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AIR RESEARCH AND DEVELOPMENT COMMAND EDITION

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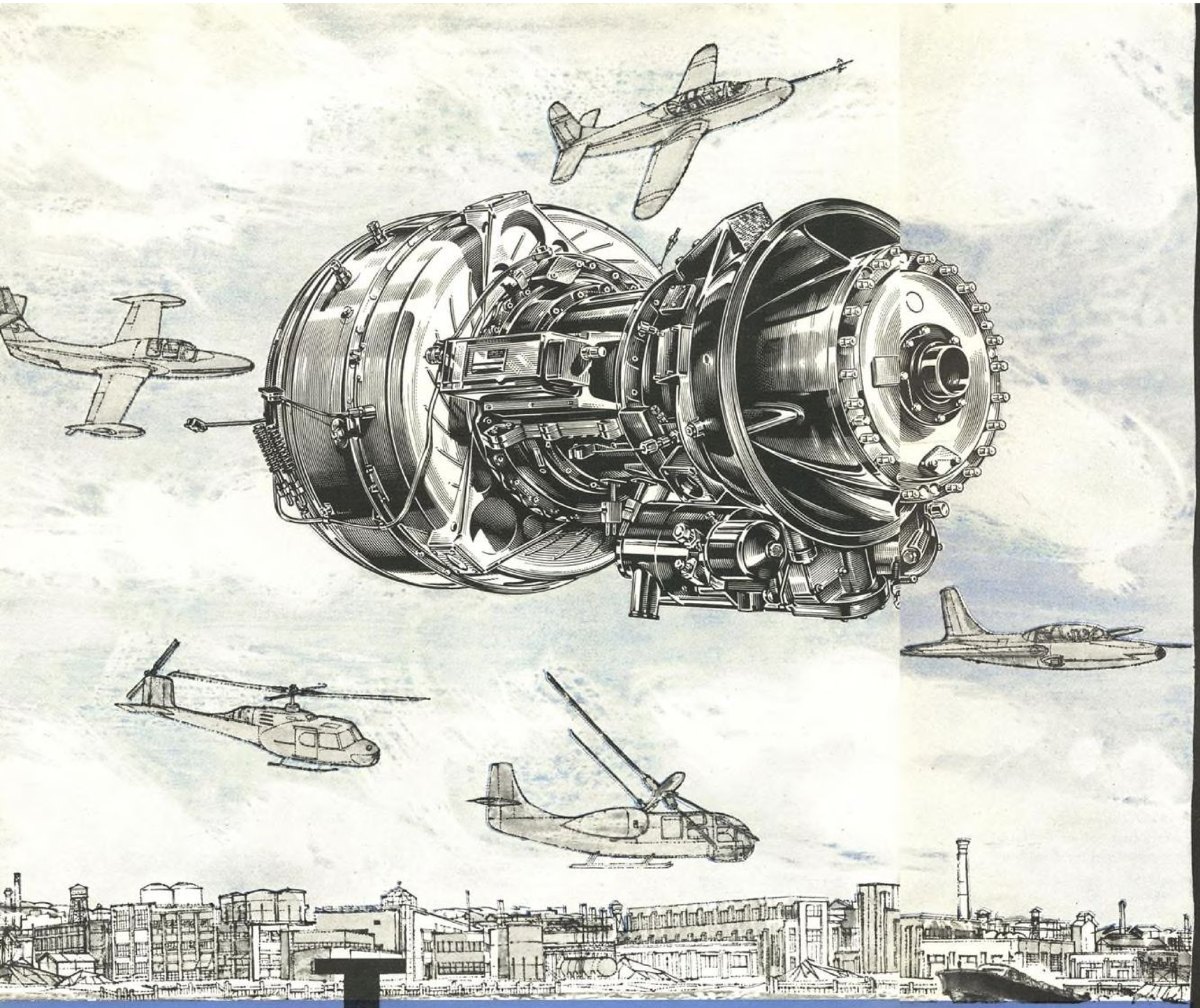

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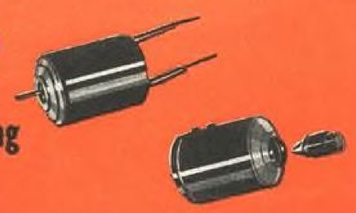

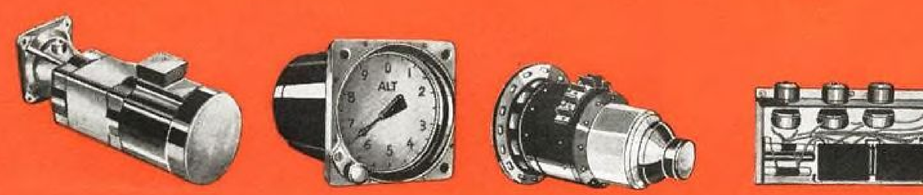

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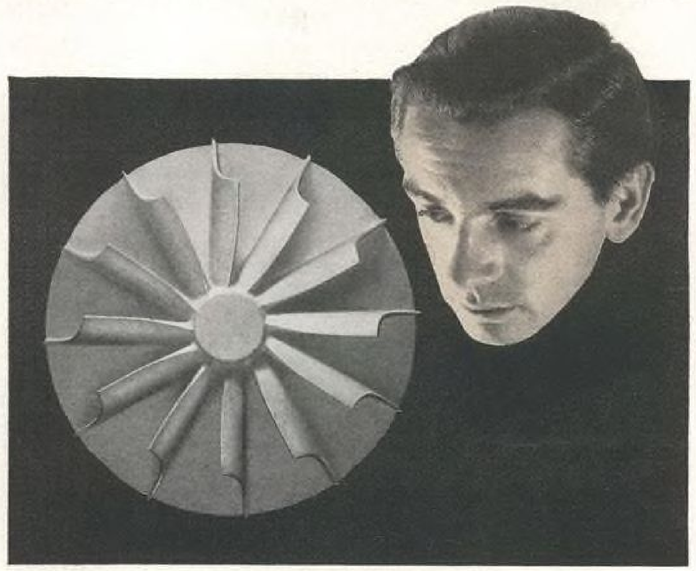

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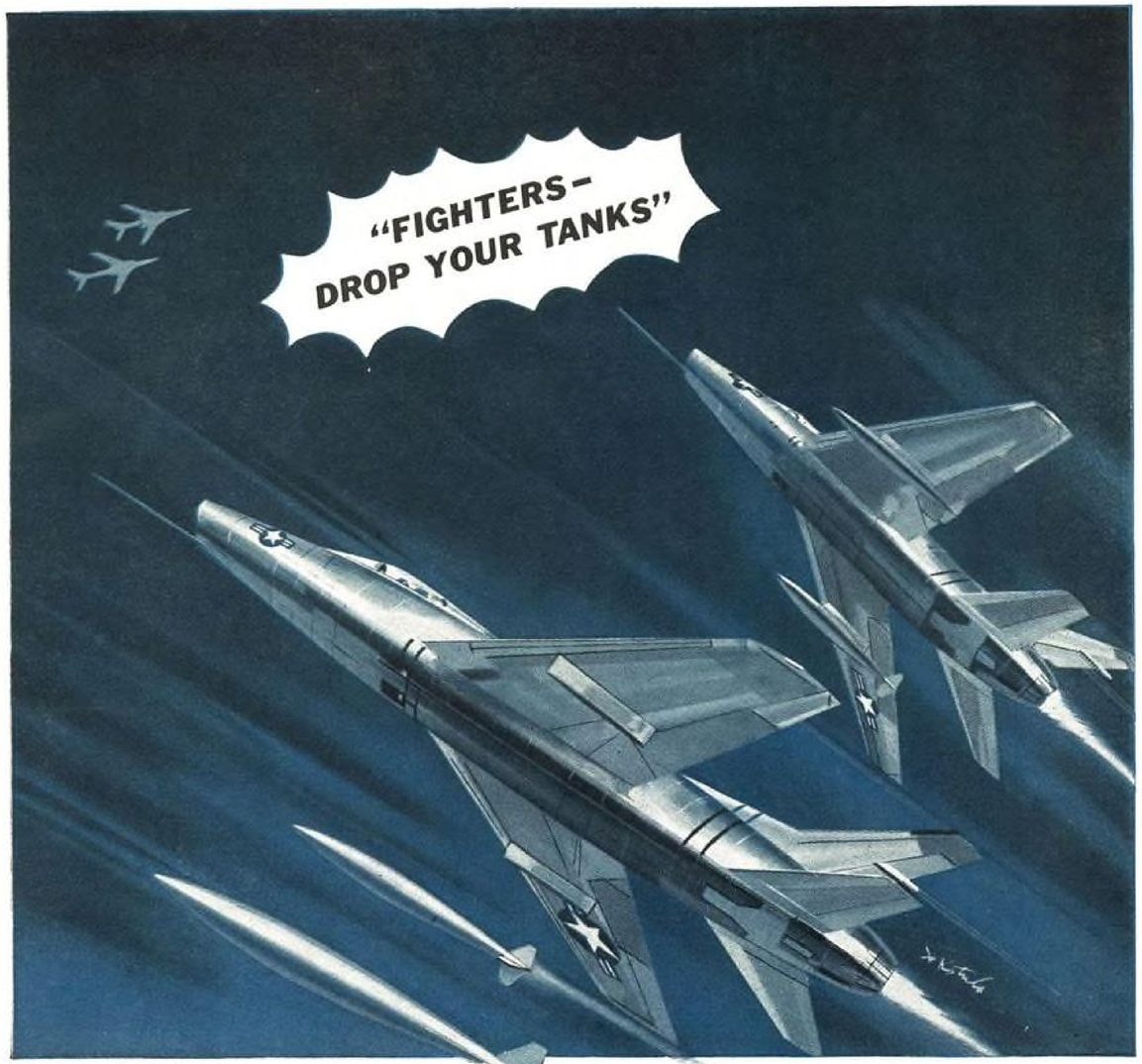

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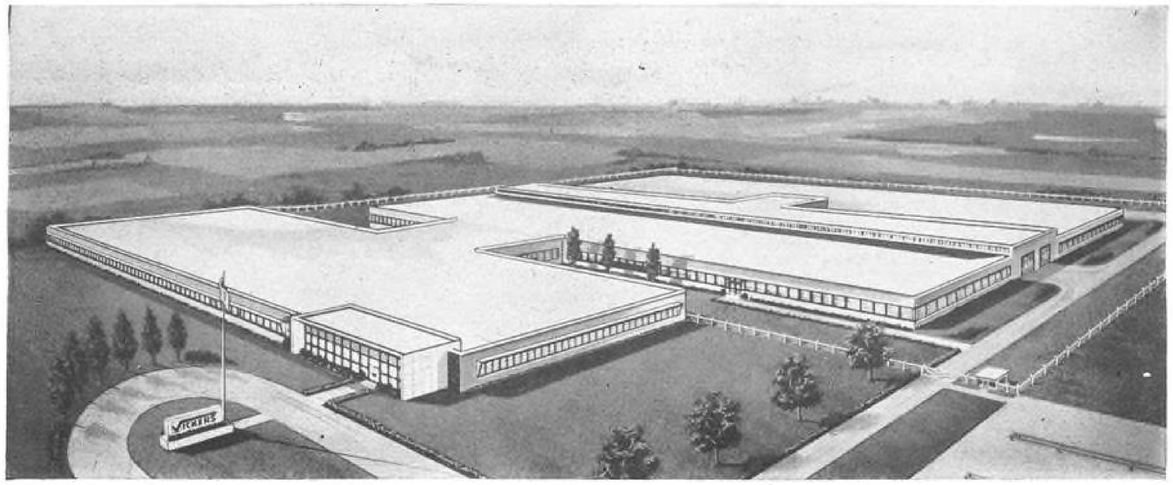

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Vickers, a pioneer in oil hydraulics for a wide variety of uses, has maintained leadership through the years by means of aggressive and extensive research.

Continuing rapid expansion of the oil hydraulics requirements of industry has brought with it the need for augmented research and engineering facilities. To meet this need, Vickers has just completed this new building in suburban Detroit . . . 150,000 square feet devoted entirely to research, development, engineering application and administration.

A milestone in Vickers progress, this new Administrative and Engineering Center is also a promise of future benefits to users of Vickers hydraulic components and systems.

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How Holley's Compressor Governors Help New Jets to Supersonic Speeds

"City-savers" Air Force men call them: the J-57-powered F-100, F-101, F-102 and Navy F8U, with level flight speeds faster than sound. And city-savers they could well be. Certainly their rapid approach to the fringe of Mach 2 heralds a new era in the progress of jet flight.

Sharing in the development of this new brood of supersonic fighters, Holley engineers, working closely with Pratt & Whitney Aircraft on the J-57 engine, designed the compressor bleed governor.

This new Holley compressor bleed governor is one more example of Holley's continuing leadership in the design, development and manufacture of superior engine control systems for both military and civilian use

Leader in the design, development, and manufacture of aviation fuel metering devices.

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11955 E. Nine Mile Road — Van Dyke, Michigan

A-24

ON OPERATION DEEP FREEZE, a Sikorsky helicopter flies over the Antarctic volcano Mount Erebus. The commanding officer of the Navy Task Force praised the performance of the four HO4S helicopters on Operation Deep Freeze. Typical of their accomplishments, one helicopter in a 24-hour period ferried 200 men to the shore base from ships five miles away. No other transportation was possible because of breaking ice.

AROUND THE WORLD WITH SIKORSKY HELICOPTERS

S-55s FOR SOUTH AFRICA—The South African Air Force has bought two Sikorsky S-55s. These aircraft, with a third now on order, will be used for rescue and other emergency duties. Above, a pilot officer checks controls before takeoff from the Sikorsky plant on a training flight. S-55 type helicopters serve with all armed forces of the U. S. and those of many free nations.

FOR OIL WORK OFFSHORE—Among oil companies using Sikorsky helicopters to speed drilling offshore in the Gulf of Mexico is The California Company. The company recently purchased two new S-55s to join two already flying for the firm off Louisiana. In Gulf operations the S-55s are equipped with flotation gear. Above, one of them flies past Sikorsky's new plant control tower.

JOINING THE MARINES—This huge twin-engined Sikorsky HR2S assault helicopter topped performance expectations on its recent flight from Sikorsky's Stratford plant to the Naval Air Test Center, Patuxent River, Md. It was the first production delivery flight. This helicopter, known as the H-37 in the Army version and as the S-56 in the commercial version, has retractable landing gear and two Pratt & Whitney R-2800 engines. Its speed, range, and payload capabilities reflect marked advances in the art of helicopter design and production.

HELICOPTER HISTORY

FIRST MARINE CORPS HELICOPTER

In November, 1947, at Quantico, Va., this Sikorsky HO3S became the U. S. Marine Corps' first helicopter. Progressing from such early uses as air-sea rescue, being demonstrated in this photo, the Marine Corps has created new assault tactics built around the mobility of the helicopter and its unique ability to transport men and equipment anywhere. Today, huge HR2S helicopters promise the large scale airlift capability essential for vertical envelopment.

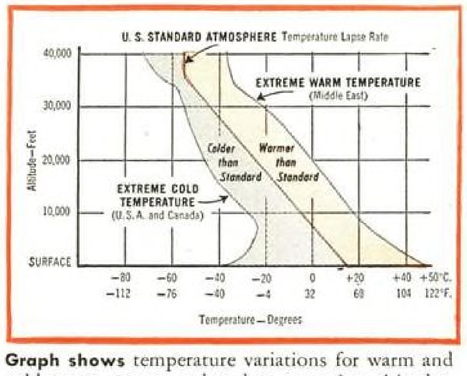
SIKORSKY AIRCRAFT
BRIDGEPORT, CONNECTICUT
One of the Divisions of United Aircraft Corporation

FLY WEATHER-WISE

These weather items prepared in consultation with the United States Weather Bureau

TURBO-PROP OPERATION

Fuel Requirements in Warm and Cold Climes



Graph shows temperature variations for warm and cold areas—on ground and at operating altitudes.

In turbo-prop operation, payload and fuel performance are closely tied together. When selecting the fuel's characteristics, ground temperatures in area of operation play an important part.

COLD CLIMES—Trans-Canada's Viscount planes are based in areas where winter ground temperatures drop as low as −46°F. Under these conditions, they use Mobiljet 4. With a freeze point of −76°F. it is free-flowing at lowest temperatures . . . easy to pump and won't clog filters.

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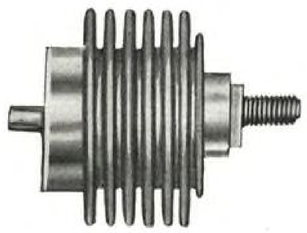
ABSORB EXPANSION OR VIBRATION

Sylphon stainless steel bellows and assemblies provide the strength and fatigue resistance to absorb thermal and pressure effects.



