful kill was scored on a drone target dropped from an RCAF Lancaster bomber.

Jan. 30—*Thor* launched from Cape Canaveral in the 25th test of the IRBM and the 32nd flight of the *Thor* vehicle.

Feb. 3—*Titan* failed to leave its launching pad in the second unsuccessful flight test. Malfunction forced automatic shutoff of the engine.

Feb. 3—*Atlas*, last of B-series fired from Canaveral. Reported "successful," going about 4300 miles. Missile was 20th of test series.

Power . . . is not a complete answer . . .

. . . As long as we have people with ideas

. . . Very real competence in the services

This is not a new one . . .

Future of Electronics: Growth with Astronautics

EIA President David R. Hull gives a probing look at missile electronics today and predicts tomorrow's uses

Electronics Industries Association is the national trade association for the electronics industry. In this exclusive interview, m/r editors Raymond M. Nolan and Peer Fossen question David R. Hull, vice-president of Raytheon Manufacturing Company and president of EIA.

Q. What do you feel have been the significant developments in military electronics, as applied to the missile field particularly, during 1958?

A. It is always difficult to pin developments down to any specific given year, because normally the advance from conception of an idea to the practical product covers a span of years. However, I would say as far as 1958 is concerned, the two most significant developments may have been, first, advancements in materials and, second, improvement in power radiating in radio frequencies, particularly microwaves. In materials, we have seen much improvement in the semi-conductor areas leading to transistors, frequency and power-handling capabilities. Solar batteries can provide power for almost unlimited transmission time from satellite-telemetering radio transmitters, particularly when coupled with the semi-conductor devices just mentioned. Third, I would list the greatly improved materials for electronic parts such as resistors where we have tremendously increased temperature and humidity tolerances. On the power transmissions side, the backward wave-type device advancements certainly have given improved capabilities for interception of ICBM's.

Q. You mentioned advances in power transmission toward detection of ICBM's and yet there has been industry talk that our future in missile detection lies not in large power radiation, but rather in exploration of some magnetic phenomena or possibly infrared.

A. There are a variety of possibilities in this field. Power in itself is not a complete answer. In a complete radar system you have a combination of power and sensitivity. Again, getting back to basic materials, we certainly will improve the potential sensitivity receivers through our MASER developments. That is one combination which would be of tremendous help in a radar. On the other hand, we certainly have made terrific advancements in sensitivity in infrared devices. This gives us another avenue for long-range interception of missiles.

Q. Speaking of MASER, or if you like, molecular electronics, I wonder just what the future holds for the smaller manufacturer in that field? When you get in a cryogenic area, considerable capital is needed for research or development or for turning out products. Do you feel that, as we get more and more into solid state molecular electronics, smaller companies are going to have a place here or will it be the larger organizations?

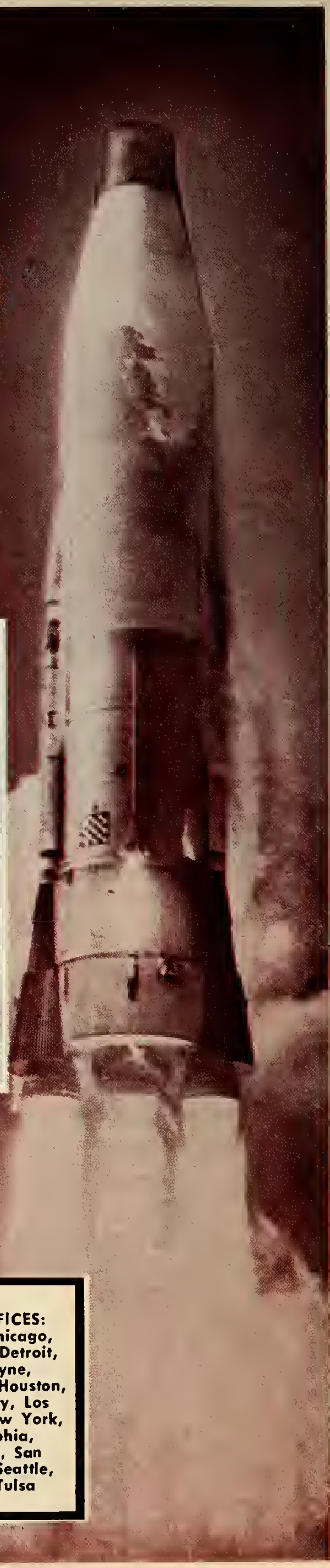
A. I feel that smaller organizations have a very definite part in this picture. In fact, many now classified as small industry are active in development and have development contracts from the services or sub-contracts from larger organizations. These and all companies will play a very important part.

Q. Maybe we are speaking of different fields. I am thinking back to the classic success story in electronics: the fellow that could start in his garage and develop some product so that he could get his foot in the door as a subcontractor or possibly as a prime contractor for a military organization. It doesn't appear that someone on this scale is going to be able to get into this field where he has to have extremely low temperature capability and highly expensive components before he starts.

A. The capital problem is always hard on small industries but, on the other hand, there are tax concessions and other laws favoring small industry. I am convinced that as long as we have people with ideas we will have small

 Circle No. 37 on Subscriber Service Card.

Stratoflex assemblies help fuel
THE MIGHTY ATLAS



Every time a Convair Atlas intercontinental ballistic missile lifts from its Cape Canaveral launching pad, fantastic demands are made of the fueling system and powerplant.

A touch of the blast-off button triggers hundreds of simultaneous chain reactions in the giant ICBM's fuel system. Under tremendous pressure, liquid oxygen is delicately and precisely force-mixed with a kerosene-like fuel and flashes through the lines as vapor to feed the fires burning in the combustion chamber. This blend, mix, fire sequence must commence in a split second and continue at tremendous speed if the launch is to be successful. Fuel line plumbing on the Atlas must be absolutely leakproof, immune to strong vibrations, and able to withstand continuous temperature variations.

Despite the infinite possibilities for human mistake and material malfunction, the Air Force, aided by Convair technicians, has successfully launched the Atlas ICBM time after time at Cape Canaveral. (In the spectacular December 18, 1958 firing, the 85-foot Atlas was placed in orbit around the earth.) Stratoflex is proud that its specially-designed Teflon* hose and metal tubing assemblies are vital parts of the Atlas fuel line system.

* A DuPont trademark

STRATOFLEX Inc.
P.O. Box 10398 • Fort Worth, Texas
Branch Plants: Los Angeles, Fort Wayne, Toronto
In Canada: Stratoflex of Canada, Inc.

SALES OFFICES:
Atlanta, Chicago, Cleveland, Detroit, Fort Wayne, Fort Worth, Houston, Kansas City, Los Angeles, New York, Philadelphia, Pittsburgh, San Francisco, Seattle, Toronto, Tulsa

SF1-9

industries developing.

Q. Many people in the missile field feel that we have reached almost the ultimate in chemical propulsion. We can only advance from here by brute force, grouping rockets and so forth. Most people feel that the future is in several things such as plasma, ion and photon engines. Do you feel that these things could properly be termed electronic devices?

A. In a sense, you could term everything electronics if you reduce them to electronics. I have never considered propulsion as electronics. Electronics gets into propulsion through controls, telemetering and the like. You have a mix of arts, of course, when you get into the plasma approaches to propulsion, and in a sense the same thing in adapting nuclear power to propulsion. I would hesitate to give you a specific answer to this . . .

Q. I asked this question because an RCA scientist suggested in a recent paper that perhaps the real answer to controlled fusion is microwave ignition and containment, and that if this is the case, fusion becomes almost secondary to the way you contain and ignite.

A. This is in a sense what I meant by electronics having the control of any of these systems. It is hard to say at this state of the evolution just what will happen.

Q. A newspaper recently described an installation by Daystrom on a process control industry in Louisiana. Daystrom is guaranteeing with penalty clauses that their solid state process control unit computer will run at 99% efficiency for six months. Have you heard of this?

A. I have heard of it and I can believe it. As a matter of fact you can get really terrific reliability if you design to run components conservatively. The repeaters incorporating vacuum tubes in the transatlantic cables operate this way. They run very, very conservatively and I expect they will operate without any service for 20 years.

Q. Why don't we do this in military electronics?

A. Because military electronics is based on advancing the state of the art to a degree which doesn't permit conservative utilization of the pieces. You will find that practically every military specification requires something a little beyond what now exists. Therefore you are forcing pieces to do just a little more. You take what you have and hope you will have something better. In the meantime you bring the most out that you possibly can.

Q. Who expounds this philosophy? Are you in agreement with it?

A. Personally, no. This is one man's opinion. In too many instances we have advanced to a point of limited reliability and unfortunately beyond the average human operator.

Q. Who starts this? Who develops this philosophy?

A. It develops from the operational requirements. It is quite understandable. The buyers want something way beyond what they can see at hand. The technical people in the services in turn have to translate these requirements into specifications which really wring out the laboratory and the producer. I am not in any sense condemning anybody for this situation. I can well understand this desire for something advanced even at the expense of reliability.

Q. The problem today for almost anything in space flight and missiles seems to be power. We don't have it. We can't generate it efficiently. Where are we going to get the power? This is disregarding the solar devices we have now. Do you feel that someday within the realm of electronics we are going to be able to tap some of the energy available in space?

A. Yes, I do.

Q. Do you think this is the answer?

A. I think this might well be the answer. I think it is entirely possible that electronics as such can provide propulsion. I feel that before too long there will be a major breakthrough and that electronics in its pure sense will provide propulsion.

Q. Someone from General Electric said not too long ago he felt that one of our great assets was that within the commercial field we can develop products in pretty short order and compete with anyone in the world. His question was, why can't we do this with military products? You answered it somewhat, but I wonder if there is too much overengineering.

A. I think I will have to be critical of the military technical specification writers in this case. Too many times we have detailed specifications that go right down to the size of the nut and bolt. We should have the parameters specified—the input, the output and the performance—and give latitude to the individual engineer or engineering groups in the design. I am sure this would avoid a good 50% of the difficulty.

Q. Are the government people who write these technical specifications competent to do their job—more competent than the manufacturer they ask to produce the equipment?

A. There certainly is some very real competence in the services. There are some really dedicated people who work hard to insure that they are abreast of the art. They are faced with a very fundamental problem. They have to spell out the specifications in detail for honest competitive approaches. This is really the thing that binds them . . .

Q. In other words, as long as we have competitive bidding we will always be faced with this problem?

A. Yes, it will become more difficult as time goes on and systems become more complex. If advertised competitive bidding is continued, you will find the specifications becoming increasingly detailed rather than less so.

Q. What about weapons systems or the team approach? Isn't part of the philosophy in the weapons systems approach that the prime contractor or the team leader is given a little more leeway in specifying to his sub-contractors?

A. That is correct. The objective of the weapon system or team approach is very logical.

Q. I have heard some objection to it. That is, if two given services with vaguely similar objectives go out into weapons system development, the weapon system manager very likely could go to their next tier of sub-contractors for identical things and bring up the parallelism that the Department of Defense is trying to get away from.

A. This is a problem because you can take a device which will fit into two weapon systems and can find that manager A went to company X and manager B went to company Y. You could wind up with two totally different devices with the same end use and thereby complicate the service of supply.

Q. What do you do to prevent this?

A. I think a compromise is indicated. Where there are certain things common to various weapon systems, I believe that the services should maintain an element of control of what goes into a given weapon system to be sure there is no wastage of the type I just mentioned.

Q. We don't have anything like that now?

A. We had the other extreme, of course, before the weapon system was introduced. The end vehicle supplier complained because so many things were held closely by the military services and some didn't fit his particular vehicle. We have thrown the gauntlet to the weapons system approach with this weakness I mentioned. I think there should be compromise where the services have some control of what goes into weapon systems to avoid duplications.

Q. How would you mechanize such a compromise?

A. I think organizations within the services should have groups—project people if you like—to oversee each weapons system. All project groups should refer to a series of technical sections covering a variety of things, such as engines and navigation equipment, to find which is the best development in a given technical speciality for use in each weapon system.

Q. Since they would he joint groups, who would administer these project and technical people? Would this come under ARPA, mayhe, or directly under DOD? I ask this hecause it seems unlikely that they are going to any new committees in DOD.

A. Well, as much as I hate to see the services seemingly submerged, I do think that in this space era we need the consolidation indicated by the formation of NASA for the non-military and the ARPA group for the military applications. I further feel that to solidify space weapons it is essential that this authority be lifted above any given military service and given technically to a single group in order to eliminate inter-service rivalries.

Q. I'd like to ask you a question ahout a point—I've heard some criticism lately ahout military philosophy being dictated hy educators.

A. This is not a new one.

Q. I realize it is not a new one, hut I sometimes wonder if perhaps the pedantic nature of educational minds doesn't in some ways impede our progress?

A. The biggest problem comes from military operating people coming in contact with scientific "long hairs" who are enthusiastic about their fundamental ideas and who also have no idea of problems involved in trying to squeeze out an operational device from a thought in about two months.

Q. Would you say this was insecurity on the part of the military?

A. No, not really insecurity. But obviously they are grasping for advanced ideas, which gets back to some of my earlier comments on the problems of translating an operating requirement to a practical device and the bugs that are inevitable when you try to rush it.

Q. My next question concerns how to improve R&D and speed it up. I think you have pretty well answered this, hut I would like to extend it a little bit and ask you what EIA is doing?

A. EIA has a very strong engineering department with headquarters in New York. It has many committees covering a wide variety of products. This is a group means of injecting information into both engineering and manufacturing in order to bring out the best and most practical ideas as to what will go together . . . This is not a static group; it's a forward-looking group. It is not confined to EIA membership. As a matter of fact, as many non-members companies participate in our engineering committees' activities as member companies; so we have a very good sounding board. This part of our organization works very closely with the electrical standards group located in Red Bank toward setting the parts specification used by the military. We are doing our utmost at EIA to insure the best possible equipment consistent with the state of the art and at the same time are looking forward to the future.

Q. What sort of reception do you get from DOD?

A. As a matter of fact, we have had a greatly improved reception in DOD. We give the services what is now available and at the same time generate some specifications which we can foresee as attainable at certain stages in the future. You'd stagnate advances if you did not do so.

Q. I certainly agree, I was just curious—you say the reception has heen greatly improved and I take it that it wasn't too good in the past?

A. That is correct, but on the other hand we now have created such relations with DOD that we are having EIA specifications which are realistic accepted and translated into military specifications.

Q. Speaking of the industry in general, do you expect that the dollar volume of electronics will remain constant—I'm thinking about a constant growth rate—or will there he large jogs upward even without significant hreak-throughs?

A. There will certainly be an increase in the slope simply because the electronic content of so many things is increasing. By just normal growth plus this increase you can expect a steeper slope and therefore a greater increase in the rate of electronic growth than that of other industries. The breakthroughs may come to cause these jogs you mentioned, but obviously you can't forecast them. There may be some, such as the power which I hinted at a while back . . . We look back only a quarter of a century and see airplanes with a tachometer, roll and bank indicator and airspeed indicator. This was the total instrument content without any electronics. Now we see aircraft with a whole variety of radar devices for bombing and interception. We see navigation equipment, communication equipment, missile guidance devices, electronic counter-measures. You run a whole gamut of things in many cases covering over 50% of the cost of the aircraft or missile or vehicle or whatever it may be . . .

Q. Well, someone said recently that there was quite a future for electronics in electronic counter-measures, missile detection and what-have-you in the Antarctic. Have you thought about that?

A. Yes, I've certainly thought about it. We can't restrict our thinking to any point of this globe anymore. If you look at the defense installations, we have been considering the shortest possible paths. But why limit ourselves to that? We put our weakest defenses in the other areas, so why shouldn't a potential enemy seek out those areas for his approach? The Antarctic cannot be disregarded.

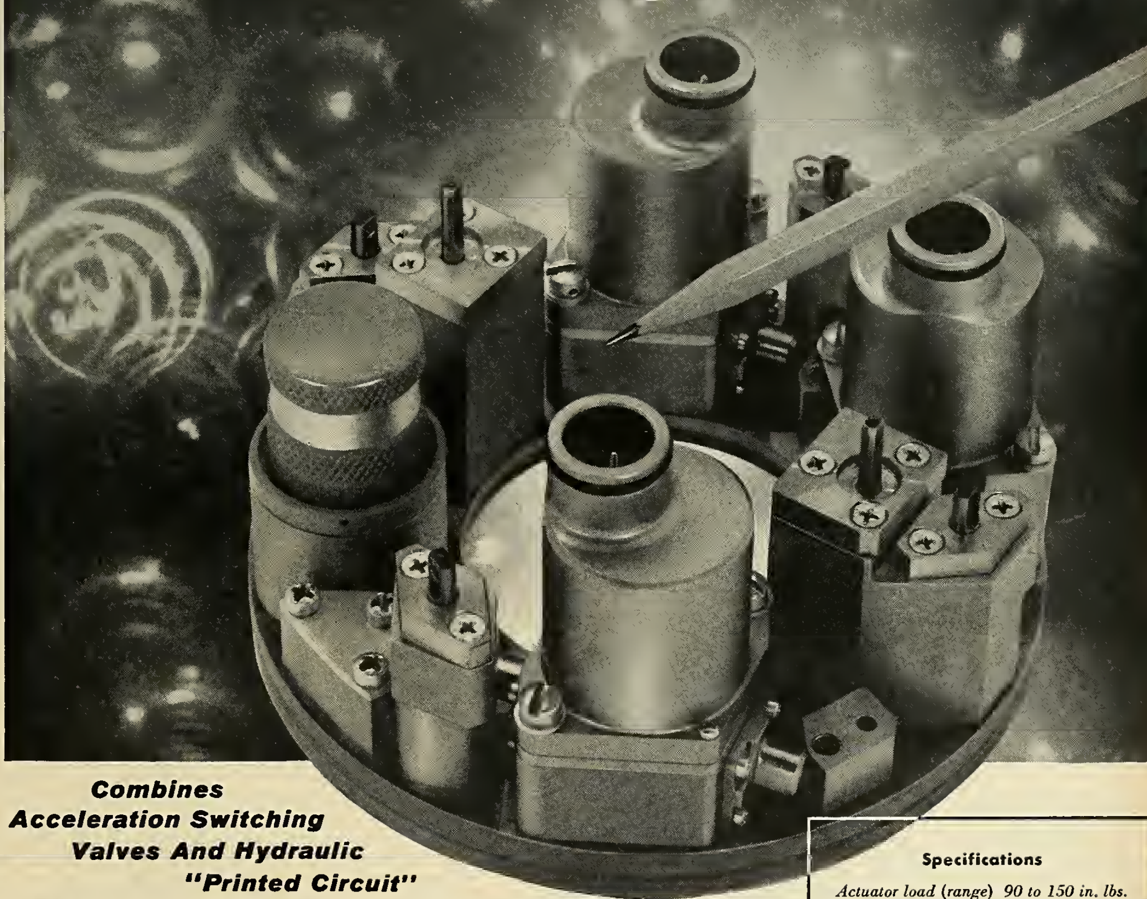
Q. Within the aircraft industry over the past 15 years we have been looking at what you might term a shake-down. Many small or weak companies fell hy the side and there was a gradual pattern of growth until you have the member companies of Aircraft Industries Association today—big, strong companies that control the aircraft industry pretty tightly. I wonder if this isn't going to he the pattern with electronics. You quoted the analogy a while hack of airplanes a quarter of a century ago—I wonder if electronics won't experience the same thing that the aircraft industry is.

A. Well, frankly I don't foresee it at this point. Certainly there are some advantages in large companies with plenty of capital having the ability to set up basic research groups which would contribute to their growth. But we certainly have found many breakoffs from these large companies where individuals or small groups have been able to make a go of whatever product resulted from their particular pet ideas and grow from that. As a matter of fact, if you take any existing large company and look back to its inception you will find there was an individual who had an idea and started an organization.

Q. That is true, hut that isn't really what I meant. For every one of those companies that hreaks through this way and hecomes large hecause of a good product, luck, or what-have-you, many other companies who would normally still he in husiness with a small product and not too great a demand aren't in husiness anymore hecause a larger company has assimilated their function —you can certainly appreciate this in the electronics husiness, I imagine . . .

A. Yes, there is a tremendous amount of assimilation, so the companies that have been actually going out of business through failure or bankruptcy are very few. We won't get into statistics along these lines—but there has been a lot of amalgamation. However, you will note in these absorptions that usually the small becomes a significant part of the large.

NEW AiResearch steering control system



Combines Acceleration Switching Valves And Hydraulic "Printed Circuit"

More reliable and responsive... this lightweight electro-hydraulic steering control system converts low-level electronic signals from the main guidance system into hydraulic energy which actuates the mechanisms steering the missile.

Packaged as an integrated unit, the three servo valves and six control actuators are mounted on a common manifold and powered by fluid or hot gases. The simplified "printed circuit" system of integral passageways within the manifold eliminates all external plumbing and leakage.

The acceleration switching servo valves provide positive control of spool velocity, thereby achieving greater resolution, reliability and response even at extreme temperatures.

Easily installed and removed as a complete, interchangeable unit, acceptance testing of this compact system can be accomplished prior to missile installation. Suggested applications are: missile surface controls, jetavator controls, and vector and nozzle steering controls. Your inquiries are invited.

Specifications

Actuator load (range)	*90 to 150 in. lbs.*
Electrical input (nominal)	*28 volts DC—10 Milliamperes*
Pressure range	*500 to 3000 psi*
Rated flow	*½ to 2 gpm*
Mounting	*Manifold*
External leakage	*None*
Proof Pressure	*4500 psi*
Burst Pressure	*7500 psi*
Temperature operating range	
Fluid	*-65°F to 450°F*
Ambient	*-65°F to 750°F*
System filtration	*10 microns*

ENGINEERING REPRESENTATIVES: AIRSUPPLY AND AERO ENGINEERING, OFFICES IN MAJOR CITIES

THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, ELECTRONIC, NUCLEAR AND INDUSTRIAL APPLICATIONS

Circle No. 11 on Subscriber Service Card.

Unlimited Coupling

Tremendous range of Aeroquip Coupling designs is demonstrated by B. A. Main, Jr., Vice President af Engineering, seated an a 10-inch coupling while holding a miniaturized coupling in his hand. The couplings shown here are only a few of the infinite variety developed by Aeraquip far use with hydraulic fluids, ordinary and exotic fuels, gases, oils, air, liquefied gases, ammonia, nitric acid, ethylene axide and many other fluids.

Designs!

WITH A WEALTH OF EXPERIENCE PLUS UNMATCHED FACILITIES, AEROQUIP DESIGNS, TESTS AND PRODUCES COUPLINGS TO MEET YOUR SHORT LEAD-TIME REQUIREMENTS

Call on Aeroquip for the solution to your fluid coupling problem. Let us know your requirements on fluid, temperature, pressure, size and application, and Aeroquip will recommend, design and produce the coupling that meets your needs . . . and do it FAST!

This is the service that Aeroquip is especially well qualified to provide for manufacturers of missiles, aircraft and accessories and components.

Years of experience gained in building millions of couplings enables Aeroquip to approach your problem with complete knowledge and understanding. Development facilities include extraordinary engineering depth plus extensive laboratory, shop and test equipment. Production and quality control facilities are the finest and most modern in the industry.

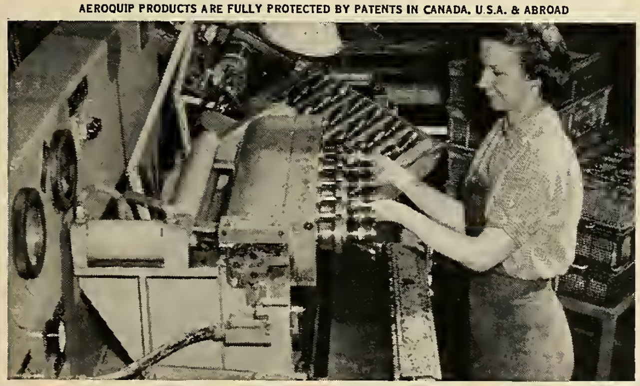
At Aeroquip, coupling designs and facilities are UNLIMITED!

Aeroquip
REG. TRADEMARK

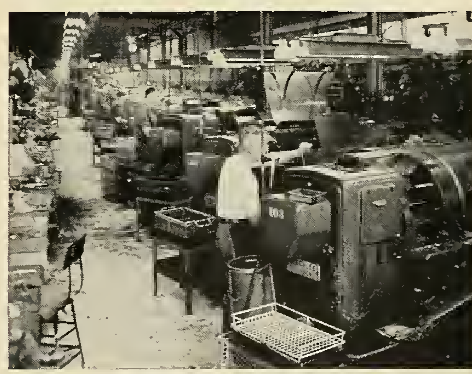
AEROQUIP CORPORATION, JACKSON, MICHIGAN
AEROQUIP CORPORATION, WESTERN DIVISION, BURBANK, CALIFORNIA
AEROQUIP (CANADA) LTD., TORONTO 19, ONTARIO
AEROQUIP PRODUCTS ARE FULLY PROTECTED BY PATENTS IN CANADA, U.S.A. & ABROAD

Birthplace of many new coupling designs is this modern design section in Aeroquip's development-engineering center at Jackson, Mich. Another engineering staff is maintained at the Western Division in Burbank, Calif., which also produces couplings.

Testing equipment that duplicates conditions ranging from arctic cold to the searing heat generated by jet or rocket engines in flight is included in the development-engineering section, at Jackson, which occupies over 15,000 sq. ft. of floor space.



Aeroquip's high standard of reliability is assured by final proof testing of all couplings. The proof test machine pictured above was specially designed by Aeroquip for maximum dependability and speed. Final testing follows numerous quality control checks during production.



Production facilities in the Jackson plant include this battery of automatic screw machines. Complete manufacturing operations are duplicated in Aeroquip's Western Division plant.

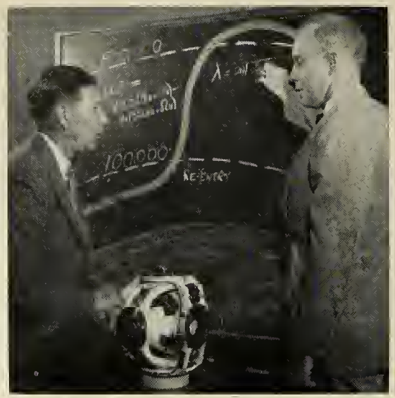
FILL IN AND RETURN THIS COUPON FOR COMPLETE COUPLING INFORMATION MR-2

Aeroquip Corporation, Jackson, Michigan
Please send me further information on Aeroquip Couplings. I am chiefly concerned with the following:

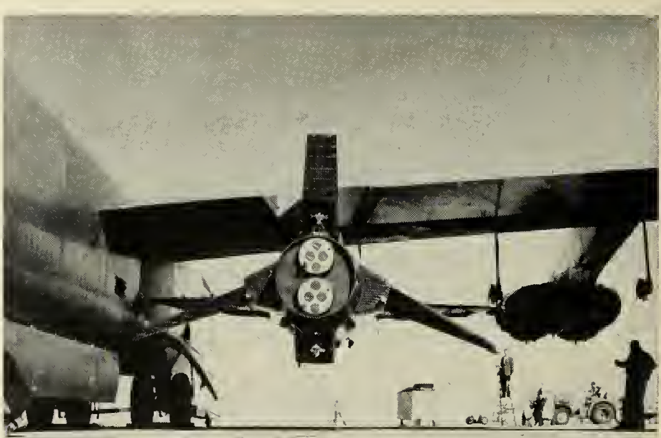
Fluid to be used__________
Temperatures from__________° to__________°.
Pressures from__________psi to__________psi.
Size_____I.D. Operation ☐ manual ☐ remote ☐ other

Name__________Title__________
Company__________
Address__________
City__________Zone_____State__________

astronautics in the news . . .

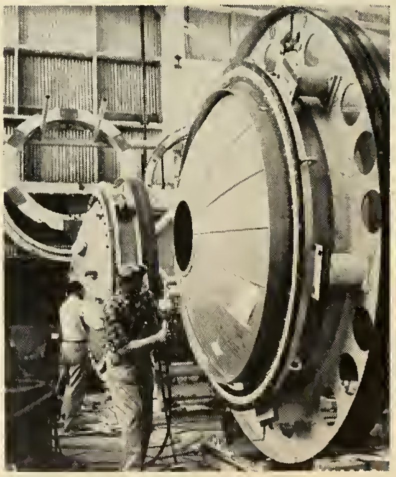


HEART OF THE *X-15* inertial guidance system developed by Sperry Gyroscope Co. First of six systems was recently delivered to Edwards AF. Dr. Carl Frische 'left' president and Nathan P. White, discuss system.



***X-15* ROCKET-POWERED high-altitude research craft attached to its pylon under the wing of the B-52 mother ship. Three main fittings secure the *X-15* and additional quick disconnect lines allow a launch panel operator in the B-52 to feed nitrogen and LOX to the rocket ship.**

REPLICA of the *Jupiter-C* rocket and the *Explorer I* satellite was presented to the Smithsonian Institution last week.



TANK BULKHEAD section of *Thor* is attached in large rotating fixture at Douglas plant.

Space Navigation Poses New Requirements

Automatic, self-contained inertial systems will be required to provide precise velocity vector control

by Frederick Stevens

Manager, Electronic Systems & Equipment, NORTRONICS Division, Northrop Corporation

HAWTHORNE, CALIF.—Present navigational art, which man has developed so painfully over the centuries, will be of little use to him in the age of space exploration, now irrevocably upon us.

Traversing the enormous distances of this and other solar systems will require a great revolution in the science of automatic navigation.

The rudimentary navigational techniques now being used in early efforts to probe space will soon become inadequate. In a very short time we will be in a sort of "mid-period" of space exploration when vehicle control by radar tracking and radio command will lose its effectiveness because of the square-law degradation of radio signal strength with distance.

As we move into this mid-period of high-orbiting earth satellites and systematic space probing, it is clear that we must utilize to an increasing extent automatic, self-contained guidance systems, carried on board the space craft, which can provide very precise control of the velocity vector.

• **Technique is there**—Luckily, a technique for automatic navigation of space vehicles during the mid-period is in existence, requiring only refinement and adaptation for space travel. This technique is the outgrowth of intensive research and development for intercontinental guided missiles, and the result of a technological revolution in automatic terrestrial navigation which began during and shortly after World War II.

The technique, of course, is inertial guidance, which involves the sensing and suitable interpretation of accelerations acting on a vehicle traveling through inertial space. A gyro-stabilized platform provides an inertial reference, and accelerations are sensed by accelerometers. Acceleration signals are integrated to obtain a measure of a present velocity vector. A second integration yields "space position." Computers are employed to maintain a "track" and to predict the ensuing trajectory of the vehicle.

• **How it began**—In this country, inertial guidance had its origin in the laboratories of intercontinental guided missile contractors shortly after World War II, when military requirements as well as certain technological advances in the gyro and electronics fields made it possible to construct satisfactory systems.

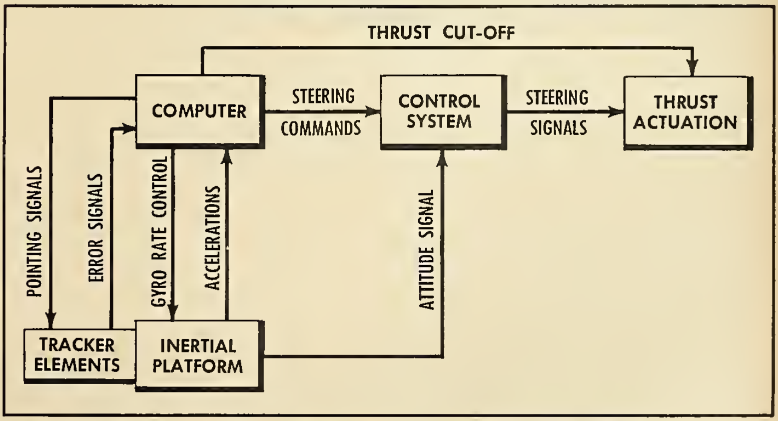
Systems development has proceeded along two lines. Inertial systems of the "pure" variety have been developed and used where relatively short periods of operation are involved and where the inherent tendency of gyroscopic mechanisms to drift will not seriously disturb system accuracy. Hybrid or "aided" inertial systems have been developed for application to intercontinental "cruise" type missiles where relatively long periods of system operation are encountered.