ACTUATE SWITCHES

Sylphon stainless steel assemblies can convert temperature and pressure changes into movement that makes or breaks switch contact.

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BELLOWS HEADQUARTERS U.S.A.

Fulton Sylphon stainless steel bellows improve operation and safety in a wide variety of aircraft ducts, joints, controls, valves, and other equipment . . . particularly in applications involving extreme temperature, high pressure, vibration, corrosion, shock conditions, etc.

Engineered and manufactured to specification, Sylphon bellows and bellows assemblies meet the exacting requirements of the aircraft industry. In complete assemblies the

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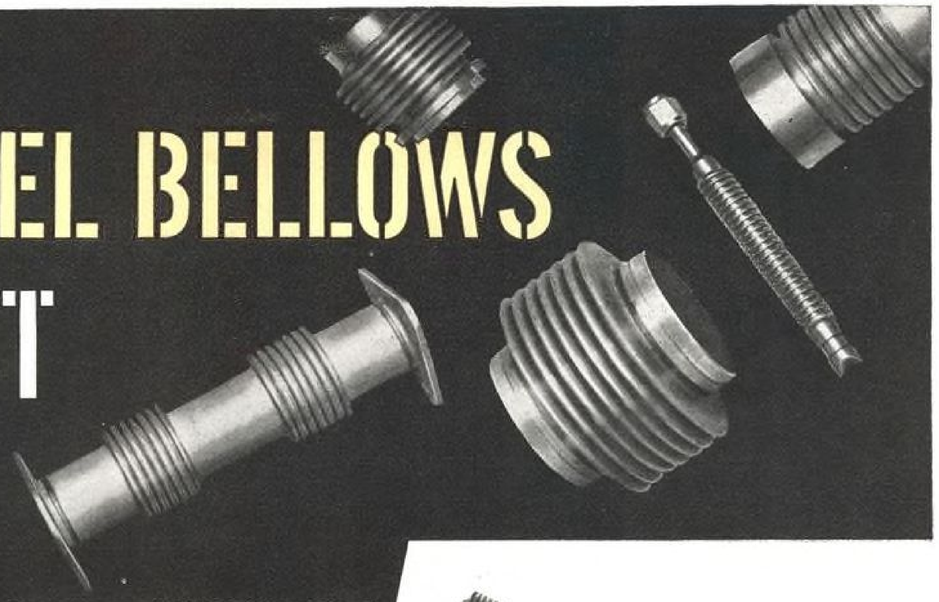

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Sylphon stainless steel bellows and assemblies provide leakproof, non-corrosive seals for valve stems, shafts, and other members.

TRANSMIT MOTION

Sylphon stainless steel assemblies permit force or motion to be transmitted with minimum friction loss in hydraulic systems or mechanisms.

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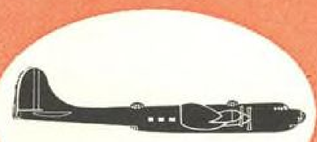

XB-19 Flying Laboratory
1941

A-26 Invader—**1942**

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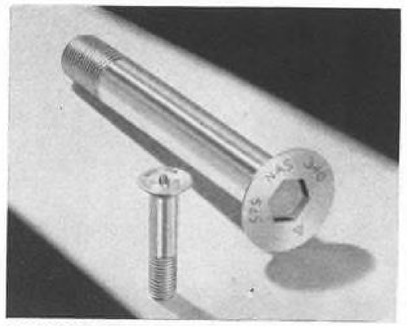

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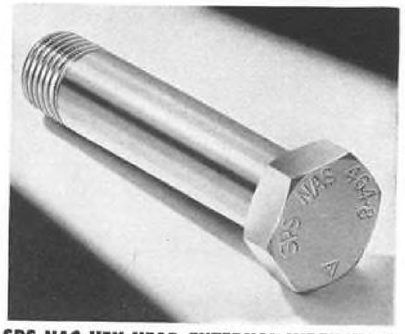

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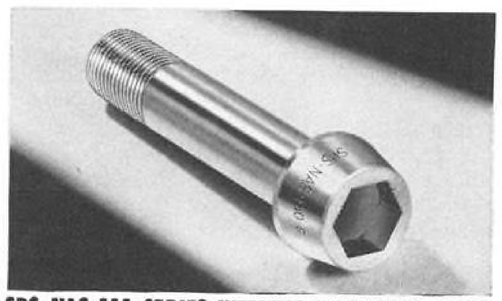

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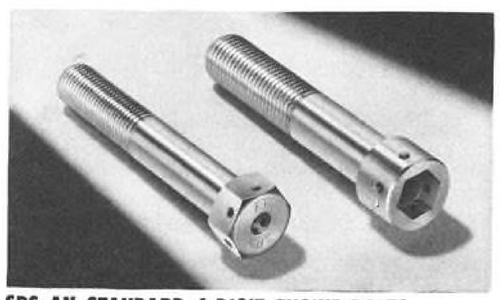
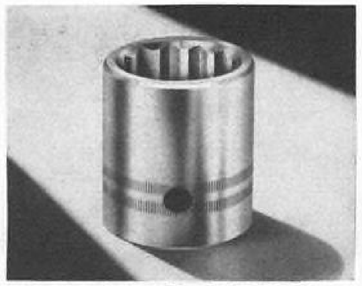


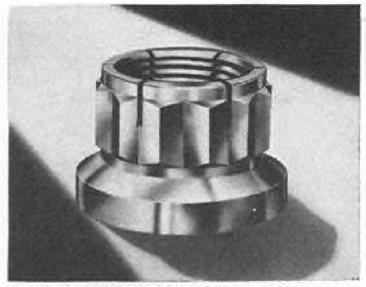
SPS AN STANDARD 6-DIGIT ENGINE BOLTS

All sizes
External hexagon head type or internal hexagon socket head type. Made of aircraft alloy steel or corrosion-resistant steel. Supplied with drilled head or drilled shank.



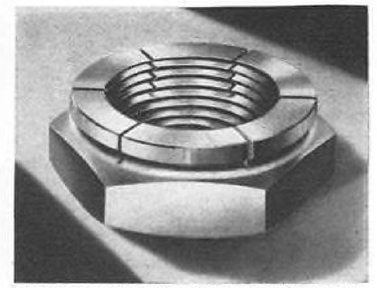
SPS NAS INTERNAL WRENCHING LOCKNUTS

¼-28 through 1¼-12
Procurement Specification AN-N-5 except as noted on NAS 443
Made of aircraft alloy steel, cadmium plated. They are self-locking units with positive locking provided by two nonmetallic plugs inserted through the body of the nut and contacting the threads of the bolt.



FLEXLOC EXTERNAL WRENCHING LOCKNUTS

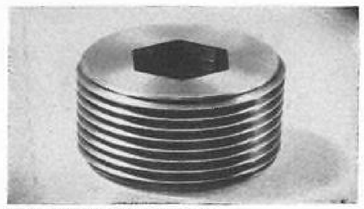
¼-28 through 1½-12
Procurement Specification AN-N-10a and NAS 353 or any other specification that may apply.
Made of aircraft alloy steel. One-piece, all-metal lock and stop nuts. Locking is accomplished by the slotted section locking on the bolt threads. Approved to 550°F.



FLEXLOC SELF-LOCKING NUTS, THIN, AN 364

6-32 through 1¼-12
Procurement Specification AN-N-5b
Made of steel, cadmium plated. They are one-piece, all-metal lock and stop nuts. Positive locking is accomplished by the slotted locking section which locks on the threads of the bolt. Designed for temperatures to 550°F.

FOR THE AIRCRAFT INDUSTRY

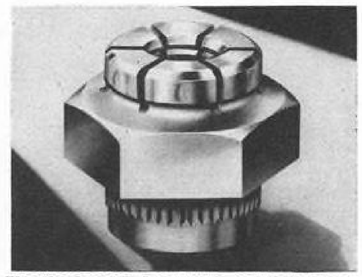


SPS PRESSURE PLUGS

⅛ through 1¼ ANPT
Procurement Specification MIL-F-5509
Made of heat treated alloy steel, aluminum alloy or magnesium. Threads are fully formed to provide positive sealing without compound. Alloy steel plugs are cadmium plated in accordance with QQ-P-416 or zinc plated in accordance with AN-P-32. Aluminum plugs are anodized. Magnesium plugs are unplated.

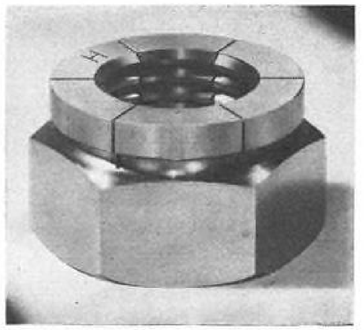
SPS SPRING PINS

MS 171401 through MS 171900
Nominal Diameter—.062 through .500
Procurement Specification AMS7207
Made of AMS5506 corrosion-resistant steel. Hardness, Rockwell "C" 43-52. Also made of heat treated carbon steel—zinc or cadmium plated, or phosphate coated.



FLEXLOC SELF-LOCKING CLINCH NUTS

4-40 through ¼-28
Made of steel, cadmium plated. They are self-contained units, incorporating the positive self-locking of regular FLEXLOC locknuts. Have knurled hollow shanks for fastening to material in which nut is to be used. For use on aircraft equipment and component parts such as instrument mountings and electrical equipment.



FLEXLOC SELF-LOCKING NUTS

AN-363 6-32 through ¾-16
AN-363C 6-32 through ¾-16
AN-365 4-40 through 1¼-12
Procurement Specification AN-N-10a and AN-N-5b
AN-363 and AN-365 nuts are made of steel, cadmium plated. They are designed for temperatures to 550°F. AN-363C nuts are made of corrosion-resistant steel, silver plated. They are designed for temperatures to 800°F. All are one-piece, all-metal lock and stop nuts of regular AN height. Positive locking is accomplished by the slotted locking section which locks on the threads of the bolt.

For complete information about SPS Fasteners for the aircraft industry, write Aircraft Products Division, STANDARD PRESSED STEEL CO., Jenkintown 3, Pa.

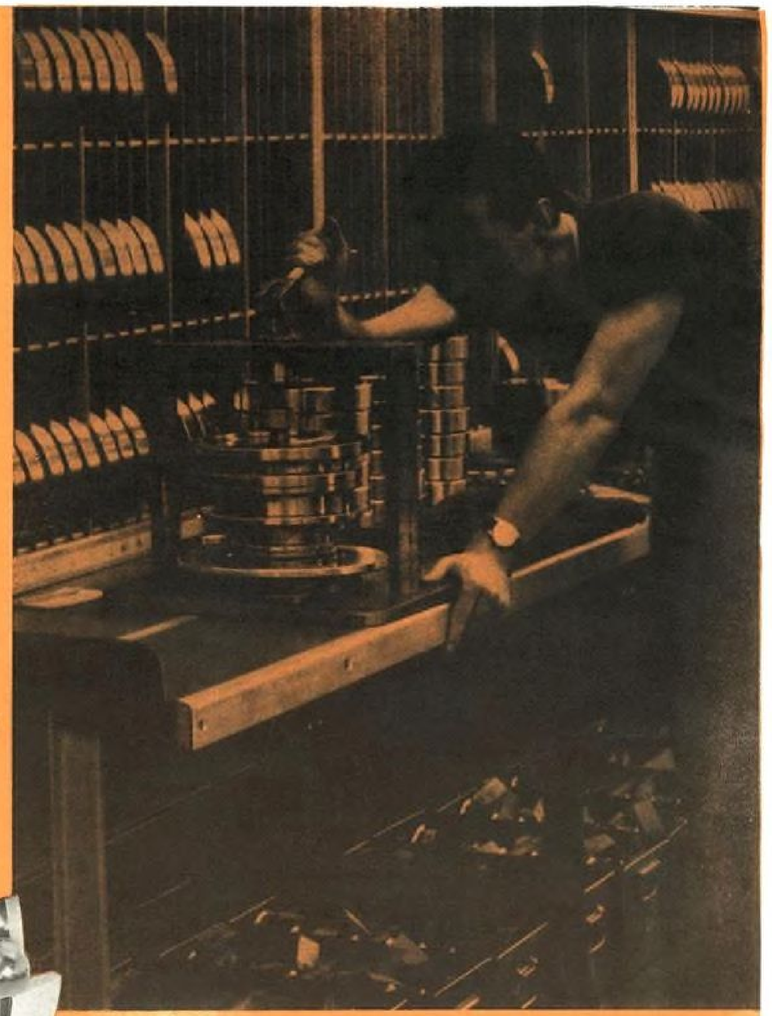
STANDARD PRESSED STEEL CO.

AIRCRAFT PRODUCTS DIVISION

SPS

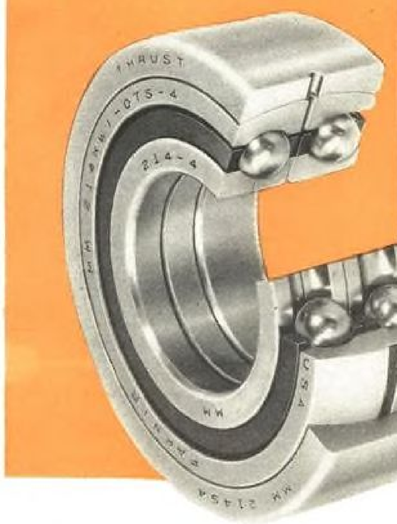
JENKINTOWN PENNSYLVANIA

Does dimensional control like this mean something to you?



▲ Measuring the contact angle of an assembled jet engine ball bearing by rotation

◀ Fafnir Super-Precision Ball Bearing for main rotor shaft of jet engine



There is nothing typical about this measuring device or the bearing being tested, yet the ingenuity, skill, and facilities involved are available to help you solve a bearing problem or improve a bearing application.

The measuring device illustrated is a Fafnir creation developed specifically for checking the angle of contact on super-precision jet engine ball bearings. It is one of several ingenious and exclusive quality-control devices used in the super-precision division of Fafnir.

A better idea of the facilities available may be gained from the design and construction of the Fafnir jet engine bearing illustrated. Close examination reveals that this super-precision bearing involves 2 angular-contact bearings assembled in a one-piece, self-aligning type outer ring. Each component is precisely made. All must fit together and function as a super-precision unit. Jet engine bearings are tailor-made. Each requires special engineering from design to application.

The manufacture of jet engine bearings reflects the Fafnir attitude and aptitude for solving bearing problems. Perhaps this combination can help you. Contact your nearest Fafnir Sales Branch, or write The Fafnir Bearing Company, New Britain, Conn.

FAFNIR

AIRCRAFT BEARINGS

FIRST at the turning points in aircraft design

Packaged landing gear for Lockheed's *Electra*

Score Another First for Menasco!

The nose and main landing gear produced by Menasco for the Lockheed Electra will be delivered as complete pre-tested, functional systems, ready for installation in the airframe. This includes tires, wheels, brakes, steering system, wiring, plumbing, gear-mounted valves and switches.

It is fitting, too, that the Electra, America's first turbo-prop airliner, utilizes the latest advance in landing gear design and manufacture—Uniwelding of high heat treat steels—a combination pioneered and offered exclusively by MENASCO, specialists in aircraft landing gear.

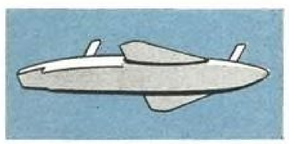
First in development, quality, delivery and service

menasco manufacturing company

805 South San Fernando Boulevard, Burbank, California

SPECIALISTS IN AIRCRAFT LANDING GEAR

The remote corners of the world are now accessible to aircraft designed to include the Stroukoff Pantobase landing system. A product of Stroukoff research and development, Pantobase will permit landings and take-offs from snow, ice, water, sand and unimproved terrain as well as standard runways. The increased versatility of the aircraft will reduce the need for conventional airports and contribute materially to the advancement of logistical techniques. The safety of the Pantobase landing system, is assured by the extensive experience and complete reliability of the Stroukoff organization.



Pantobase — When designed into an aircraft the Stroukoff Pantobase system enables the plane to land and take off from many types of surface without changes or additional landing equipment.

BLC — Boundary layer control as developed by Stroukoff increases the effective lift and delays stalling of the wing, thereby reducing required speeds and distances for take-offs and landings.

Achievement is a tradition at Stroukoff. Leaders in the development and design of cargo and transport aircraft, Stroukoff offers challenging opportunities to creative engineers.

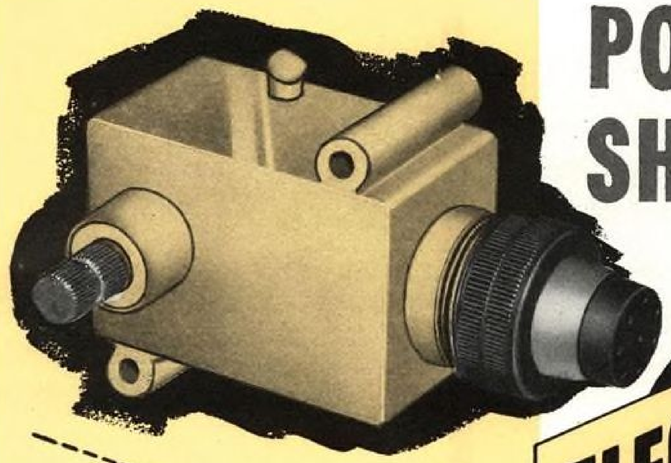
Extending the Frontiers of Aircraft Performance

Stroukoff AIRCRAFT CORPORATION

WEST TRENTON, NEW JERSEY

NOW AVAILABLE . . .

the *One* hermetically-sealed rotary switch WITH POSITIVE SHAFT SEAL!



H10-7
actual size

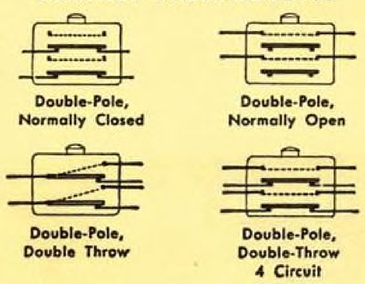
ELECTRO SNAP

- The only rotary switch with seal bonded to BOTH shaft and case!
- Leakage rate LESS than 1 micron/cu. ft./hour! Full rating to 70,000 ft.
- Choice of adjustable or fixed actuating arms.
- Full travel of 120°.
- Drawn steel case . . . 2-bolt rigid mounting!

SPECIFICATIONS

ELECTRICAL RATING	
125/250 V a-c	15 Amps
30 V d-c (Resistive)	15 Amps
(Inductive)	10 Amps
Pretravel	15° Min.
Movement Differential	10° Max.
Overtravel	105°(Approx.)
Min. Mechanical Cycles	100,000
Min. Electrical Cycles	100,000
Operating Force	1 in.-lb.(Approx.)
Overtravel Force	3 in.-lb.(Approx.)
Difference in Operating and Reset Point Between Each Pole	0° –30′ Max.
Ambient Temperature Range (Higher Temperatures Available)	–100 F to + 250 F
Weight	6 ozs. (Approx.)

CONTACT ARRANGEMENTS



Double-Pole, Normally Closed

Double-Pole, Normally Open

Double-Pole, Double Throw

Double-Pole, Double-Throw 4 Circuit

Specify ELECTRO-SNAP H10-7 for the only rotary switch that is *positively* hermetically sealed — not merely equipped with a tight-fitting packing around the shaft. The H10-7 seal is bonded to both shaft and case, which is evacuated and pressure filled with a dry inert gas. Repeated actuations will not loosen the rigid 2-bolt mounting, and the splined shaft will not permit slipping of the actuator arm.

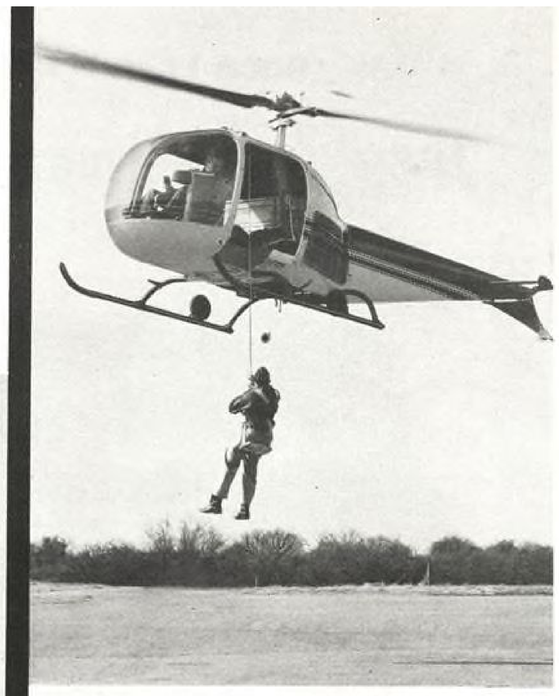
Simultaneous make-and-break (regardless of speed of the actuator travel) of up to 4 separate circuits permits reversing of 3-phase motors, substitution for expensive relays, etc. Designers can make excellent use of this electrical versatility and freedom from environmental worries. Obtain more information on the H10-7 by writing for data sheet H 10M-8

ELECTRO-SNAP
SWITCH & MFG. CO.
4232 W. LAKE ST. • CHICAGO 24, ILL.

TOTE THAT BARGE... LIFT THAT LOAD!

Bell HSL helicopter tows 300-ton derrick barge at approximately 8 knots. Towing boom on Bell HSL is raised and lowered by Western Gear drag boom hoist.

Kaman HOK-1 twin rotor helicopter with Western Gear hoist, shown here in simulated rescue trials.



Bell 47J helicopter uses Western Gear hoist for rescue operations. Bosun's chair or litter can be used.

Closeup of Western Gear hoist installation for Bell 47J helicopter showing compact, lightweight design.

you can count on WESTERN GEAR hoists!

Western Gear hoists will take the load off your mind if you are perplexed over lifting and lowering problems — Scores of different hoist designs have been developed and produced for both airborne and ground installations. Our hoist engineers can be entrusted to provide the right solution to your hoist requirements, effectively and economically. We're waiting to serve you. Address General Offices, Western Gear Corporation, P.O. Box 182, Lynwood, California.

"The difference is reliability" • Since 1888

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WESTERN GEAR Corporation
ENGINEERS AND MANUFACTURERS

PLANTS AT LYNWOOD, PASADENA, BELMONT, SAN FRANCISCO, (CALIF.)
SEATTLE AND HOUSTON—REPRESENTATIVES IN PRINCIPAL CITIES

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Esso

When business or pleasure takes you to New England, or anywhere from Maine to Texas, you'll find the convenience of flying matched by the convenience of an Esso Dealer Airport.

There are more than 600 Esso Dealer Airports serving your private, corporate or company planes with high quality Esso Aviation Products. These are the famous fuels and lubricants used by the world's leading airlines and backed by 46 years of flight testing and research.

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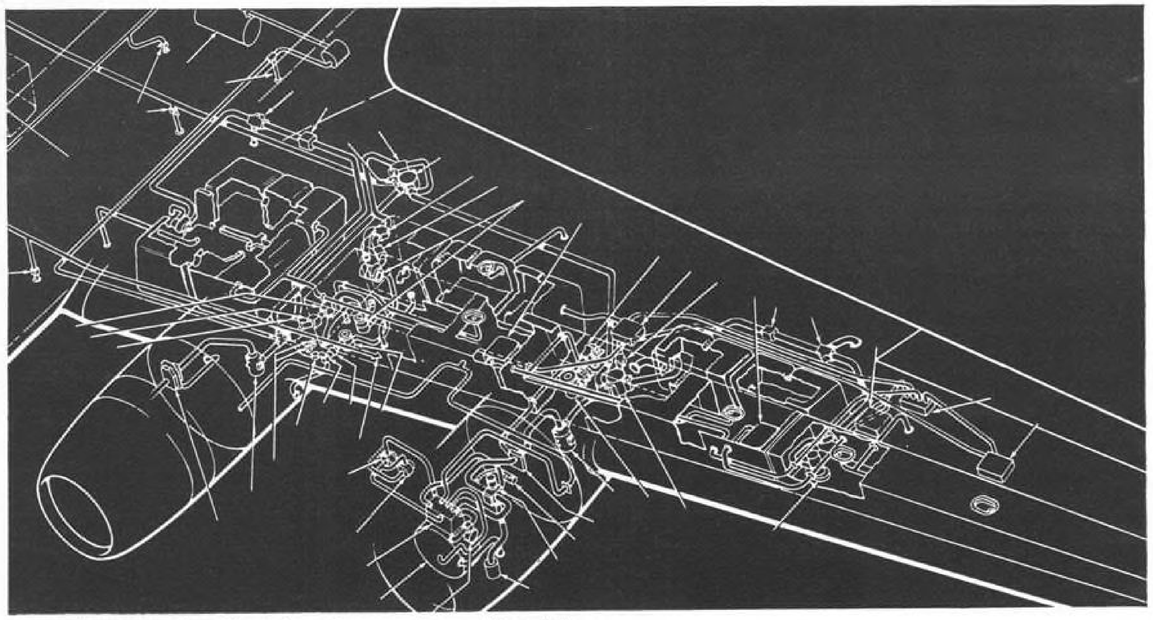
FREE TO PILOTS! *For your free copy of "You and Instruments" by Col. Duckworth, packed with important information, be sure to see your nearest Esso Aviation Dealer.*

SUPERIOR TUBING

BEST FOR 1001 AIRCRAFT APPLICATIONS



A complex modern aircraft, as shown here, requires a wide variety of special-purpose tubing in many different sizes and alloys.

Superior can supply *all* your small metal tubing needs with premium quality tubing that meets all these requirements: light weight; close tolerances; workability; ability to withstand vibrations, shock, high temperatures, and high pressure surges. Shown here are some of the many aircraft applications for tubing, the necessary qualities required of it, and the analyses in which Superior makes such tubing available.

HYDRAULIC TUBING

Superior produces aircraft hydraulic tubing in a wide variety of sizes in stainless steel analyses AISI 304, 321 and 347. This tubing possesses a number of outstanding characteristics. It will withstand bursting pressures up to 12,000 psi. It is free from fissures, porosity, scratches and seams. It is clean and free of oxide film and metallic particles. It will flare without difficulty. This ductile, high strength, fatigue and corrosion resistant tubing will meet such rigid specifications as MILT 6845, MILT 8504, AMS 5565, 5566 and 5560. All tubing undergoes inspection for flareability, and is 100% hydrostatically tested.

AIRCRAFT OIL LINES

This hydraulic tubing is produced by Superior in low carbon steel C-1008 to meet JIC and SAE standards, and Specifications AMS 5050E and ASTM A179. Low carbon content of 0.12% maximum gives high ductility for easy hand bending and flaring. This tubing is made from non-aging steel to prevent loss of ductility and impact resistance. All tubing is 100% hydrostatically tested at maximum working pressures, and all tubing has clean, smooth ID and OD surfaces to minimize pressure drop.

AIRFRAME STRUCTURAL TUBING ENGINE MOUNTS (SMALL CRAFT)

Produced in C-1025 carbon steel to Specifications MILT 5066 and AMS 5075, this tubing has good welding properties. Also produced in 4130 alloy steel to Specifications MILT 6736 and AMS 6360, 6361 and 6362—can be hardened by heat treatment, and in annealed condition possesses good workability for flaring, bending, upsetting, etc., and has an excellent strength-weight factor.

AIRCRAFT ENGINE PUSH RODS

Produced in 4130 alloy and 1035 medium carbon steel. Very smooth surface finish, extremely close tolerances, and controlled properties. Has very good strength-weight factor.

DUCTING AND FUEL LINES

Large OD thin-wall tubing in Seamless or Weldrawn® grades is produced in a wide range of analyses and in sizes as large as 2½ in. OD with .025 in. wall maximum. Meets Military Specification 6737. Close tolerances, very light weight, clean, and extremely ductile. Large OD thin-wall tubing has many applications in modern aircraft. Available in long lengths—up to 30 feet.

SPECIAL TITANIUM HYDRAULIC LINES

This tubing is produced from vacuum annealed, commercially pure titanium. Both flareless and flared fittings can be used. A full range of sizes up to 1¼ in. OD is available.

IGNITION HARNESS

Tubing for this application is produced from stainless steel types 304, 321 and 347, plus Inconel and Inconel X. Easily fabricated, retains excellent properties at elevated temperatures, produced to very close tolerances.

MANOMETER LINES AND PITOT TUBES

This mechanical hypodermic needle tubing is produced in austenitic chromium-nickel stainless steel in 27 standard gages, each in 3 standard wall thicknesses. Special hard-drawn temper for maximum hardness and flexibility, and bright, clean ID and OD surfaces.

SPECIAL AIRCRAFT INSTRUMENT GAGE BOURDON TUBING

Available in beryllium copper, Monel, 4130 alloy steel, Type 304 and Type 316 stainless steel, and Ni-Span-C. It is fatigue and corrosion resistant with low hysteresis and high electrical conductivity.

AIRCRAFT ANTENNAS

Tubing produced of beryllium copper has been used very successfully for radar antennas on small craft. It has unusually low hysteresis, high strength, and good electrical conductivity.

FIRE DETECTION EQUIPMENT

Produced in stainless steel, Inconel and 42 Alloy. Tubing has extremely close tolerances and special surfaces.

SPECIAL PURPOSE AIRCRAFT TUBING MATERIALS

Superior produces not only a wide variety of standard tubing, but also tubing considered a "specialty" in many other mills.

Super Alloys

The first group comprises some of the super alloys from which Superior produces tubing to customer order. Tubing of all these analyses performs well under severe conditions, and has high strength and oxidation resistance above 1200°F. Applications include thrust chambers and fuel and control lines in guided missiles and rockets. (Any of these higher quality materials can be used in the lower classifications shown.)

Inconel X[1]	*Haynes 25[2]
*Timken 16-25-6	Hastelloy C[2]
*A-286	*Hastelloy F[2]
*S-816	*Hastelloy X[2]
Type 310	*19-9DL
Type 316	

Oxidation Resistance Materials

The analyses listed below primarily offer excellent oxidation resistance above 1200°F.

Type 309	Inconel[1]
Type 347	Nichrome V[3]
Type 321	Type 446

General Purpose Materials

The following materials offer diverse advantages at temperatures up to 1000°F.

*1722 A (S)	Type 410
T 5	Nickel
Type 430	Monel[1]

*Materials marked with an asterisk are not normally carried in inventory, but can be obtained from supplier on customer order. For that reason, orders specifying these materials will take longer to fill.

1. Reg. TM International Nickel Co.
2. Reg. TM Haynes Stellite Co.
3. Reg. TM Driver Harris Co.

Let Superior tubemanship and experience help you solve your aircraft tubing problems. Write Superior Tube Company, 2040 Germantown Ave., Norristown, Pa., for your free copy of Bulletin No. 40.

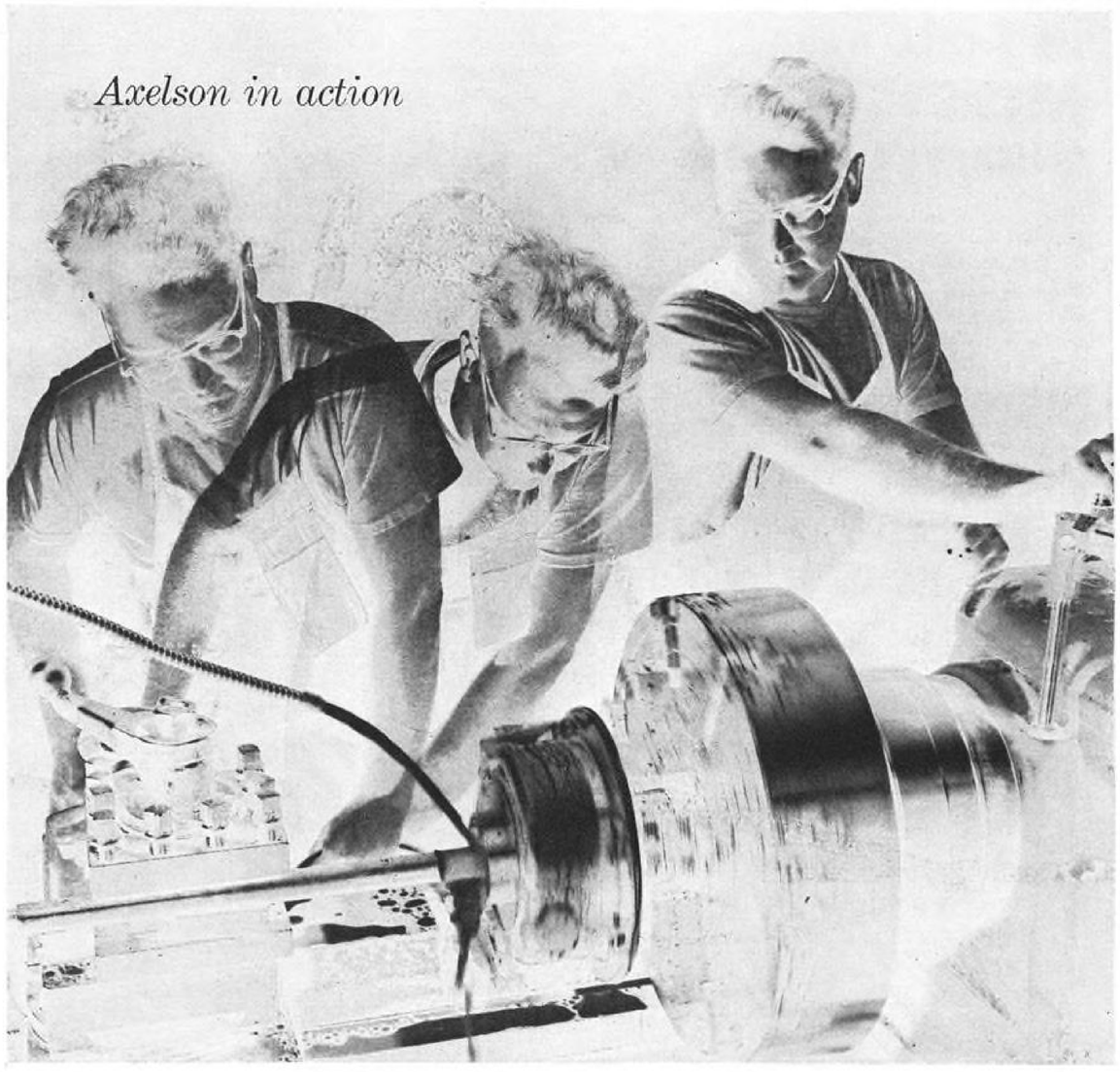
Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company • 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331



negative problem... positive solution

Removing metal accurately and quickly can be a problem. It requires the skill and experience of master craftsmen . . . the finest machine tools . . . it requires a positive approach. Only then can the product meet exacting specifications of economy and precision.