Hybrid systems employ additional and sometimes redundant monitoring subsystems to correct for gyro drift and other errors. Chief among these monitoring subsystems are automatic star trackers, capable of tracking a wide variety of navigational stars during broad daylight as well as during the hours of darkness. Stellar data is used to periodically reorient the inertial platform. Radio "aids" are also utilized for monitoring purposes, transmitting position and velocity information to the system.

The success of these systems in providing very accurate guidance for intercontinental guided missiles is well known. Most of the important ballistic missiles have "pure" and radio-inertial systems which provide accurate velocity control in the boost phases of flight.

• **Research continues**—With inertial systems of various types in quantity production for most of the operational and near-operational intercontinental missiles in our inventory, considerable research and development for more advanced applications of inertial guidance principles is in progress, including techniques for enhancement of system reliability.

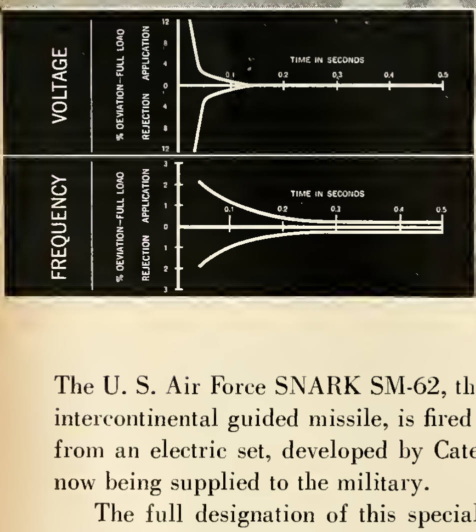
The current trend is towards system miniaturization, and inertial systems of the "pure" and "aided" variety with a total system weight equivalent to the weight of a human navigator will soon be available. Miniaturization has been made possible by advances in the solid state electronics field, by more sophisticated system design, and by refinement of platform stabilization and acceleration sensing techniques. There is also a trend towards digitalization of inertial sensing elements, undoubtedly permitting great size and weight reduc-



RELATION OF guidance system elements to velocity control and cut-off.

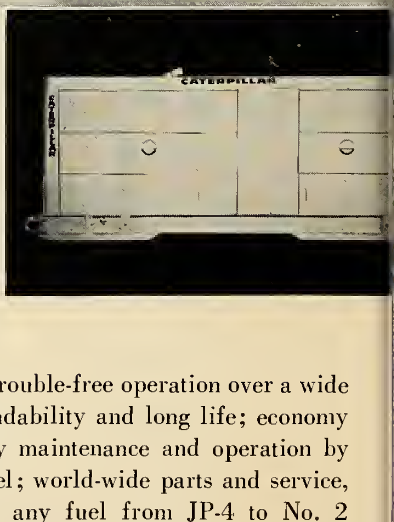
engine power BY CATERPILLAR

CATERPILLAR POWER FIRES SNARK...FIRST U. S. INTERCONTINENTAL MISSILE



The almost instantaneous return to normal of the new low-silhouette Cat power unit under conditions of full-load application, and load rejection (117.4 volts), is shown in the graph.

Low-silhouette Cat power unit with close voltage regulation is now being used in connection with ground support for jet starting and firing. The 400-cycle phase is specifically adapted to missilry.



The U. S. Air Force SNARK SM-62, the first U. S. intercontinental guided missile, is fired with power from an electric set, developed by Caterpillar and now being supplied to the military.

The full designation of this specialized power unit is Caterpillar 60 KW 400-cycle 120-208 voltage low-silhouette portable ground support unit with precision voltage regulation.

The secret of this unit is the almost instantaneous recovery to both applied and rejected loads. Other advantages found in all Caterpillar Engines include: trouble-free operation over a wide load range; dependability and long life; economy of operation; easy maintenance and operation by unskilled personnel; world-wide parts and service, and operation on any fuel from JP-4 to No. 2 furnace oil.

Creative engineering and quality of manufacture make Caterpillar the diesel leader. For detailed information on the Cat 60 KW 400-cycle portable power unit or other Caterpillar Engines, write to Engine Division, Caterpillar Tractor Co.

Engine Division, Caterpillar Tractor Co., Peoria, Ill., U.S.A.

Circle No. 18 on Subscriber Service Card.

tions and increased accuracy.

The advanced state of the inertial guidance art will soon permit systems capable of providing very accurate space navigation. Current technology can solve navigation problems during the coming mid-period.

• **Likely types**—The inertial system in space will resemble inertial systems for terrestrial navigation. There will be the usual gyro-stabilized platform, somewhat more sophisticated in design than the terrestrial platform. Because of the problem of gyro drift, which may never be completely solved, there will be a gyro-monitoring subsystem—undoubtedly a tracking device. For earth orbits, it will track the horizon of the moon or other planets, or perhaps the sun. For lunar orbits or for exceptionally high earth orbits, it will track fixed stars.

The tracking subsystem will perform essentially the same function that it has in the "aided inertial" terrestrial system described previously. There will be acceleration sensing devices mounted on the inertial platform, and there will be an airborne computer.

For the navigation of near-earth satellites and early lunar and space probes, a "pure" inertial system would perhaps be adequate, without tracker elements. In this case, there would be a "pure" inertial platform, with three gyros, three accelerometers, and four gimbals for all-attitude reference. This would not, however, provide the accuracy needed for precision interplanetary navigation.

In precision navigation of earth satellites and lunar and space probes, tracker elements would be required. In addition to the three-gyro, three-accelerometer, and four-gimbal platform, there would be three or less automatic telescopes for maintaining platform orientation in inertial space. Such a system would be entirely adequate for all but the most extended of interplanetary missions. If manned interplanetary missions are to be considered, planet trackers may be added to the system in order to improve the accuracy of intermittent position fixes.

• **Reliability stressed**—One of the chief problems in the development of inertial systems for space navigation is that of reliability and the attendant implications of component reliability. Fortunately, existing inertial guidance technology provides solutions to this problem. Component reliability techniques have been developed to provide unusually high reliability for terrestrial systems.

The inertial system in space will perform two basic functions, though there are necessarily many collateral functions. It will provide very accurate velocity control, and a constant indication of position in space.

• **Velocity control**—Velocity control will be achieved through instantaneous sensing of changes in the speed and direction components of vehicle velocity. While a vehicle is in a "parking" orbit, accelerometer signals are, of course, null. While the vehicle is moving towards the point of entry into orbit, however, craft accelerations, when singly integrated and compared with predicted velocity, will serve as control signals for placing the craft in orbit. Precision onboard velocity control will be particularly useful for positioning space vehicles in orbits, especially in the more exotic orbits where very high accuracy will be required.

One of the most interesting exotic orbits is the so-called 24-hour orbit permitting a vehicle in effect to hover over a given point on the earth's equator. To achieve such a useful orbit, it will be necessary to place a vehicle into orbit altitude with great precision. This will not be conveniently done solely through radio transmission of velocity data acquired through radar tracking. The altitude of the 24-hour orbit will be slightly above 23,000 miles, where signal degradation and time delay will be excessive. But an inertial system, being entirely self-contained, will provide instantaneous and continuous velocity data, with no time delay and no signal degradation. A suitably accurate trajectory to the point of orbit can thus be maintained.

• **Position data**—The inertial system will provide positional information in two ways. During periods of thrust, the system will operate much as it does in terrestrial missiles. The inertial platform will remain stable through the operation of platform gyros, and periodic platform stabilization will compensate for gyro drift by means of earth, sun, or star tracking. Accelerations will be sensed by platform-mounted accelerometers, and double integration of acceleration will obtain positional data.

Once a vehicle enters an orbit, however, there will be no accelerometer output because of the zero-g environment. Nonetheless, the system will have observed precisely the velocity of the vehicle at the moment of entry into orbit. If a computationally-derived measure of mass attraction forces is available, that observed velocity may be used by the inertial system computer to give a constant indication of position in orbit.

Positional data will be used in directing the vehicle from one orbit into another. The inertial system computer will initiate thrust at the exact point of escape. Thereafter, during cruise to the new orbit, the inertial system will provide position information which may be compared with data for a standard trajectory. Periodic corrections may be made to guarantee arrival at destination.

In a like manner, positional data will also be used in providing for escape from orbit to return to the earth or to land on other planets.

• **Side jobs**—In addition to velocity control and positional indication, there are collateral functions which may also be performed by the system. One difficult problem encountered in orbiting vehicles to date is tumbling, which disturbs the radio transmission of observed data and destroys the zero-g environment which may be desired for certain observations. The inertial system will sense this tumbling, thus permitting a corrective thrust application. Conceivably, by utilizing the principle of conservation of angular momentum a gyro-controlled platform could eliminate tumbling by selective programing into the platform gyro wheels of changes in angular momentum.

It is also conceivable that power could be taken from the stored energy in gyro wheels by running spin motors as generators during periods when power generation through solar energy is not possible.

One interesting possibility is the use of paired inertial systems for measuring gravitational gradients. Relative position in space could be thus determined by reading gravitational differences. Accelerometers sufficiently sensitive to perform the sensing function are not yet available, but they may be on hand in the near future.

New Engineering Center Planned For New York

New York—A new engineering center designed to serve 280,000 members of the profession is being planned by United Engineering Trustees, Inc. A building fund drive to raise $8 million is underway.

The planners of the new center, which will replace the present inadequate facilities, include the American Society of Civil Engineers, the American Institute of Mining, Metallurgical and Petroleum Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Institute of Chemical Engineers. United Engineering Trustees, Inc. is a joint corporate agency of these societies.

Midcourse Guidance Is Necessity for Interplanetary Travel

Venus flight would require orbit about the sun and eventual capture by planet

by L. T. Seaman

Manager, Navigation and Control System Design, Missile and Space Vehicle Department, General Electric Company

PHILADELPHIA—Space navigation may be defined as the means to measure the present position and motion of a space vehicle, to predict its future position and motion, and to apply orbit trajectory corrections so that the vehicle will reach a point in space at the same time the destination planet or moon is there.

The three functions—measurement, prediction and trajectory correction—are interdependent. This article illustrates the basic relationship between the accuracy of position measurement and the propulsion power required for trajectory corrections.

The general field of navigation of space vehicles includes launch guidance, midcourse guidance, and terminal—or landing—guidance. We are chiefly concerned here with midcourse guidance, which extends from cessation of launch guidance at booster burnout until the vehicle lands on the destination body or goes into orbit around it.

• **Present limitations**—Systems already are being developed for applications ranging from earth satellites and lunar probes to interplanetary vehicles. But the present limitations of launch guidance are demonstrated by the recent moon probes.

These lunar probes show that man is now or will be in the very near future, able to place a space vehicle at a range of the moon's orbit radius to an accuracy of one lunar diameter. However, applying this launch guidance ability to the more demanding field of interplanetary travel would result in intolerable misses for even the nearest planets. Midcourse guidance will be a necessity.

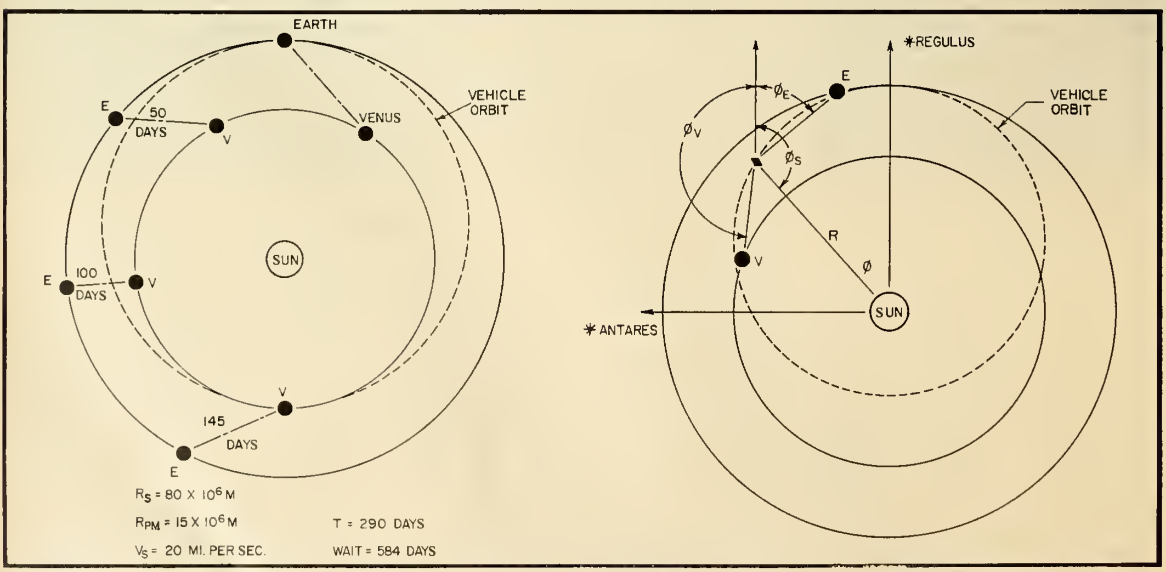
• **A Venus flight**—To illustrate the problems of space navigation, let's consider a trip to the planet Venus. It would be done in three phases:

1. Escape from earth's gravitational field. This may include an intermediate earth orbiting phase for refueling or improving launch guidance accuracy.

2. Orbit about the sun. The orbit must intersect Venus' orbit at a time when Venus is at or near the point of intersection.

3. Capture by the planet. This includes cutting or modifying the vehicle velocity so that an orbit about Venus or a landing is attained.

• **Midcourse**—Phase 2 involves the longest time and distance. The space vehicle will be so remote from the planets that active means of navigation such as radar will be difficult to use. The sun's gravitational field is predomi-



MINIMUM ENERGY orbit transfer shows it would require 145 days to traverse 250 million miles (Figures 1 and 2).

Just an annoyance?

A symphonic note?

Is it harmful?

How can it be put to use?

Waste energy?

What are its psychological and physiological results?

What is a phonon?

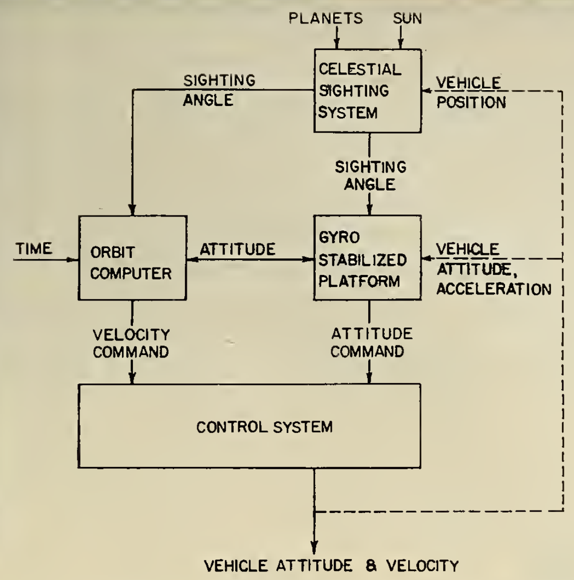
A precise definition of sound is important to Allison because energy conversion is our business and sound is a form of energy. We convert the energy of sound to destroy materials, to nondestructively peer into material, to join materials without applying heat from an arc or a torch, and for myriad other applications.

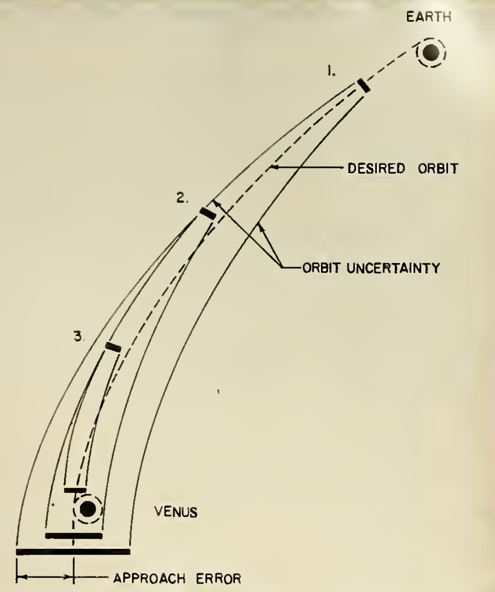
Using the knowledge obtained from our inquiries, Allison is applying its systems engineering concept to new research projects. In this effort we complement our own capabilities by drawing upon the intellectual and physical resources of General Motors Corporation, its Divisions, and other individuals and organizations. Thus we increase the effectiveness with which we accomplish our mission—exploring the needs of advanced propulsion and weapons systems.

Energy conversion is our business

ALLISON

Division of General Motors,
Indianapolis, Indiana





BLOCK DIAGRAM of a space navigation system including reaction thrust for stabilization. (Figures 3 and 4)

nant from at least 150,000 miles above the surface of Earth to roughly the same distance above Venus, or a third of that distance above Mars. At these altitudes, the force of the sun's gravity equals that of the planet for an object located on the line between them.

A minimum energy orbit transfer between Earth and Venus is shown in Fig. 1. It illustrates the immense distances, high velocities, and long periods of time that are characteristic of space travel. The space vehicle is roughly 80 million miles from the sun and 15 million miles from the two planets at the midpoint of its flight. It is moving at an orbital velocity of roughly 20 miles/sec. (its velocity relative to the planets is, of course, less than this). The journey to Venus requires 145 days to traverse a total distance of 250 million miles.

Although the minimum energy orbit requires the least propulsion power for a trip to a planet, it has the major disadvantages of long flight time and restrictions of launch time. The vehicle must be launched when the two planets have the relative positions shown in Fig. 1. If the launch is delayed due to mechanical or other difficulties, it must be delayed 584 days until the planets assume the same relationship again. For this reason alone, non-minimum energy orbits are highly desirable.

• **Basic measurements**—An example of the general measurement problem in space travel is shown in Fig. 2, which depicts a non-minimum energy flight from Earth to Venus. The space vehicle is shown at an intermediate position that is defined in polar coordinates. Rectangular coordinates may as easily be used and the selection of either will depend on any computer simplification possible.

The ecliptic planes of Earth and Venus differ by 3° 24′ so that the navigation problem is not coplanar as indicated.

The reference coordinate system can be accurately set up by star sights. A trajectory plane parallel to Earth's or Venus' ecliptic plane may be chosen. As shown in Fig. 2, the first magnitude stars, Regulus and Antares, since they are approximately 90° apart and near to the ecliptic plane, may be sighted to establish the trajectory plane. The star Polaris may be used to determine the normal to this plane, if compensation is made for its declination from the Earth's ecliptic pole of 23.5°.

If the accuracy of instrumentation warrants, compensation for the stars' heliocentric parallax may be made. However, this effect is small—the nearest star, Alpha Centauri, is 4.3 light years away and has 0.76 seconds parallax.

To determine the vehicle's orbit, and to predict its position error on arrival at Venus, we must measure position, velocity, acceleration, attitude, and time.

• **Position**—The location of the space vehicle may be determined by sighting three celestial bodies such as Earth, Venus, and the Sun.

Alternate means of position measurement include radar or the inertial guidance method of double integration of acceleration.

• **Velocity**—Velocity is a derived quantity based on either the integration of acceleration or the differentiation of position. The former is suitable for short time periods and for powered flight conditions, and therefore, is useful for trajectory corrections made during orbital flight.

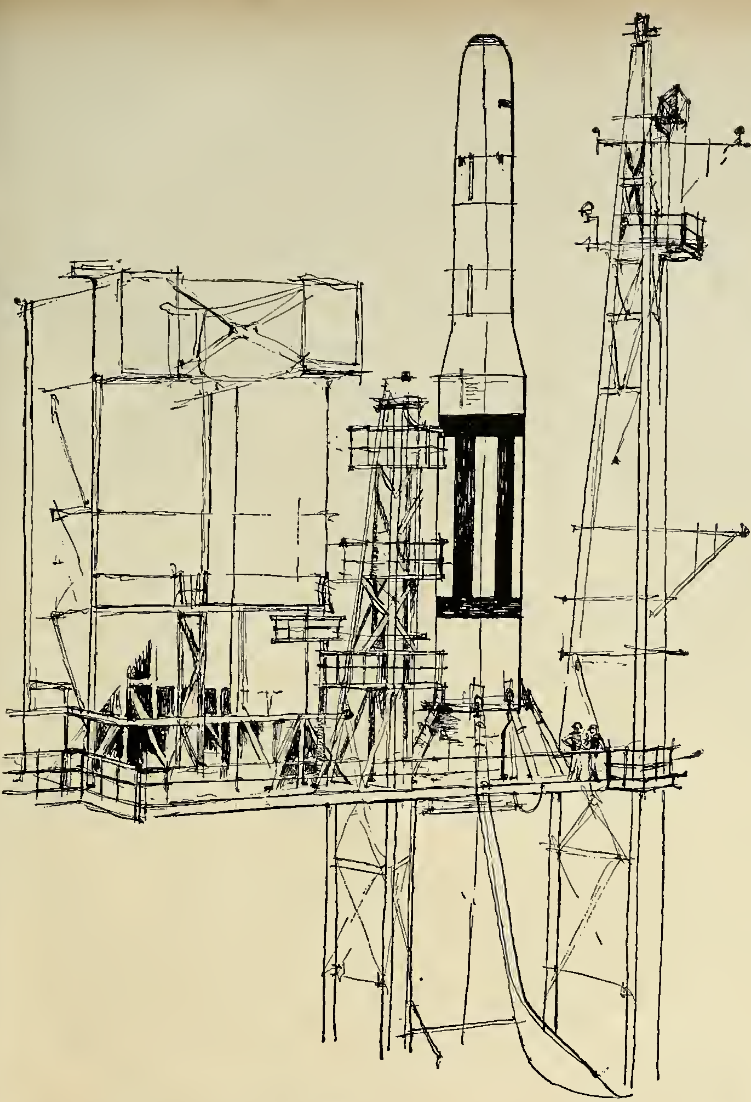
The method of position derivative is the best means of determining velocity during orbital flight. It may be expressed as

$$V = \frac{d}{dt}(s) = \frac{S_1 - S_2}{t_1 - t_2}$$

Its accuracy increases as the time interval between position readings increases. For this reason, and because the trip to Venus may take over 100 days, velocity calculations probably will be made with an "averaging" period of over one day.

The doppler principle of measuring range rate may, in theory, be used to measure velocity. However, present radars are not equal to the range requirements. The doppler effect in the visual light spectrum has been used to determine the speed of distant stars. However, its accuracy is in the order of miles/sec. and, therefore, inadequate for space navigation.

• **Acceleration**—The measurement of acceleration during trajectory corrections may be made with today's precise accelerometers. An accuracy equal to that of ballistic missile guidance sys-



tems is adequate.

• **Attitude**—The attitude of the space vehicle must be known accurately during trajectory corrections to align the control rockets to the desired orientation. Attitude may be determined by celestial tracking and by a gyro-stabilized platform. Long-term corrections for gyro drift will be made from the information obtained by celestial tracking.

• **Time**—The measurement of time is all-important to space navigation. Accuracy may require relativistic corrections to the apparent time.

Once the orbit of the space vehicle is known and its approach position error at Venus predicted, the orbit may be modified to reduce this error. Trajectory corrections may be made by a short-duration reaction impulse that generates a pre-computed vector velocity increment. Although present chemical fuel rockets are capable of this type of correction, the frequency and magnitude of trajectory corrections is limited in available rockets by the weight of propulsion fuel required.

Improvements in chemical fuels will permit greater corrections to be made for the same weight of the midcourse guidance system.

• **Navigation plan**—A simplified block diagram of a space navigation system is shown in Fig. 3. It consists of a celestial tracking system for measuring orbital position, a gyro-stabilized platform for stabilized attitude indication and for precise determination of acceleration during trajectory correction thrust periods, and an orbit computer that determines the actual orbit from the position, acceleration, and time information and computes the correction necessary to achieve an orbit that intersects the destination planet at the proper time. The system shown includes the reaction-thrust means that stabilize the vehicle in attitude and apply the correction thrust as called for by the orbit computer.

Accuracy depends on three factors:

1. Resolution of detection means—The entire electromagnetic spectrum should be considered in obtaining suitable detection means. Visible light may be used with visual or photoelectric sensing. The infrared spectrum may be sensed with suitable detectors. Radio waves, including those generated by the stars and planets themselves, are also a possibility.

2. Sighting mechanism—The mechanism used to align the "telescope" for celestial sighting must be extremely precise and relatively complex.

3. Readout—The electrical readout of the sighting system must use a digital technique. Analog equipment is limited to accuracies in the order of minutes of arc unless extremely complex tech-

niques are used extensively.

Precision and complexity also are major problems in the orbit computer. This equipment must compute new trajectories that take the vehicle from its present position in space to a new estimate of Venus at arrival time. Hence it must be capable of almost an infinite number of complete orbit computations. It is comparable in complexity to a large, high-speed general purpose digital computer that—somehow—must be made small enough and of a low enough power consumption to be carried and used on a space vehicle.

• **Tracking accuracy**—An approximate determination of celestial tracking angular accuracy requirements may be made by the approach shown in Fig. 4, assuming a flight from Earth to Venus. The following are assumed control system objectives:

1. To insure that the approach to Venus is sufficient to subsequently attain a circular orbit about the planet. For the present purpose, it is assumed the space vehicle must intersect an orbital altitude with an error of less than 10,000 miles.

2. To use minimum fuel.

When the vehicle is near to Earth, the orbit uncertainty resulting from position and velocity measurements creates a large approach error at Venus. When the vehicle is half the distance to Venus, the uncertainty in the vicinity of Venus is much smaller, assuming the same inaccuracies in orbit measurements. At this time, a trajectory correction is made, resulting in a reduced approach error. As the flight progresses, the procedure is repeated every time the distance to go is reduced to one-half of that when the last trajectory correction was made.

In actual flight, corrections would be made whenever significant accuracy could be gained, since fuel is saved by correcting as early as possible.

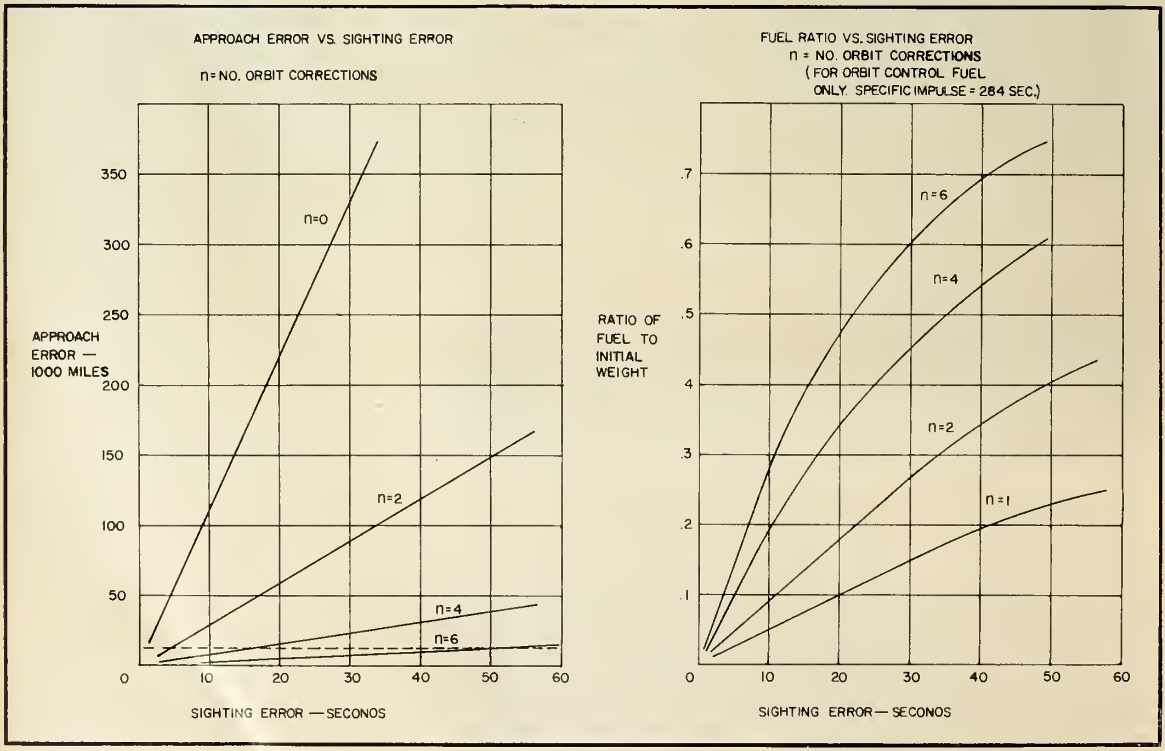
It was assumed that the orbital velocity relative to Earth and Venus was roughly 6 mi/sec., and that position measurements obtained by sun and planet sighting were "averaged" over a one day period to determine velocity.

The variation of approach error with sighting error is shown in Fig. 5. For no trajectory correction (N = O), the sighting accuracy must be less than 1 second of arc to "hit" Venus within 10,000 miles. However, with six trajectory corrections an accuracy of 50 seconds is sufficient. It is also evident that if unlimited corrections can be made (unlimited power), accuracy is no longer important, and the space navigator could "drive" to Venus with only visual contact.

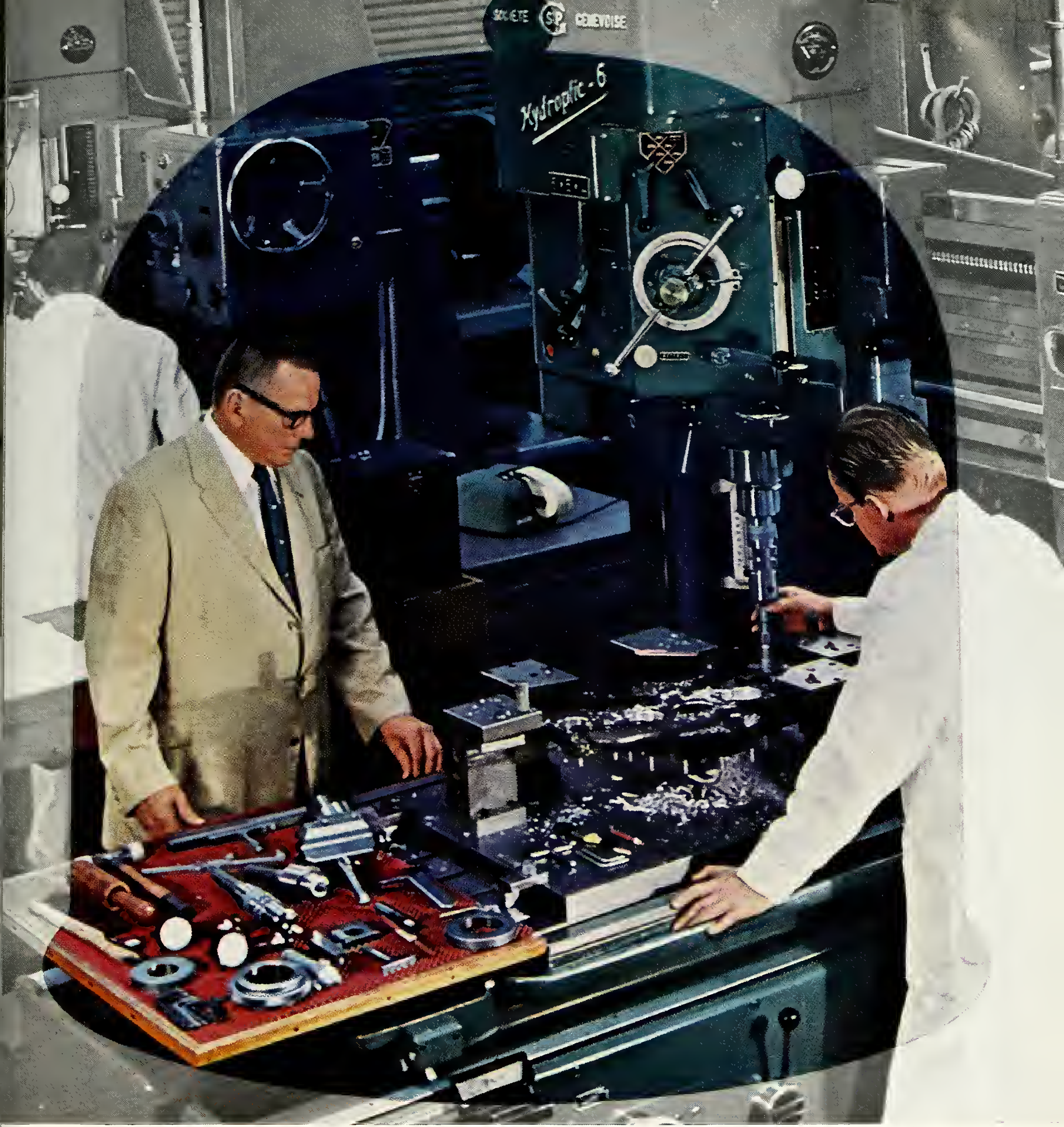
• **Fuel needs**—The ratio of fuel to initial weight for various sighting errors is shown in Fig. 6. The ratios plotted are only for the fuel required for orbital control—the propulsion power for escape from Earth and orbit attainment about Venus is not included. A specific impulse of 284 seconds is assumed.