For more than thirty years Axelson has specialized in the positive solution of difficult production problems for aircraft components and subassemblies. Today, our history of accomplishment is being perpetuated by Axelson's production technicians, carefully trained in the specific machine tool operations required for the production of precision aircraft parts.

Our expanded facilities are equipped with the most reliable, precise machine tools available . . . we have augmented our staff with top-flight engineers . . . to make available to you—in addition to Axelson's experience in production — service in research, design and development.

Call on Axelson early . . . to take over your program at the planning stage and carry it through to successful completion.

AXELSON AIRCRAFT

Axelson Manufacturing Company

Division of U. S. Industries, Inc.

6160 South Boyle Avenue, Los Angeles 58, California

There are some flight emergencies a pilot can't practice—except in a simulator *on the ground*. For instance bad weather, night landing, abnormal turbulence, even engine fire during landing or takeoff, are just a few of the many flight emergencies which can be reproduced fully and realistically in Link Flight Simulators.

All flight techniques can be practiced in Link's B-47B Jet Flight Simulator, developed by Link Aviation, Inc., in cooperation with Wright Air Development Center, USAF.

In such simulators as this B-47B Jet Flight Simulator, pilots develop correct reactions and correct techniques to meet *all* flight situations—without risk of life or equipment—and at very little cost in time and money.

There is no more economical way to train student pilots in the handling of normal and emergency flight procedures than in a flight simulator.

Pioneer and World's Largest Producer of Jet Flight Simulators

LINK AVIATION, INC.

BINGHAMTON, NEW YORK

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORP.

a giant's grip ... that's feather light!

If great strength plus extreme lightness are your aircraft design goals, you should be utilizing the advanced engineering, chemistry and production know-how that have made Metlbond* structural adhesives the standard of reliability throughout the aircraft industry.

Send today for Narmco's illustrated brochure on Metlbond 302 ...a wealth of structural bonding design information.

More than a decade ago, Narmco pioneered aircraft adhesive bonding—a design revolution that has since enabled engineers to build unparalleled strength and performance into structural components by the very nature of this uniquely efficient fastening method. Today, Narmco's accumulated skills stand behind a distinguished line of custom-developed adhesives, including Metlbond* 302, a multi-purpose supported adhesive designed for metal-to-metal and sandwich applications requiring prolonged temperature integrity to 500° F.

Narmco technical field representatives throughout the United States and Canada, can assist in solving your structural design problems quickly, efficiently and economically. For immediate assistance, write, wire or telephone.

Metlbond 302 offers exceptional "handability." It drapes easily to drastic contours at room temperature, has excellent storage life and requires no priming, thus saving fabrication time and tooling costs. Because of excellent flow properties, Metlbond 302 requires low curing pressures (10 to 25 p.s.i.) and no post-cure. In sandwich applications, core materials need not be coated or perforated.

Metlbond 302 exhibits remarkably uniform performance properties over a wide temperature range, and is highly resistant to aircraft fuels, salt spray, and other corrosive chemicals. Available in five standard thicknesses ranging from .007 to .025 inch.

*Trade Mark Registered

NARMCO

NARMCO RESINS & COATINGS COMPANY, DEPT. 741—600 Victoria Street, Costa Mesa, California

It has to be better to reach

MELETRON'S STANDARDS

The *tier-tube* is one of the most recent developments at Meletron. This switch, like its predecessors, will be required to pass ten quality control tests. Each test will reveal how well it will perform, even under unpredictable stress.

Rigidly enforced compliance with our quality standards explains why industry and aircraft rely on Meletron pressure actuated switches. These products have a long record of dependable performance. They have to be better, to reach Meletron's standards.

Meletron's Tier Tube Solves Known Problems and Is Designed to Solve Potential Problems

Tier-tube switch does not require a return line, thus allowing system weight reduction. Simple adjustment places actuation value at any point within working range. Available in aluminum or stainless steel.

Direct Inquiries to Salesmanager, MELETRON CORPORATION, 950 No. Highland Ave., Los Angeles 38, Calif., or to Ray Matlock, western factory representative, 435 Teaneck Rd., Teaneck, New Jersey; J. M. Wallace Co., Boeing Field, Seattle 8, Wash.; Joseph C. Gallaghan & Associates, 1612 Eye St., N.W., Washington 6, D. C.; J. N. Power Co., Inc., 49 W. Hancock Ave., Detroit, Mich.; George E. Harris & Co., Inc., 3241 E. Douglas Ave., Wichita, Kansas; 701 E. 63rd St., Kansas City, Mo.; 7811 Carondelet Ave., St. Louis, Mo.; 503 Circle Drive, Arlington, Texas (Dallas-Ft. Worth).

MELETRON® CORPORATION

950 N. HIGHLAND AVE.
LOS ANGELES 38,
CALIFORNIA

Manufacturers of pressure actuated, vacuum actuated and altitude actuated pressure switches, for all applications from zero absolute to 12,000 psi gauge.

Hand work assures quality not found in mass-produced switches.

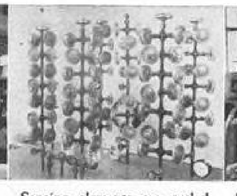
Metals used are carefully specified and thoroughly checked.

Switch parts are checked and rigidly inspected at end of each step.

Depth of cadmium plating is determined by magnetic and acid tests.

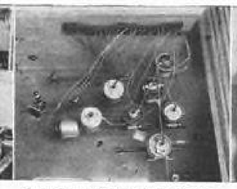
Heli-arc welding (which excludes oxygen) is used to insure cleanliness.

Most metals, subjected to severe cold forming, are susceptible to internal stresses. Each diaphragm and bourdon tube is heat treated to reduce internal stresses to a minimum.



Sensing elements are cycled to the proof pressure 1,000 times. Cycling relieves any stresses left in metals. Any small leaks are detected in this test.

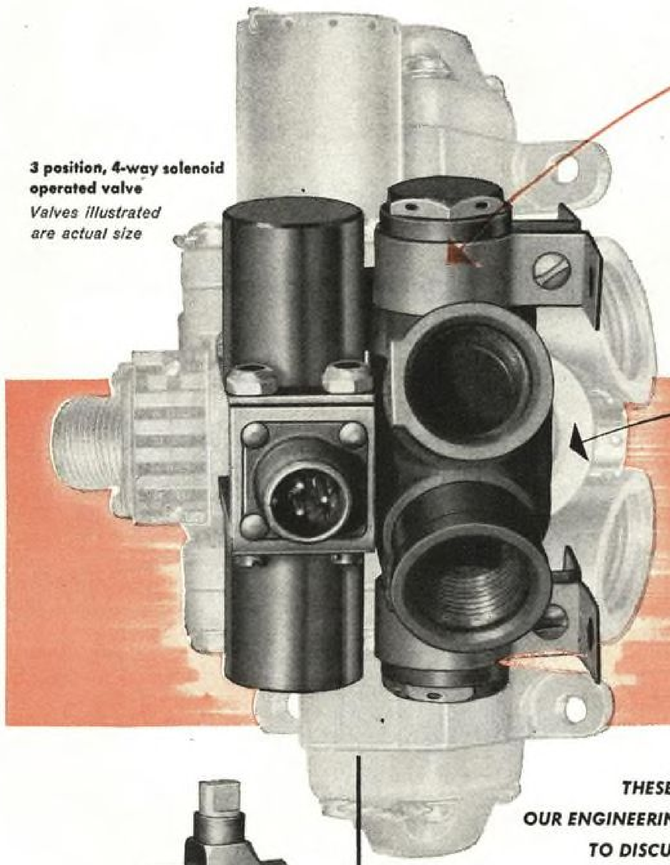
Since sensing elements might be corroded by the atmosphere, this photo shows how they are plated to prevent corrosion.



Pressure switches may be required to work in high altitudes, dry climates, high humidity or over rough terrain. These switches are being tested in a high temperature.

In final test calibration, special Meletron developed equipment operates every switch several hundred cycles; then each switch is individually inspected.

Now! ADEL offers a new line of HIGH TEMPERATURE MINIATURE VALVES



3 position, 4-way solenoid operated valve
Valves illustrated are actual size

Here it is.

A new line of valves that will meet every requirement demanded by today's accelerating aircraft designs.

Performance and environmental demands, in conjunction with design simplicity, size and weight—all requirements a valve must face—are met by these revolutionary new models.

Months and months of exhaustive engineering time in all fields have gone into the development of this line. Research in metallurgy, endurance, stress and surge control have all contributed to the end product.

Versatile, high temperature performance in a miniature package ...pioneered by ADEL

THESE VALVES ARE NOW IN PRODUCTION. OUR ENGINEERING SALES REPRESENTATIVES ARE READY TO DISCUSS THEIR APPLICATION TO YOUR REQUIREMENTS.

Hydraulic pressure pilot operated relief valve

2 position, 3-way solenoid operated selector valve

2 position, 4-way solenoid operated hydraulic valve

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PRECISION PRODUCTS
A DIVISION OF GENERAL METALS CORPORATION

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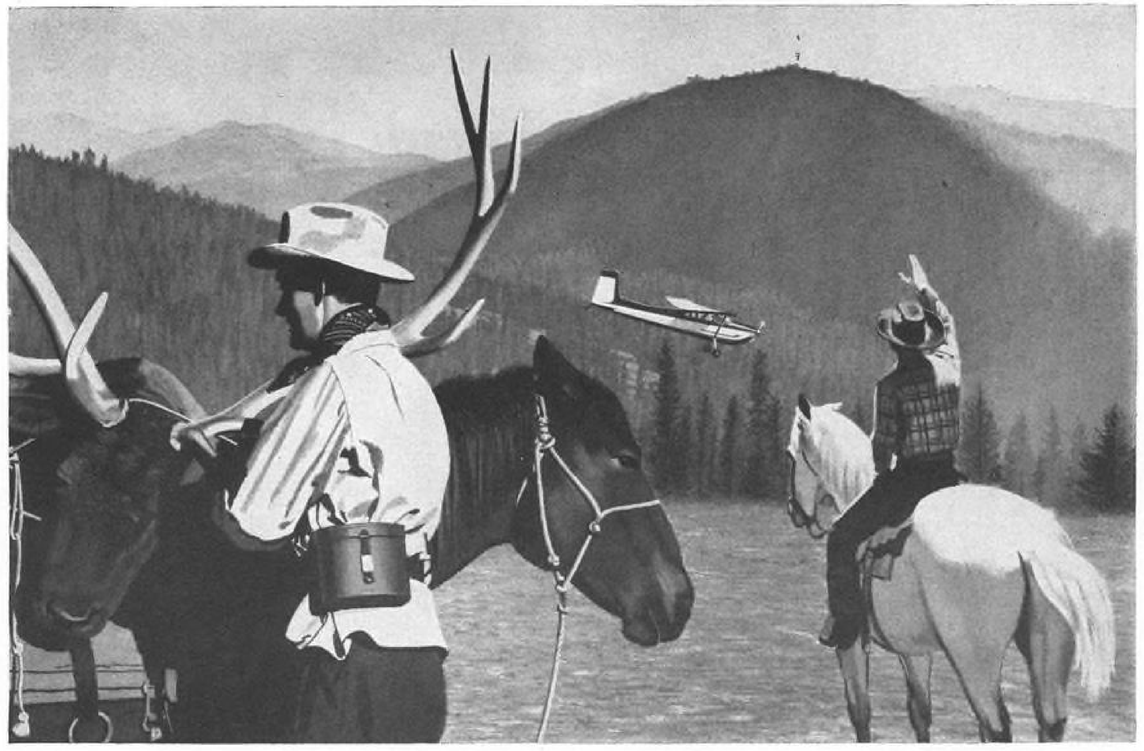
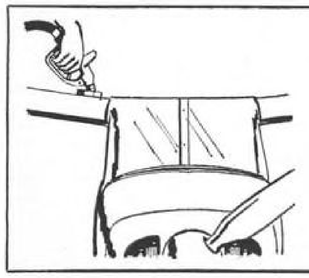


A four-day pack trip in 45 minutes

Flying sportsmen into Idaho's big-game paradise, Tom Kiiskila covers the 90 miles to the rugged Selway Primitive Area in less than an hour after takeoff from his home port of Orofino. He drops into narrow canyons to unload his passengers, then airlifts other hunters *and* their heavy game back to civilization.

"Almost all my flying is over rough timber country," says Mr. Kiiskila. "We make game counts from the air, check timber for disease, and fly right at tree-top level when we have to lead fire fighters to a fire. One big problem is high head temperatures in our kind of flying. But even climbing out of a canyon where the air is really hot and dead, Chevron Aviation Gasoline 80/87 gives full power without knocking. It never fouls plugs, either; with Chevron 80/87 I never clean them between 100-hour checks.

"You'd think we'd have ring and valve troubles because of the high engine temperatures and frequent takeoffs, but RPM Aviation Oils give full-time protection. We get as much as 800 flying hours between top overhauls, and never have trouble with sticking valves. 'RPM' is tops."



TIP OF THE MONTH

When refueling, leave a little room in the tanks for expansion. Every 10 gallons of cool gas can expand as much as an extra quart if your plane is in the hot sun.

CHEVRON AVIATION GASOLINE — RPM AVIATION OIL

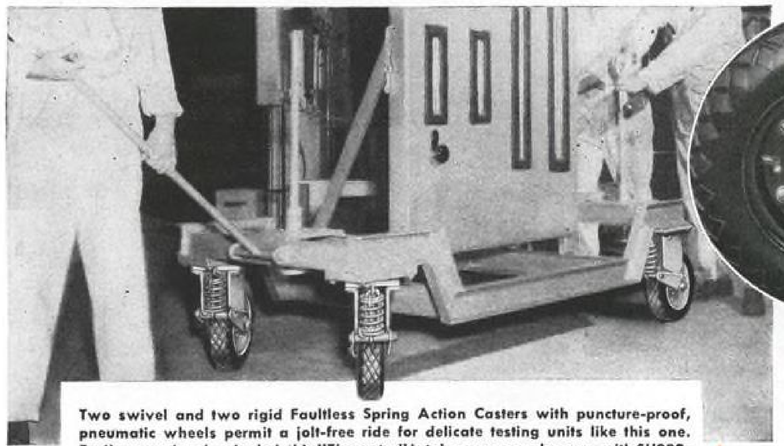
We take better care of your plane

T.M.'S "RPM," "CHEVRON," "PLANE FAX," REG. U. S. PAT. OFF.