If a fuel ratio of 0.2 is acceptable, the sighting error must be 7 seconds of arc for the 6 trajectory corrections required for a 10,000-mile approach error. A low fuel ratio is obviously desirable—if we assume an escape fuel ratio of 0.9, a Venus orbit fuel ratio of 0.5, the above fuel ratio amounts to 20% of the payload on only a one-way trip. Comparison of Figs. 5 and 6 demonstrate that the necessity for low fuel weight requires more precise sighting accuracy than that required for low guidance errors:

Therefore, for a fuel ratio of 0.2, and an approach to Venus error of 10,000 miles, the angular accuracy of celestial tracking must be less than 7 seconds of arc for present day propulsion fuels. An increase in the specific impulse of the fuel has an almost direct effect on this requirement. An increase to 1500 seconds, approximately 5 times, permits a sighting accuracy of 30 seconds or roughly 4 times the above requirement.



VARIATION OF APPROACH error with sighting error (Fig. 5). Ratio of fuel to initial weight for sighting errors (Fig. 6).



Like in a huge bell jar, temperature and humidity are controlled to exacting standards in I. G. W.'s precision jig bore room.

Precision is our only product!

At Indiana Gear, precision goes far beyond the usual customer requirements. Precision is a part of order coordinating, engineering, production, inspection . . . a part of *every* Indiana Gear operation. Precision is a way of thinking at Indiana Gear . . . a method of always working beyond the fringe of the state of the art.

IGW

INDIANA GEAR WORKS, INC.
INDIANAPOLIS 7, INDIANA

Indianapolis, Ind., ME 8-2331, TWX IP-174-U • Redondo Beach, Cal., FR 5-7597, TWX 7856-U • Westport, Conn., CA 7-0262, TWX 486-U

The How and the Why of Inertial Guidance

While basic principles have been known for many years, solution of some of the problems peculiar to ballistic missiles is only now becoming a reality.

by F. K. Mueller

Inertial guidance is the only near-perfect system yet known for directing the flight of big missiles. Many attempts have been made to outline the real problem and the solutions now being used. But most explanations—deeply oriented in inertial guidance of winged aircraft—have one basic fallacy when applied to ballistic missiles: the stable reference is never self-contained. Rather, it is always assumed in terms of the Schuler Pendulum—a proper device in considering sub- or near-sonic speeds, but completely useless in terms of ballistic velocities.

Because of the increasing interest in inertial guidance of IRBMs and ICBMs, m/r in this issue presents a primer in the subject by one of the world's experts—F. K. Mueller, deputy director of the Guidance and Control Laboratory, Development Operations Division, Army Ballistic Missiles Agency. Readers will remember Mueller's article, "The New Look in Gimbal Systems," in the March, 1958 issue. Gimbal systems like those he described then, together with the principles presented here, were the basis for this country's first operational true inertial guidance system—the guidance and control arrangement on the Redstone.

HUNTSVILLE — Tremendous effort has gone into the development of inertial guidance systems over the past few years to satisfy a basic requirement of ballistic missiles:

Measurements must be made continuously—and directly on the missile—during its flight, in order to guide the missile inertially and make it hit its predetermined target. These measurements—to determine angular orientation and motion of the center of gravity—must be referred to a fixed three-axis coordinate system within the vehicle, where actual conditions are automatically compared to a predetermined flight program. And from these comparisons, necessary signals must be generated to cut off thrust and make corrections in attitude and trajectory.

In theory, the answer is comparatively simple: gyro-stabilized platforms and accelerometers would do the trick. But although the basic principles of inertial guidance were known 25 years ago, the solution of some of the problems peculiar to missiles is only now beginning to emerge.

Very briefly, an inertial guidance system works this way: The stabilized platform provides a fixed coordinate reference system, and also a carrier for the accelerometers. The accelerometers measure components of the linear missile acceleration, in directions previously established by the reference system, thus making it possible to compute missile velocity and distance covered—two basic elements of any navigational problem.

• **Obstacles**—But missiles immediately posed some very special problems. One of these had to do with the gyroscopes that are the basis of the stabilized platform. The precession rate of conventional ball-bearing-mounted gyroscopes can vary from a few to 50 degrees/hour in a matter of minutes. Such a precession rate—in a gyro mounted in a ship or an airplane—is not a particularly serious matter. The relative speed is low enough that the deviation seldom can assume serious proportions, and it can be easily monitored by other devices, including magnetic compasses.

But the enormous acceleration and speed of the missile, and the fact that complicated supervisory devices must be cut out, make it imperative that the gyros in missilery be as nearly frictionless as possible, to reduce the precession possibilities to the barest minimum.

This problem has been brought under control by the development of so-called frictionless bearings—floating either in liquid or under pressure in gas.

Aside from such problems as these, there are numerous environmental conditions to be coped with:

Practical logistic support requires rugged instruments that may be stored for a long time and transported by conventional means without special temperature and humidity. They must require no recalibrations, be easy to check out and have easily-exchanged components. These are not features normally associated with high-accuracy instruments.

To meet these needs, rugged and symmetrical designs have been made with materials carefully selected in regard to dimensional stability, thermal expansion, low creep and corrosion.

Finally, the flight itself presents many problems: The instruments are subject to high-thrust acceleration—changing in magnitude, and partially in direction—and to vibration. While the acceleration forces are known, those of vibration are not—the designer must anticipate them as best he can.

• **Start of progress**—Designers of a missile component must understand the various phases of the flight of their bird, before working out details of the component.

Careful plotting of the trajectory of a ballistic missile is illustrated in the accompanying Fig. 1, tracing the action from launching point through thrust cut-off, free flight and return to the atmosphere—and the target. During the propelled phase, acceleration increases, and direction changes gradually; during free-flight, the missile and

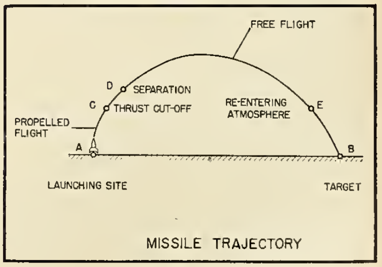
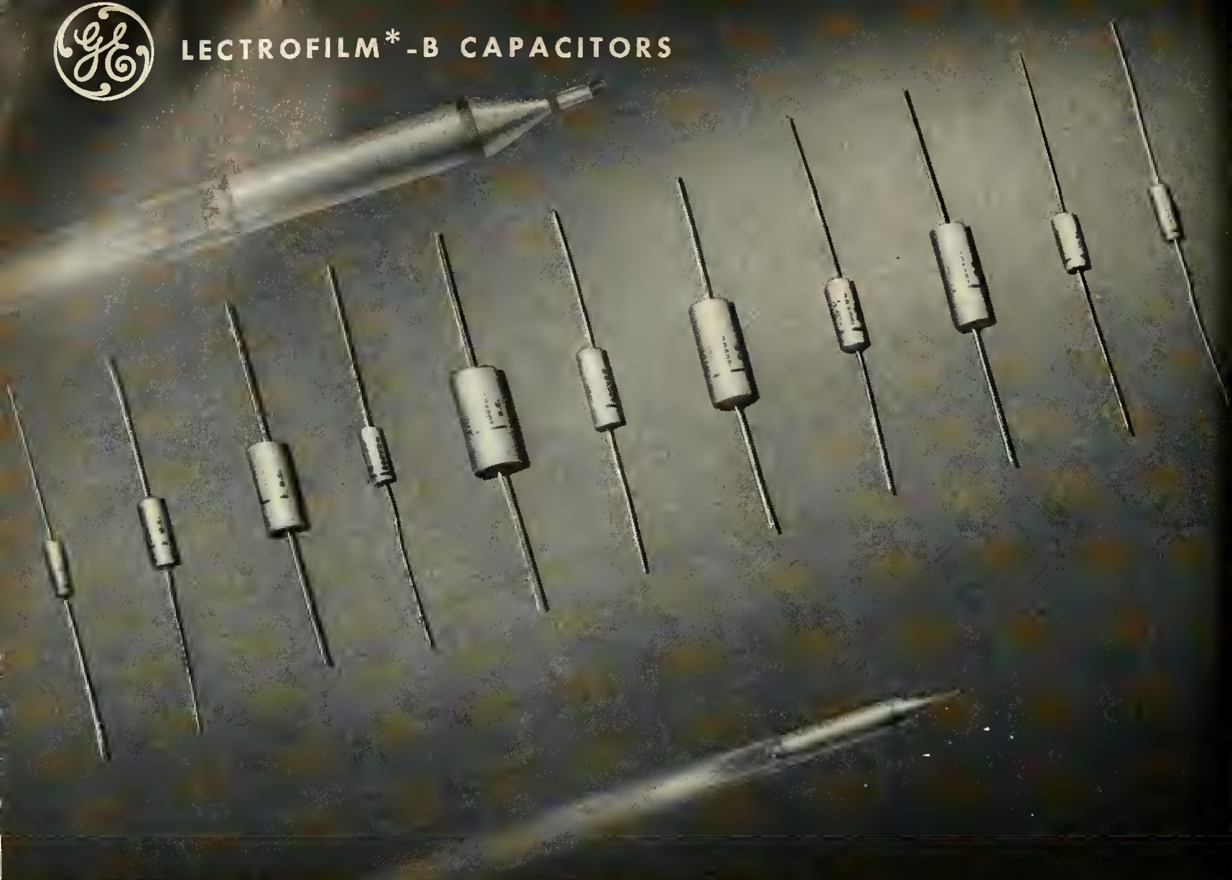


Figure 1.



General Electric Announces for Missile Use . . .

New Lectrofilm*-B Capacitors for 44,000 Hours of Reliable Life

New G-E Lectrofilm-B capacitors offer you maximum reliability at lowest possible cost . . . results of over 3,000,000 unit-hours of life test data (per G-E Spec. MTC-3) indicate a probability of survival in excess of 0.99 for 44,000 hour life under rated voltage at 85C. Under rated voltage at 125C, the indicated probability of survival is in excess of 0.98 for 44,000 hour life.

LOW FAILURE RATE AND LONG LIFE of these inexpensive G-E capacitors result from using only the highest quality materials and the closest of process controls . . . units are tightly wound with high-purity aluminum foil and capacitor-grade Mylar† film dielectric. No solder is used, and introduction of contaminants through impregnation is eliminated.

SMALL, LIGHTWEIGHT ENCLOSURE consists of tape wrapped around the compact roll and sealed with epoxy resin, forming a rugged case which resists humidity, vibration and shock.

TO MEET YOUR APPLICATION REQUIREMENTS, 14 case sizes are available in five ratings—100-, 200-, 300-, 400-, and 600-volts. Capacitance range within each rating is: 0.015 to 0.68 uf in 100 volts; 0.010 to 0.47 uf in 200 volts; 0.0047 to 0.22 uf in 300 volts; 0.0033 to 0.15 uf in 400 volts; and 0.0010 to 0.10 uf in 600 volts.

GET A QUOTATION TODAY ON NEW LECTROFILM-B CAPACITORS by contacting your General Electric representative. Ask for your copy of life-test data and G-E Specification MTC-3. Or, write to Section 447–4, General Electric Co., Schenectady, N. Y.

*Trade-mark of General Electric Co. †Reg. trade-mark of DuPont Co.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle No. 27 on Subscriber Service Card.

its components are subject only to the forces of gravity, and in the final stage, the missile slows down.

During these stages, various means may be used to control the missile and insure its arrival on target: air vanes or swivelling of the motor during propulsion; jets, during the free-flight period; air vanes after re-entry into the atmosphere.

In all cases, sufficient data must be stored in the missile's inertial control system so that proper measures are taken to control the flight to the target.

In detail, here is how these control systems work:

• **Stabilized platform**—The stabilized platform establishes a space-fixed (star-fixed) reference coordinate system. A three-axis gimbal arrangement, supporting the stabilized part, allows for angular motions of the missile. The missile attitude angles are measured on the gimbal rings.

Predetermined tilt programs are introduced on the gimbal system against the stabilized part. Accelerometers are mounted on the stabilized part with their measuring directions suitably oriented to the space-fixed reference coordinate system.

The platform is stabilized in the desired fixed angular position by use of the stabilizing power of the gyros and their precession, in connection with servo systems. The deviation of the stabilizer coordinates from the initially established orientation is called the drift.

Since environmental conditions of a flying missile do not allow supervision of drift, improvement of the drift rate performance for guided missiles is a major challenge confronting the inertial guidance design engineer.

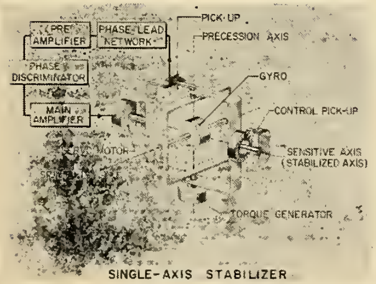


Figure 2.

Fig. 2 shows, in principle, the arrangement of a single-axis gyro stabilization. In spite of the actual three axes, the configuration is considered a one-axis gyroscope because only one axis is employed for stabilization. The associated internal servo loop consists of a servo pick-up, a phase lead network, a pre-amplifier, a phase discriminator, a main amplifier, and a servo motor. The accuracy of such an instrument is mainly restricted by the friction and other disturbing torques about the precession axis.

A complete stabilized platform combines three mutually perpendicular stabilization axes in one gimbal system, and employs for each axis a stabilization arrangement as described for Fig. 2.

To save weight and space, the stabilization axes are established by an internal gimbal system, acting as a universal joint.

Since the accuracy of a gyro is largely governed by the friction on its precession axis, a great effort has been made to develop a frictionless bearing.

• **Frictionless bearings**—In the gyroscopic devices of guidance systems, the precession axes of the gyros are suspended by frictionless bearings. Ball bearings, as they are commonly applied in traditional aircraft instruments, would produce drift rates intolerable for missile guidance.

Very early in the development of the frictionless bearing, this program branched off in two different approaches: one developed the floating bearing; the other, the pressurized bearing. (There are also combinations of these two.)

Both programs progressed so that the performance of the gyros is no longer determined by friction, but by other trouble sources.

One type of the pressurized bearing is the so called Air Bearing. It uses air or gas as a carrying medium.

In an air-bearing device, the inner or floating part is separated from the outer part or the bearing case by a thin film of air.

Compressed air enters the air gap between inner and outer sections through the air inlet, air chambers, and distribution holes, and finally escapes through the air outlets. The diameter of the distribution holes is a few thousandths of an inch, the thickness of the air film about 1.5 thousandths of an inch. Required tolerances on floating part and bearing case are well within the limits for production of precision instruments.

The fact that mechanical contact between inner and outer sections is prevented eliminates coulomb friction. The viscous damping around the air-bearing axis is negligible because of the low values of the viscosity and the angular velocity present during operation.

Carrying capability of the bearing is based on the differential pressure produced by small displacements of the floating part. A characteristic curve of the displacement over the acceleration in g's is given in Fig. 3.

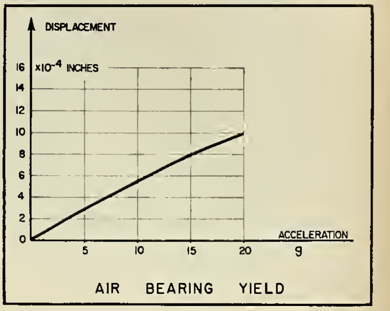


Figure 3.

Because of the elastic air gap, the bearing has a natural frequency on the order of several hundred cycles per second. The inherent damping of these linear oscillations is relatively high and assures stability. Vibrational frequencies of the missile in the neighborhood of the natural frequency of the bearing are already attenuated by the supporting structure.

Basically, the floating gyro is somewhat similar to the air-bearing type. The gyro motor is located in a can. The density of the complete can corresponds to that of the liquid. Therefore, the can or inner part floats in the liquid.

Since the liquid is not pressurized, additional pinion bearings are provided to maintain axial alignment. Although the liquid film is much thicker than an air film, there is considerable viscous damping because of the relatively high viscosity of the liquid.

But even gyros supported by frictionless bearings have some low-level disturbance torques. They can be divided into two groups:

1) Torques inherent in the bearing. Frictionless bearings are never ideal and have some torques due to small imperfections. However, these torques can be kept small enough to be of minor importance.

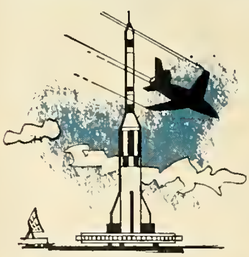
2) Torques caused by the shift of the center of gravity of the floating part. Because they are sensitive to acceleration, such torques are the major problem for gyros in guided missiles. Dimensional stability under flight condition and isoelasticity of the floating part determine the accuracy of the gyro.

All disturbing torques must be kept within moderately small limits for both types of frictionless bearings. Maximum allowable values depend on accuracy requirements and the value of the angular momentum of the gyro.

While disturbance torques of con-

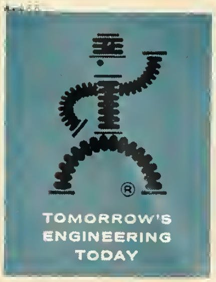
Intricate ducting system or individual components . . .

FLEXONICS HAS WHAT IT TAKES TO SERVE YOU BEST



For more than half a century, Flexonics has pioneered in precision-forming thin metals into flexible carriers for a variety of media . . . and still leads. This special talent of Flexonics engineers and designers is available to you in the development of ducting systems and flexible connections.

For the most authoritative product and design recommendations covering ducting systems, flexible connectors, bellows, metal hose, and Flexon T (Teflon)—contact your Flexonics Sales Engineer or write for Flexonics Aeronautical Engineering Manual.



Flexonics

AERONAUTICAL

FLEXONICS CORPORATION • 1414 SOUTH THIRD AVENUE • MAYWOOD, ILLINOIS

Divisions

INDUSTRIAL HOSE • EXPANSION JOINT • BELLOWS • AERONAUTICAL • AUTOMOTIVE

Flexonics Research Laboratories, Elgin, Illinois

In Canada: Flexonics Corporation of Canada, Limited, Brampton, Ontario

Circle No. 25 on Subscriber Service Card.

ventional gyros are expressed in centimeter grams, a unit about a thousand times smaller—the centimeter dyne—is used for frictionless bearings.

• **Gyromotor**—In systems based on frictionless bearings, the shift of the center of gravity or unbalance of the floating part becomes the most important reason for drift. It is caused by dimensional changes of the can and gyro support structure, and by relative displacements of parts making up the gyro motor itself.

The can and the supporting structure should be as sturdy and solid as possible in order to minimize deformations. Air-bearing gyros allow high overall density for the floating part; this gives the designer a free hand in choosing dimensions and materials.

The most critical item is the gyro motor itself, located inside the floating can. Any electrically-driven gyro motor is built up of a number of different materials: bronze or stainless steel for the rotor, silicon steel for the stator, steel for the axle, paper and lacquers for insulation, and copper for motor windings.

The temperature coefficients of expansion of these materials vary over a wide range, so that heating and cooling cycles create slight relative motions of the different parts. It is very unlikely that after such temperature cycles the relative position of parts will correspond exactly to the initial one.

Thus the heat generated in the motor will cause a shift of center of gravity, resulting in a disturbing torque subject to acceleration. To avoid unbalanced effects of this nature as much as possible, the gyro is built symmetrical about its equatorial plane. (See Fig. 4.)

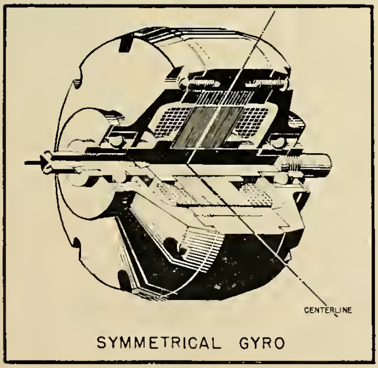


Figure 4.

This kind of gyro motor is of the hysteresis synchronous type, requiring no windings and no electrical connections on the rotating element. Other features are low power consumption (to keep the temperature differences low when in operating condition), close temperature control of the surrounding medium, and stabilization of heat flow by exact control of power consumption and frequency.

Extreme care must be taken to design all the other parts—such as end-bells, shafts, and inner parts—for high rigidity and isoelastic deformation. Disturbance torques caused by unequal elastic deformations depend on the square of acceleration.

• **Drift**—All disturbances occurring in the frictionless bearing, in the can, in the gyro support, and in the gyro motor, produce torques around the precession axis of the gyroscope, and thus cause drift. The three modes are:

a) Constant torques, independent of acceleration.

b) Torques depending on magnitude and direction of acceleration.

c) Torques depending on the square of acceleration and its direction.

Torques dependent on square of acceleration can produce considerable drift rates. They are described by the equation:

$$T = m^2g^2Y \cdot \left(\frac{x}{y} - 1 \right) \cdot \sin 2a;$$

where m = mass, g = acceleration, x and y = yield rates in direction of the main axes, and a = angle between the direction of acceleration and the direction of a main axis.

The g^2 term makes the gyro also susceptible to vibrational accelerations. Since vibrations occur in any direction, angle "a" can be 45°. This means that maximum vibrational torques must be considered. Actually, the drift caused by such vibrational torques can easily exceed those caused by linear acceleration. With respect to thrust acceleration, the angle "a" can be kept small by particular arrangement of the gyros on the stabilized platform.

For missile guidance, another type of supervision was developed: "stellar supervision, or star tracker." Such a star tracker, mounted on the stabilized platform and relying on the position of a fixed-star, indicates the gyro drift and provides proper correction signals.

Even in this case, the requirements on the gyro drift are still very high. The missile has to be guided to considerable altitudes, and the selected star must still be within the restricted aperture of the star tracker after the elapsed flight time. It is obvious that stellar supervision, with all its inherent complications, pays off only for long-range missiles with a long guided-flight phase.

• **Servo loops**—gyro stabilizers require servo motors and associated electrical servo loops to support their gyros and maintain their position. They operate this way: A gyro transforms any torque about its stabilizing axis in an angular velocity about its precession axis. A pick-up on this axis gives an output proportional to the precession angle, which means that this pick-up delivers an integrated value which lags with reference to the torque input. Through correcting networks and amplifiers, the output controls a servo motor on the stabilizing axis to compensate the original disturbance torque.

Considering transients, the networks have to compensate for the phase shift caused by the integrating feature of the gyro and for any inherent time constants. They also have to provide enough phase shift for damping.

Where a gyro can be used with a relatively large angular momentum, it will provide direct stabilizing power to the platform, taking care of transient torques. The servo motor deals mainly with the steady-state torques. In such a system, gain-and-response requirements on the servo loops are not too stringent.

But gyros with relatively small angular momentum require higher gain and much faster response in servo loops and servo motors. While the large gyro provides brain and muscles, the small one provides brain only, and stabilization depends entirely on its servo system. For weight, space, and simplicity, a good compromise must be found.

The type, as well as the relative size, of the stabilizing gyro influences the servo loop. Liquid floating gyros provide a considerable amount of viscous damping on the precession axis, easing the servo loop stability problem by omitting the torqueless precession axis.

Air-bearing gyros, for all practical purposes, do not have a viscous damping on the precession axis. Hence the servo loop must provide all the damping. Incorporation of the first and second derivative of the angular servo pick-up signal is required.

To maintain extreme reliability of the servo loops under pre-flight and flight conditions, transistor or magnetic amplifiers should be applied wherever possible.

• **Accelerometers**—Another major component in inertial guidance is the accelerometer. There are two principal types in development: the reaction type and the gyro type. Both use the inertia of an unbalanced mass to create a torque proportional to acceleration.

In the reaction type, the unbalance torque is compensated by an electrical torquer. The current required by this

torquer is proportional to the torque produced by the unbalance. Its value has to be measured. Velocity and distance may be obtained by integrating this value in a computer—once and twice, respectively.

There is a special type of reaction accelerometer, usually known as the double integrating accelerometer. A frictionless bearing supports a can with a pendulous weight and a position pick-up. A motor with a high-inertia rotor is mounted inside the floating part with its axis parallel to the axis of the frictionless bearing.

An acceleration perpendicular to this bearing, and to the pendulous weight, results in a torque and in an output of the position pick-up. This output controls the speed of the motor in such a way that the reaction torque compensates the acceleration torque.

Therefore, the instantaneous angular velocity of the rotor corresponds to the first integral of the acting missile acceleration over the time—in other words, to the velocity of the missile. The angular position of the rotor at any given moment corresponds to the second integral of the missile acceleration over the time—the distance covered by the missile.

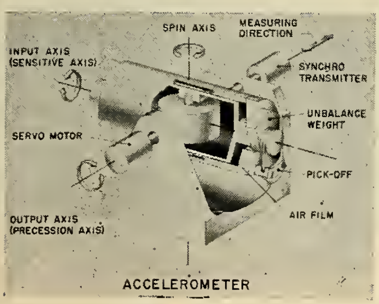


Figure 5.

In the gyro type accelerometer, shown in Fig. 5, the unbalance weight is mounted on the input axis of a gyro. It will produce a torque about this axis proportional to the acceleration. This torque in turn will produce a precession rate about the output axis, which is also proportional to the acceleration of the missile in the measuring direction.

The angle through which the precession axis turns is the integral of the rate of turning over a certain time. It corresponds to the velocity of the missile. Only one additional integration in a separate computer is necessary to obtain the distance covered by the missile.

Friction and other disturbing torques about the input axis of any accelerometer must be kept at a very low level. They sum up with the effective unbalance torque and therefore introduce an error. To meet the accuracy requirements of guided missiles, it is mandatory to keep the ratio between effective unbalance torque and disturbance torque high.

This means that a frictionless bearing must be applied, and extreme care must be taken to hold any other disturbing torques small. The gyro type accelerometer allows a relatively large effective unbalance torque, since there is no limitation by a possible reaction torque.

A particular requirement for an accurate gyro accelerometer is that all axes be initially aligned perpendicular and remain so within a few seconds of arc. This is achieved by precise machining and calibrating.

The instrument requires an internal servo loop like any other gyroscope. This servo loop must be very rigid to hold the alignment of the unbalance weight in the measuring direction, and very well damped to restrain the effects of missile vibrations transmitted through the stabilized platform to the accelerometer.

The a-c supply frequency for the gyro drive has to be regulated very accurately since the angular momentum of the gyro is directly proportional to the frequency, and the angular momentum is a constant in the computation of velocity and distance. Thus a special frequency governor is used to provide the required accurate frequency.

• **Integrators**—Depending on the overall guidance scheme and the type of accelerometers used, one or two integrations must be performed to acquire velocity and distance covered by the missile. These integrations can be accomplished by either electrical or mechanical means.

Electrical integrations call for computers with analog or digital output. The mechanical integrations most commonly feature a ball and disk integrator. Weight and space considerations normally prevent mounting the integrator directly on the stabilized platform. They are placed separately in the missile instrument compartment with temperature control and vibration damping.

A transmitter system of high accuracy is required to connect accelerometer and integrator. The type of transmitter depends also on an accelerometer and integrator system. In the case of the integrating gyro type accelerometer, and a ball and disk integrator, a synchro transmitter and receiver system is used.

Fig. 6 shows the principle of the ball and disk integrator in connection with an integrating accelerometer. On the left is the accelerometer, with the synchro transmitter on the upper end of the output axis. The transmitter is connected to the synchro receiver by a highly accurate, responsive, and well damped servo system.

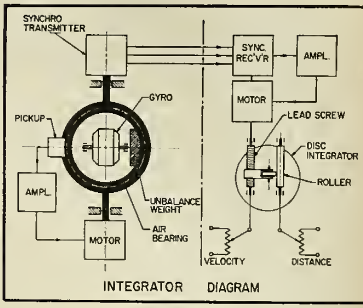


Figure 6.

The servo system repeats the angular position of the output axis of the accelerometer. It introduces this value into the ball and disk integrator with a clutch and a lead screw as a linear position of the ball from the center of the disk.

In the accompanying picture, the ball is shown as a small wheel, to indicate its rotational axis. The disk rotates with a highly accurate constant velocity driven by a synchronous motor. The bill, pressed by its carriage and a spring against the disk, rotates due to friction. Its angular velocity is a function of its distance from the center of the disk.

The rotational angle of the ball corresponds to the integral of its angular velocity. If input on the lead screw corresponds to the velocity of the missile, the output angle of the ball represents the distance covered by the missile. The rotational angle of the ball is picked up by a roller which covers the length of the lead screw. The velocity of the missile and the distance covered are finally picked up as electrical voltages on potentiometers. These voltages are used in the control computer to compute the thrust cut-off point and to guide the missile along the flight path.

Considerable development work has been done on such integrators. They have been used in computers for Navy ships and anti-aircraft equipment. But a number of modifications had to be made to develop a unit which would perform accurately under missile accelerations, vibrations and temperature conditions.

• **Alignment**—The inertial guidance system must be set with respect to a predetermined reference system, considering the exact relationship of launch and target points. Final accuracy of the missile cannot be better than the initial alignment of the

inertial guidance system.

Because launching point and target point are earth-fixed, it is essential to keep the inertial system earth-fixed up to the moment of launch. But the gyro-stabilized platform is space-fixed by nature. Hence, during the pre-launch time, the gyros have to be influenced in a manner that will maintain their position fixed relative to the rotating earth.

At the moment of launch, the inertial earth-fixed system is converted into a space-fixed system. Because all trajectory calculations are made for the space-fixed system, no corrections need be fed to the gyros during the flight—a great aid to accuracy.

The inertial reference systems must also have a certain relationship to the missile coordinate system. This can be done, within a few tenths of one degree, during assembly of the missile, using a special adjustable frame. It is difficult to obtain a higher accuracy, because of the flexibility of the missile structure and the exact determination of the coordinate system of the missile structure itself.

Since initial alignment of the guidance system requires much higher accuracy, alignment by setting the missile on the launching table with the required accuracy appears impractical and probably impossible. Therefore, the inertial system has to be aligned independently of the missile structure.

For the horizontal axes, sensitive plumb-line detectors or accelerometers can be applied to torque the appropriate gyro with amplifiers and torque generators. A special plumb-line detector has been developed which is sufficiently sensitive and has a very high degree of zero point stability. Perfect symmetry of design and use of an air bearing made this achievement possible.

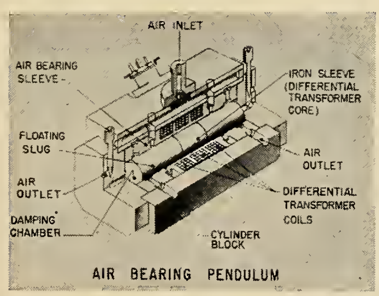


Figure 7.

Fig. 7 shows a cut view of this device, the air bearing pendulum. It consists mainly of the bearing support, the floating slug, the differential transformer and the damping chambers.

Fig. 8 shows transfer functions of the various elements required for alignment about one horizontal axis, while inertia of the pendulum and inertia and friction about the stabilizer axes are neglected.

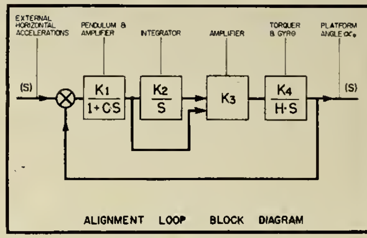


Figure 8.

Alignment of the inertial reference system with respect to firing direction must be equally accurate. This is normally done by optical means—human observation and correction or automatic scanning devices. It requires optical observation of reflectors mounted on the stabilized platform, or on the platform mounting frame with which the platform is initially aligned.

The loop and its transfer functions are similar to those described above for the horizontal axes. It also includes the integrator for the earth rotation bias.

At the moment of launching, the plumb-line detectors and course setting device are de-energized and the inertial reference system becomes a completely independent space-fixed system. The gyros take over their elementary task—to resist angular motions under the most crucial conditions caused by missile vibrations and accelerations.

• **Testing**—New components must be extensively tested before they can be used for active missile guidance.

Whenever possible, an experimental missile is used and the component rides along as a passenger. During flight, performance values are measured and telemetered for evaluation. In other cases, sled tests are performed simulating expected flight conditions. Again, the critical characteristics are telemetered.

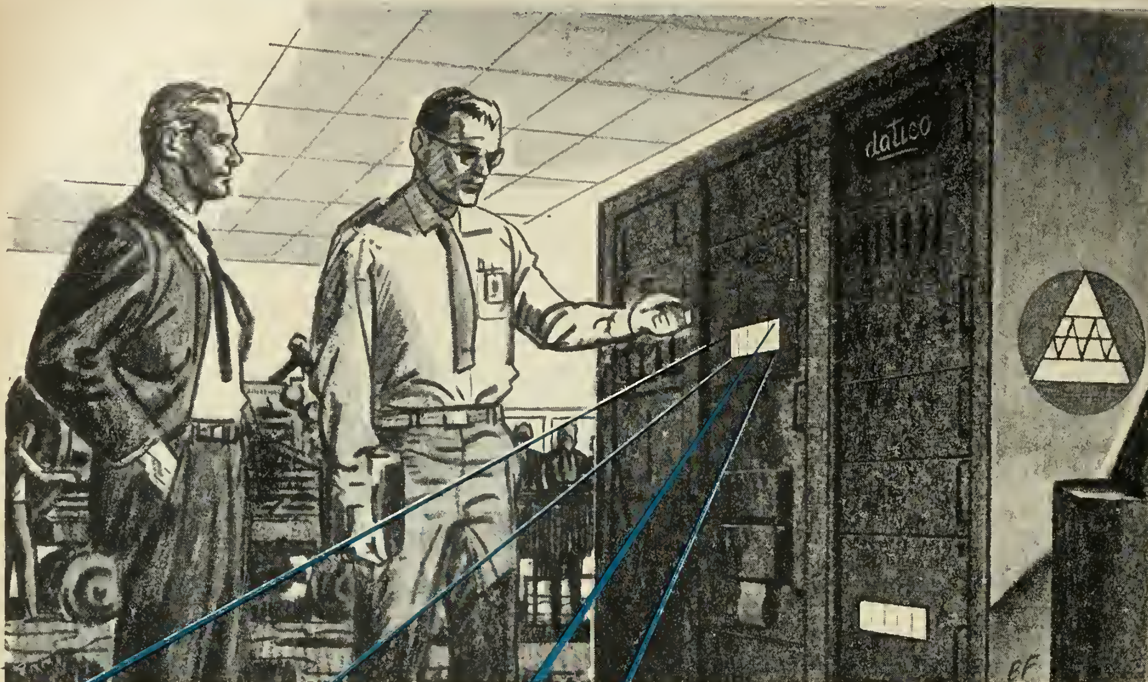
Both sled tests and passenger flight tests are limited to more or less functional evaluations, making it necessary to perform the accuracy tests in the laboratory.

The novelty of the instruments and their range of accuracy requires newly-developed test devices. In some cases the readout has to rely on precision optical instruments. A typical example is the stabilizer test stand.

This stand is used to determine the drift rate of the three-axes stabilized platform. It features a sidereal time axis aligned parallel to the rotational axis of the earth and driven with side-

 Circle No. 31 on Subscriber Service Card.

Transistorized NLS M-24 Selected for Missile Checkout System



Analog to digital conversion in Nortronics' Universal Datico is accomplished by the ultra-reliable NLS M-24, the transistorized Digital Volt-Ohmmeter that automatically and accurately measures and displays AC and DC voltages, voltage ratio and resistance.

In Datico, program control is performed by a punched paper tape. Test stimuli are automatically controlled by Datico and output signals (voltage, voltage ratio, and resistance) from the system under test are automatically selected and fed to the NLS M-24. The M-24 digitizes the system outputs to 0.01%, and provides numerical data to the indicator and control chassis for distribution to the data recorder, digital comparator, and visual display on a special NLS in-line readout.

The tape also establishes the go-no-go limits for comparison with the M-24's digital output. It then directs the system to the next channel to be measured.

Operation of the NLS M-24 in this system is completely automatic . . . the instrument is remotely operable, does not require zero setting, and is extremely stable over very long time periods. Over-all system speed is not compromised by analog to digital conversion time, the M-24 making each measurement in just 330 milliseconds.

The NLS M-24 meets the unusually great reliability demanded of automatic test equipment for modern electronic weapons systems. This reliability is assured by transistors, mercury-wetted contact relays (rated at 10 billion measurements), advanced circuit design, and thorough production and field testing.

Proved in the field in a variety of applications, the NLS M-24 Digital Volt-Ohmmeter is in production and ready to go to work for you. Write today for detailed information concerning this outstanding example of NLS leadership in the development and manufacture of digital instruments. A complete catalog of NLS instruments will be sent upon request.

NLS

Originators of the Digital Voltmeter

non-linear systems, inc. DEL MAR (San Diego), CALIFORNIA

NLS — The Digital Voltmeter That Works . . . And Works . . . And Works!

Circle No. 33 on Subscriber Service Card.

real angular velocity.

During the test, the whole system, stabilized platform and readout collimators revolve with sidereal velocity compensating for earth rotation. The collimators therefore remain in a space-fixed position and allow by means of reflecting mirrors, low drift measurements of the space-fixed gyro platform.

During such tests, missile oscillations can be simulated by uncaging the incorporated gimbal axes of the test stand and introducing corresponding angular motions.

• **Outlook**—The present status of development is evidence of tremendous progress. In fact, the systems of today exceed in many ways what was hoped for when this particular development began.

It can be said that inertial guidance has so far kept in pace with overall missile development. But the missiles, satellites and re-entry vehicles of tomorrow are presenting new problems.

First, there is the task of drastic miniaturization. Guidance components must be smaller and lighter. They also should consume considerably less power and perform with even greater accuracy and reliability. New principles may have to be applied to reach these goals.

The new vehicles will be subject to extraordinary environmental conditions —some of which can be produced in test laboratories for very short periods only, or not at all. Obviously, new test equipment must be developed.

It adds up to another tremendous challenge for the guidance design engineer.

Technician Shortage Is Due to Become Worse

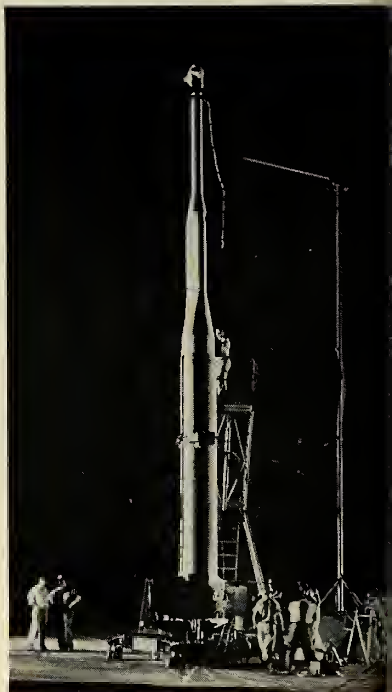
WASHINGTON—At the beginning of what might be called the "scientific revolution," the United States finds itself dangerously short of trained technicians, engineers and scientists.

This is the assessment of the President's Committee on Scientists and Engineers, established in 1956, which recently submitted its final report.

And the committee is fearful that the present shortage of trained manpower will get worse.

The Committee points to a drop in 1958 enrollments at engineering schools, and warns that in 1965 the "lean generation" resulting from lower birth rates in the depression and war periods will provide the country's labor force with fewer men in the 25 to 34 age group.

To correct the shortage, the committee of educators, scientists, labor union, business and government representatives urged the White House to



take direct responsibility for coordinating and stimulating efforts by public and private groups to meet the problem.

The committee reported that *Sputnik I* woke the American people up to the nation's scientific needs. What is now needed, according to the Committee, is a "follow-through" by Congress and the Administration.

Convair Investigates Environmental Tolerances

SAN DIEGO—Human tolerance of extreme environments is under continuing investigation at Convair-San Diego. Principal projects involve reaction to high acceleration forces and toleration of temperature extremes as related to special protective garments.

The acceleration study is almost completed. Primary purpose has been to prove a theory held by Dr. R. C. Armstrong, space and radiation medicine group, that increasing breathing air supply pressure can decrease human stresses produced by exposure to high acceleration forces. Study results have substantiated the theory, Dr. Armstrong says, and the data will serve as guides for space vehicle environments.

"Application of the principles can significantly affect the ability of space pilots to tolerate the combined stresses of space flights and thus increase the safety of the man and his mission," he predicted.

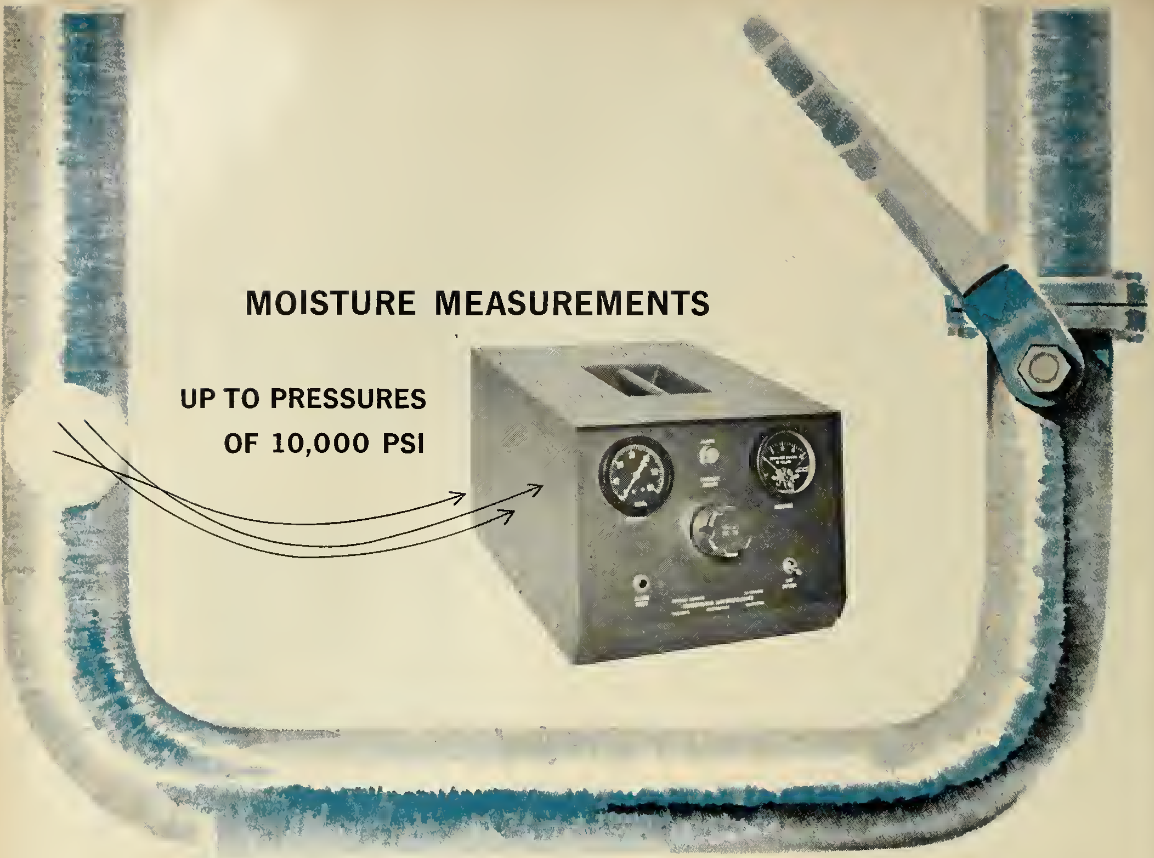
All acceleration experiments were conducted at the University of Southern California's human centrifuge laboratory.

The second program, a study of human ability under temperature extremes both with and without protective garments, is being conducted at Convair's dynamic laboratory under direction of Dr. Armstrong and Dr. E. G. Aiken of the human factors section.

Physical and psychological reactions to simulated re-entry temperatures or heat generated by Mach 5 aircraft flights are being studied in a special heat chamber. Subjects are Convair volunteers.

Air temperature is increased in the chamber from 80°F to 200°F in 19½ minutes—held at 200° for six minutes—then returned to 80° for another 19½ minutes. Cold air (–13°F) is blown into the chamber to reduce air temperatures during the cycle. Chamber temperature itself is maintained at 285°F by a 40,000-watt infrared light bank.

During the high-heat cycle, cool air is used to ventilate a special pressure suit under study which is designed to maintain a normal body temperature of 98.6°F. The "pilot" is supplied with his own filtered and refrigerated air, piped



Here's the newest addition to CEC's line of moisture monitors... the high-pressure 26-350 Series. Available in several models, they measure trace quantities of water in gases and gaseous mixtures at pressures up to 10,000 psi. These "absolute" instruments require no calibration ... deliver precise data with full-scale response in 90 seconds. They operate over a moisture range of 1 ppm to 1,000 ppm, and provide continuous readings on a rugged meter calibrated in ppm water by volume. When moisture content exceeds desired limits, adjustable alarm contacts actuate audio/visual signals ... during either batch or continuous sampling operations.

A battery-pack accessory plugs inside the case for portable use of the 26-350 Moisture Monitors in remote areas where line power is not available. **Other outstanding members of the CEC Moisture Monitor family** include the industry-proved 26-301 and 26-302 Laboratory and Extended-Range Moisture Monitors, designed for standard applications and providing operating ranges of 1 - 1,000 ppm and 1 - 20,000 ppm, respectively. And now measurements of water content in liquids can be accomplished with CEC's Liquid Moisture Monitor—newly developed for laboratory and process applications. Call your nearest CEC sales and service office for details, or write for Bulletin CEC 1851-X2.

Analytical & Control Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS *300 N. Sierra Madre Villa, Pasadena, Calif.*

CEC's 26-310 Process Moisture Monitor, designed for continuous in-plant operation, assures precise monitoring of process streams — even in Class I, Group D, Division 1 hazardous locations.

For employment opportunities with this progressive company, write Director of Personnel.

Circle No. 20 on Subscriber Service Card.

in by direct means.

While subjected to temperature changes, the chamber occupant must concentrate on a tracking problem by chasing a random dot on an oscilloscope and place it in the scope center by manipulating ultra-sensitive controls in the dummy cockpit.

The 45-minute-long tests deliver data on environmental temperatures, body temperatures, blood pressure, respiration, and electrocardiographic information in addition to psychological reactions. The subject is closely monitored by closed circuit television.

AEC Names Group To Study Human Factors

WASHINGTON—The Atomic Energy Commission and the Air Force have named a six-man team to define human factors problems of the aircraft nuclear propulsion program (ANP). Designated the Life Sciences Working Group, it will meet semi-annually at Air Force, AEC, or contractor facilities to examine health and safety characteristics of specific propulsion systems.

The group is composed of Maj. Charles M. Barnes, USAF, of the ANP Office, Chairman; Dr. Leo K. Bustad, General Electric Co.; Dr. Titus C. Evans, State University of Iowa Medical School; Col. Gerrit L. Hekhuis, School of Aviation Medicine, USAF; Dr. Donald M. Ross, Biology and Medicine Division, AEC; and Dr. Arthur C. Upton, Oak Ridge National Laboratory.

Aerojet Constructing Boron Pilot Plant

SACRAMENTO—Construction of a large pilot plant on Aerojet-General Corporation's 20,000-acre facility near here is underway following assignment of a $2,000,000 USAF prime contract to Stauffer-Aerojet Chemical Co. for production of high-energy boron fuels.

A new process for production of the new fuels—which are expected to increase the range of missiles, rockets, ramjets and jet aircraft—was developed by the chemical firm formed a year ago as a joint venture of the Stauffer Chemical Company of New York and Aerojet-General, a subsidiary of General Tire and Rubber Co.

J. B. Cowen, 40, Aerojet employee since 1947, has been appointed to the newly-created position of manager of administration for the Solid Rocket Plant. He has been manager of manufacturing at the same plant. His job will be to supervise contracts, materiel, customer relations and technical services.

The Difference is in the Quality

Four and Five-Digit Transistorized

DC VOLTAGE INSTRUMENTATION

For Rapid, Precise Voltage Measurement

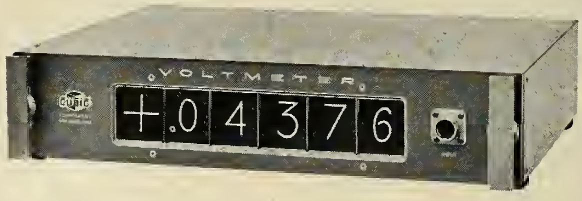
Designed for Versatility
Engineered for Reliability
Precision Built, yet Rugged
Easy to Use, Easy to Maintain

NOT JUST A 'VOLTMETER' . . .

. . . this superior Cubic instrument can measure with great accuracy every phenomenon of science which can be converted to a usable DC voltage level . . . pressure, temperature, depth, volume, salinity, etc. Great economy can be effected through use of the Digital Voltmeter in applications which require precise, legible readings to the unskilled worker without danger of costly operator error. Outstanding engineering and design talents have been combined to produce this fine DC Voltmeter, the most reliable Digital instrumentation available today.

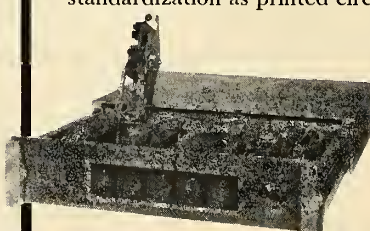
SPECIFICATIONS

Available with 4 digit (Model V-41) or 5 digit (Model V-51) display, the Digital Voltmeter is powered by Control Unit Model C-1, which includes a power supply, precision reference and differential amplifier, and which, separately housed, supplies power to as many units as are required in a Digital System. The Cubic Voltmeter provides an accuracy of .01% plus or minus 1 digit, between ±.0001V and ±999.9V (Model V-41) and ±0.0001V and ±999.99V (Model V-51). Low level voltages ±10 microvolts may be measured by the addition of the Preamplifier unit, Model PA-1.



THE SUPERIOR DIGITAL INSTRUMENT

Space Age know-how that goes into Cubic Corporation's missile tracking systems is also an important engineering and production component of Cubic DC Voltage instrumentation. The 4-digit and 5-digit Voltmeters, powered by the Cubic Control Unit, offer such quality features as unit plug-in construction, a precise two-part filter that eliminates the effect of AC ripple on DC readings, shock-mounted stepping switches with "controlled drive," in which the switch turns off the drive circuit part way through its cycle, ending overdrive and eliminating impact wear. Clear visual display is provided by an ultra-brilliant, edge-lighted read-out containing in-line numerals one inch high. Transistorization ends warm-up time, lengthens instrument life. Cubic's attention to fine detail increases the precision, reliability and functional capability of each instrument and at the same time provides such outstanding features of standardization as printed circuit boards that are interchangeable and stepping switches that swing up and out for ease of routine maintenance. Cubic quality is your guarantee of truly fine instrumentation.



Unit construction of the Cubic Voltmeter and other Digital instruments provides maximum flexibility in creating "systems that design themselves." Inter-*case* wiring and standard-size plug-in units make every Cubic System a customized system using standard units. "Building Block" units which can be added easily to increase systems capabilities are the DC Preamplifier, AC-DC Converter, Digital Ohmmeter, Ratiometer, Master and Auxiliary Scanners and Printer Control Units. Write today for further information.

CUBIC

CUBIC CORPORATION
5575 Kearny Villa Road, San Diego 11, Calif.

ELECTRONIC ENGINEERING WITH A DIMENSION FOR THE FUTURE

Circle No. 21 on Subscriber Service Card.

Interplanetary Guidance for Man in Space

Existing components will be accurate enough for unmanned probes with possible radio control for cutoff and staging. But next generation of manned vehicles will impose a different set of requirements headed by reliability.

by Lawrence S. Brown

Manager, Missile Development Division, Ford Instrument Company—Division of Sperry Rand. Chairman of the Instrumentation Committee, American Rocket Society

LONG ISLAND CITY, N.Y.—The guidance and instrumentation hardware for interplanetary travel is in being. Present techniques and existing components have been used successfully to guide space vehicles, albeit on a limited scale. The rapid advance of the past 15 or so years has been truly remarkable.

Although the next 15 years inevitably will see the refinement of present mechanisms, breakthroughs into exotic realms during this period are unlikely. Fundamental principles of physics relating to the guidance of an object through space will be exploited with increasing success. But until new, perhaps relativistic, ideas are evolved, we shall have to be content with increasingly sophisticated applications of Newton's laws. Here, the ultimate limitation imposed by attainable machining tolerances is rapidly being approached.

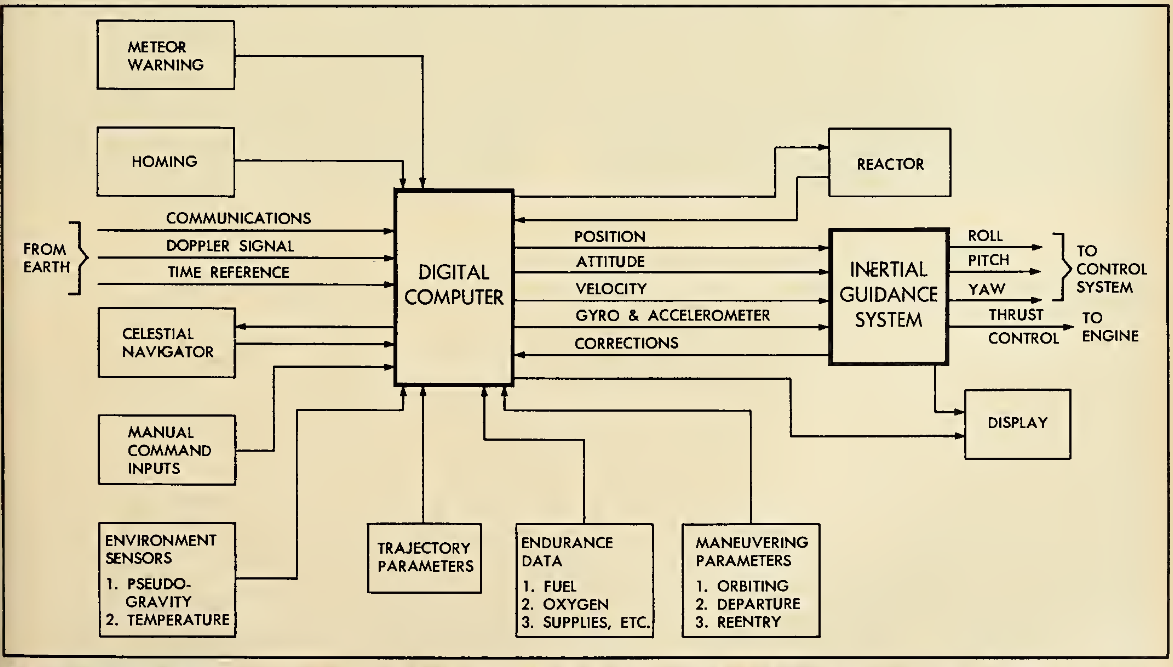
• **Present possibilities**—Nevertheless, existing components will be accurate enough for the first generation of space vehicles. These vehicles, already aloft or in advanced stages of development, are satellites and lunar and planetary probes—all unmanned. Present guidance systems can put a payload into orbit around the earth or a probe in the vicinity of the Moon, Mars or Venus. The international competition for space will prompt early launchings of increasingly ambitious vehicles of these types.

For some time to come, their guidance systems will be essentially identical to those of the ballistic missiles from which they are evolving—inertial components active until first- or second-stage cutoff, with possible radio control for cutoff and staging.

The accuracies attainable with these schemes will be acceptable as long as the payloads consist of instruments or animals. Ultimately, however, man will be satisfied only with transporting into the heavens that most versatile and discriminating of data-processing and decision-making instruments—himself. If progress continues at its present rate, vehicles for this purpose may well be on the launch pad by 1965.

• **New specifications**—Instrumentation for manned space navigation poses an entirely different set of requirements than does the "shot from guns" approach of current ballistic missile systems. The governing consideration is *reliability*. There is little purpose in sending a man into space without assurance that his vehicle will safely transport him to his destination and back to earth.

Here then is *the* challenge to our science and industry: to design guidance systems of *inherent* reliability and ruggedness, for these characteristics cannot be tested into a component. A round trip to the nearest planets may take two years or more. The physical environments to be encountered are still largely unknown. There will be little or no opportunity for maintenance or repair. The possibility of outright failure of a component must be reduced to the absolute minimum, and serious deterioration of performance is inadmissable. The specifications for a manned space vehicle will be the most



PROPOSED OVERALL block diagram for guidance system of the future using a digital computer as the central element.

rigid to be presented to industry.

The "breakthrough" necessary for space travel is a reversal of the current trend towards complexity of design. Leaning towers of electromechanical and electronic components and the philosophy of "Well, to fix that suppose we add this" will not provide the answer.

• **Digital emphasis**—Digital techniques will be widely employed, not only in computation but in stabilization, gyro and accelerometer control, program storage, power supply regulation, etc. This is all to the good for, in addition to their inherent accuracy, digital circuits can take full advantage of micro-miniaturization, printed circuitry, semi-conductors and modular construction. Digital guidance and control instruments give every promise of being small, light, rugged and reliable. The missile industry is giving them increasing attention.

• **Improved mechanics**—Mechanical components (and their attendant problems) cannot be dispensed with entirely. Stable platforms, gyros and accelerometers in somewhat their present configurations will be with us for a long time. Here, reliability and size requirements tend to conflict. Gyro accuracy, for example, being proportional to rotor angular momentum, demands large rotors and high speeds. The first is undesirable from the standpoint of size; the second from the standpoint of reliability. A possible solution may lie in the application of gas hydrodynamic bearings to gyro rotors.

Such bearings, offering negligible friction and wear, could permit rotor speeds on the order of 250,000 rpm. Presently attainable minimum gyro drifts (as low as 1/50th of a degree/hour) could thus be reduced by a factor of about ten. Reduced gyro and accelerometer drift would not only improve in-flight accuracy, but also make possible more precise initial alignment of the stabilization system.

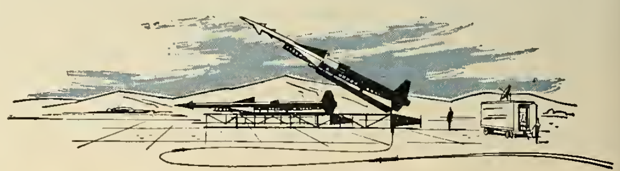
• **New accelerometers**—Accelerometers probably will undergo more design changes than other guidance components. Present accelerometer sensitivities extending down to 10^{-4g} will need improvement, perhaps to as low as 10^{-12g}. Gyroscopic accelerometers may give way to vibrating string types, rotating pendulums, or airfloated, magnetically-restrained pendulums. These are but a few of the advanced designs being studied or tested. Since the upper measuring limit of such ultra-sensitive accelerometers will probably not be much greater than 10^{-4g}, we may also require an auxiliary set of conventional accelerometers capable of measurements to 20g.

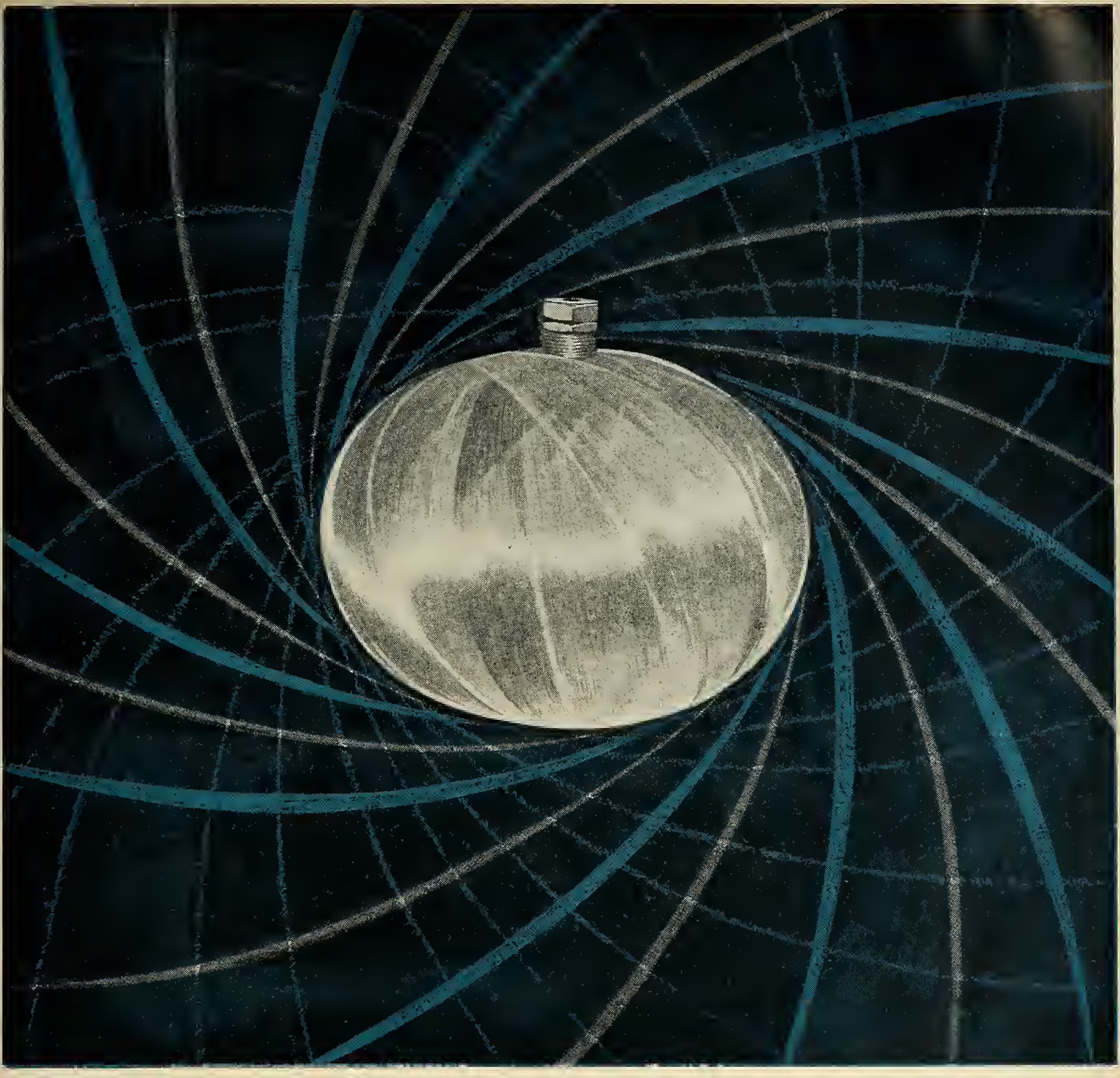
Present accelerometer accuracies of one part in 10^5 can probably be retained in the smaller measuring ranges and should prove adequate. Reliability of the new types is, however, still an unknown factor, and it may be necessary to develop more sensitive varieties of the proven gyroscopic pendulous accelerometer.

Implicit in all component design problems is the guidance and control system in which the components are to be employed. Systems jury-rigged from a random assortment of components, no matter how sophisticated or ingenious, are destined to fail. As always, reliability, accuracy and minimum size will govern selection. Given these requirements, what type of guidance systems can be envisioned for space vehicles of the near future?

It appears quite certain that system design will follow an extension and combination of present-day concepts. We will choose from among inertial, star-tracking, radio command, and homing systems. Each has certain desirable attributes and may be used singly or in combination with other systems depending upon the particular mission involved.

• **Suggested script**—The program for further space exploration probably





should read like this:

ACT I

Scene 1. Unmanned probe to orbit or impact the moon.

Scene 2. Unmanned probe to the vicinity of Mars and/or Venus.

Scene 3. Manned, recoverable earth satellite.