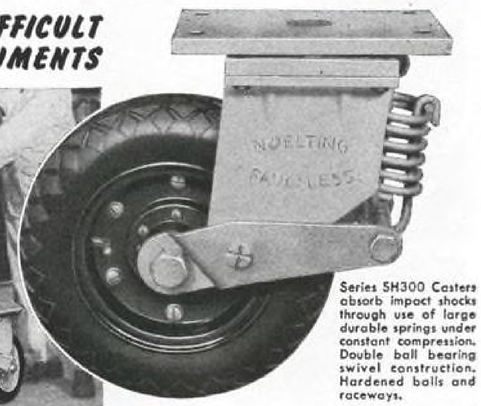
NOELTING

HOW Faultless AIRMASTER CASTERS ARE SERVING AVIATION

DOUGLAS AIRCRAFT COMPANY, TULSA, SOLVES DIFFICULT MATERIALS HANDLING PROBLEM FOR INSTRUMENTS



Two swivel and two rigid Faultless Spring Action Casters with puncture-proof, pneumatic wheels permit a jolt-free ride for delicate testing units like this one. Easily moved and swiveled, this "Flowrator" is taken over rough areas, with SH332-12x3 (swivel) and SH732-12x3 (rigid) Shock Absorbing Casters smoothing the ride.



Series SH300 Casters absorb impact shocks through use of large durable springs under constant compression. Double ball bearing swivel construction. Hardened balls and raceways.

In the gigantic plant of Douglas Aircraft Company, Tulsa Division, many tough materials handling problems are solved with specially constructed castered dollies. For example, highly delicate equipment is used to test installations in the planes. A way was needed to transport this test equipment over rough ground without jarring the instruments. Douglas Tool Engineers designed the Flowrator, mobile test unit, mounted on Faultless Double Action Spring Casters. Sensitive test equipment thus is moved speedily and safely over uneven floors and terrain—inside and out-of-doors. Production costs are cut at testing locations because readjustment of the gauges is unnecessary. Equipment arrives ready for immediate use. To get the complete story on the Douglas caster application mentioned above, simply call your local Faultless Caster Distributor listed in your phone directory, or write us today.

Two of many AIRMASTER Casters produced for the Aviation Industry

DUAL-WHEEL SPRING LOADED

Made in accordance with Military Specifications and approved for use. Write for free illustrations and specification data.

SPRING ACTION POSITION LOCK ON SWIVEL

3 FEATURES EXCLUSIVE WITH AIRMASTER CASTERS

- **Shock-Absorbing Spring Action *parallel to the center line of King Bolt* to balance the load and allow wheel to be in contact with floor at all times, regardless of rough floors or bumpy terrain. Spring assembly is an interchangeable member.**

- **Caster wheels of standard design are *easily interchangeable with stock wheels* to minimize maintenance and "down" time.**

- **Spring Action Caster *continues to function as conventional Caster* in case overload exceeds maximum spring load rating. An important safety factor to load and operators.**

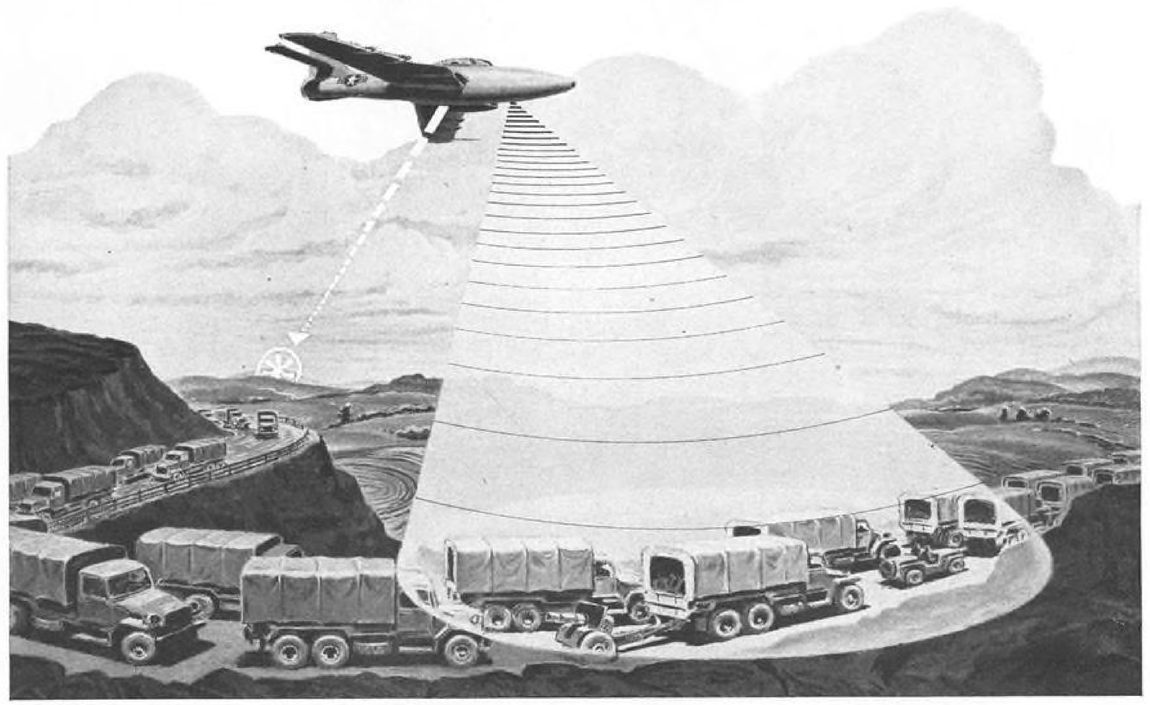
IMPORTANT: A skillful combination of these design features enabled Faultless Swivel and Rigid Types Double Action Spring Casters to successfully *pass all* of the endurance tests conducted by materials handling experts, while all other types of shock absorbing casters failed at one construction point or another. Further facts gladly furnished, no obligation.

FAULTLESS CASTER CORPORATION

EVANSVILLE 7, INDIANA

Offices in Atlanta, Baltimore, Boston, Buffalo, Chicago, Cleveland, Dallas, Detroit, Grand Rapids, High Point, Indianapolis, Los Angeles, New Orleans, New York, Philadelphia, Portland, St. Louis, Seattle. Canadian Factory: Stratford, Ontario.

Air Force "Super-Snooper" SEES ALL . . . TELLS ALL



Reconnaissance television moves GHQ directly over any target zone

Today, the United States Air Force has perfected a far-seeing "third eye". . . strategic airborne television. Now the Military Command can watch the TV screen as though it were a living, moving map . . . and direct distant maneuvers and operations. Philco is proud to have developed a special airborne TV system, to meet the high technical and performance standards of the U.S. Air Force.

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U. S. Air Force Photo

An Air Force cargo plane delivers vital Air Force supplies to an overseas base.

AIR MATERIEL COMMAND IS GLOBAL LINK BETWEEN RESEARCH AND COMBAT UNITS

Supplying the Air Force with the right equipment, at the right place at the right time is the mission of Air Materiel Command. Its procurement, supply and maintenance operations fill the area between research and development on one side and combat units on the other. It is the largest business in the country.

Because our Air Force is operating in all quarters of the earth, AMC is a globe-circling operation with its headquarters centered at Wright-Patterson AFB near Dayton, Ohio.

The vital logistic mission for the Air Force involves billions of dollars in procurement, thousands of airplanes, and more than a million different kinds of supply items. Organizationally, AMC includes fourteen air materiel areas, or major area depots, located in the United States, Europe, North Africa, and the Pacific. Geographically, air materiel operations extend throughout the free world.

Working with weapons systems contractors in private industry, AMC procures the equipment which has been developed and tested by the Air Research and Development Command, and distributes the equipment to combat units as needed. The never ending objective of the Air Materiel Command is to maintain an instant combat readiness, logistic-wise, in this era of super speeds and super weapons to support Air Force operations at any point on the globe. The philosophy of Air Materiel Command is that such readiness must be characterized by the closest interrelations of combat and logistic elements, by speed, flexibility, mobility and economy.

This is one of a series of ads on the technical activities of the Department of Defense.

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DIVISION OF SPERRY RAND CORPORATION
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of unusual abilities can find a future at FORD INSTRUMENT COMPANY. Write for information.

Highly skilled technicians at Ford Instrument Company assembling complex aircraft instruments for the U. S. Air Force.

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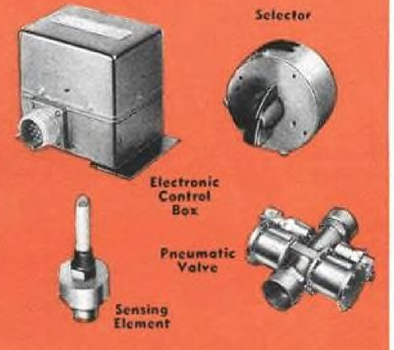
Aircraft Controls

for a clear view ahead and comfort aboard the Martin B-57B

Called a "jack-of-many-trades" aircraft, the Martin B-57B often encounters radically varying weather and temperature conditions. To assure constant cabin comfort and an unobstructed view wherever it flies, a Barber-Colman automatic cabin temperature control system plus Barber-Colman windshield anti-icing controls are used on this versatile light bomber.

TYPICAL BARBER-COLMAN CABIN TEMPERATURE CONTROL SYSTEM



In addition to supplying temperature control systems for many types of military craft, Barber-Colman Company produces automatic temperature controls for aircraft flown by 25 leading domestic airlines, 50 foreign airlines, and some 225 business firms operating their own multi-engine planes.

The complete line of Barber-Colman aircraft controls includes: Actuators; Positioning Controls; Temperature Controls; Small Motors; Valves; Ultra-Sensitive Relays; Thermo-Sensitive Elements. Consult the Barber-Colman engineering sales office nearest you: Los Angeles; Seattle; Baltimore; New York; Montreal; Melbourne.

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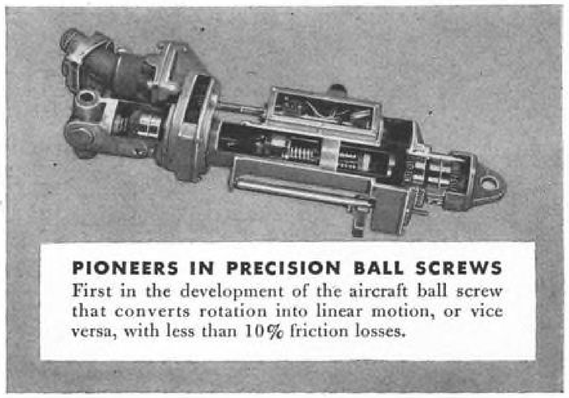
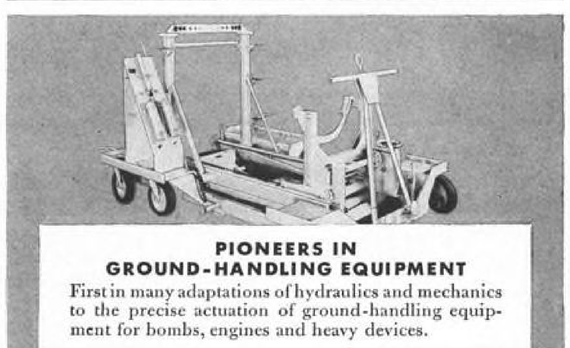
Creative Pioneers in Transport

PIONEERS IN LANDING GEARS
First in the design, engineering, and production of landing gears for every type of airplane, helicopter, blimp, and missile.

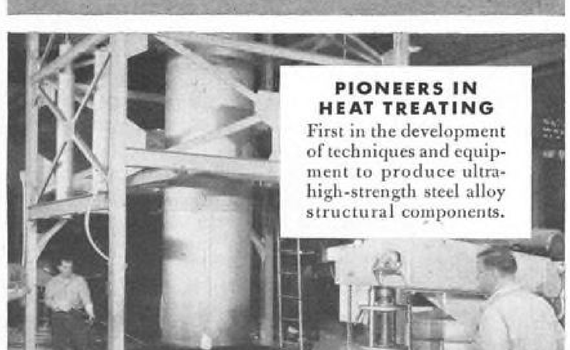


PIONEERS IN PRECISION BALL SCREWS
First in the development of the aircraft ball screw that converts rotation into linear motion, or vice versa, with less than 10% friction losses.



PIONEERS IN GROUND-HANDLING EQUIPMENT
First in many adaptations of hydraulics and mechanics to the precise actuation of ground-handling equipment for bombs, engines and heavy devices.

PIONEERS IN WELDING TECHNIQUES
First in the development of flash-welding techniques to alloy steel parts. We have the world's largest, most powerful flash-butt welding machine.



PIONEERS IN HEAT TREATING
First in the development of techniques and equipment to produce ultra-high-strength steel alloy structural components.

Let us tell you how our facilities and experience can work for your engineering and production departments.

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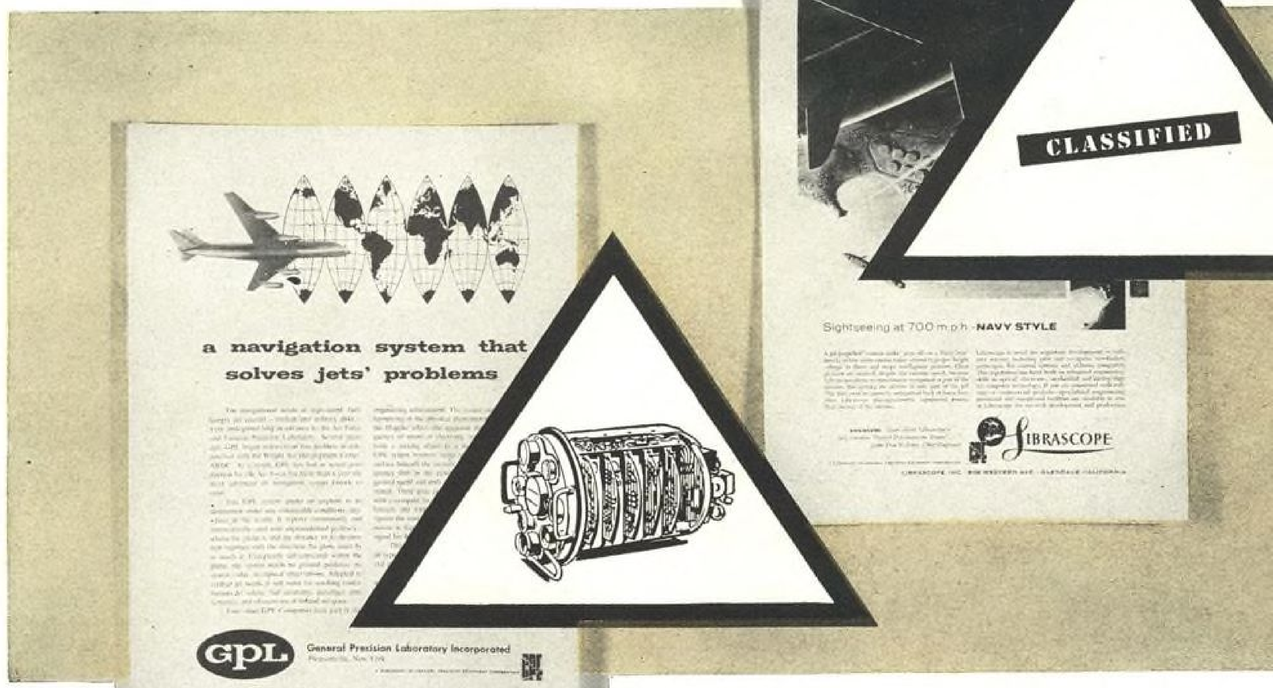
Sales offices in Seattle, Los Angeles, Fort Worth-Dallas and Levittown, L. I.



TECHNOLOGICAL BENCH MARKS

GPE

AERONAUTICAL SYSTEMS have made vital contributions to the progress of jet aviation and its expansion into the civil transport field. Many have won recognition as the finest in the industry, bench marks of American technology.

Whole generations of airmen, for instance, have been trained in flight simulators developed and produced by Link, pioneer of on-the-ground flight training. This GPE Company has delivered over 800 jet flight simulators—more than all other manufacturers put together. It has just been selected, on the basis of superior technology and equipment, to produce America's first simulators for jet air liners. Link-developed DC Computer Systems in Link supersonic simulators are the only ones meeting the needs of these advanced aircraft.

Equally dominant are the gyro-magnetic compass systems of Kearfott, another GPE Company. This company's new lightweight J-4 Compass System weighs only 18 pounds. Yet it provides accurate heading information at all latitudes, is rugged enough to maintain its high accuracy despite the jolts and speeds of jet flight. The Air Force has just selected it as standard for all new fighter craft. Kearfott's N-1 Compass System has been the navigational standard for Air Force bombers for 5 years.

Still another member of the GPE Group, General Precision Laboratory, has developed and is currently making quantity deliveries of the most advanced airborne navigation systems in use. These GPL systems, which are self-contained and fully automatic, have flown millions of operational miles with unprecedented accuracy. Their adaptations to civilian jet needs—GPL's RADAN Systems—are expected to make equally far reaching contributions to the commercial jet transport field—in the way of increased safety, fuel economy, passenger convenience and efficient use of limited air space.