(Intermission)

ACT II

Scene 1. Manned vehicle to orbit moon and return.

Scene 2. Manned, permanent earth satellite.

Scene 3. Manned landing on lunar surface and establishment of permanent station.

(Intermission)

ACT III

Scene 1. Manned vehicle to orbit Mars or Venus and return.

Scene 2. Manned landing on Mars or Venus, exploration, and return.

Unmanned probes of the moon and neighboring planets will continue to use inertial guidance systems with varying degrees of assistance by radio-controlled cutoff and staging. These systems offer a reasonable probability of success, though their accuracy is not likely to ensure impact on the moon or establishment of planetary orbits. Terminal guidance homing on the albedo of the moon or planets may be attempted. The probes to Mars and Venus tentatively scheduled for this year may well be equipped with a photoelectric homing device to supplement their midcourse guidance.

Whether or not these probes reach their advertised targets, their escape from the earth's gravitational field will render the experiments successful, for a great deal will be learned about the performance of systems and components in outer space. Considerable effort is being devoted to improving electrical power sources and reducing power requirements to prolong the operation of components in such an environment.

• **Man in Space**—By 1960, the "Man in Space" program probably will be well underway. Its guidance and control problems will exceed those of the previous satellite programs. It will take some doing to provide the necessary degree of reliability and successful re-entry, but again, present inertial guidance systems coupled with other techniques appear adequate for at least the initial experiment.

It is unlikely that the human passenger will play the primary role in guiding this first manned vehicle. Man's reaction to the new environment is unpredictable, and he may not be physically or psychologically able to interpret data accurately or make and carry out decisions. Radar commands from ground computers probably will sup-

plement on-vehicle guidance.

If the "Man in Space" program succeeds in proving that man can survive and function in space, it certainly will be followed by a manned lunar vehicle. In that case, the capabilities of the human passenger would be utilized to the fullest. Admitting man as an active part of a missile guidance and control system will entail significant changes in existing system concepts.

• **Pilot control**—A manned vehicle probably will be "flown" in much the same sense that an airplane is. The ballistic concept will give way to a navigational guidance system in which corrections will be made throughout flight at the discretion of the pilot and/or guidance system. Although all functions will be made fully automatic to anticipate human failure, the pilot will at all times be able to override the system and enforce his own decisions.

This will require some form of present position and velocity display, together with a reference display indicating the desired values for these quantities, the errors, and whether the guidance system is responding to correct the errors. Necessary reference information and guidance commands may be transmitted from the ground.

On the other hand, the system will have to guard against illogical or dangerous commands by the pilot. Fuel and supply reserves, vehicle stresses, engine temperatures, and other considerations not immediately apparent to the pilot may require that an obviously indicated correction be delayed or modified. Certainly, human engineering principles will have to be amalgamated with existing system concepts if we are to integrate man and machine.

• **Something like SAGE**—Maneuvers such as establishing an orbit around the moon, departure from orbit, and re-entry must be precisely timed and executed. This concept embodying the necessary relation between man, machine, and external guidance is most nearly approached by our newest, SAGE-controlled manned interceptors. There, the pilot, though assisted and directed by radar commands, can exercise his own judgment and make the final decisions. The guidance and control system for the manned lunar vehicle may well combine such principles with conventional inertial components.

• **Manned station**—The next step would be construction of a manned space station, generally conceded to be a necessary prelude to launching an interplanetary vehicle of appreciable size. Only by piecemeal assembly of material and fuel can a large-scale interplanetary vehicle become feasible. (It has been calculated that, without a space station, a large Mars vehicle de-

parting from earth would consume over 100 tons of fuel during the first second of takeoff.)

A mass in orbit, however, is already travelling at nearly escape velocity. A vehicle assembled at the space station could thus depart from the orbit under the small thrust available from the ionic engines envisioned for interplanetary flight. Although some 68 tons of fuel would be necessary to place each ton of payload into orbit, the necessary bulk could be delivered incrementally by vehicles of reasonable size.

The space station would also be valuable as a proving ground for guidance and control components. Gyros and accelerometers designed to function outside the influence of gravity could be evaluated in the environment of space. Uncertainties in the measurement of earth's gravity would degrade test data of an accelerometer designed to measure down to 10^{-12}g. A gravity-free space station would provide the ideal laboratory for test and calibration of inertial components.

Guidance systems for the rockets assembling the space station and for the supply vehicles will be of the manned inertial style similar to (but less complex than) those proposed for the lunar vehicle. Terminal guidance homing on a radar beacon in the space station will be a necessity.

The sheer number of flights needed to assemble and provision a space station in preparation for a Mars vehicle would serve to evaluate and improve components and vehicles.

• **To the planets**—Once the space station becomes a going concern, the design of a manned interplanetary vehicle will proceed apace. It must be assumed that nuclear power plants will be available—not only for propulsion, but for auxiliary power as well. Conventional batteries cannot provide instrument power for a lengthy voyage, and there will be practical limitations on redesigning instruments for minimum power.

In principle, chemical fuels would suffice for an interplanetary vehicle, but the probability of success of a chemical rocket is rather marginal. The most likely application of nuclear power to rockets appears to lie in an ion engine. Heat from an atomic reactor would be converted into electric power to generate and accelerate propelling ions. Adequate sub-system power would then also be available.

The guidance and control system would reflect this choice of power plant. The extremely low accelerations developed by an ion engine (as low as 10^{-4}g) means that propulsion would be active during the entire flight. For approximately half the journey, the vehicle would accelerate; thereafter, the thrust would be reversed to decelerate it for orbiting or landing.

The orbit could be established by landing on one of the tiny satellites of Mars. These bodies, having negligible gravity, would permit limited exploration and the establishment of structures and facilities. In effect, a service station could be left behind for subsequent vehicles.

The use of continuous propulsion will permit the monitoring of errors to achieve small but continuous corrections. This calls for extremely sensitive inertial components. A 10^{-12}g acceleration error, which would be trivial in a ballistic missile of 5000-mile range and 30 minute flying time, becomes significant over a distance of 40,000,000 miles and a time of 400 days. It is doubtful that present inertial systems will, by themselves, be capable of the required accuracies over such prolonged intervals. Celestial observations will be necessary for continuous monitoring and correction of the inertial system.

• **Guiding** stars—The fixed stars, such as Vega, Regulus and Aldebaran, would provide the reference frame for vehicle attitude. Nearer celestial bodies, in which parallax can be observed (Earth, Mars, the Sun, and Jupiter, for example), would be used as positional references.

Celestial observations will require extremely accurate time references (perhaps ammonia MASERS) which may not be readily transportable. Some equipment could, of course, remain on earth and necessary information could be radioed to the vehicle. A radio data link would also give doppler velocity information as a further check on the inertial guidance system. The inertial system may thus evolve as a "middle man" between the celestial navigation and data link equipment on the one hand, and the vehicle on the other.

The vehicle's instantaneous reference will be with respect to the inertial system which will, in turn, be continuously adjusted by the star trackers and doppler.

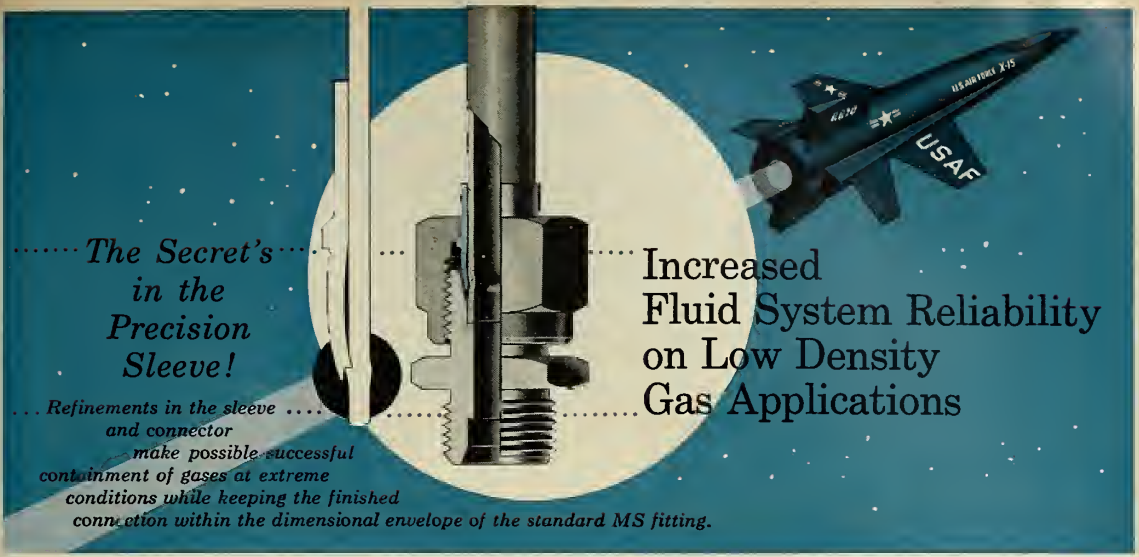
Present star observation systems are accurate to approximately 4 seconds of arc and doppler velocity can be measured to within ½ foot per second. Within these limits, the error at 40,000,000 miles would be less than 10,000 miles (1 part in 40,000) and could readily be corrected by a homing device or by visual observation.

• **Help from computer**—Other aspects of the guidance system, primarily involving action by the pilot, include: center of gravity control; meteor collision warning and avoidance; communications; homing; and data display. One can envision a rather elaborate digital computer to oversee these matters and to advise and instruct the pilot. The computer would also serve to control and to interpret the celestial observations, apply corrective signals to the inertial system, and continuously plot the most suitable trajectory. Logic components now in the laboratory will, in time, reduce such a computer to a package of reasonable size and complexity.

Communications between the vehicle and earth for the doppler system and other purposes appear entirely feasible. Recent advances in the fields of radio astronomy and satellite telemetry have given us the techniques and components which will permit effective transmission and reception at extremely long distances.

Fifteen years ago a program such as outlined here would have been dismissed as visionary. Today it can be considered a realistic prediction. Fifteen years hence it will be an accomplished fact.

For we shall truly see these refinements as guidance is exploited with increasing success.



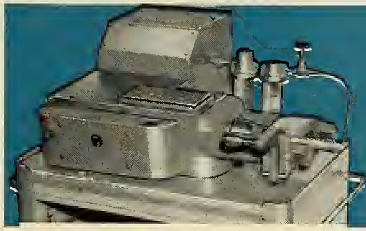
New WEATHERHEAD Design Insures Superior Sealing

Proved under rigid test conditions, the refined version of the industry-accepted MS(ER)® flareless fitting incorporates special high-quality sleeve and mating parts. This latest Weatherhead advance provides increased fluid system reliability under thermal shock conditions with low molecular weight gases, as encountered in gas turbine and rocket propelled vehicle applications. Because of its superior sealing qualities, the new Weatherhead precision fitting promises to be the answer for future hypersonic rocket research ships.

Optimum pneumatic integrity is assured by the new design plus these other essential factors:

- Special protective packaging of precision sleeves in sealed containers.
- Establishment of uniform presetting procedures, for the material combinations required, which result in a sleeve that does not rotate on the tubing.

This is another example of Weatherhead's policy of continuing research to develop products in advance of industry's needs — another reason why Weatherhead pneumatic and hydraulic components are currently in use on such vehicles as Atlas, Bomarc, Nike-Ajax, Thor, Jupiter, Bullpup, Polaris, Redstone and the North American X-15 manned aircraft. Look to Weatherhead for the "precision answer" to your fluid system requirements!



MT-10062 NEW Machine for Mass Production Presetting

The fully automatic Presetting Machine contributes to production line speed and efficiency in presetting MS(ER)® sleeves. It has single push button control and single air pressure setting of all sizes for fast, easy operation. It correctly presets sleeves on aluminum, carbon or stainless steel tubing in all standard sizes ⅛″ through 2″ in diameter.

send for descriptive literature

... "Refinement of Precision Flareless Fittings"
... "New MT-10062 Presetting Machine"

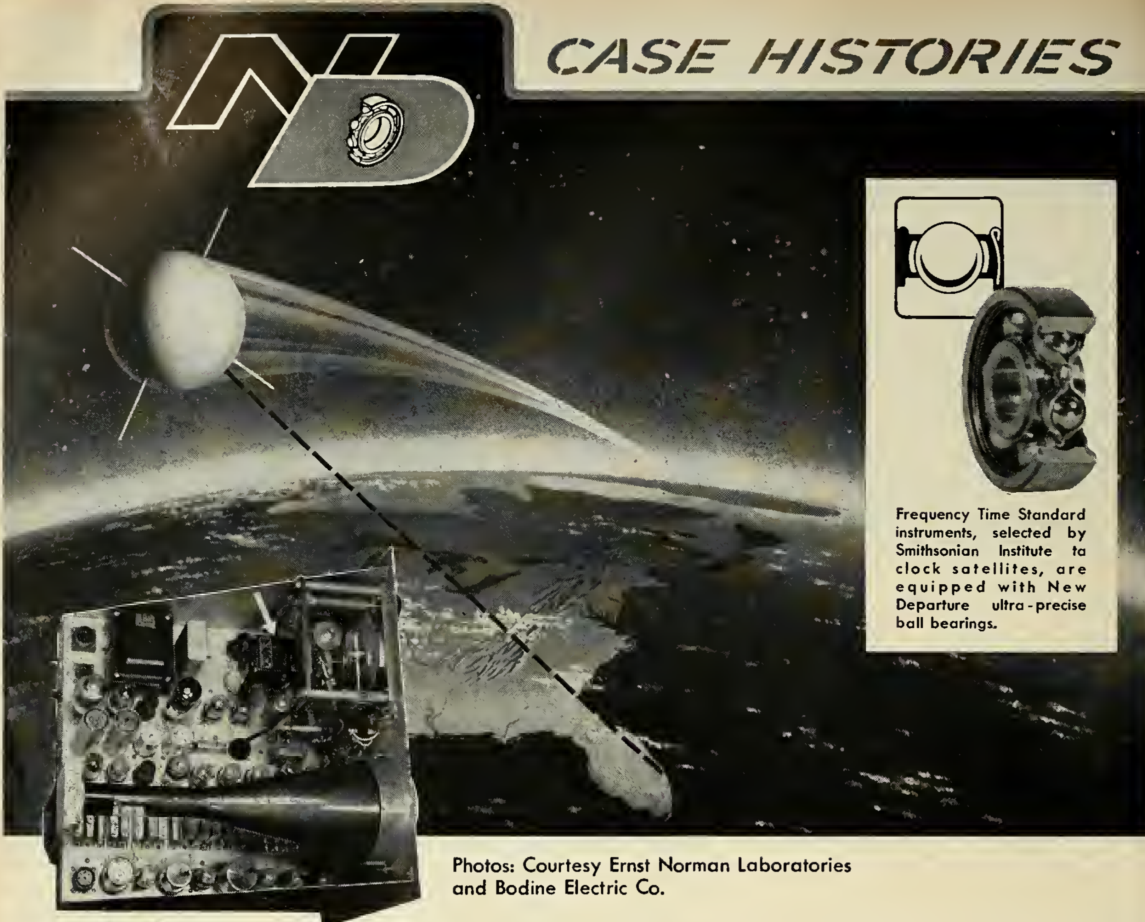
Write to The Weatherhead Company, Aviation and Missile Group, 300 East 131st Street, Cleveland 8, Ohio

WEATHERHEAD AVIATION and MISSILE GROUP

WESTERN DIVISION	SPECIAL PRODUCTS DIVISION	EASTERN AIRCRAFT PRODUCTS CORP.
1736 Standard Avenue	300 East 131st Street	229 River Street
GLENDALE, CALIFORNIA	CLEVELAND, OHIO	ORANGE, NEW JERSEY

In Canada: 127 Inkerman Street, St. Thomas, Ontario • Export Cable Address: WEATHCO, Cleveland

 Circle No. 45 on Subscriber Service Card.



Photos: Courtesy Ernst Norman Laboratories and Bodine Electric Co.

Ultra Precise Ball Bearings Help "Clock" A Satellite!

CUSTOMER PROBLEM:

Require ultra-precise bearing design for Bodine electric motor used in satellite-tracking micro-clock. Bearings must provide uniformly low starting torque, precise location of rotor shaft and minimum maintenance, to help mechanism achieve time determinations to 0.001 second.

SOLUTION:

N/D Sales Engineers studied special bearing requirements, and recommended New Departure ultra-precise ball bearings. These ball bearings measured up to every requirement for micro-clock motors . . . thanks to New Departure's advanced equipment for research, development and production. N/D equipped micro-clocks, selected by the Smithsonian Institute, are operating in a dozen locations around the world right now, keeping track of vital satellite movements . . . to accuracies of one milli-second and better!

If you're manufacturing or designing electric motors for any high precision applications, including instruments, why not call on New Departure? N/D engineering and research facilities are turning out the latest in high precision instrument ball bearings and advanced ball bearing designs. For more information write Department K-2.

NEW DEPARTURE

DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

NOTHING ROLLS LIKE A BALL

USAF Reports Issued on Capacitors, Transistors

WASHINGTON—The government has released USAF reports describing a loaded resinous system as a high dielectric constant material for solid wound capacitors and reviewing recent research on development of a silicon power transistor.

The first report, "Solidified Wound Capacitors," is numbered PB 151203 and is available from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C., for $2.50. It discusses a loaded resinous system, epoxy-titanium dioxide, successfully applied as a high dielectric constant for solid wound capacitors.

The capacitors showed long-time performance at high temperatures under operational voltage, with the high dielectric constant supplying a substantial volume reduction for a given capacitance.

The epoxy-titanium dioxide material applied in films of one mil or less on aluminum foil yielded dielectric constants of 15 to 19. Flat plate capacitors of coated aluminum foil tested at 150C and applied voltages of 105 and 210 volts DC operated successfully over 1000 hours. They maintained capacitance, dissipation factor and insulation resistance. Highest microfarads produced at 150C was 54.

Wound capacitors of coated aluminum foil with the dielectric material also operated 1000 hours at 210 volts DC. The report includes descriptions of the dielectric, its application to aluminum foil and porous paper, measurement facilities and sample capacitors.

The other report, titled "Semiconductors Devices Research Program," is numbered PB 151201 and is available from the same address for $3. It says that developmental research showed that silicon power transistors can be fabricated by diffusing impurities in from the surface to form the base and emitter regions. Gallium and phosphorus were the impurities most thoroughly studied. The simultaneous diffusion process was used for transistor fabrication in pilot experiments and the effects of external variables upon this process were determined.

Emitter, base and collector contacts were made using titanium or tungsten support plates. The transistors were mounted in a hermetically sealed, welded package of low thermal resistance. The fabrication process included diffusion, lead attachment, etching and packaging.

Characteristics of preliminary laboratory units are given.

contract awards

ARMY

$1,887,027—**Nortronics Division, Northrop Corp.,** for check out equipment.

$1,007,435—**Douglas Aircraft Co., Inc.,** for launching area items and repair parts.

$425,537—**Western Electric Co.,** for *Nike* spare parts and components (11 contracts).

$132,863—**Forest Builders, Inc.,** Pittsburgh, Pa., for construction of warhead buildings and related facilities at *Nike* launcher sites in Pittsburgh area.

$99,100—**Massachusetts Institute of Technology,** for studies of the spectra of vertical fluxes of momentum, heat and moisture in the atmosphere boundary layer.

$60,999—**H. I. Lewis Construction Co., Inc.,** Middletown, Pa., for construction of buildings and related facilities at *Nike* launcher sites in Cleveland, Ohio, area.

$55,555—**Dick Corp.,** Large, Pa., for *Hercules* conversion of underground missile storage structures at launching sites in Pittsburgh area.

$48,360—**Missile Air Division, United States Chemical Milling Co.,** Manhattan Beach, Calif., for bulkheads.

$32,364—**Raytheon Manufacturing Co.,** for field maintenance on *Hawk.*

$31,433—**California Institute of Technology,** for R&D.

AIR FORCE

$1,800,000—**Vitro Laboratories Division, Vitro Corporation of America,** for operation and maintenance of land and water ranges at the Air Proving Ground Center, Eglin AFB, Fla.

$346,324—**Hughes Aircraft Co.,** for overhaul, repair and modification of *Falcon* system items.

$200,000—**Avion Division, ACF Industries, Inc.,** for radar beacons for *Titan* nose cones. (A series of sub-contracts from Avco Mfg. Co.)

$162,028—**Eclipse-Pioneer Division, Bendix Aviation Corp.,** for angular accuracy testers, test stands, and maintenance and engineering data.

$59,997—**Douglas Aircraft Co., Inc.,** for modification kits for loading latch assembly on *Genie.*

$49,991—**Chu Associates,** Littleton, Mass., for study of multiple beam interval scanner for AICBM radar antenna.

ELECTRO SNAP

Creators of over 6,000 Precision Switches and Controls

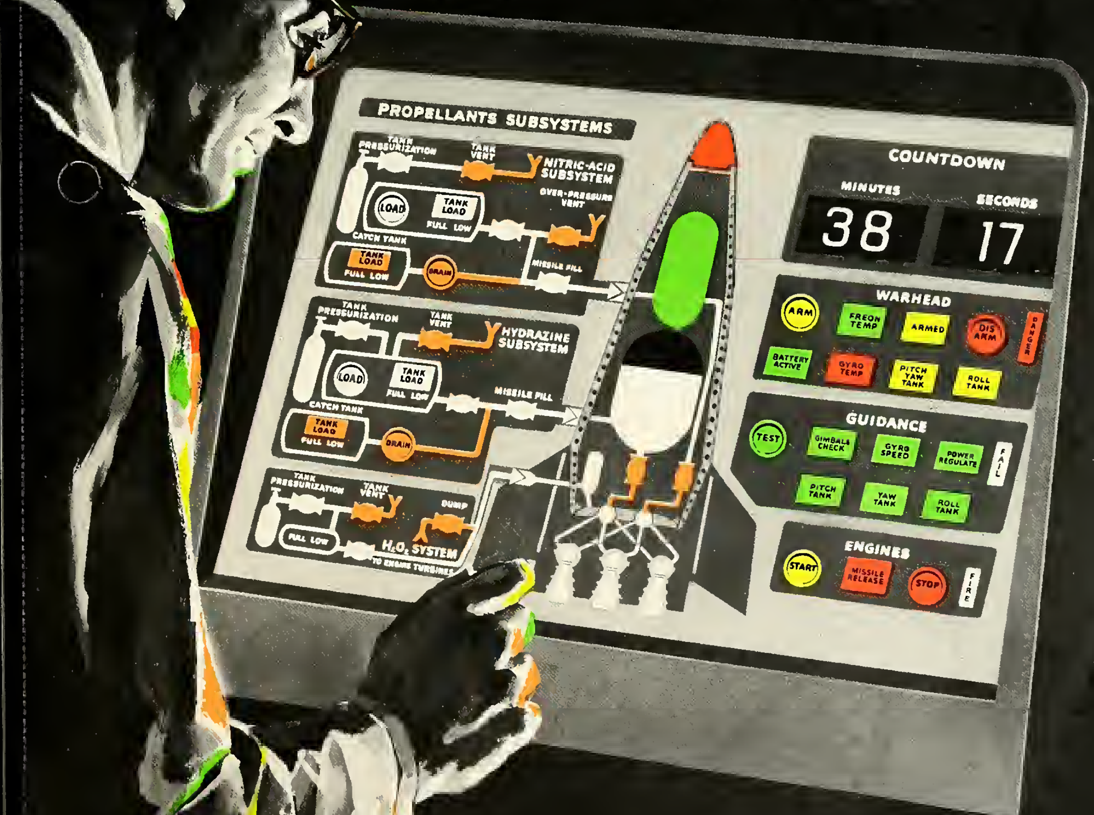
presents . . . A new panel concept that promises to revolutionize monitoring or control of Missiles and Rockets

the astromatic panel concept

"THE MOST EFFICIENT LINK BETWEEN MIND AND MACHINES"

Consider These Obvious Advantages in Your Designing

- ★ OFFERS INSTANT VISUAL CONTROL WITH EXTREME ACCURACY
- ★ REDUCES HUMAN ERROR TO AN IMPROBABILITY
- ★ PROVIDES SIMPLIFICATION OF THE MOST COMPLEX OPERATION
- ★ ALLOWS REMARKABLE CONSERVATION OF VITAL SPACE
- ★ WITHSTANDS EXTREME LIMITS OF TESTING SPECIFICATIONS
- ★ APPLICATION POSSIBILITIES AS UNLIMITED AS THE IMAGINATION



Study the following specifications with your project in mind . . . .

ASTROMATIC DIVISION
Electrosnap Corporation
4218 West Lake Street, Chicago 24, Illinois

the astromatic panel concept by ELECTROSNAP

Ready now for tomorrow's higher control requirements

This new concept in panel techniques combines the latest advances in scientific, technological and psychological achievements to insure the highest possible degree of efficiency and accuracy in control or monitoring of equipment.

PRECISION ENGINEERED

. . . Meets or exceeds most exacting specifications

SHOCK AND ABUSE TOLERANT . . . Laminated Fiberglas panel resists chipping, shattering, crazing. Coefficient of expansion identical to aluminum sub-assemblies eliminates buckling under stress or extreme cold or heat conditions.

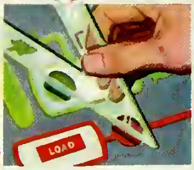
LASTING LEGIBILITY . . . Exclusive process imbues color into Fiberglas . . . resists wear-off of legend and diagramming. Vivid colors actually photoprinted—will not chip or scratch off. Meets all requirements of MIL-P-7788 for Aircraft Cockpit Panel.

QUICK LAMP REPLACEMENT . . . Front panel hinged for quick access to components below, permitting 10-second bulb change if necessary.

EASY TO ALTER . . . During prototyping legend and schematic diagramming can be easily changed to visualize any new findings. Components under panel may be relocated.

VERSATILITY OF DESIGN . . . The module concept of construction makes the Astromatic panel technique extremely versatile. WHATEVER ACTION YOU DESIRE TO VISUALIZE, ASTROMATIC CAN SUBMIT A PANEL DESIGN TO SURPASS YOUR EXPECTATIONS.

HUMAN FACTOR ENGINEERED for highest efficiency with extreme accuracy

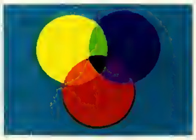


100% FLUSH PANEL . . . Eliminates protruding hardware . . . unless specified by human engineering requirements. Switching functions may be recessed, flush, or over-flush.

TRI-COLOR LIGHTS . . . Each light module contains 3 separate bulbs and circuits to permit triple indications such as GO, NO-GO and CAUTION signalling.

CONCENTRATED GROUPING OF CONTROLS . . . Multiple function of TRI-LITE controls permits high component density, saving from two to four times space required by ordinary panel. Permits instant visual recognition and action by operator, minimizing time-loss found in larger panels.

VERSATILE SWITCHING . . . The switching and indicating techniques are specifically designed for maximum compatibility with this advanced panel. Momentary, positive feel and alternate action switching is available.



LIMITLESS COLOR COMBINATIONS . . . The unique combination of TRILITES plus multi-color photo printing of panel allows unlimited color guidance, distinctly identifiable even by color blind.

SCHEMATIC DIAGRAMMING . . . Photo color printing of panel surface permits visual schematic diagramming. Increases speed and efficiency of operators and recognition of system indications. Reduces indoctrination period for operator training. Eliminates the written word.

MAIL COUPON BELOW FOR ADDITIONAL TECHNICAL INFORMATION . . . OR PHONE ROBERT PROVART, TECHNICAL DIRECTOR COLLECT, VAN BUREN 6-3100

Astromatic Division, Electrosnap Corporation
4218 W. Lake Street, Chicago 24, Illinois

Gentlemen: ☐ Have your Design Engineer call for an appointment.
☐ Please count me in on any Symposium held in my area.

Name__________ Title__________

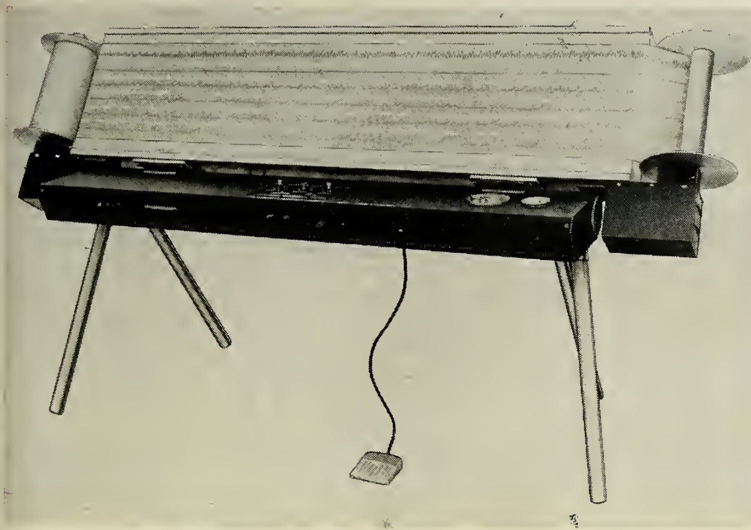
Company__________

Address__________

City__________ Zone____ State__________

ASTROMATIC DIVISION
Electrosnap Corporation
4218 W. Lake Street, Chicago 24, Illinois
VAn Buren 6-3100, TWX CG-1400

Oscillogram Scanner Solves Data Problems



The **Gerber Scientific Instrument Co.** has designed a new model (S-10) of its oscillogram scanner to solve data reduction problems where an operator is required to scan a record over a large area.

Oscillogram strips up to 1,000 feet in length may be tracked across the 66" illuminated scanning surface. Controls are provided in a panel set flush at desk level. The operator may adjust record speed to a maximum of 100 feet per minute; select light intensity; or control record tension, direction, and braking.

The illuminated scanning surface along with the transport mechanism may be set at any convenient angle to the extent of forming a horizontal work table. Under each roller is an extremely flexible, self-contained drive system. Modular construction facilitates quick replacement of all important subassemblies.

Several reading heads, yielding digital or analogue outputs are available.

Circle No. 225 on Subscriber Service Card.

New Strip Resistor Fits Directly into Circuit

A new "two dimensional" strip resistor, which fits directly into stripline circuit and is as thin as the copper-clad conductor has been marketed by the **Filmohm Corp.**

The base of the resistor is a thin film of specially-selected natural mica. The resistance film is an alloy of pure metals, approximately 50 millionths of an inch thick and sealed with a micro-thin coating of quartz. Fired silver terminations can be supplied for dc connection of the resistor to the copper center conductor of the microstrip or stripline circuit.

The mica base is made as thick as the height of the copper conductor, that is 2 mil mica for 1.8 mil copper and 3 mil mica for 2.8 mil copper. Width is equal to the width of the copper and length is determined by requirements of electrical match, power and resistance.

A section of the stripline is etched out and the resistor is placed on the

plastic dielectric between the copper conductors. Electrical contact is made by using conductive silver epoxy cement to join the silver tab on the resistor to the copper strip. Adhesive varnish is then applied over the resistor and contact areas.

The resistors can be supplied as matched loads, fixed pads, variable attenuator elements, terminations. Resistance of a few ohms to several hundred ohms can be supplied. Stripline resistors are available as straight rectangular or square sections, tapered rectangular sections for electrical match, or curved.

Circle No. 229 on Subscriber Service Card.

New Amplifiers Cut Down Drift

The **Edwin Division of Epsco, Inc.** has announced the addition of two new models to the #B-Series line of amplifiers designed for a wide variety of both rack-panel and portable oscillograph recording needs.

The highly stable 8108B amplifier

NOTE: *For additional information about any product mentioned in this section of Missiles and Rockets use the attached prepaid reply cards. Circle numbers shown on the reply card that correspond with numbers appearing beneath items described. If no circle number accompanies the article or advertisement, give page number (and advertiser's name) on line provided at bottom of the card.*

Your requests for information will be forwarded promptly to the companies concerned.

The Editor

drifts less than 19 uv equivalent input per hour and will operate from 115V, ±5V power lines without additional regulation. Unusual features of the 8122B amplifier is that it drifts less than 30 uv equivalent input per hour and includes plug-in frequency compensation to extend the range of the galvanometer to 200 cycles. High input impedances permit the units to be operated with a wide variety of transducers. Both amplifiers contain an automatic signal overload protection device to prevent galvanometer burnout.

For maximum operational simplicity and an uncluttered work area, output connections are located at the rear of each amplifier, while inputs are at both the front and rear. Models are available with or without steel cabinet for portable applications.

Circle No. 226 on Subscriber Service Card.

Latest Low Noise Preamplifier Marketed

Microwave Associates, Inc. have announced the introduction of a low noise parametric RF preamplifier designated Model Number MA-1C. This Harris type preamplifier when coupled to conventional UHF receivers operating in the 350-500 mc band reportedly

achieves greatly improved low noise receiver performance.

Overall receiver noise figures below 1.0 db (approximately 80° Kelvin) are achieved with bandwidths of approximately one percent throughout the specified tuning range. The preamplifier performs as a straight-through parametric low noise amplifier with RF output obtained at the signal frequency.

Each MA-1C provides two MA-460 varactors (one of which is a spare) and a resonant tank circuit with micrometer tuning adjustment. Type N fittings are incorporated for convenient connection of 50 ohm coax for the RF input signal, pump oscillator and output to receiver. Each is completely assembled and pre-tested for proof of performance. The preamplifier is normally used in conjunction with an existing receiving installation.

Circle No. 247 on Subscriber Service Card.

Light Ceramic Foams Withstand 1,000 Degrees

Two series of ceramic foams for electrical and electronic use, designated Eccofoam LM-43A and Eccofoam WC-8, are now available from **Emerson and Cuming, Inc.**

Both materials are light in weight and capable of use in excess of 1000°F.

Eccofoam LM-43A is supplied at dielectric constants 1.3, 1.4, 1.5 and 1.6. Dissipation factor is below 0.001. Eccofoam WC-8 is supplied at dielectric constants 1.7, 1.8, 1.9, 2.0, 2.5, 3.0, 4.0 and 5.0. Dissipation factor is well below 0.003. The Eccofoam LM-43A materials are below 20 lbs./cu. ft.; the Eccofoam WC-8 series varies from about 20 to 70 lbs./cu. ft. dependent upon dielectric constant. Flexural strength remains high, even at 1000°F. The foams can be fabricated readily with standard tools.

These ceramic foams are used in antennas, radomes, lenses and as dielectrics in microwave systems. They supplement the standard Eccofoam line of adjusted dielectric materials and extend the temperature range of use.

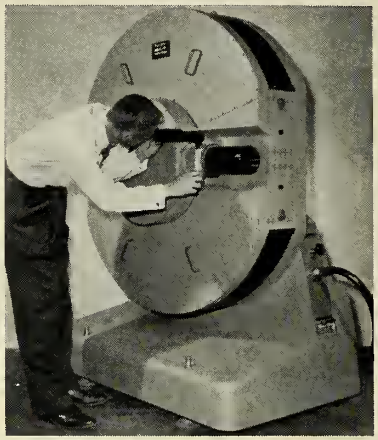
Circle No. 228 on Subscriber Service Card.

35-mm Camera Operates with No Blind Time

Recording 82 35-mm frames for a 55-microsecond period, the new Model 192 **Beckman & Whitley** continuous-writing framing camera is designed to accommodate magnification-velocity products up to 3 mm per microsecond, or at conventional magnification, object velocities to Mach 35.

Complementing the specifications of the widely used Model 189 framing camera, the new instrument operates with no blind time, which means that it can be used to photograph high-speed events which do not lend themselves to synchronization with the position of the rotating mirror in the camera.

Because of this feature, the Model 192 is reported ideal for high-speed



aerodynamic studies, for thermal-barrier studies in ballistic investigations (such as nose cone re-entry problems), for hypersonic wind tunnel instrumentation and for exploring the behavior of rocket propellants.

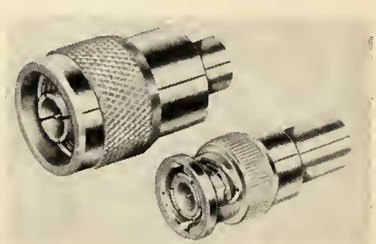
Supplied complete with operating controls, the Model 192 has boresight optics and rack-and-pinion focusing arrangements. Daylight loading and unloading are provided for with standard 35-mm film casettes.

Dimensions of the camera are 84 in. by 60 in. by 36 in. high. The camera proper weighs 1,800 pounds, lists at a standard price of $69,500.

Circle No. 230 on Subscriber Service Card.

Miniaturized Power Loads Are Made by Microlab

A new line of Coaxial Terminations has been announced by **Microlab.** These terminations are miniaturized low



power loads designed to operate from dc to 10,000 mc. They are intended for airborne and other applications requiring compact, lightweight components and consist of a resistive film center conductor terminated within a carefully matched housing. They have a nominal power rating of two watts which can be increased by providing an external heat sink or forced air cooling.

Known as the TA series, the terminations are provided with either male or female connectors of type N, BNC, or TNC. Their impedance is 50 ohms and the input VSWR over the entire frequency range is 1.1 maximum.

Circle No. 231 on Subscriber Service Card.

Frequency Meter Covers Broad RF Spectrum Range

Broad RF spectrum coverage and accuracy to .005% are combined in a new frequency meter manufactured by **Divco-Wayne Electronics,** Cincinnati.

Designed for battery or power supply, the ruggedly built unit will give laboratory performance in the field, according to V. D. Heitfield, director of engineering.

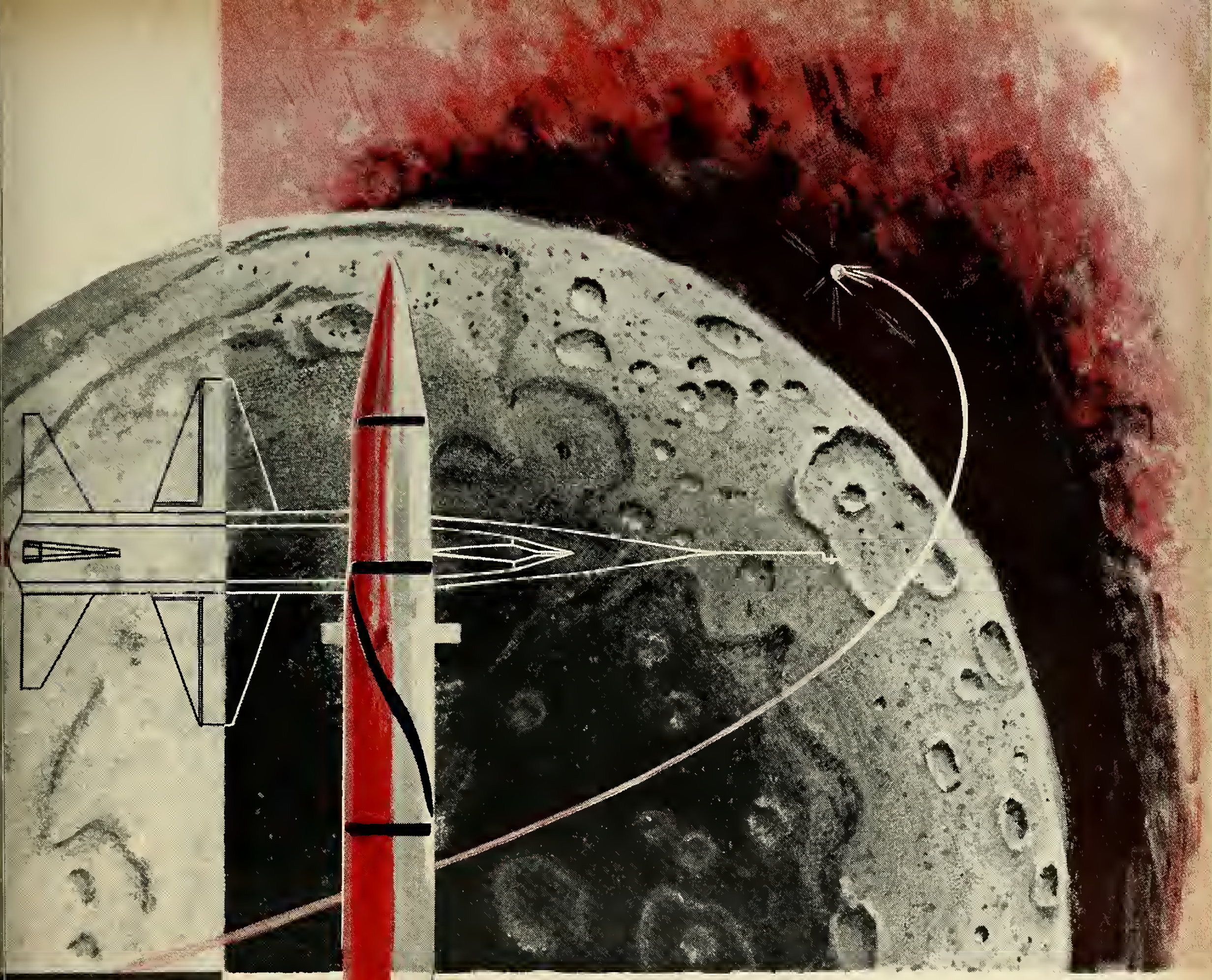
Called the D-W-E 1021, the meter provides the broad spectrum coverage normally requiring three separate narrow band units. It measures frequencies from 125KC to 1000MC and gen-

erates voltages of known frequency from 125KC to well over 1000MC.

The manufacturer states that each meter is pre-conditioned in a Tenney environment chamber at temperature extremes for conditions under which it will actually operate. Accurate calibration data is supplied for 5000 dial readings, allowing unskilled operators to make accurate measurements.

Wide range frequency coverage of the D-W-E 1021, according to Heitfield, is gained by the use of three frequency ranges:

- Range A coverage is from 125 to 250KC with the second, fourth, eighth and part of the tenth harmonic series extending to 2.5MC.
- Range B coverage is from 2.5 to



pment for:

- ORMING
- TRAIGHTENING
- 'COMB PRODUCTION
- ORGING
- DING MANDRELS iles, Etc.)
- AL STRETCH FORMING
- AULIC GROUND SUPPORT
- ND HANDLING

Announcing

a new service

TO THE AIRCRAFT, MISSILE AND ROCKET INDUSTRY

Clearing's newly formed Aircraft and Missile Division is a group of engineers who specialize in solving equipment problems for the aeronautical industry. These are a selected group of Project Engineers with design background in spin forging, stretch forming, and other advanced manufacturing techniques.

Clearing has already designed hot forming equipment, and is currently working on design concepts for other processes as shown at left. If you are faced with these or related equipment problems, call on us. Together we may be able to work out a new and improved manufacturing method for your company.

USI

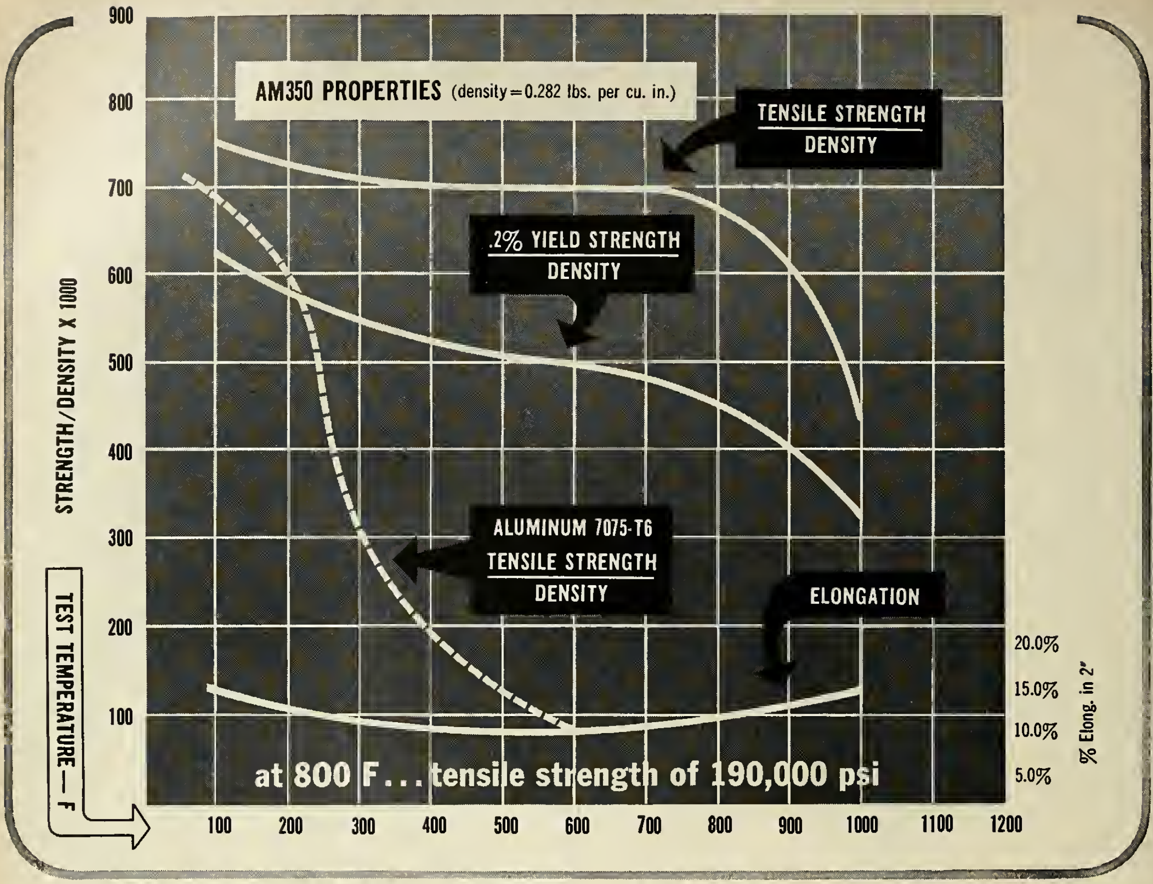
Clearing DIVISION OF U. S. INDUSTRIES, INC.

Aircraft and Missiles Division • 6160 S. Boyle Avenue • Los Angeles 58, California • LUdlow 5-2141

Main Plant: 6499 W. 65th Street, Chicago 38, Illinois • PO 7-8700

Circle No. 19 on Subscriber Service Card.

Experience—the extra alloy in **Allegheny Stainless**



Here are the facts on AM350 and AM355, Allegheny Ludlum's precipitation hardening stainless steels

A unique combination of highly desirable properties is the usual description of Allegheny Stainless AM350 and AM355 Steels. They combine high strength at both room and elevated temperatures, excellent corrosion resistance, ease of fabrication, low temperature heat treatment, good resistance to stress corrosion.

They are proving the answer to many problems of the air age. Airframe and other structural parts, pressure tanks, power plant components, high pressure ducting, etc. are all natural missile and supersonic aircraft applications for AM350 and AM355.

Availability: AM350, introduced several years ago, is available commercially in sheet, strip, foil, small bars and wire. AM355, best suited for heavier sections, is available in forgings, forging billets, plate, bar and wire.

Corrosion resistant: Being stainless steels, these alloys resist corrosion and oxidation. Compared to the older, more familiar stainless grades, their corrosion rating is better than the hardenable grades (chromium martensitic) but generally less than the old corrosion resistant standbys, the 18 and 8's. Stress corrosion is resisted at much higher hardness levels than with martensitic stainless.

Simple heat treatment: High strength is developed by two methods, both involving less than ordinary temperatures and minimizing oxidation and distortion problems. The most popular, and one that develops slightly better properties, is the Allegheny Ludlum developed sub-zero cooling and tempering (SCT condition). The material is held at minus 100 F for 3 hrs plus 3 hrs at 850 F. Alternate method is Double Aged (DA): 2 hrs at 1375 F plus 2 hrs at 850 F.

Easy fabrication: AM350 and AM355 can be spun, drawn, formed, machined and welded using similar procedures as with the 18-8 stainless types. In the hardened condition (SCT & DA) some forming may be done . . . 180 degree bend over a 3T radius pin. Also it can be dimpled in the hard condition to insure accurate fit-up.

For further information, see your A-L sales engineer or write for the booklet "Engineering Properties, AM350 and AM355." *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.* Address Dept. MR-14

WSW 7327

ALLEGHENY LUDLUM

Export distribution: AIRCO INTERNATIONAL

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

Circle No. 13 on Subscriber Service Card.

5MC with the second, fourth, eighth and part of the thirteenth harmonic series extending up to 65MC.

Range coverage is from 65 to 130MC with second, fourth and eighth harmonic series extending up to 1000MC.

Each D-W-E 1021 is supplied in a water-tight case, with cable, connector adapter, antenna, headset, headset extension cord and AC 115/230 volt power supply.

Circle No. 232 on Subscriber Service Card.

TV Camera Designed for Rocket Engine Tests

One advantage of closed-circuit television is that the TV camera can be located where no person would dare to stand. The camera can withstand atomic radiation, heat, cold, and hazards of accidental explosion—all the

while providing a close-in view of the experiment or test in progress.

Newest development is a TV camera designed specifically to resist sound levels that would shatter the hearing of a human observer. It is manufactured by the **KIN TEL Division of Cohu Electronics.**

The Model 1986CN Camera can operate in noise environments up to +145 db without an acoustical housing. With a housing, it is virtually impervious to noise of any level. It has been successfully used in sound levels above 190 db.

Immediate application for the new camera is on rocket or jet engine test stands. Previous cameras have suffered from microphonics caused by the engine's roar. The new Model 1986CN is essentially free of microphonics. It features a video-signal amplifier with subminiature tubes mounted in an unusual heat sink. The result is a dampening out of sound vibrations, plus full thermal protection.

The 1986CN Camera provides full 600-line resolution. Picture circuits have a bandwidth of 20 cps to 8 mo + ½ db, resulting in a picture of unusually high definition. Used with a KIN TEL camera control unit, the Model 1986CN automatically adjusts to changing light conditions over a 2000:1 range.

The camera weighs only seven pounds, and can be used in conjunction with pan-tilt units, auto-zoom lenses, and other TV equipment.

Circle No. 233 on Subscriber Service Card.

Telemetry Antennas Have Circular Polarization

The availability of telemetry antennas featuring circular polarization has been announced by **Technical Appliance Corp.** The antenna is designed for use in the reception of telemetering information from orbital and into-space transmitters.

The TACO G-1054 design promotes a choice of helical feeds, a 6-, 8- or 10-foot diameter parabolic reflector, and a manually-controlled mount for either ground or vehicle installation.

. . . new missile products

Gain of the antennas is in the area of 23 to 26 db over an isotropic source, while the nominal beam width is 8° to 14° depending on antenna size. Frequency range of the new antenna is 940-980 MC, and is available on special order for other frequencies. VSWR of the complete antenna is less than 1.3.

The antenna is completely balanced, permitting easy and accurate manual orientation. It has an azimuth adjustment of 360° and an elevation adjustment of 0-90°. Positioning is accomplished by means of a hand-operated, positive, clamp.

Degree markers are provided for both azimuth and elevation readings.

Transmission line feed is through a type N connector with a terminal impedance of 50 ohms.

In addition to orbital and into-space telemetering, the TACO Model G-1054 may be mounted on top of a van or trailer and effectively used for TV-Studio Transmitter Links (STLT) by feeding the dish with a 1990-2110 MC feed.

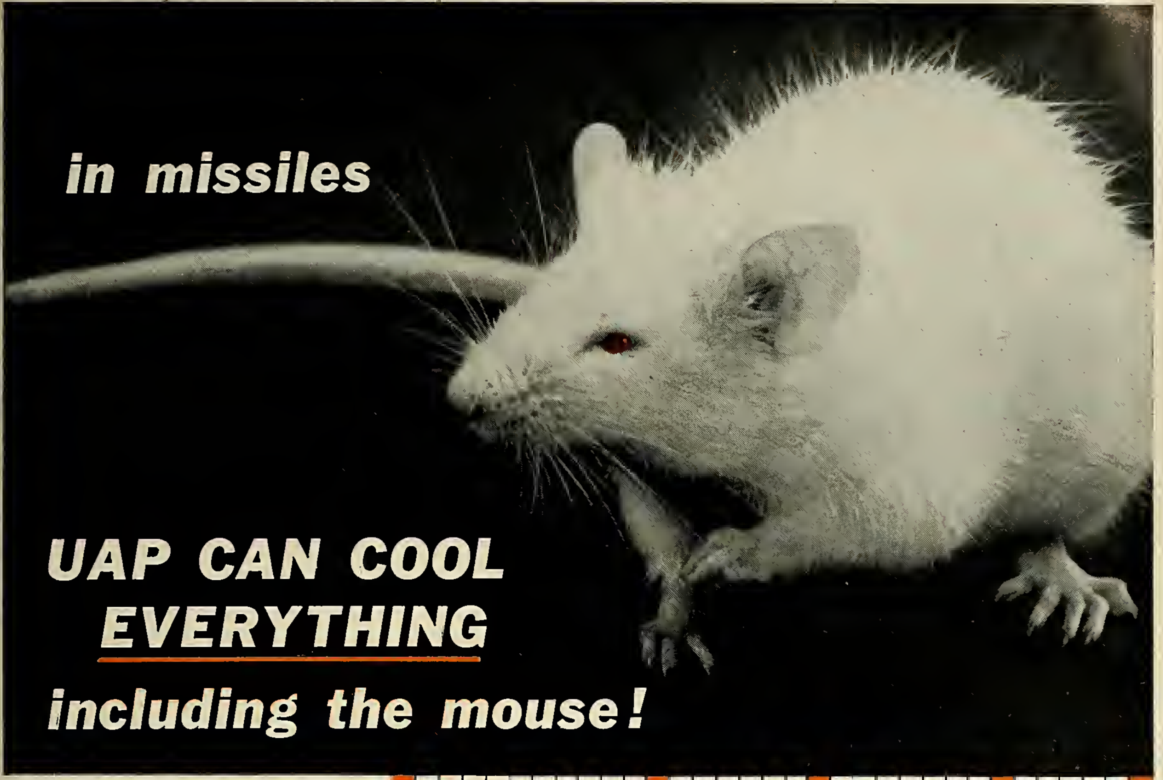
Circle No. 234 on Subscriber Service Card.

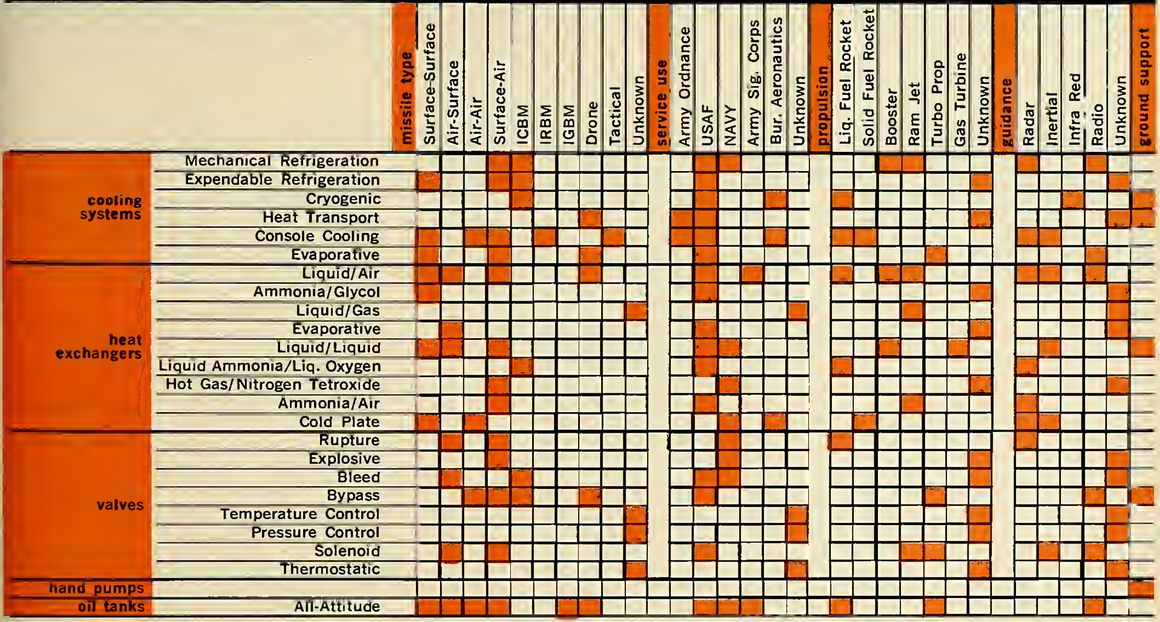
Oscillographs Developed for High Speed Testing

The **Heiland Division of Minneapolis-Honeywell Regulator Co.** has developed two new models in its 906 series of direct-recording oscillographs that provide higher recording frequencies and increased channel capacities.

The new Visicorders, designed to monitor and record a variety of electrical and mechanical phenomena during high-speed scientific and industrial testing operations, include:

The 906A-1, which features high-sensitivity miniature plug-in galvanometers and magnet assembly. This use of subminiature galvanometers permits 14





The achievement chart proves UAP's extensive experience and ability in designing and building electronic cooling systems, components and flow control devices. Whether your electronic cooling problem involves airframe, guidance, propulsion or ground control equipment, UAP has the technical know-how to solve it! Call your UAP Contractual Engineering Office today!

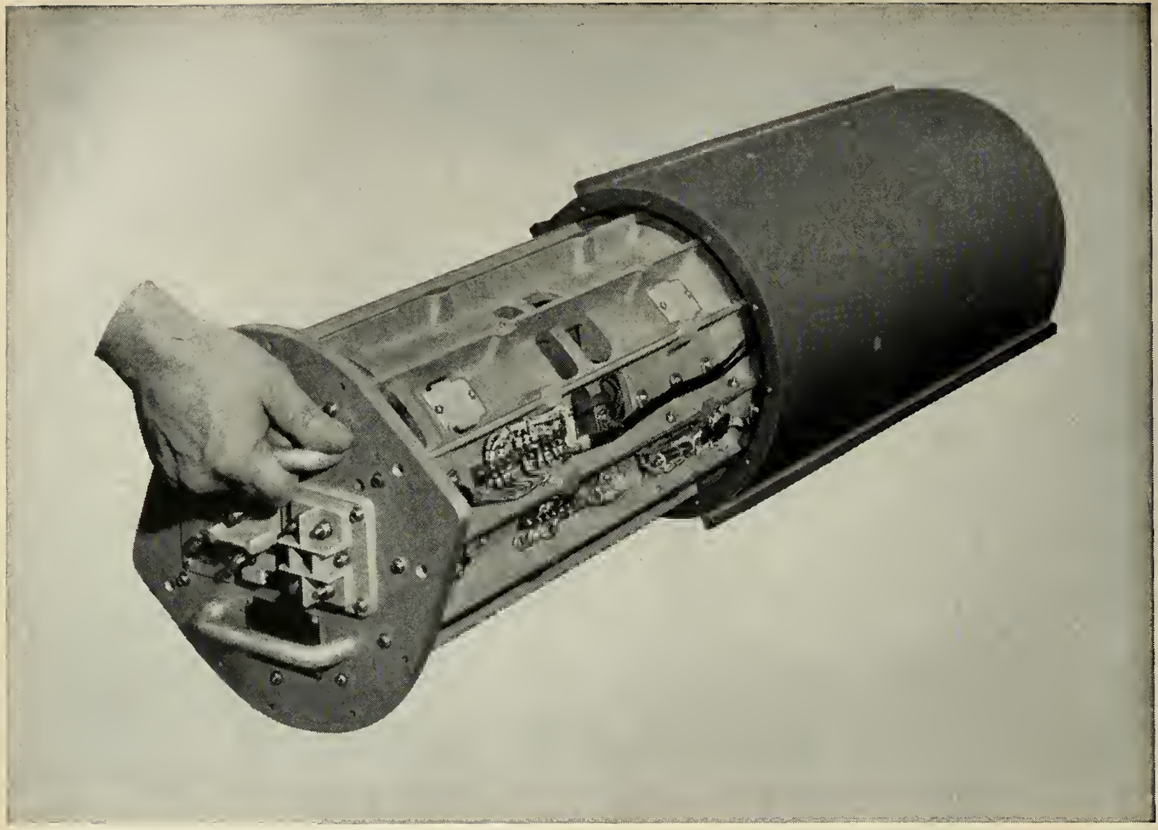
CALIFORNIA, Burbank...... VI 9-4236
NEW YORK, New York... MU 7-1283
OHIO, Dayton .... BA 4-3841
CANADA, Montreal .... ME 1-4396

a famous family of aircraft essentials since 1929

UNITED AIRCRAFT PRODUCTS, INC.

1116 BOLANDER AVENUE, DAYTON, OHIO

Circle No. 44 on Subscriber Service Card.



NEW! BENDIX CANISTERED INVERTERS

Withstand the Effects of Temperature, Vibration and Acceleration at Blast-off and Will Function Perfectly at Any Altitude, Including Outer Space

Bendix Canistered Inverters, environment-free and completely sealed, are now in production for the Atlas and Thor missiles. Designed for dependable and efficient operation, Bendix Canistered Inverters are completely sealed against the effects of altitude and can withstand conditions from sea level to outer space.

Cooling techniques employed enable these units to provide full-rated output throughout the flight without external cooling. Both voltage and frequency regulation are accomplished by static, magnetic amplifier-type regulators. Since these regulators have no moving parts, output voltage and frequency are not affected by vibration and shock. The total harmonic content of the output voltage per phase is less than 5%.

Bendix Canistered Inverters are the product of years of development and experience in manufacturing electrical power equipment for aircraft and missiles. They are engineered to meet the strenuous requirements in performance and reliability called for in today's (and tomorrow's) missiles. For more detailed information write to RED BANK DIVISION OF BENDIX AVIATION CORPORATION, EATONTOWN, NEW JERSEY.

West Coast Sales and Service: 117 E. Providencia Ave., Burbank, Calif. Canadian Distributor: Aviation Electric, Ltd., P. O. Box 6102, Montreal, P. Q. Export Sales and Service: Bendix International Division, 205 E. 42nd St., New York 17, N. Y.

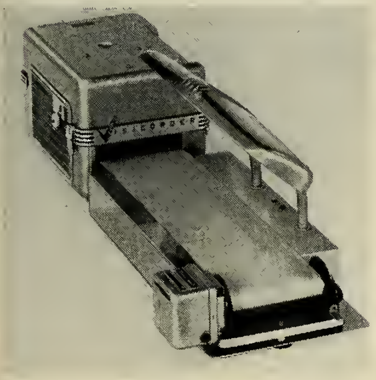
Red Bank Division Bendix AVIATION CORPORATION

Circle No. 17 on Subscriber Service Card.

channels of data to be directly recorded at frequencies from DC to 5,000 cps, and

The 906A-2, with "solid-frame" galvanometers and magnet bank, provides for eight-channel recording at frequencies from DC to 2,000 cps.

The new timing unit is a separately-housed multivibrator oscillator that



provides short, accurately-spaced pulses to timing galvanometers of .01, 0.1 or 1.0 seconds. Pulse characteristics are such that, with the timing signal applied to two 3,300-cycle natural frequency galvanometers, full width time lines will result.

Legible records within a few seconds are possible with Heiland's bench-mounted unit that latensifies and spools Visicorder records. The unit consists of a record takeup unit with drive motor and removable spool.

The motor automatically adjusts to all standard paper speeds from .2 inch per hour to 500 inches per second, with capacity of 100 feet of six-inch Visicorder paper.

The latensifier, which connects to the Visicorder for power and is equipped with a receptacle for remote operation of both units, is mounted on a platform that is equipped with two fluorescent lamps over the viewing surface.

Circle No. 235 on Subscriber Service Card.

Cartridge Type Heater Unit Now in Production

Tektron Instrument Co., has announced the stock production of a new cartridge type heater unit.

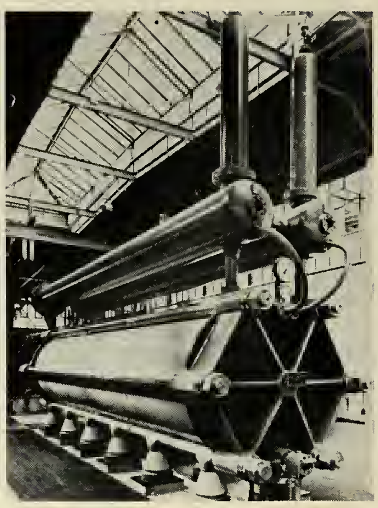
Believed to be the smallest of its type available, the unit measures .250 inch in diameter, with an overall length of 1.5 inches. The heating element is located within one inch of the inserted end. Electrical specifications are: 37 watts, 28 volts, cold resistance 21 ohms. The casing is stainless steel. They are available from stock in quantities from one to 500.