These are but some of the accomplishments in aviation for which GPE Companies, working in conjunction with the Armed Services, are responsible. Librascope, an important member of the Group, produces outstanding instruments and equipment for the field. Librascope's computers, its highly advanced equipment for photo-reconnaissance work and photogrammetric equipment for the interpretation of photo data, its periscopes, pilot and navigator finders, are all leaders. Several GPE Companies are deeply involved in inertial guidance, guided missile projects and certain nuclear power applications.

In all GPE achievements in the numerous industries in which the companies work, GPE Coordinated Precision Technology plays an important part by inter-relating the wide range of skills and resources of the Group. This operating policy, and each company's unremitting insistence on highest quality, are major reasons for the frequency with which GPE systems and equipment continue to set standards in their fields.

GENERAL PRECISION EQUIPMENT CORPORATION

92 GOLD STREET, NEW YORK 38, NEW YORK

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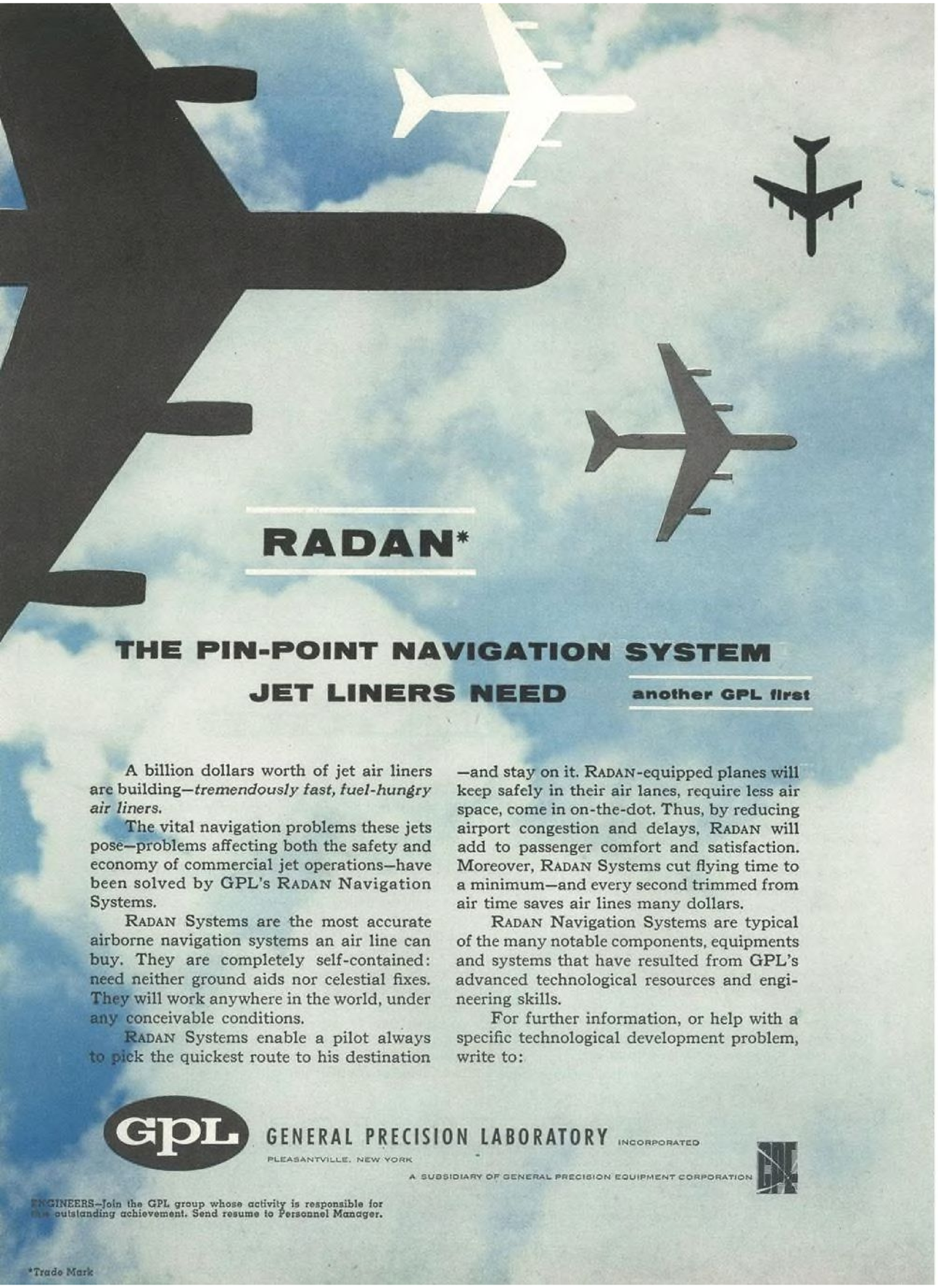

RADAN*

THE PIN-POINT NAVIGATION SYSTEM JET LINERS NEED

another GPL first

A billion dollars worth of jet air liners are building—*tremendously fast, fuel-hungry air liners.*

The vital navigation problems these jets pose—problems affecting both the safety and economy of commercial jet operations—have been solved by GPL's RADAN Navigation Systems.

RADAN Systems are the most accurate airborne navigation systems an air line can buy. They are completely self-contained: need neither ground aids nor celestial fixes. They will work anywhere in the world, under any conceivable conditions.

RADAN Systems enable a pilot always to pick the quickest route to his destination —and stay on it. RADAN-equipped planes will keep safely in their air lanes, require less air space, come in on-the-dot. Thus, by reducing airport congestion and delays, RADAN will add to passenger comfort and satisfaction. Moreover, RADAN Systems cut flying time to a minimum—and every second trimmed from air time saves air lines many dollars.

RADAN Navigation Systems are typical of the many notable components, equipments and systems that have resulted from GPL's advanced technological resources and engineering skills.

For further information, or help with a specific technological development problem, write to:

GPL GENERAL PRECISION LABORATORY INCORPORATED

PLEASANTVILLE, NEW YORK

A SUBSIDIARY OF GENERAL PRECISION EQUIPMENT CORPORATION

ENGINEERS—Join the GPL group whose activity is responsible for this outstanding achievement. Send resume to Personnel Manager.

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Since the early "Bumblebee" program Bendix-Pacific has been developing and producing highly perceptive Sensing, Command and Hydraulic Systems for virtually all types of missiles. This Division's extensive experience in hydraulics, airborne radar and other specialized electronic fields assures the mature development of the RIGHT system for each application.

POWER PACKAGES

Bendix-Pacific designs and manufactures missile sub-systems. Pictured is an air driven hydraulic and electrical power unit complete with guidance servo valves, cylinders and potentiometers manifolded into a single unit.

SERVO VALVES

Bendix-Pacific Two Stage High Response Servo Valves are electrically actuated hydraulic four-way valves. They are small in size, light in weight, and incorporate advanced design features which, in addition to providing excellent overall performance, assure greater stability at wider operational temperature ranges with exceptional reliability with respect to null shift.

TELEMETERING

Bendix-Pacific pioneered and continues today to be the largest and most important source of subminiaturized electronic instrumentation for accurate in-flight test evaluation of missiles and aircraft. Bendix-Pacific has adopted transistors and other developments in its airborne systems. Complete receiving stations also are available.

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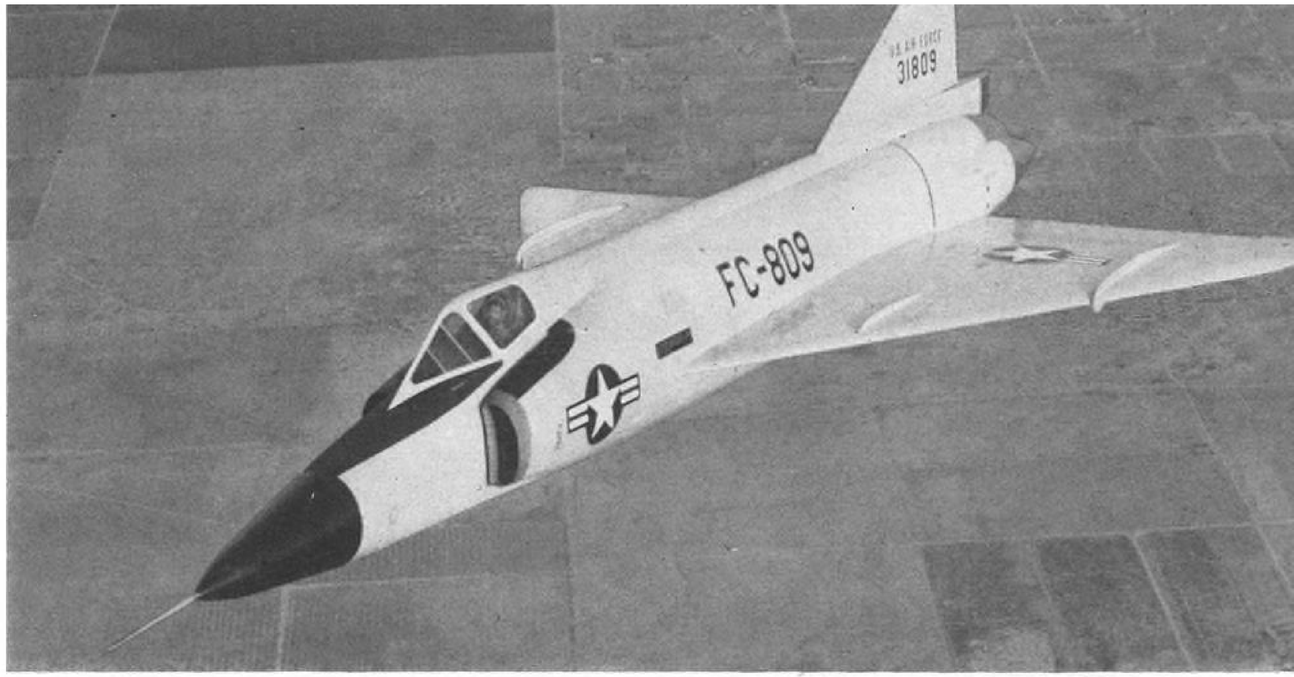
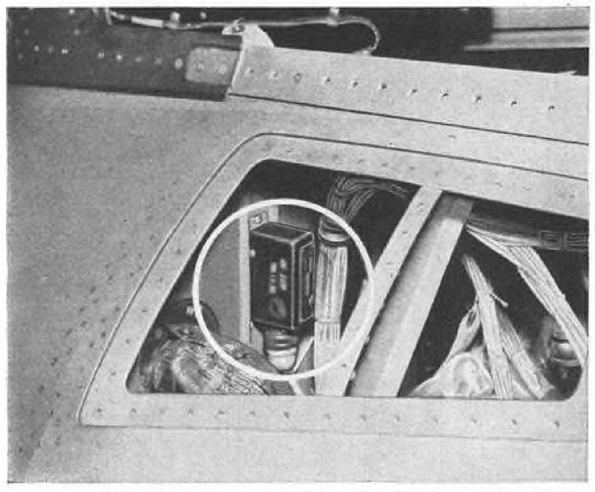
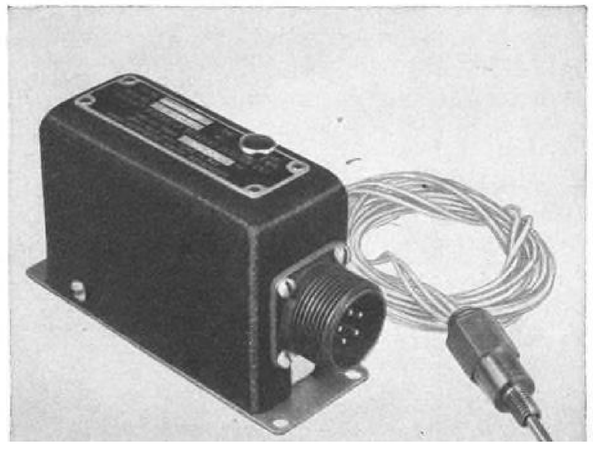
CANADIAN DISTRIBUTORS: AVIATION ELECTRIC, LTD., MONTREAL 9 • EXPORT DIVISION: BENDIX INTERNATIONAL, 205 E. 42nd ST., NEW YORK 17



IN THE CONVAIR F-102A, the Fenwal Thermistor Over-Heat Detector, 81000 Control, warns the pilot if the windshield becomes overheated. The windshield in the Convair F-102A is heated with hot air. At extremely low temperatures this serves to raise the temperature of the windshield and prevent fogging. If the air continues to heat the windshield after coming from the low temperature area, the Fenwal thermistor unit prevents the danger of the glass cracking by warning the pilot to turn off the heat.



THE THERMISTOR OF THE FENWAL 81000 is located in the tip of a spring loaded probe which conveniently screws into one of the positions normally occupied by one of the screws which hold the windshield in place. The spring loaded probe extends into the inner glass surface and laminated portions which form the center of the laminated "sandwich."



HOW FENWAL'S THERMISTOR OVER-HEAT DETECTOR PROTECTS CONVAIR'S F-102A

The Fenwal Thermistor Over-Heat Detector gives quick, dependable response to temperature changes in a variety of aircraft applications. Its compact size and light weight, plus conformance to applicable military specifications, may be the answer to one of your temperature control problems.

Write for complete data to **Fenwal Incorporated, Aviation Products Division, 128 Pleasant Street, Ashland, Mass.**

Fenwal Controls Temperature ... *Precisely*

THE FENWAL 81000 CONTROL UNIT consists of a black crackle finished aluminum housing with a five pin male receptacle for connecting the power supply, a thermistor probe, and an indicating device. The unit features an adjustable potentiometer that is accessible through the top and has a hermetically sealed relay with all components coated with a fungicide varnish.

It has an input of 20-30 volts D.C. at .05 amperes maximum. Load contacts are rated at 30V. D.C. at 2 amperes maximum: non-inductive. The adjustable range of the unit is 170°F ±10°F, to 270°F ±10°F. It has a temperature differential of 10°F maximum over adjustment range, maximum storage temperature of 212°F and operating temperature range of −65°F to 160°F. Total weight of probe and control unit is less than 0.5 lb.

. . protects aircraft wiring systems

NON-ABRASIVE, LIGHTER WEIGHT
Lighter than metal, these smoothly molded nylon grommets will not cause insulation wear and will not roll out when threading.

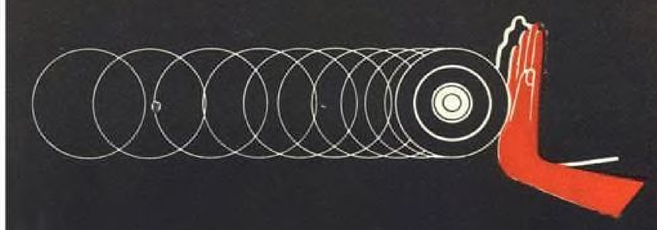
HIGH HEAT RESISTANCE
Will withstand unusually high temperatures without loss of useful characteristics.

Monadnock's new nylon grommet is available in standard sizes (from 3/16" to 3" installed inside diameter) for use in round holes or special grommets can be manufactured in volume to fit irregularly shaped holes. Samples and additional information from your nearest United-Carr or Monadnock Mills representative, or write for illustrated data sheet.

EASILY INSTALLED, SNAG-PROOF
Split allows installation of grommet before or after wiring. 45° angle prevents wires from lodging.

CHEMICALLY INERT, LONG WEARING
Nylon grommets will not react with spilled fuels, chemicals or hydraulic oils.

MONADNOCK MILLS
San Leandro, California
Subsidiary of UNITED-CARR FASTENER CORP.



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The *Accepted* Anti-Skid Braking System *Standard Equipment* on the B-47, B-52, B-66, A3D, RF-84F, F-100C&D, F-107, C-133A, C-130A. Tested on thirty-five other types of aircraft.

FUEL GATE VALVES

All standard sizes. Moving seals are teflon. Sealed actuator protects motor. Explosion proof.

4 good reasons why...

every fighter, every bomber, every transport is HYDRO-AIRE *Inc.* *equipped*

3000 WINONA AVE., BURBANK, CALIF.

the aviation subsidiary of CRANE *Co.*

HOT AIR VALVES

Types include solenoid pilot valves, pneumatically operated hot air valves, motor operated butterfly valves.

HY-V/L FUEL PUMPS

High vapor/liquid ratio fuel booster and transfer pumps. Outstanding performance . . . exceptional economy. Now flying on the F8U-1, F-101A, F-5D, B-52, the Regulus, the Navaho.