This unit is now being used in missile engines to heat the liquid oxygen pump lubricant. Many other uses are possible, including high altitude instrument and hydraulic temperature control, laboratory and instrument temperature control.

Circle No. 236 on Subscriber Service Card.

Pressure Electrolysis Produces Hydrogen, Oxygen

Highest purity industrial hydrogen and oxygen now can be economically produced by means of pressure electrolysis. The process is made possible by availability of the Zdansky-Lonza Pressure Electrolyzer, developed by Lurgi of Frankfurt, West Germany, and offered throughout the United States and Canada by **Winfield Equipment Co.**



Compared with earlier and conventional electrolyzers, which operate at atmospheric pressure, the Zdansky-Lonza unit utilizes tremendously high pressure generated without use of compressors—30 atmosphere gauge pressure on an industrial scale. Basically, use of high pressure, rather than atmospheric pressure, decreases cell-voltage requirements corresponding to the specific power consumption and power consumption is reduced bringing about a savings of 20% in energy.

Furthermore, 50% savings in equipment floor space is effected. These benefits, plus elimination of need for additional purification processes, lower operating and maintenance costs. The only labor required is reading of gauges periodically.

Purity obtained is 99.9% for hydrogen and about 99.8% for oxygen. Thus they are ready to use, or sell, at the end of this self-contained process.

Circle No. 237 on Subscriber Service Card.

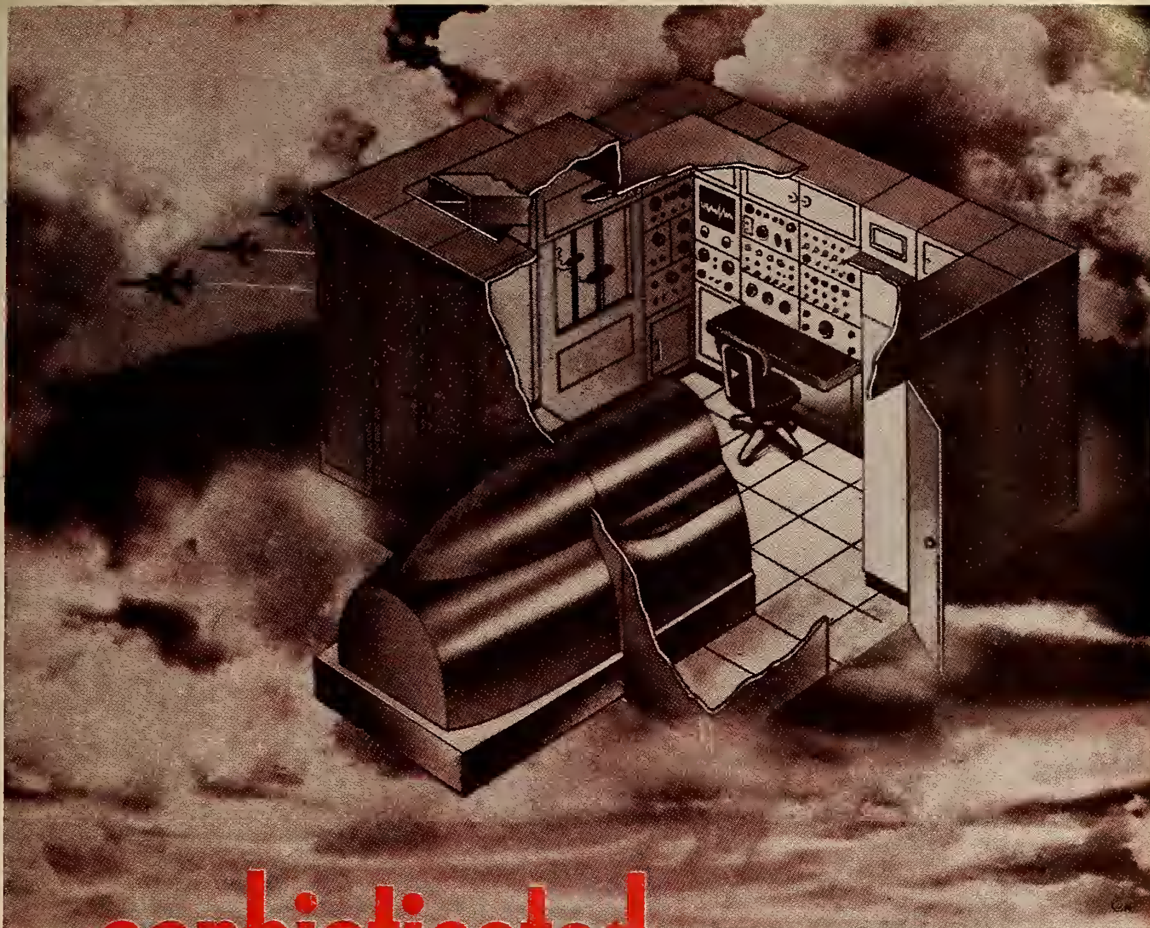
Electromagnets Controlled by Unit's Error Signals

A new nuclear magnetic resonance field control unit, the model FC-501, has been made available by **Harvey-Wells Electronics Inc.**

The new instrument is designed to provide a means of precise regulation of electromagnets by producing an error signal, derived from the field under control, suitable for closed-loop regulation of the magnet power supply.

The range of the FC-501 is 310 to 20,000 gauss with standard probes. For control of fields out of this range, special probes are available.

The unit consists of three interconnected parts: (1) probe, (2) oscillator, (3) field control unit. The latter con-



sists of a power supply, lock-in amplifier and modulator. The company says the oscillator is stable to greater than ten parts in a million and even greater stability can be obtained by cohering it to an external frequency standard.

The modulation sweep range is zero to 20 gauss. Increased modulation facilitates the location of resonance and a modulation control allows decrease of modulation to optimize field control action.

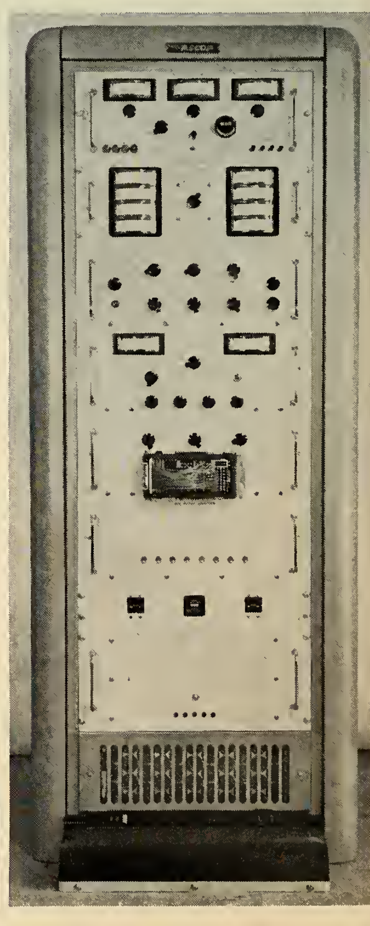
The unit operates at 115 volts, 60 cycles at 2.5 amps. Both the oscillator and field control unit are compactly designed and weigh 45 lbs.

Circle No. 231 on Subscriber Service Card.

Decommutation Equipment Handles Sampling Rates

New telemetry decommutation equipment that can handle sampling rates from 24 to 3600 p.p.s. in both Pulse Amplitude (PAM) and Pulse Width (PWM) doding is now in production at the Applied Science Corp. of Princeton (ASCOP).

Besides the dual PAM/PWM ca-



MEN AND IDEAS IN MOTION: AERONUTRONIC

This is Aeronutronic — men, ideas, and the tools for research. Aeronutronic — a dynamic new name in science — created by the Ford Motor Company to meet the demanding technological needs of a nation on the move.

Aeronutronic is moving into the future and moving fast. Space sciences, missile technology and space vehicles... computers, electronics... tactical weapon systems... these are major research, development and manufacturing activities conducted at ASI's modern 200-acre Research Center under construction at Newport Beach, California.

Exceptional engineers and scientists are needed now. If you are forward-looking and want to be an important part of a forward-moving organization, you'll find a new challenge and rewarding future at Aeronutronic — *where men set ideas in motion.*

For information regarding positions, interests, facilities or products, write to Mr. K. A. Dunn, Aeronutronic Systems, Inc., Bldg. 6 1234 Air Way, Glendale, California, or call CHapman 5-6651.

AERONUTRONIC

a subsidiary of FORD MOTOR COMPANY

NEWPORT BEACH, GLENDALE, SANTA ANA AND MAYWOOD, CALIFORNIA

OFFICE OF ADVANCED RESEARCH • SPACE TECHNOLOGY DIVISION • COMPUTER DIVISION • TACTICAL WEAPON SYSTEMS DIVISION

pacity and the wide sampling rate capability, the new equipment also features long term system accuracy of better than ±0.5%, including any system nonlinearity and drifts and an undecommutated but thoroughly corrected output for convenience in digitizing.

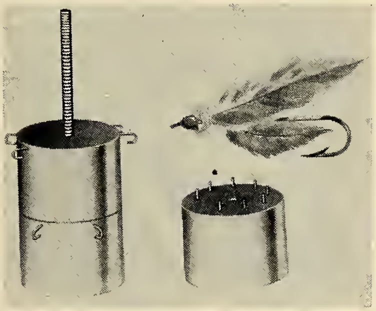
The sampling rate capability makes the new equipment compatible with both standard IRIG configurations and a large number of non-standard rates.

The new M-Series design emphasizes flexible modularization. Miniature tubes and components are mounted in plug-in modules which are standard throughout each system. This permits rapid plug-in replacement of modules. New M-Series chassis have a 7-inch modular front panel and can be mounted in all standard equipment racks.

Circle No. 243 on Subscriber Service Card.

Unit Features Optimum Temperature Stability

Arnold Magnetics Corp. has announced the addition of a temperature-stabilized type to its line of small-size toroidal inductors. The unit features



optimum temperature stability across the military temperature environment range of –55° to –71°C. Inductance can be as little as plus or minus 0.25% change in this range.

The unit uses a stabilized core, and is fully encapsulated with special materials to acquire the desired temperature stability. Built to withstand extreme shock and high temperature, it meets the specifications of MIL-E-5272A and MIL-T-27A.

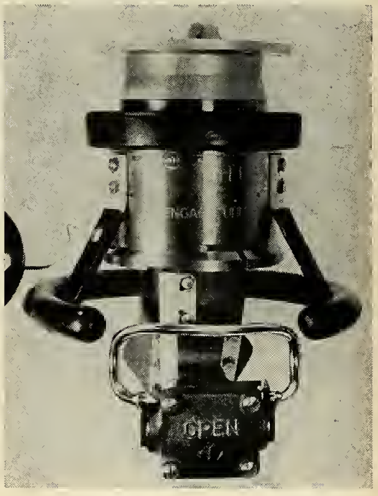
Designated as "S" type, this stabilized version is now available in all series of Arnold inductors, with inductance values ranging from 0.1 millihenry to 17 henries, and with useful frequency ranges from 60 cycles to 500 kilocycles.

The units are designed for printed circuit boards, or stacking on single screw for chassis mounting.

Circle No. 245 on Subscriber Service Card.

New Hydrogen Peroxide Nozzle Is Non-Corrosive

A new self-sealing, high flow rate hydrogen peroxide nozzle and adapter



for servicing aircraft or missiles using hydrogen peroxide as an oxidizer has been announced by **Flight Refueling Inc.**

Safety requires the nozzle to be manually locked to the adapter before the internal valves can be actuated and, collaterally, the internal valves must be completely closed before disengagement.

Another important feature is that working parts are fitted externally and do not come in contact with the fluid, eliminating the possibility of corrosion.

Circle No. 227 on Subscriber Service Card.

Test Stand Filter Handles up to 5,000 psi

Filter capable of handling systems with working pressures of 3,000 and 5,000 psi, a new line of high-pressure filters for hydraulic fluids, air, liquids and industrial fluids is now available.

Designated as Model 13460 by the manufacturer—**Bendix Aviation Corp.**—these units may be applied to missile hydraulic and pneumatic test stands, and can also be used to remove contaminants from chemical and related industrial fluid processing systems. The units also provide protection for hydraulic and pneumatic control systems in machinery.

The filters are available in eight sizes, with particle ratings from 5 to 250 microns. In fluid contamination control, maximum particle size can be limited to 15 microns.

Circle No. 246 on Subscriber Service Card.

Launching Ratio

To the Editor:

As a regular reader of MISSILES & ROCKETS which to me has often been a source of first class information, I was somewhat astonished to read an article by Alfred J. Zaehringer (m/r, Dec. 15), that the ratio launching weight/payload of Russian satellite rockets is supposed to be 1000:1.

As evidence against this supposition, I point to an article published by U. A. Pobiedonosstsev in Priroda which seems to give details of the launching of *Sputnik II*. Pobiedonosstsev's figures are:

Launching weight, 111.6 metric tons; four steps; payload, 300 kgs; dry weight of step four, 216 kgs; ratio, 372:1.

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

Editor Zaehringer replies:

I did not imply that Soviet Sputniki has ratios greater than 1000:1. My article dealt with the possible lash-up of standard, heavy, artillery rockets to provide for "quick" satellites for the satellite nations. In this respect, the improvization of such satellites would be done with heavy, relatively inefficient hardware—much like the American Explorer vehicle.

I have not seen any figures on vehicle weights for the Soviet Sputniki. Perhaps your figure is correct. However I am inclined to use more conservative figures. Kölle of Germany estimates that the launching weight of Sputnik II was something like 132,500 kg instead of the 116,000 kg figure you mentioned. You have to be very careful in analyzing what the Soviets say—especially if it is indirect such as the Priroda statement.

My figures indicate that the ratio of the launching weight to payload weight of Sputnik II was between 616: and 1380:1.

Space and the World

Professor Teofilo M. Tabanera, vice-president of the International Astronautical Federation and South America's leading exponent of rocketry and astronautics, has written the following letter to m/r expressing a viewpoint which may be widespread among world scientists. It is reproduced below (somewhat condensed for reasons of space). We would like to hear from others interested in world astronautics.

It has been over a year now since one of the most remarkable events in recorded history occurred, and the word *Sputnik* has become firmly established in our everyday vocabulary . . . Successful artificial satellites represent the starting point of man's greatest adventure, flight into space.

Nearly four years have passed since announcement of the U.S. *Vanguard* program and the part it would play in the International Geophysical Year. It was emphasized that the outcome of satellite and space research would be made known to scientists of all the participating nations of the world, Russia included.

Shortly afterwards the USSR announced a similar program, and during 1958 we saw them place three satellites whirling in space. Rocketry is being developed both by the Russians and the Americans on a colossal scale, and elaborate projects, including manned interplanetary flights are widely predicted.

But what is the rest of the world doing? Are we, who are neither Russians nor North Americans, going to take part in this great enterprise or are we to remain mere spectators? So far, we have done little but watch in awe . . .

Nearly five hundred years ago mankind started another great enterprise, the discovery and conquest of another new world. Two nations, Spain and Portugal, almost exclusively undertook the early explorations. At first the rest of the world showed very little interest in this important event . . .

Now we are starting on another great enterprise, far greater in magnitude and more magnificent in concept . . . Again we find two major nations involved, one representing old Eurasia, the other the young, striving American civilization. But there is a more fundamental difference between the two undertakings: the former's new world explorations were not carried out in a spectacular way; they went by quietly and there was no pretense of having other nations initially share in them. Today's enterprise has commenced quite differently: it is spectacular and noisy, and it is reluctant to allow the rest of the world to share in its development.

The U.S. and the USSR have been working on rocketry and astronautics in a state of practical isolation from each other, and from the rest of the world. All research and tests have been surrounded by utmost secrecy . . .

What has been the effect of all the secrecy? First, the other 98 nations of the world have been denied much valuable information and second, the two giant powers possessing it have kept it from each other.

The melancholy result has been that both countries . . . have had to invest more energy, more time and more money in researching the same area, thereby doubling their own efforts.

Almost immediately following the Russian satellite achievements, the Americans rushed to at least partially improve their situation by putting up a series of small *Explorer* satellites. Externally, it seemed likely that they would reach an agreement with Great Britain to carry out certain joint tasks, and already *Thor* and other missiles have been made available to them.

Thus, a gap has been opened and a rather tardy effort is being made to correct a great mistake, the negative results of which are evident. But only partially may it be corrected. The walls are closing in again and a new lunar exploration stage is to start.

The mistake lies in the barrier, and this mistake of discrimination is based on another mistake of appreciation—believing that only the scientists shut in behind the artificially erected walls can create new things. Luckily, this is wrong, for the genius or the intellectually-gifted man may arise anywhere . . .

When America was discovered and "colonized," the world made the mistake of not participating, leaving it for a long time in the hands of only two countries. Five hundred years ago this could be considered natural. But when we begin the exploration of the cosmos a large part of the world should not be put aside, remaining a mere spectator . . . That outer space does not belong, and should not belong to any group of men (no matter how well-meaning it may be) seems quite obvious. And it does not belong to mankind either. It does not belong to anybody, particularly nor generally. All men are entitled to take part in this great enterprise . . . And all men have not only the right but the duty to do so . . .

We have an International Astronautical Federation, now nine years old, numbering among its members the most important astronautical and rocket societies in the entire world, East and West alike. The IAF (whose current president is an American and one of whose vice presidents is a Russian) assuredly is the qualified organization to look for the best solution of this complex problem. It is very likely that, in the long run, the world will have to get together in developing the space age, if for no other reason than to avoid mutual destruction. Why not at least experiment through the IAF now? . . .

Ing. Teofilo M. Tabanera
Buenos Aires, Argentina

keeping track

by Peer Fossen

It looks like everybody must have his say in the discussion over whether the Russian moon rocket was a hoax, a favorite topic in Washington these days. Some sources base the hoax reports on briefings given to Congressional leaders by Central Intelligence Director Allen W. Dulles. After one of these sessions, Sen. Styles Bridges (R-N.H.) reportedly said there was something to the stories, but he declined to elaborate "because of the classified nature of the meeting."

A few days later, however, Bridges declared on ABC-TV's College News Conference that "there is nothing that any nation has in existence today that will prove this last *Lunik* or "Sunik" actually reached the sun and went into orbit around the sun. "There is no tracking operation. It may be a huge propaganda scheme. We know they launched the huge missile and that it went to a great height. For all we know, it may have disintegrated, or it may still be going around the sun. But there is no proof," he said.

Regardless of the Senator's statement, there are several reports from various sources indicating that the Russian space vehicle was actually tracked in the U.S.

One of the first such reports came from JPL's Dr. William H. Pickering who said that the United States apparently "tracked" the cosmic rocket as it passed beyond the moon.

According to Pickering, the Army's Goldstone facility picked up the signal on Sunday, Jan. 4, about two days after the Kremlin announced the launching, and after earlier tracking efforts had failed.

He said the signals came from the region west of the moon, and that the angle between the moon and the signal source increased with time, indicating that the signal source had passed beyond the moon. The Goldstone facilities had to be modified substantially before the tracking could take place since the frequencies reported to be in use by the Russians were much lower than the frequency at which the station was originally set up to operate, (960 megacycles for *Pioneer III*). The Goldstone tracking is supposedly the first outside Russia.

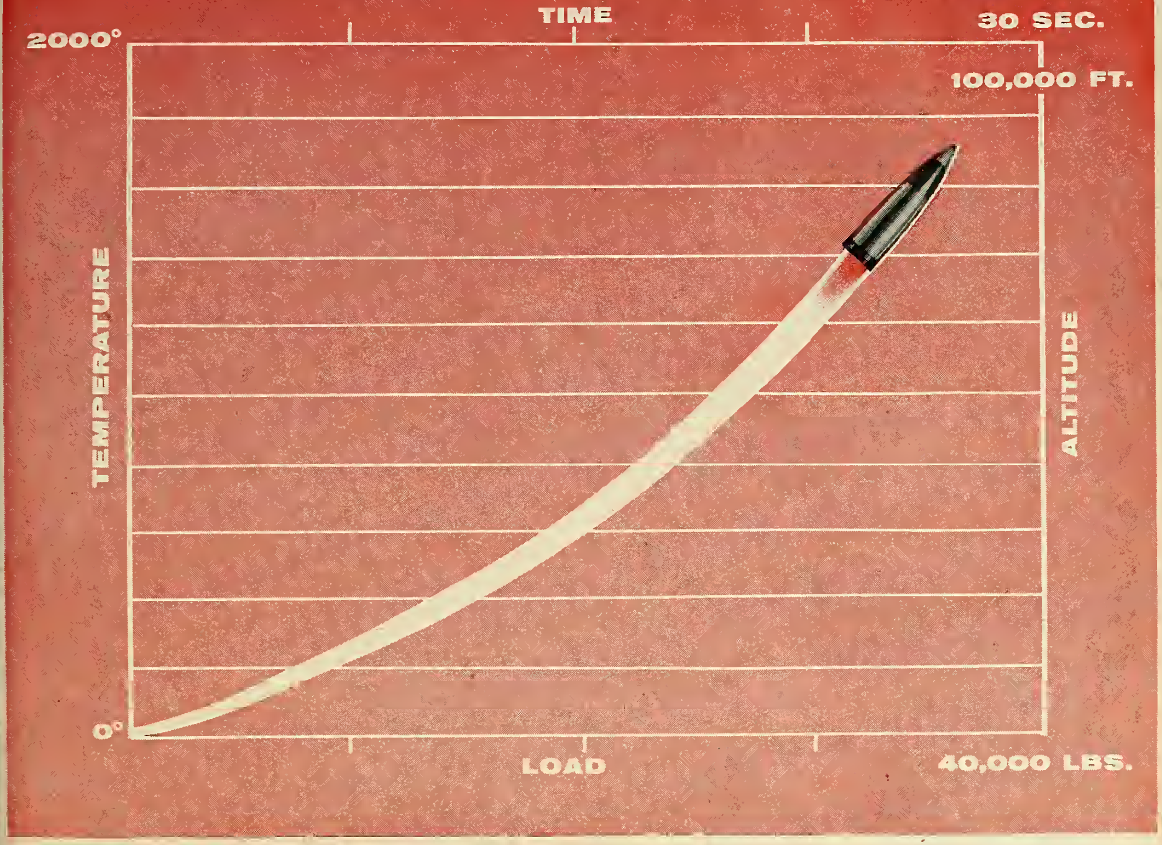
Dr. Pickering carefully avoided saying whether the signals picked up at Goldstone came from the Russian vehicle, admitting only that the observed data—as far as time and space was concerned—was about what could be expected on the basis of Soviet announcements—after the vehicle passed the moon.

Other facilities reported to have been involved in the *Lunik* tracking include Ft. Monmouth, Millstone, Cape Canaveral, and Cambridge, but the authorities have not submitted any definite statement whether these facilities actually did any tracking.

An interesting *Lunik* story circulating in Washington is that the Pentagon clamped down on the release of information by direct order of the President. The story has it that Eisenhower blew his top after the Pentagon had okayed a congratulatory message to the Russians before anyone knew for sure that their announced space stunt was not a hoax.

University of Michigan scientists have proposed a radar space observatory containing a nuclear power source to supply electrical energy. It would be used to determine the best location for landing on the moon to avoid sinking in the lunar dust. The university indicates that the space vehicle could be built with "on-the-shelf" equipment, but this does not quite add up. They have estimated the gross weight of the rocket to 500,000 pounds with about 750,000 pounds of thrust required for the first stage. It doesn't seem possible that we have that kind of equipment "on the shelf."

OUTBOUND



Second by second, higher-order performance is required of today's missile design—even as temperatures and loads are on the increase geometrically.

These are familiar problems to Shafer Engineers who have pioneered in the research and development of bearings to meet these higher-order requirements on many of today's outbound missiles. For example, Shafer research on the coefficient of expansion of materials—and the many other physical properties at elevated temperatures—establishes Shafer as a leader in high-temperature bearing design.

The famous exclusive design features that have made Shafer first choice for the toughest bearing applications in the airframe industry—greater capacity for its envelope dimensions and weight... integral self-alignment with full capacity... greater resistance to shock loadings and vibrations—may provide the answer to your missile control system bearing problems.

The time for you to draw on Shafer experience is now—before you lay in bearings on your latest missile design. And remember, too, Shafer advantages can provide important answers to bearing problems on ground support equipment as well as the "birds" themselves. Before you lay bearings in—call on Shafer experience.

Shafer Bearing Division, CHAIN Belt Company, Downers Grove, Illinois.

SHAFER® BEARINGS

CHAIN BELT COMPANY

Circle No. 80 on Subscriber Service Card.

west coast industry

by Fred S. Hunter

Lockheed Aircraft Corporation is completing plans for establishing a new electronics division to deepen its penetration in this field. Lockheed's Chairman Robert E. Gross has long felt the need to build a well-rounded electronics capability in the company to improve its potential in managing complete weapons systems.

In 1957, Lockheed formed a diversification task force to study mergers or acquisition of other companies that might help bring this about. Some actual negotiations were started. Lockheed is not giving up this hunt for a suitable company, but it has decided to wait no longer for another company to come along.

Lockheed already has a wide range of experience and know-how in electronics through the work of its Missiles and Space Division; its highly-instrumented, early-warning aircraft; its radar-packed patrol planes and similar efforts. The character of Lockheed's divisional setup also makes creation of a new division for electronics a logical move for expansion in a new growth area. Lockheed should be able to work up quite a race between its Missiles and Space Division and a separate electronics division.

And speaking of electronics, here is another indication of the way the wind is blowing. Forecasts for Ryan Aeronautical Company, an aircraft manufacturer of nearly 30 years standing and distinguished for technical competence in metal work, such as components for aircraft and hot parts for engines, show that the electronics division it recently established is on the road to accounting for 50% of the company's dollar volume of business. It was growth in this division that caused a sharp shift in Ryan's plans after it acquired a new production plant at Torrance because it was convenient to the Douglas Aircraft's DC-8 factory at Long Beach. Ryan found it had to have this production space for the electronics developments that were coming along so fast, and there were ways to keep the assembly of DC-8 engine pods in San Diego.

The *Atlas*, incorporating the second-stage *Centaur,* will become the "work horse of space" predicts Karel J. Bossart, "Father of the *Atlas*" and assistant to the vice-president of Convair for missiles and space exploration. "I do not see any competition for the *Atlas-Centaur* combination for getting a payload, not only to the moon, but beyond for many years to come," said Bossart.

Bossart does not believe the Russians have solved the weight problem for rockets as well as have Convair engineers. He points out that comparison of *Atlas* and *Sputnik* orbits show that the *Atlas* has less weight for its size. Bossart adds that Convair engineers knew the *Atlas* was capable of putting itself in orbit four years ago, but they had to wait until it had demonstrated its planned capability as a military missile.

One of the interesting innovations introduced in labor contracts on the West Coast last year was the "floating" holiday. It was devised, in the main, to round out four-day Christmas holiday periods. Last year the floater was December 26, the day after Christmas, and this year it will be December 24, the day before Christmas. But it won't work so well in 1960 when December 25 falls on Sunday, or in 1961 when it falls on Monday. Of course, new labor contracts are to be negotiated in the spring of 1960, but have no fears about retention of the "floating holiday."

Space problems, apparently, are reaching overwhelming proportions. Lockheed planned a dinner following the *Discoverer I* launching and found itself with a large and expensive prime ribs of beef on its hands when the shot was postponed. Rising magnificently to the occasion, Lockheed personnel found a buyer, but were not so lucky when the shot was scrubbed a week later. Until culinary and missile state-of-the-arts meet, it looks as though the answer to this technical problem will have to be cold cuts.

FROM EXPERIENCE **COMPETENCE**

TO MEET YOUR MOST CHALLENGING PROBLEMS

ASTRIONICS • AVIONICS • INSTRUMENTATION

Whether you're pondering a perplexing chess gambit or developing a data acquisition system . . . experience makes the difference.

Radiation, Inc., a pioneer in relatively new areas of research and development, offers you practical experience coupled with skill and training. But, even more, Radiation offers you the verve and vigor that often finds the solution beyond existing horizons.

If you seek a firm with *proven* solution-finding skills, send for our record of achievement.

Simply specify the field of endeavor that interests you most — Antenna Development, Telemetry, Data Systems, Missile Checkout, Instrumentation, Radar Reflectivity, or Counter-measures.

****The "Chess Pieces" shown are Radiation's telemetry tracking antenna, Vanguard data processing trailer, missile checkout system.*

RADIATION INC.

MELBOURNE AND ORLANDO, FLORIDA

Circle No. 36 on Subscriber Service Card.

propulsion engineering

by Alfred J. Zaehringer

Pre-packaged liquid propellant announced by the Navy at NOTS, though not named, may be based on mixtures of nitro hydrocarbons and nitric acid. China Lake openly reports burning rate studies on the following systems: (1) 2-nitropropane with 95-99% nitric acid; (2) 2-nitropropane and 97% nitric acid with and without powdered "Lucite" plastic; (3) butyric acid, nitrogen tetroxide and 99% nitric acid, and (4) isobutyric acid and 99% nitric acid. Propellants were among over 95 studied to investigate transition from smooth to turbulent combustion.

Ignition delay time of hypergolic rocket propellants can be reduced by the use of iron catalysts. Work was carried out by Stuttgart, Germany firm of Bolkow Development. Tests were carried out with nitric acid and various fuels such as amines and hydrocarbons.

Rocket chamber length ties in with chemical composition according to NASA. Using vaporization rate as a criteria, oxygen is found to have a shorter chamber requirement than for fluorine. This might mean that present oxygen engines would have to be radically modified in order to use fluorine. As far as fuels are concerned, hydrazine and ammonia seem to need longer lengths than the hydrocarbons. Work at the Russian Energy Institute is also aimed at correlating physical and chemical factors of fuels on combustion.

Liquid ozone has a detonation velocity of over 16,000 ft/sec. and a detonation pressure of nearly 600,000 psi at an initial temperature of –290°F. Temple University team has also reported values for gaseous ozone. Violent detonation characteristics of pure liquid ozone have held back U.S. rocket use.

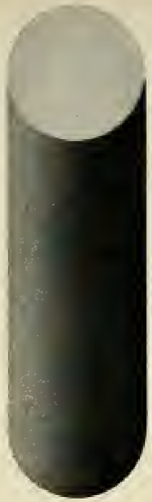
Methyl nitrate is being looked at as a possible propellant ingredient by French researchers. Big problem has been the detonable nature of this powerful liquid. Water layer over the nitrate has been found to stop a detonation while heat alone (to 392°F) results only in slow decomposition.

Slag problems resulting from combustion of boron and other metallic high energy fuels might be lessened if work at Haifa's Palestine Electric Corp. is any indication. Dolomite as a fuel oil additive increases the melting point of slag and ash and prevents adherence to combustion chamber walls. Sticky deposits of boron oxide have been a plague to turbojet, ramjet, and rocket people in propulsion development programs. Additives might be one way of lessening the problem.

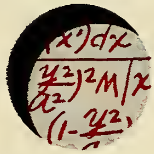
Powdered solid fuel rocket motor has been successfully test fired by Pan-Tech Corp. of Ann Arbor, Mich. It looks good for multiple on-off, controllable auxiliary power units. Propellant flow is relatively insensitive to temperature.

Solid propellants for India? Ministry of Defense at New Delhi has been working on the burning of double base propellants at low pressures for some time. Strand burning techniques, as reported, are considered an important first step in the development of homogeneous propellants for artillery rockets and small missiles.

Fusion rocket chances look dim. One scientist sees a minimum reactor of 195 ft. diam and 390 ft. long due to quenching and loss at the walls. Another visualizes direct expansion. Both are plagued by "sun-like" working temperatures. "Cold" fusion systems are fairly unknown and appear to remain in the unknown of the distant future.