Precision Parts by the Yard!

By the Harper extrusion method using glass as a lubricant, it is possible to form intricate parts as rapidly as you squeeze toothpaste out of a tube.

Besides carbon steels, alloy steels and specialty bronze, the Harper Company also extrudes titanium, stainless steel and heat-resistant alloys.

Here are some of the advantages:
- Die costs are low
- Small orders are practical
- Machining is reduced or eliminated
- Close tolerances are held
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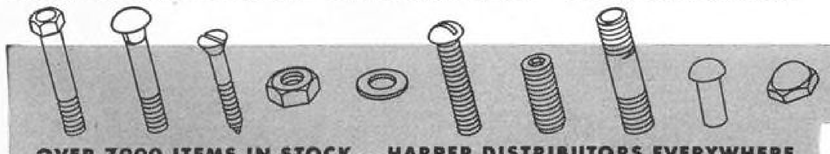

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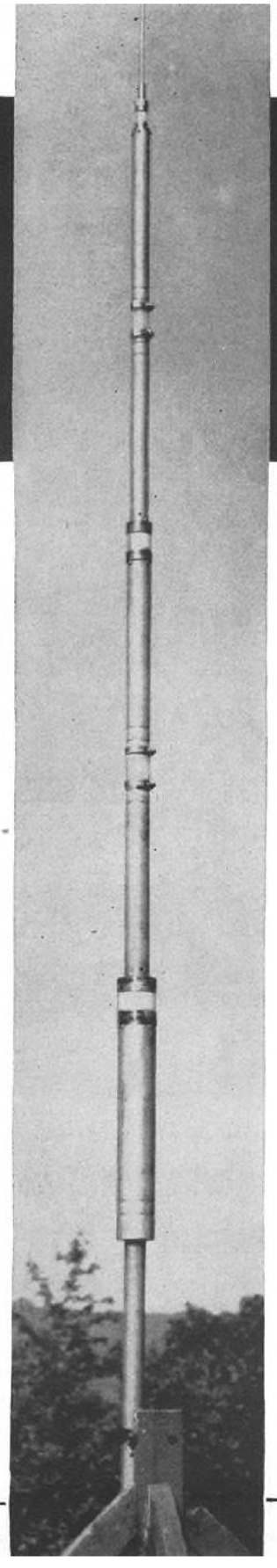

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In such critical applications where superior strength, uniformity, dimensional accuracy and corrosion resistance are needed, Shelby Seamless Tubing of USS Stainless Steel is consistently chosen to meet the requirements. Shelby Seamless Tubing, available in a wide range of diameters, wall thicknesses, various shapes and steel analyses, is produced to exacting standards by the world's largest manufacturer of tubular steel products. If you wish, our engineers will make a study of your requirements, and will help you apply Shelby Seamless Steel Tubing to your specifications.

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*CERAMETALIX Bendix brake stator faced with Cerametalix—an entirely different kind of friction material. Cerametalix is a sintered compound of ceramic and metallic ingredients that has amazing resistance to heat and wear. As a result, friction loading and energy absorbing capacity can be approximately doubled.

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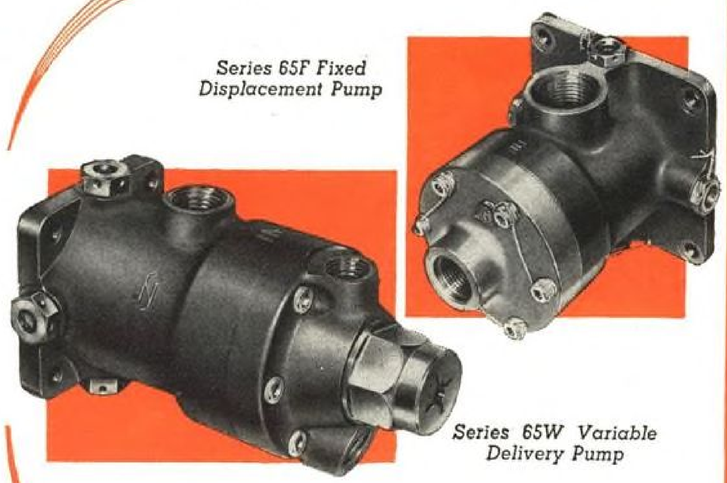

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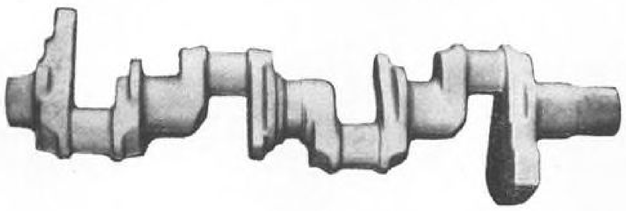
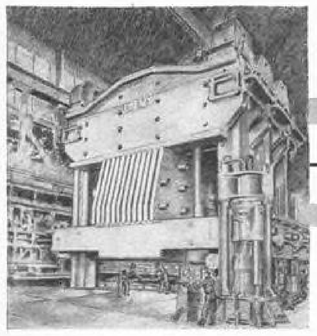
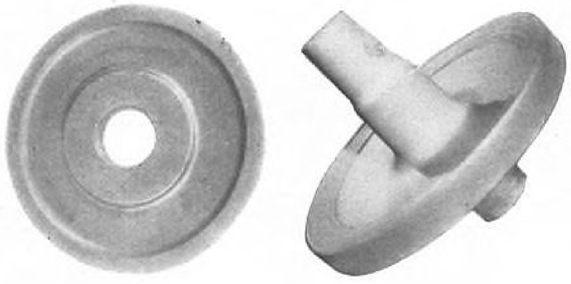


The crankshaft is the backbone of the piston-type engine. Illustrated above is the crankshaft forging for the most powerful piston-type aircraft engine ever produced.



The history of Wyman-Gordon's contribution to aircraft progress dates from the inception of the "flying machine". The jet age is now calling on the unparalleled resources of Wyman-Gordon, which include the widest range of hammer and press equipment and the greatest technical know-how in the industry. Larger and more intricate forgings than heretofore available of aluminum and magnesium are being produced on presses up to 50,000 ton capacity, and giant hammers are fulfilling the growing need for forgings of titanium, high density materials or so-called super alloys. Now, as for nearly 75 years, there is no substitute for Wyman-Gordon experience and ability for — Keeping Ahead of Progress.

At the bottom left is a turbine disc forging made from high density heat resisting alloy, and next to it is a titanium compressor wheel forging for two of the most powerful jet engines yet produced.



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3) Checks thermocouples within the harness for continuity.
4) Checks thermocouples *and* paralleling harness for accuracy.
5) Checks resistance of the EGT circuit *without the EGT indicator*.
6) Checks insulation of the EGT circuit for shorts to ground and for shorts between leads.
7) Checks EGT Indicators (in or out of the aircraft).
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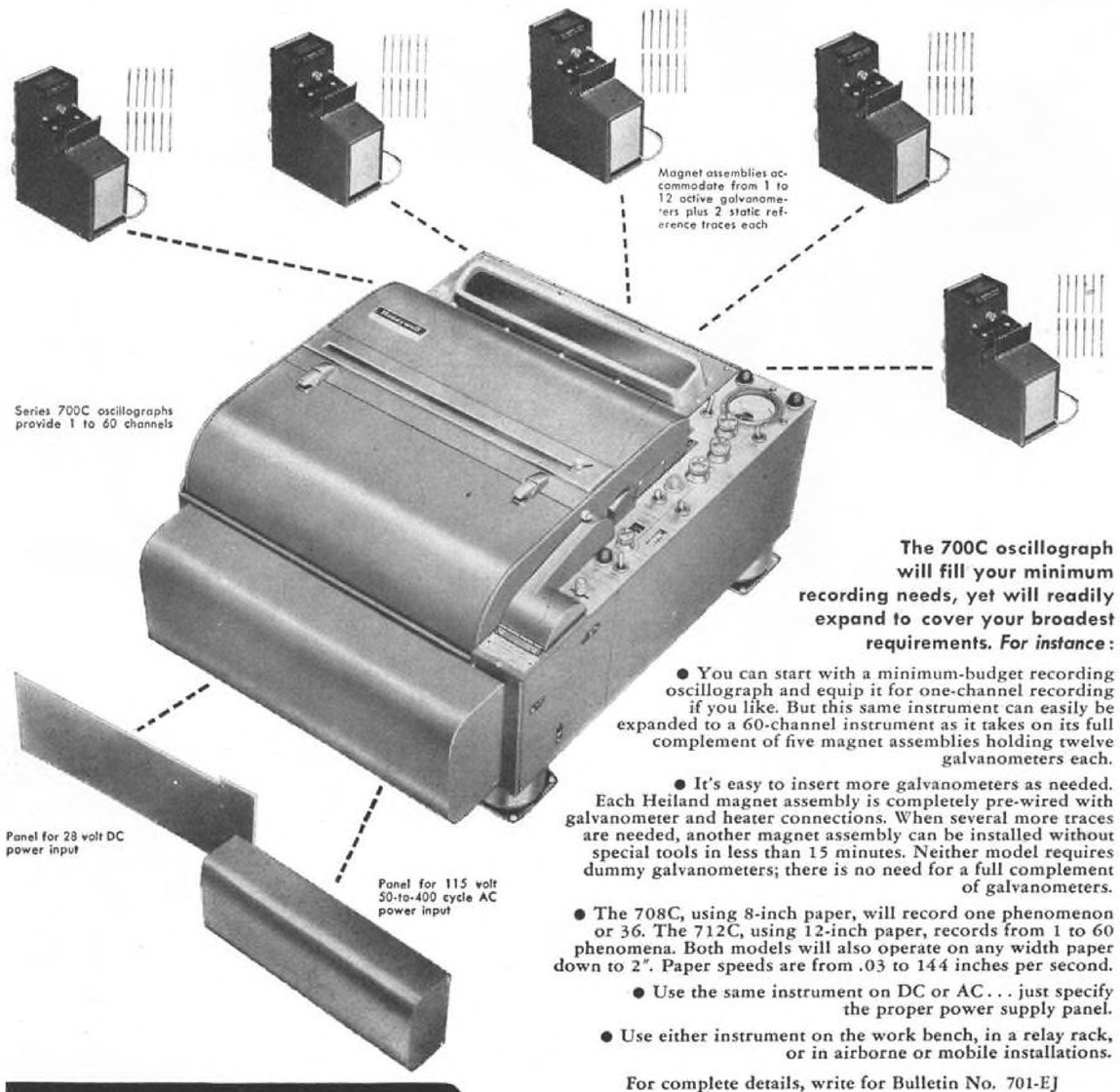

The 700C oscillograph will fill your minimum recording needs, yet will readily expand to cover your broadest requirements. *For instance*:

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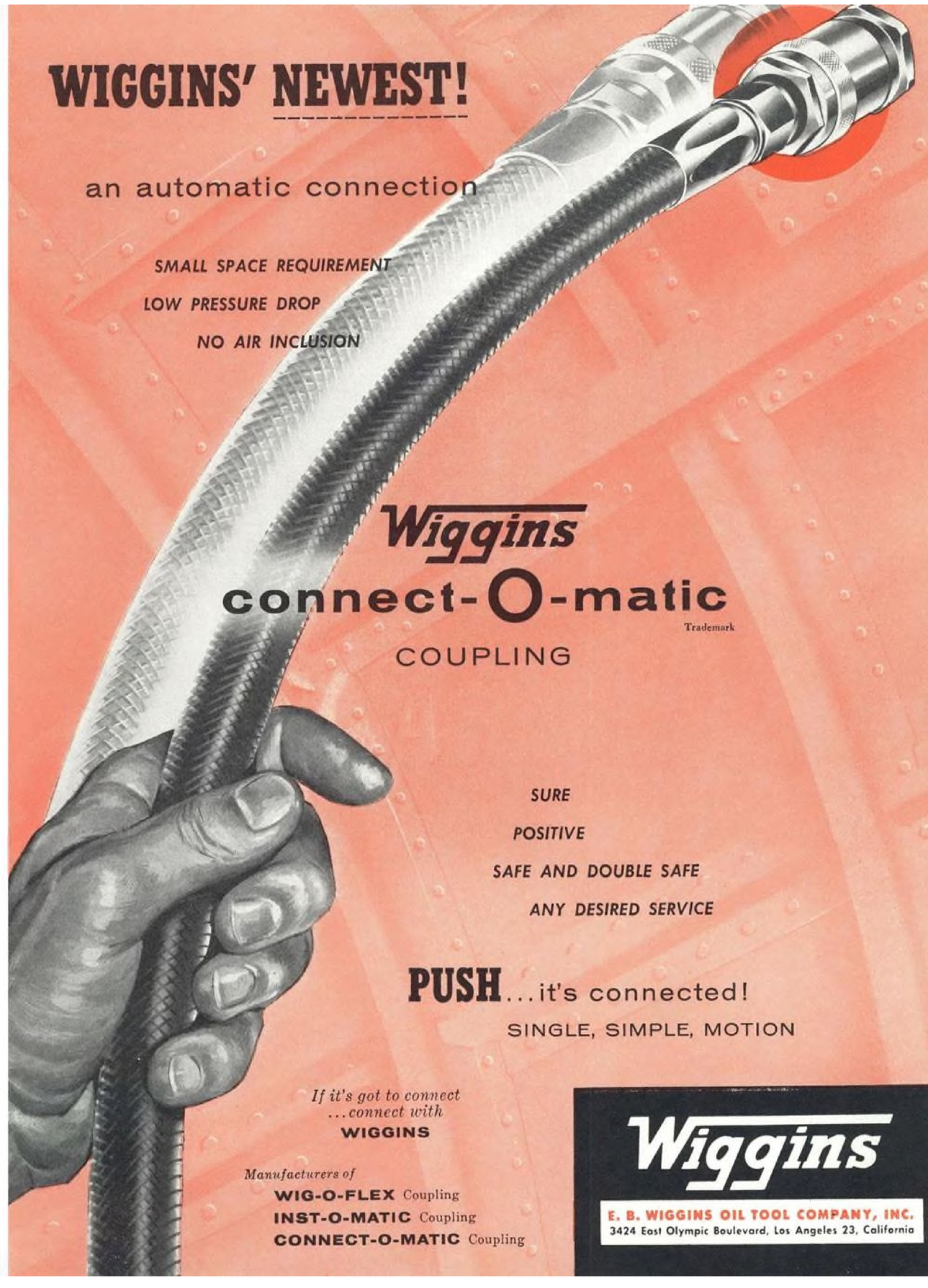

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August 6, 1956
Volume 65
No. 6

AVIATION WEEK

AIR RESEARCH AND DEVELOPMENT COMMAND EDITION

● COVER: Northrop Snark Firing at Patrick AFB

ARDC DOCUMENTARY REPORT

This special Air Research and Development Command Edition of Aviation Week was prepared for the U. S. Air Force and the industry and science that serve it. It is a documentary report on the major policy changes and new problems that guide the technological race to produce superior airpower.

Aviation Week editors traveled 80,000 miles by air in executing this assignment. They covered ARDC headquarters in Baltimore and all of the 11 research, development and test centers and interviewed hundreds of ARDC officers and civilian scientists. In this effort, they received complete and effective cooperation from Lt. Gen. Thomas S. Power, ARDC commander and his staff.

A Message from ARDC

There is no person in this country who is not, directly or indirectly concerned with the race for qualitative supremacy in the air—the keystone to our survival as a free and prosperous people.

To achieve and maintain such supremacy, the United States Air Force has created a management tool unique in the history of military warfare—the Air Research and Development Command.

In the accomplishment of its vital mission, ARDC has joined forces with other Air Force commands and government agencies, with American science and industry, to create the greatest team ever assembled for one single purpose—qualitative superiority for the Air Force-in-being as well as the Air Force-to-be.

It is difficult to grasp the vast scope and full significance of ARDC's over-all effort without a complete and detailed knowledge of the individual and varied efforts of its far-flung research, development and test centers.

Nor is it sufficient merely to cite statistics about these centers, no matter how impressive they may be. For ARDC's uniqueness is founded on the manifold talents of its personnel and the unusual nature of its facilities as well as on the manner in which these talents and facilities are welded into an effective operating system.

In providing a comprehensive account of ARDC, its concept and its mission, AVIATION WEEK is, therefore, rendering an invaluable service, not only to ARDC itself and to its teammates but, above all, to ARDC's 160 million stockholders—the American people.

Thomas S. Power

Thomas S. Power, Lieutenant General USAF
Commander, Air Research and Development Command

The Critical Race for Research

RESEARCH AND DEVELOPMENT in the broad technical fields that are now encompassed by aerial weapon systems is one of the most important investments citizens of the United States can make in the future of their country.