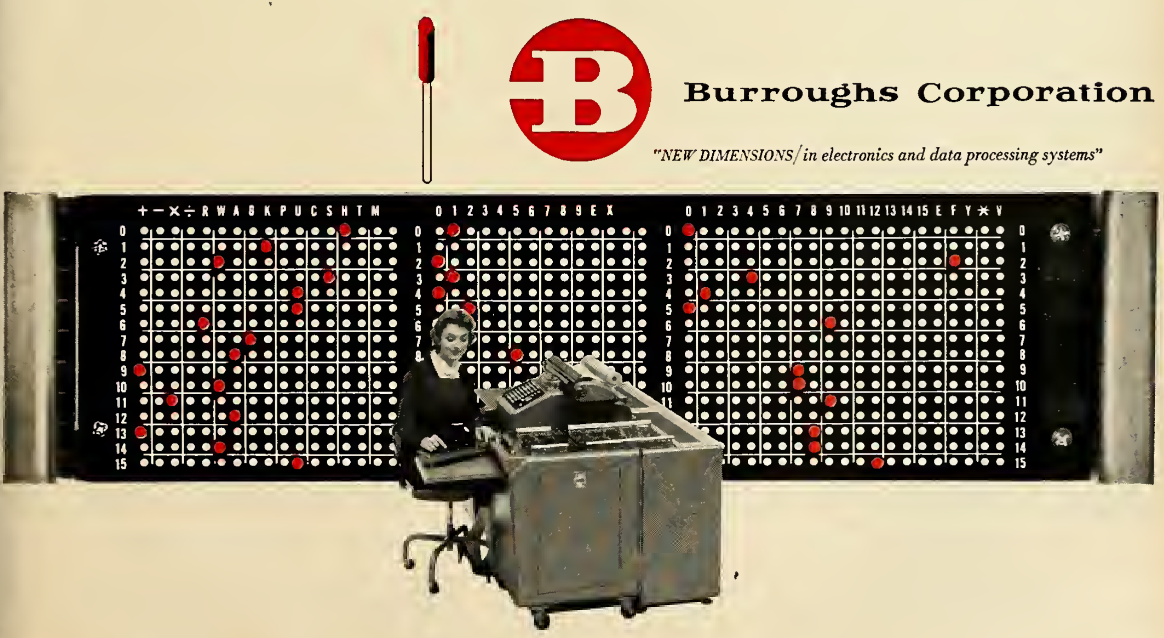
pinboard programming : easy as putting a round peg in a round hole



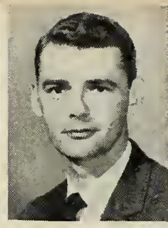
Simplified pinboard programming of the Burroughs E101 electronic digital computer multiplies technical talent. Scientific personnel report time savings of 20 to 1 over manual calculators. Ease of operation makes practical the "open shop" computer approach, with extensive savings of high-priced man hours in scores of installations. Optional input-output units for punched paper tape and punched cards further extend data-handling / problem-solving capacity. From small computers to giant data processing systems, Burroughs equipment means new efficiency...and profits...for you. Write for E101 Brochure today. ElectroData Division, Pasadena, California.

Burroughs Corporation

"NEW DIMENSIONS / in electronics and data processing systems"



Circle No. 23 on Subscriber Service Card.



astrionics

by Raymond M. Nolan

People in industry who are subjecting transistors and other semiconductors to radiation have found that the results are not always displeasing. Most semiconductors suffer severe degradation under radiation. But if the dose is not lethal, they can recover and perform at something close to original specifications. One major manufacturer who has been testing sub-systems and systems in one of the AEC's facilities was pleasantly surprised when the equipment finally exhibited a memory and came back within specifications.

While many people believe that semiconductors will be the major source of trouble with nuclear warheads or engines, there are those who see other problems. Chief among these are components which depend on a petroleum or similar base for operation. Liquid-floated gyros, for example, normally are kept from final test to firing at an ambient of something like 180°F. Designers are concerned that prolonged (or even short-time) radiation will change the state of the flotation fluid, causing unwanted precession in the gyro due to viscosity or other changes in the fluid.

Another area might be oil-filled capacitors or transformers where the radiation could cause a change in characteristics. However, no report of any research or investigation in this field has been reported. At any rate, a healthy sign is that the problem of radiation is being considered in the areas where the most damage is expected. Engines, of course, are pretty much in the future, but the ambient radiation in nuclear warheads can be expected to cause trouble in the more immediate future.

The recent announcement of a "scientific breakthrough" by the White House when an atomic battery was exhibited was pooh-poohed by the more experienced people around Washington. Reason: Congressional testimony last January and February by USAF Col. Jack Armstrong with the Atomic Energy Commission revealed that the idea was picked up originally through a translation by Westinghouse of a Russian paper. Further information, however, indicates that the Russian approach was discarded and that the operating unit as it stands today is essentially an American unit. Maybe this means that "breakthrough" is the proper word.

Incidentally, along those same lines, m/r reported some months ago that Space Technology Laboratories went out to industry for bids on a similar device. Reports are that STL received a concrete bid from one battery manufacturer—specifications: one hundred pounds, three hundred watts, $10 million. The component would use Polonium 210 as the isotope source. Everything sounded fine to STL but the price, so it discarded the program. Even though the results would have been spectacular in any sort of an orbiting object, the specs people felt that the outlandish price did not justify the purchase.

Anyway, STL or some similar organization might be back at the old stand one of these days as we draw closer and closer to television and communications satellites. Here, long life of the power supply is of the essence. It might be possible to use solar cells, but the relatively large size would probably rule such items out in programs such as these. Maybe the only answer to problems of this type is the real "breakthrough" that we will experience when we discover how to use the limitless energy in space.

in the 215 mc
to 245 mc
telemetering band

The Model REL-09-HF is a ruggedized miniature R-F power amplifier. With a solid history of reliability in current missile systems, the unit has proved capable of withstanding the most rigorous airborne applications. The 5-inch, 1-pound amplifier delivers an 11-watt output to a 52-ohm load with a 1.4-watt input drive.

For full specs, write for Data File MR-504-1

The REL-09 functioned smoothly as a part of the Vanguard satellite successfully launched into orbit.

in the 215 mc
to 260 mc
telemetering band

The Model REL-10 R-F Power Amplifier is a high-output unit for airborne applications. With power outputs from 10 to 100 watts, it dramatically increases the range of missile and aircraft telemetering systems...teams up with presently available FM transmitters...meets missile environmental requirements.

For full specs, write for Data File MR-500-1

The REL-10 functioned perfectly during 1,760 mile ride on Thor missile, on 75,000 mile journey into space in U. S. Lunar Probe, and in orbit as part of the Atlas Project Score satellite.

high input
impedance with
extremely low drift

The Model REL-120 is a completely transistorized, direct-coupled, instrumentation d-c amplifier featuring:
(1) long life resulting from the use of such passive elements as transistors and diodes;
(2) low heat generation from an average required input power of only 10 watts; and
(3) a self-contained power supply that works directly from either 60 or 400 cycles.

Write for Data File MR-501-1

RHEEM MANUFACTURING COMPANY
Defense and Technical Products Division
11711 Woodruff Ave.
Downey, Calif.

Rheem

missile people

The National Aeronautics and Space Administration has named chairmen for its 13 new research advisory committees which will give technical counsel on future research efforts and act as NASA's liaison with the scientific community.

The committees, which will have about 15 members each, and their chairmen are:

Fluid Mechanics; Prof. **William R. Sears,** Head of the Graduate School of Aeronautical Engineering, Cornell University. Aircraft Aerodynamics; **R. Richard Heppe,** Manager of Advanced Aerodynamics Research, California Div. of Lockheed Aircraft Corp. Missile and Spacecraft Aerodynamics; **Dr. H. Guyford Stever,** Associate Dean of Engineering, MIT. Control, Guidance, and Navigation; **Dr. Louis N. Ridenour,** Assistant General Manager of Research and Development, Missiles and Space Div., Lockheed Aircraft Corp.

Chemical Energy Processes; **James A. Reid,** Executive Vice President and General Manager of Astrodyne, Inc. Nuclear Energy Processes; **Dr. Walter H. Jordan,** Assistant Director of the Oak Ridge National Laboratory, Union Carbide Nuclear Co. Mechanical Power Plant Systems; **Gordon Banerian,** Manager of the Turbo-Machinery Div., Aerojet-General Corp. Electrical Power Plant Systems; **Dr. Krafft A. Ehricke,** Assistant to the Technical Director of Convair-Astronautics, Div. of General Dynamics Corp.

Structural Loads; **E. Z. Gray,** Systems Engineering Director of Boeing Airplane Co. Structural Design; **Professor E. E. Sechler,** Professor of Aeronautics, California Institute of Technology. Structural Dynamics; **Martin Goland,** Director of Southwest Research Institute. Materials; **R. H. Thielemann,** Senior Metallurgist, Stanford Research Institute. Aircraft Operating Problems; **William Littlewood,** Vice President of Equipment Research, American Airlines, Inc.

NASA will also be advised on human factors, medical, and allied problems of the manned space vehicle program by the Special Committee on Life Sciences, under the chairmanship of **Dr. W. Randolph Lovelace II,** Director of the Lovelace Foundation for Medical Education and Research.

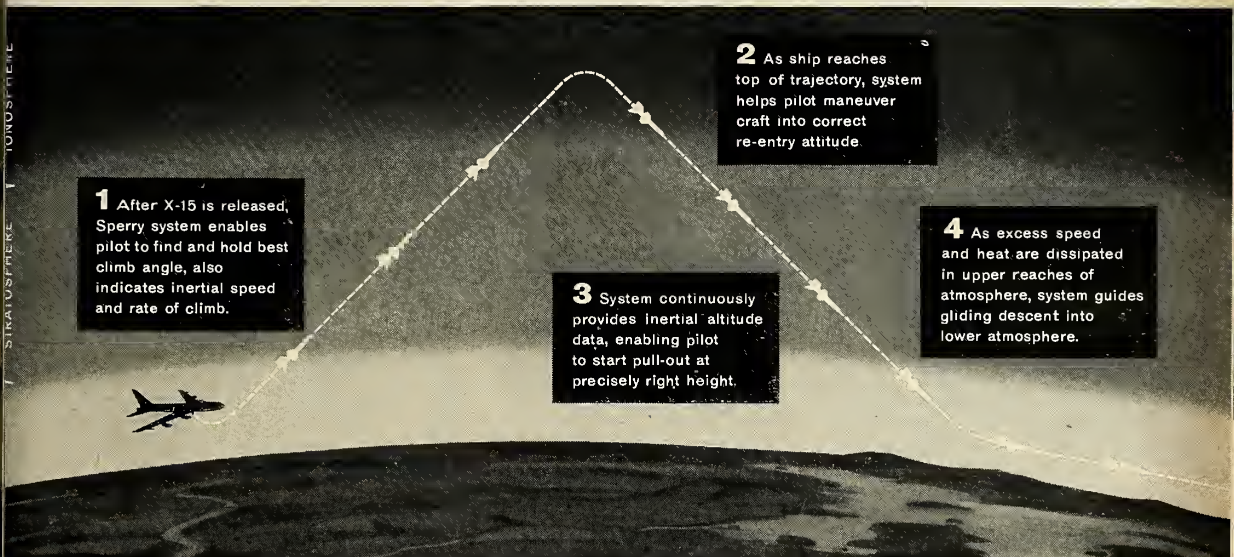
Dr. Edward B. Doll has been elected a Vice President of Space Technology Laboratories, Inc. Dr. Doll, who played a key role in the recent Project *SCORE* which placed the "talking satellite" in orbit around the earth, will assume new responsibilities as Associate Director of STL's Systems Engineering Division. He will also continue to serve as program director for the USAF's *Atlas,* a position he has held since 1956. He joined Space Technology Laboratories in 1955.

Harley S. Jones, who served as Air Force aircraft and missile production planner through two wars, has been named Executive Vice President of Republic Aviation Corp. After retirement from the Air Force as a brigadier general, Jones received the Distinguished Service Medal for his formulation and implementation of production techniques. Following his retirement he rendered consulting services to Boeing on the *Bomarc* and to Republic on the F-105.

Bendix Radio's Division has expanded into the underwater communications and detection field and has appointed **Hans von Schultz,** ultrasonics expert, to the advanced development staff of the division's government products group.

/PERSONIC X-15, powered by a mighty rocket engine, will follow bullet-like jectory during flight, similar to path of ballistic missile.

WEARING SPECIALLY-DESIGNED SPACE SUIT, X-15 pilot is protected against environmental extremes as he maneuvers the rocket to the edge of space.



X-15 WILL THRUST 100 MILES INTO SPACE UNDER CONTROL OF NEW INERTIAL SYSTEM

rapped firmly into his cockpit, an Air rce pilot soon will ride the North merican X-15 rocket research ship 100 iles and more into the sky at speeds ove 3600 mph—over a mile a second.

A highly advanced Sperry inertial sys- m, developed in conjunction with the light Control Laboratory of Wright Air evelopment Center, will supply control ta for this historic venture. When the lot and his revolutionary craft drop om a B-52 jet bomber, the inertial sys- m will give him data for maneuvering d navigating the X-15 with extreme curacy. As the stainless steel research plane flashes outward through the thinning atmosphere, the Sperry system will "show" the pilot how to correct for even the smallest deviation from flight path. It will display flight information on specially developed instruments; at the same time feeding the data to ground and airborne recorders for a permanent record of the flight.

An important additional contribution of the Sperry system will be to guide the pilot in bringing the X-15 safely back into the earth's atmosphere. During this critical phase of the flight, attitude of the X-15 on re-entry must be precisely controlled to avoid exceeding its structural limitations.

On this daring journey into space, the super-sensitive Sperry system will have to function perfectly under conditions ranging from extreme acceleration to complete weightlessness, through temperature swings that may heat the X-15's exterior to 1,000 degrees in a few seconds.

SPERRY *GYROSCOPE COMPANY*
Great Neck, New York
DIVISION OF SPERRY RAND CORPORATION

Circle No. 40 on Subscriber Service Card.

Advertiser's Index

Advertising correspondence should be addressed to Advertising Sales Manager, Missiles and Rockets, 17 East 48th Street, New York 17, N.Y.

REGIONAL OFFICES:

New York City: 17 E. 48th St., New York 17. Edward D. Muhlfeld, Advertising Sales Manager; P. B. Kinney and G. T. O'Mara, regional adv. mgrs. Phone: PLaza 3-1100.

West Coast: 8929 Wilshire Blvd., Beverly Hills, Calif. Fred S. Hunter, manager; Walton Brown, regional adv. mgr.; James W. Claar, regional adv. mgr. Phones: OLeander 5-9161 or OLympia 7-1555.

Chicago: 139 N. Clark St., Chicago 2, Ill. George E. Yonan, regional adv. mgr. Phone: CEntral 6-5804.

Cleveland: 244 Hanna Bldg., 1422 Euclid Ave., Cleveland 15, Ohio. Douglas H. Boynton, regional advertising manager. Phone: PRospect 1-2420.

Detroit: 201 Stephenson Bldg., Detroit 2, Mich. Kenneth J. Wells, regional advertising manager. Phone: TRinity 5-2555.

Florida: 208 Almeria Ave., Coral Gables, Fla. Richard D. Hager, advertising sales representative. Phone: Highland 4-8326.

Canada: Allin Associates, 12 Richmond Street East, Toronto 1, Ontario. Phone: Harbour 6898. Allin Associates, 1487 Mountain St., Suite 4, Montreal, Que.

Geneva: American Aviation Pubs., 10 Rue Grenus, Geneva, Switzerland. Anthony Vandyk, European Director. Cable address: AMERAV GENEVA.

London: Norall & Hart Ltd., 28 Bruton Street, London W. I., England. Phone: Grosvenor 8356.

Paris: Jean-Marie Riche, 11 Rue Condorcet, Paris (9e), France. Phone: TRUdaine, 15-39, Cable address: NEWS AIR PARIS.

when and where

FEBRUARY

IRE, AIEE 1959 Solid State Circuits Conference, University of Pennsylvania, Philadelphia, Feb. 12-13.

Conference for Manufacturing and Engineering Management, Computer and Data Processing in Industry, Purdue University, Lafayete, Ind., Feb. 12-13.

Heat Transfer Div. of American Society of Mechanical Engineers, Third Annual Symposium on Thermal Properties, Purdue University, Feb. 23-26.

1959 Engineering Exposition, Balboa Park, San Diego. For information, contact exposition office at 422 Land Title Bldg., San Diego, Feb. 26-March 1.

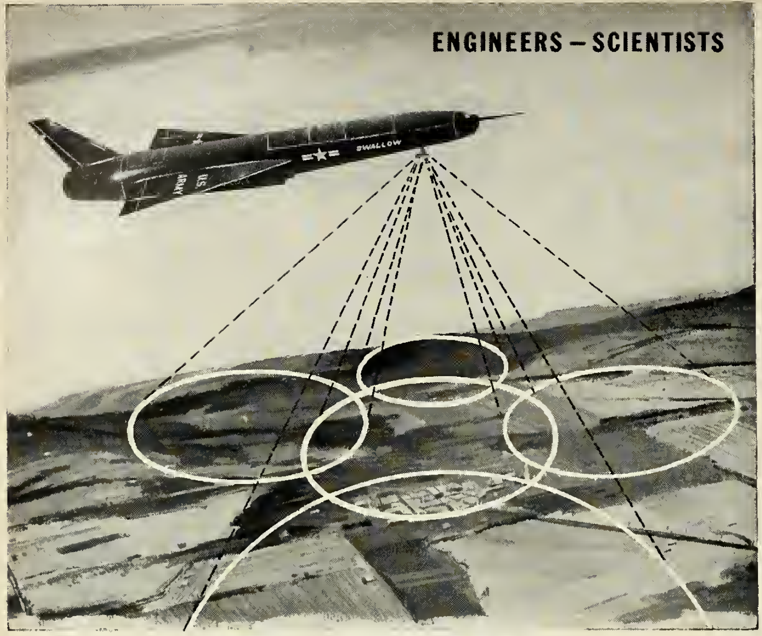
MARCH

IRE, AIEE and Association for Computing Machinery, 1959 Western Joint Computer Conference, Fairmont Hotel, San Francisco, March 3-5.

Institute of the Aeronautical Sciences, Flight Propulsion Meeting (classified), Hotel Carter, Cleveland, March 5-6.

Second Western Space Conference and Exhibits, Great Western Exhibit Center, Los Angeles, March 5-7.

Gas Turbine Division of the American Society of Mechanical Engineers, Turbine in Action, Cincinnati, March 8-11.



NEW CONCEPTS IN COMBAT SURVEILLANCE OFFER YOU A MORE PROMISING CAREER

Over $25 Million in New R&D Contracts for SWALLOW Awarded Missile Systems Division of Republic Aviation

It has been the dream of every combat commander to possess *accurate* information concerning tactical disposition of enemy troops and materiel, *before, during and after the battle.* One of the telling answers to this vital problem is the Swallow SD-4. Engineers joining this program will find challenge in:

...new sensing techniques (infrared, optical, radar and other)
...sophisticated, split second guidance
...optimum aerodynamic solutions for high velocity, ground-controlled vehicles

The Swallow SD-4, and the SD-3 are two of *many* expanding programs—ECM, anti-ICBM and missile guidance—that offer unusual openings in the following areas:

ELECTRONIC ENGINEERS for work on digital computers, inertial guidance, ranging systems, airborne navigational systems, ECCM, and automatic flight control systems

AERODYNAMICISTS for stability analysis, aerodynamic characteristics, trajectory optimization, flutter analysis, and wind tunnel programs

HYDRAULIC ENGINEERS for design and development of automatic flight control systems, control surface actuators, other flight control equipment and ground support equipment. Also system simulation studies

Send resume in complete confidence to:
Mr. Paul Hartman, Engineering Employment

MISSILE SYSTEMS DIVISION
REPUBLIC AVIATION
223 Jericho Turnpike, Mineola, Long Island, New York

Third Annual Shock Tube Symposium, Old Point Comfort, Ft. Monroe, Va. For details: Armed Forces Special Weapons Center, Kirtland AFB, Albuquerque, N.M. Attn.: SWRS R. R. Birnkoff. March 10-11.

American Society for Metals, 11th Western Exposition and Congress, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles, March 16-20.

The American Rocket Society, 1959 Sectional Meeting, Daytona Plaza Hotel, Daytona Beach, Fla., March 23-25.

Institute of Radio Engineers, National Convention, Coliseum and Waldorf-Astoria Hotel, New York, March 23-26.

Society of the Plastics Industry, 16th Annual Conference, Pacific Coast Section, Hotel del Coronado, San Diego, March 25-27.

Society of Automotive Engineers, National Aeronautic Meeting, Hotel Commodore, New York, March 31-Apr. 3.

APRIL

Conference on Electrically Exploded Wires, sponsored by the Thermal Radiation Laboratory of the Geophysics Research Directorate of the Air Force Cambridge Research Center, Somerset Hotel, Boston, Apr. 2-3.

1959 Nuclear Congress, Municipal Auditorium, Cleveland. For information: Engineers Joint Council, 29 West 39th St., New York. Apr. 5-10.

American Welding Society, 1959 Welding Show and 40th Annual Convention, International Amphitheatre and Hotel Sherman, Chicago, Apr. 7-10.

Air Force Association, World Congress of Flight, Las Vegas, Nev., Apr. 12-19.

American Society of Tool Engineers, Annual Meeting, Schroeder Hotel, Milwaukee, Apr. 18-22.

American Rocket Society, Man-in-Space Conference, Hotel Chamberlain, Hampton, Va., Apr. 20-22.

Institute of Radio Engineers, Spring Technical Conference on Electronic Data Processing, Cincinnati Section, Engineering Society Bldg., Cincinnati, Apr. 21-22.

Institute of Environmental Engineers, 1959 Annual Meeting, LaSalle Hotel, Chicago, Apr. 22-24.

American Rocket Society, Controllable Satellites Conference, Massachusetts Institute of Technology, Cambridge, Apr. 30-May 1.

CLASSIFIED

Manufacturer's Representatives Wanted

To sell to industrials. Established electronic line, consisting of amplifiers, bridges, potentiometers, calibration instruments and computers. Several territories available. Non-conflicting lines satisfactory. Write full details, present principals, number of salesmen. State territory desired

Box 122, Missiles & Rockets Magazine, 1001 Vermont Ave., N.W., Washington, D.C.

35mm Color slides of Guided Missiles Close-up, on the pad action at Cape Canaveral. Atlas-Thor-Jupiter-Snark Bomarc-Navaho-many others. All Official Air Force Photos. Sample slide of Thor-Able "Moonshoot" .25¢ Free List Write Tom Wyman, Box 92, Cocoa Beach, Florida.

AN FITTINGS & HARDWARE

Stainless, Aluminum, Brass, Steel. All sizes—immediate delivery from world's largest shelf stock. Buy direct from manufacturer. Lower prices—Quicker service. Send for free wall charts showing complete line of AN & MS fittings and hardware. We also machine parts to your own special print.

COLLINS ENGINEERING CORPORATION
9050 Washington Blvd., Culver City, California

SUBSCRIBER SERVICE

missiles and rockets

For additional information about any product or service advertised mentioned in the editorial pages of this issue of Missiles and ockets:

Use the attached prepaid reply cards. Circle numbers shown on e reply card that correspond with numbers appearing beneath items scribed. If no circle number accompanies the article or advertisent, give page number (and advertiser's name) on line provided at ttom of the card.

Your requests for information will be forwarded promptly to the mpanies concerned.

NEW PRODUCT BRIEFS

L RATE GYRO. One gyro that will e work of two units has been deed by Humphrey, Inc., the comr says. The new RG-18 series gyro its important reductions in the required for instrument and conackages, according to Humphrey. motor is used to drive two separate s, making it possible to measure about two different axes. Another known as the RG-20 series is also ble to cover two rate ranges about ame axis. The new rate gyros are with two independent pickoffs, one ach axis or one for each range.

No. 238 on Subscriber Service Card.

RO VALVE. The new FC-30 series ow control servo valves manued by the Cadillac Gage Co., Coast Div., retains all the features e Cadillac FC-2 series. But unit e has been reduced nearly 25% lves of equal capacity, and weight een reduced 20%. The standard valve weighs 14.5 ounces, and res 1.75x2.00x2.8 inches. Valves are ble from stock covering the entire range from .15 to 13 gallons per e. Cadillac says internal leakage 4 GPM valve at neutral position, MIL-0-5606 hydraulic fluid at 90°F 3000 psi supply pressure, is .09 maximum.

No. 239 on Subscriber Service Card.

MUTATOR SWITCH—A commutype of switch, Spec. 7122, for use talink receivers, telemetering syshigh-speed commutators, and apons where 100 shorting positions non-shorting positions are required extremely small physical space, has produced by the Daven Co. The has 100 positions in a panel space y 1¾" square. Depth is ⅞". It is le pole unit. The space-saving feaf this switch, which was developed cally for use in missiles, is due to olded wedge-shaped contacts set the epoxy with extremely closet spacing tolerances. These comor bars are solid silver alloy and otor is beryllium copper with a d silver edge making contact with ator. The ratio of on-time to offn the unit shown in the attached graph is 1:1. This can be varied hat for special applications.

No. 242 on Subscriber Service Card.

PROGRAMING CONNECTORS—For special computer applications, a complete line of miniature, quick-disconnect programing connectors are now available from Amphenol-Borg. All have an insert arrangements of 14 #16 contacts. There are a total of 60 plugs, pre-wired and coded for particular circuitry, and 3 standard receptacles. The various wiring arrangements in the plugs are indicated by code on colored tenite caps. Shell material is aluminum, dielectric is diallyl phthalate. The pressurized receptacles (30 pounds per square inch) incorporate a rubber "O" ring and seal, have aluminum shells and diallyl phthalate dielectrics. Withdrawal forces are 5 to 10 pounds, insertion is 15 pounds maximum. Connectors are recommended by manufacturer for programing various circuit arrangements in digital computers, data processing equipment, automatic test equipment and other forms of automation.

Circle No. 240 on Subscriber Service Card.

VARIABLE SPEED DRIVE. A new lightweight miniature variable speed drive, small enough to fit in the palm of a hand, is being produced by Humphrey Products Div. of Humphrey, Inc. The company says the unit, designated the Servotran, offers frequency response equivalent to a hydraulic system and triple that of an electrical system in a mechanical drive weighing only 1¾ lbs. The drive without motor is only 3¾ in. long by 2 in. in diameter. A maximum of two inch ounces on the control shaft of the miniature Servotran changes speed from full forward to full reverse in .05 second. Output torque is constant and efficiency is between 85% and 95%.

Circle No. 241 on Subscriber Service Card.

PANEL METER. A 3½-inch panel meter, embodying the different design concept introduced last year in the larger Model 561 meter, has been marketed by Assembly Products, Inc. The Model 361 meter occupies panel space of 3½ x 2 inches and projects 3/16-inch. Like the Model 561, it exposes only its indicating area, with the remainder of the meter fitting behind the panel. The dial and window are slanted and may be illuminated through a translucent rear window. Sensitivity ranges of Model 361 are 0-5 microamperes to 0-500 volts.

Circle No. 244 on Subscriber Service Card.

MISSILES AND ROCKETS

FEB. 9, 1959

Expires Three Weeks After Above Date

NAME

TITLE/POSITION

COMPANY

Product Mfg./Service Offered

ADDRESS

CITY ZONE STATE

Card cannot be processed unless all information is given. Please limit requests to ten items.

CIRCLE NUMBERS BELOW FOR INFORMATION ON PRODUCTS, LITERATURE OR ADVERTISEMENTS

• **Advertisements**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125
126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175

• **Missile Literature**

200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224

• **New Missile Products**

225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249
250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274
275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299

For Other Information Give Page Numbers:

NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY CARD

First Class Permit No. 2455-R (Sec. 510 P.L.&R.) Washington, D.C.

POSTAGE WILL BE PAID BY ADDRESSEE

MISSILES and ROCKETS

17 EAST 48th STREET

NEW YORK 17, N.Y.

SUBSCRIBER SERVICE DEPT.

MISSILE LITERATURE

BROCHURE. An illustrated six-page brochure released by the DeJur Amsco Corp. gives specifications, outline dimensions and general information on right angle pin and socket connectors for printed circuit applications. These miniature right angle connectors are available in various contact sizes and molding compounds. Right angle pins dip solder to printed circuit board. Solder cups on receptable accept #20 AWG wire.

Circle No. 201 on Subscriber Service Card.

WIRE CATALOG. The 1959 catalog on Teflon insulated wires and cables is now available from the American Super-Temp Wire, Inc. This 64-page publication is completely new and contains 8 sections of the latest engineering information and prices on high-temperature magnet wire, lead wire, cables, tubing, and Teflon tape. Each section is preceded by detailed general information on the products cataloged. This information is consistent from section to section facilitating quick, easy reference on military specifications, temperature ranges, wire and cable constructions, colors, tests, etc. The catalog also contains technical bulletins and other information to provide engineers with design criteria for high temperature wiring.

Circle No. 202 on Subscriber Service Card.

AIR FILTERS. Construction and operating characteristics of the new model "B" roll-o-matic automatic renewable-media air filters are described in a bulletin recently released by American Air Filter Co. Inc. Featured is a description of what the manufacturer calls its 'miracle' media—a 65-lineal foot roll of impregnated, reinforced media composed of continuous, slightly curled, interlaced glass filaments held in place by a thermo-setting plastic bond to form a resilient pad or fluffy blanket having a nominal thickness of two inches. The new roll-o-mat media will not drip at temperatures up to 150 degrees and will not lose its adhesive qualities to dryness.

Circle No. 203 on Subscriber Service Card.

TOOL CATALOGUE. Announcement of a newly revised tool catalog, published in its ninth edition, has been made by Hi-Shear Rivet Tool Co. To keep pace with new varieties of hi-shear rivets, many new sets to drive stainless steel and harder material hi-shear collars have been added to the catalog. Very short rivet sets for use with stubby jiffy guns have become catalog items. New one piece driver blades to install hi-torque bolts in a full range of standard and miniature sizes are presently listed in the catalog.

Circle No. 204 on Subscriber Service Card.

FILTER CATALOG. A 16-page illustrated catalog describing the standard production mechanical filters manufactured by Collins Radio Co.

Circle No. 200 on Subscriber Service Card.

PRESSURE TRANSDUCERS. Pressu transducers for aircraft and missil available from Minneapolis-Honeyw Regulator Co. are described in a ne 8-page pamphlet issued by the co pany's Aeronautical Division. The boo let outlines description, specificatio and modifications for each of sev basic pressure transducer devices. Ou puts can be derived from potentio eters, synchro transmitters or different transformers. Honeywell transducers a being used in thousands of aircraft a missile autopilots.

Circle No. 205 on Subscriber Service Ca

BULLETIN. Chemical & Power Produc Inc. has released a new technical b letin on their chempro line of fill teflon bearings—Technical Bulletin N CP-558. In addition to the seven sty of bearing materials listed in this b letin, other filler materials can be corporated for special applications. Th all have excellent wearing qualities a are less subject to thermal expansion a cold flow than pure teflon. Chemp filled teflon bearings are being us with excellent results by a great ma pump companies at speeds over 40 feet/minute. These filled materials a also suitable for electrical and electro applications, including molded and m chined spacers, inserts, connectors a other parts for use in high voltage, hi frequency and high temperature el tronic equipment, wires and cables.

Circle No. 207 on Subscriber Service Ca

MAGNETIC AMPLIFIERS. "What is magnetic amplifier?" is answered in t latest issue of "Techni-Topics," publi tion of Magnetic Controls Co., ma facturer of magnetic amplifiers, te perature controls and related devic The six-page bulletin contains a br technical discussion of basic magne amplifier theory, circuitry and appli tions.

Circle No. 209 on Subscriber Service Ca

MISSILE PLUGS. The current state the art of missile umbilical plugs is scribed in a new 48-page catalog n available from Cannon Electric Co. describes and illustrates a represen tive cross-section of the latest develo ments in Cannon umbilical plugs signed for missile launching. These pl connect electrical circuits within missile to testing and control syste on the ground.

Circle No. 206 on Subscriber Service Ca

BUTTON CELL BATTERIES. A broch on button cell batteries has been p lished by Gulton Industries, Inc. T 4-page, colored and illustrated pam let describes design and potentials specifications of the VO-Series nic cadmium, button cell battery line wh includes types from 100 MAH to 1 MAH capacities in more than 50 tinct sizes and voltages.

Circle No. 208 on Subscriber Service Ca