The airpower research and development investment offers a dual return.

First, it is necessary to develop aerial weapon systems of sufficient superiority that will offer the hope of deterring any potential aggressor. In the event that this hope fails, it is the quality of these aerial weapon systems that will determine the degree of success with which this country will be defended.

Second, the progress made through sustained effort on broad scientific fronts required for the airpower program will produce a steady stream of improved technology that can be applied to the civil aspects of American industry. Nuclear power, electronics, new materials such as plastics and titanium, and civil air transport are just a few of the many civilian industrial by-products of military airpower research.

CRITICAL PHASE

WE HAVE NOW REACHED A CRITICAL PHASE in the airpower research and development program. For the first time in 15 years we are again being challenged by an aggressive foreign philosophy that is attempting to develop superior military airpower to promote its economic and political philosophies. At the same time we have reached a point where our legislative and administrative procedures can no longer match the rapid pace of technological progress and are artificially restricting our potential pace of development.

We are also facing the consequences of two decades of furious technological development that has virtually drained the reservoir of basic scientific knowledge. Major advances on all the broad fronts of science are desperately needed to keep pace with the demands of the technological race.

All of these factors combine to produce a situation unique in the history of this country. This requires new and fresh approaches by the military, industry, legislators and tax-paying citizens to work together toward efficient and economical achievement of the common goal of maintaining and increasing our margin of technical superiority, particularly in the vital areas of atomic-airpower.

One of the most hopeful trends in this direction was the Air Force recognition of the problem by creating the Air Research and Development Command five years ago. In its five year history ARDC has been aware of the necessity for basically new organizational, fiscal, industrial and technical approaches to these problems.

CHANGES NEEDED

IN THE FOLLOWING PAGES of this special Air Research and Development Command edition, the editorial staff of AVIATION WEEK is presenting a documentary report on how ARDC molded its unique military-industry-science partnership and the new policies that guide their work.

Among changes in basic policy that are necessary to achieve enduring success in the technological race are:

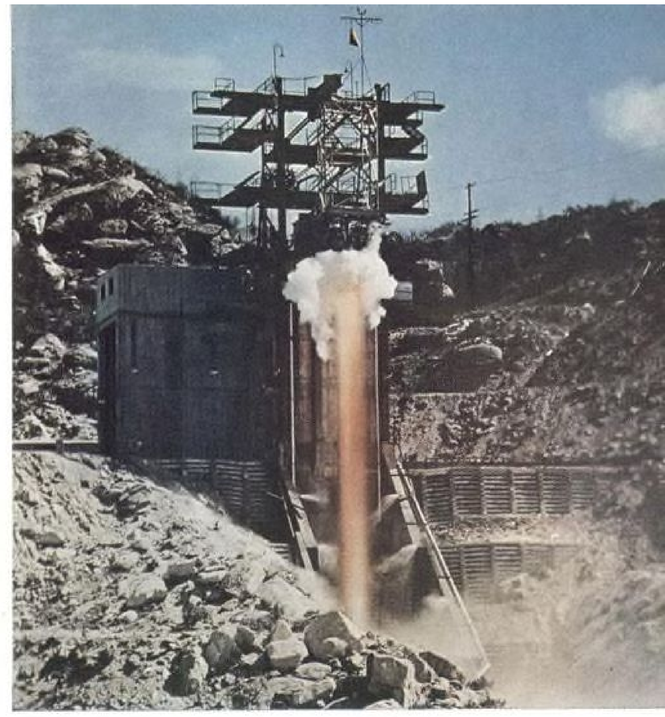
- **Long term fiscal** and technical planning policies that are more flexible than the current annual budgetary system.
- **Increased emphasis** on basic research and "state of the art" advancements in particular scientific fields related to aerial weapon development.
- **Adequate planning,** funding and construction programs for development and test facilities that will be required for future technology and would be far too costly for private industrial financing.
- **Increase in the percentage** of its resources that private industry devotes to basic research and development activity.
- **Increased emphasis** on technical education of American youth.

Achieving success in the technological race is a vital concern of every American citizen. The future of our country depends on it.

—Robert Hotz

BELL X-2 rocket aircraft explores heating problems at Edwards AFB. Note blunt trailing edges of ailerons. Its pilot is . . .

LT. COL. Frank K. (Pete) Everest, operations chief



ROCKET test stand anchors powerplant for a future USAF missile

Air Research and Development Command Gives USAF

Wright Air Development Center

Rome Air Development Center

Air Force Armament Center

Air Force Special Weapons Center

Weapons of Future

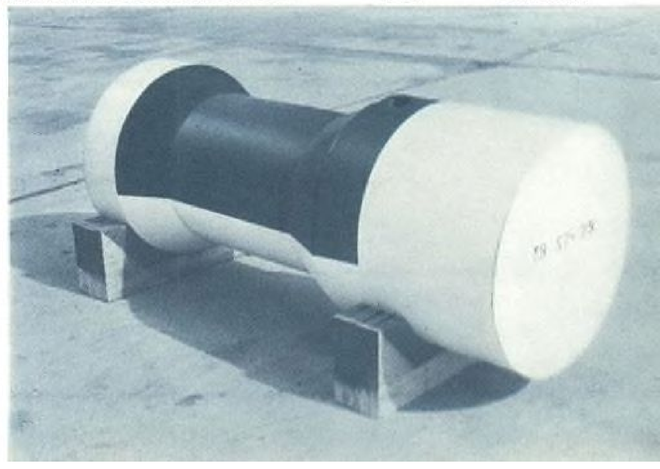
4925th Test Gp. (Atomic), Kirtland

Air Force Missile Test Center

ARNOLD Engineering Development Center, Tullahoma, Tenn., provides modern test facilities for ARDC contractors

CONTRAVES cinetheodolite pinpoints plane in space

ARMA-WADC's tail defense for B-52 'BLUFF' bomb shape

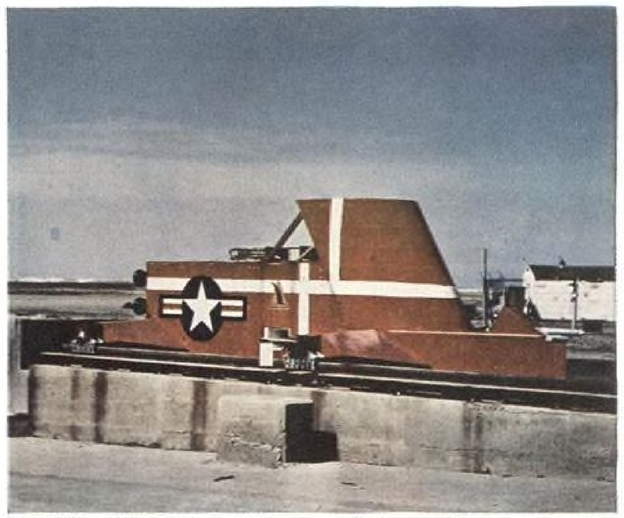


BALLOONS implement research in aeromedicine, geophysics

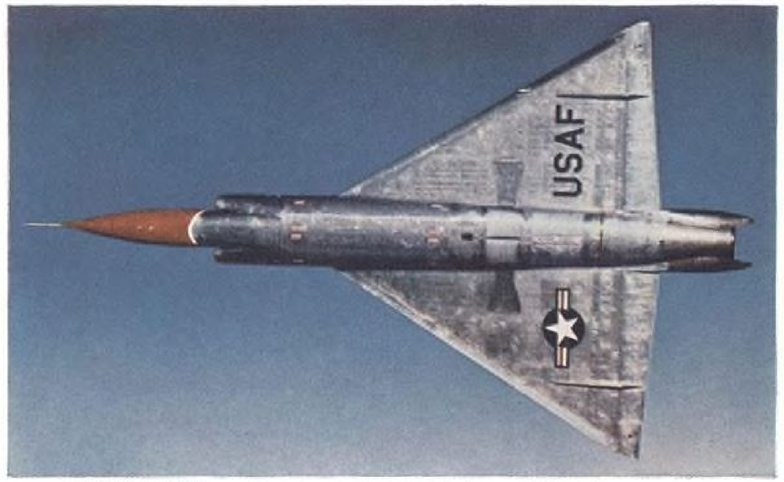
HOLLOMAN ADC tests higher-performance TM-61B Matador

McDONNELL F-101A Voodoos at Flight Test Center, Edwards AFB, Calif., where all USAF planes undergo complete evaluation

ANTENNA at Rome ADC permits co-location of TACAN, VOR



NEW SLED at HADC is designed for aeromedical research



CONVAIR F-102A goes through one of seven test phases at Edwards

FALCON missiles streak from Northrop F-89H

CONVAIR-BUILT rocket sled at AFFTC tests rain erosion on aircraft and missile parts at speed above Mach 2

Progress Proves ARDC's Mission Vital

The U. S. Air Force is riding the crest of a technological development surge that began with nuclear fission and airborne gas turbine power and shows no signs of abating. To speed the pace of this surge and to shape its character to the requirements of airpower, USAF five years ago created the Air Research and Development Command—a technical management tool unique in military history.

ARDC's job is to insure qualitative superiority of USAF's new weapons and to provide the necessary link between military requirements and the vast science-industry complex of which USAF must rely to discover, develop and produce its weapons for the future.

After five years of growing pains and constant improvement of its managerial techniques ARDC today is a cohesive organization that has integrated and expanded all of USAF's once scattered research, development and test facilities and operates according to well-defined plans and principles.

Commanded by Lt. Gen. Thomas S. Power, ARDC now has its headquarters in downtown Baltimore but is scheduled to move eventually to Andrews AFB, Md. on the outskirts of Washington, D. C. Field operations are executed through 11 centers equipped with $2½ billion worth of research, development and test facilities that are used both by USAF and its industrial and scientific contractors.

"ARDC's basic philosophy is to function as a manager and monitor of the Air Force research and development program and to rely on universities, scientific laboratories and private industry to do the bulk of the job," Gen. Power told AVIATION WEEK.

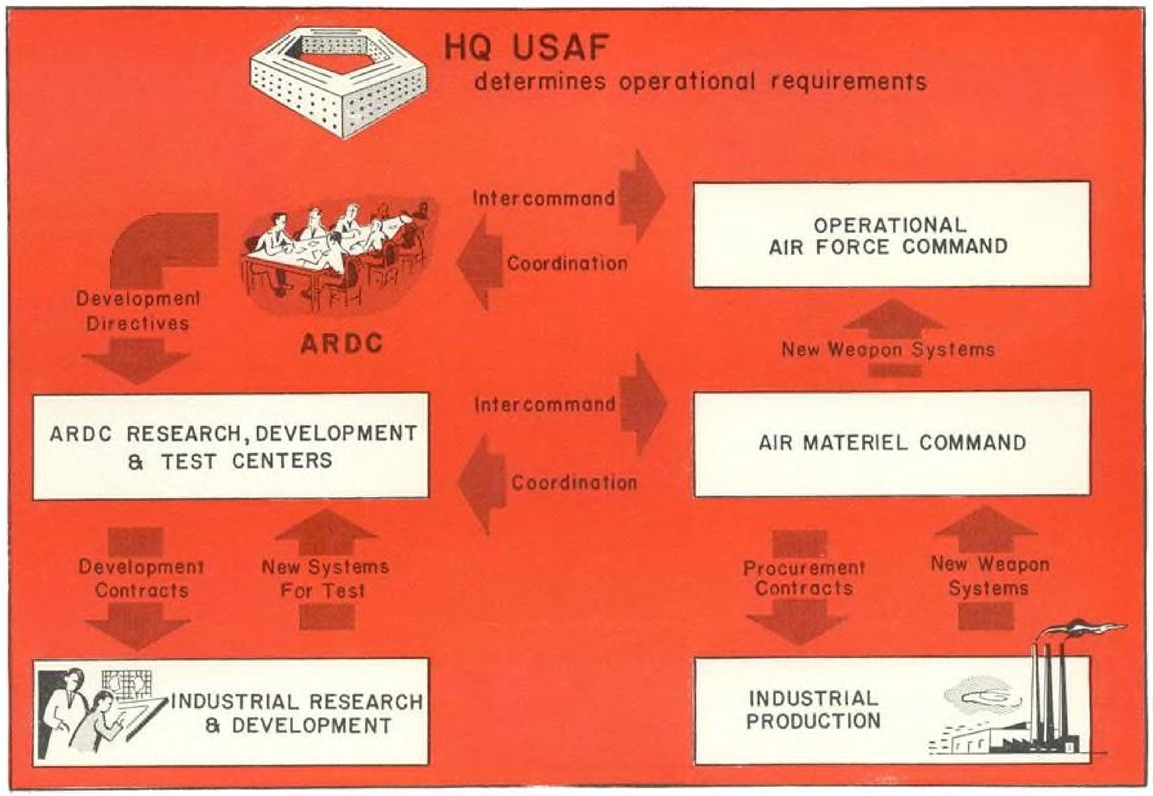
"We do only enough research and development work in ARDC laboratories and centers to maintain a technical competency in our required fields and to tackle problems that are so specialized for USAF requirements that there is no outside interest in handling them."

Since its organization in Dayton five years ago ARDC's job has grown more complex and important due primarily to the following factors:

• **Increasing pace of technological development.** Progress in the scientific fields related to aerial weapon development during the past 15 years has been increasing in geometric progression. The faster the progress, the greater the effort required to maintain the pace and the greater the opportunities offered for achieving major scientific breakthroughs. One top USAF research official told AVIATION WEEK: "We are trying to make more progress in the next five years than in the first 50 years of powered flight."

• **Increasing technical complexity of future aerial weapons.** Dr. John von Neumann, chairman of the Defense Department Ballistic Missile Advisory Committee has pointed out that the development of either the intercontinental ballistic missile or the nuclear powered bomber is infinitely more complex than the development problem involved in getting the first atomic bomb. Yet USAF is tackling both these problems, along with many others of equal complexity, all at the same time.

• **Increasing competition the technological race.** Shortly after ARDC was organized in April, 1951 Soviet jet aircraft burst into the Korean war scene with performance that astonished Western observers. Since then the Soviets have demonstrated a rapidly increasing technological capability to push a modern aerial weapon system development program over the complete range of types from helicopters and transports to long-range turbojet and turboprop bombers and supersonic fighters.



Soviet Airpower Status

At the same time the Soviet development of atomic and hydrogen-bomb weapons has exceeded Western predictions by a wide margin. There is little question among observers who recently inspected Soviet air force equipment in Russia that they are still slightly behind Western technical development in aircraft, although they are probably ahead in ballistic missiles.

Nor is there any question among these observers that unless the pace of USAF developments is accelerated and its scope expanded the Soviets will be presented with an excellent opportunity to equal or surpass Western airpower during the next five years. ARDC is in direct competition with the Soviet atomic-airpower technical development program.

ARDC is gearing its operations to achieve three principal goals for USAF:

• **Improve quality of future USAF weapons.** This is effort devoted to making big technological jumps by daring, imaginative research programs aiming at major scientific breakthroughs.

• **Increase reliability of weapons** that are ready to go into USAF's active combat inventory. This effort is aimed at translating new equipment whose feasibility has been proved by research results and development work into standard production-type products with a sufficiently high degree of performance reliability to be trusted in routine operations. In the past USAF operational commands have suffered heavily from unreliable components or sub-systems that put an entire weapon system out of action.

• **Reduce the development cycle** for new USAF weapon systems. This effort is aimed at drastically cutting the time required to translate a new weapon system concept into reliable hardware ready for production. This problem involves as much streamlining of administrative and command procedures as it does improving technical facilities.

New Policies

To drive harder and faster toward these goals ARDC has developed several basic new policies during the past year. These include:

• **Closer partnership with industry and science.** ARDC policy changes have been aimed at bringing properly qualified industrial and scientific organization into USAF technical planning at the earliest possible phase and keeping a steady flow of pertinent information on ARDC and USAF technical problems and progress to universities, private research groups and industrial organizations. Details of this program involving release of USAF technical planning documents and scientific symposiums sponsored by ARDC are described in the Weapon Systems Management section.

• **Increased emphasis on exploratory research.** Before the creation of ARDC and during its early history an overwhelming portion of USAF's research and development effort was concentrated on development problems of current hardware and only a very small portion was allocated for exploratory research. In its new philosophy of aiming for major scientific breakthroughs that make possible huge improvements in weapon system quality, ARDC now is placing heavy emphasis on fostering a broad exploratory research program utilizing available resources in its own centers, but relying principally on civilian scientists working under ARDC contract both in the United States and in Europe.

Details of the expanded research program are described in the Exploratory Research Section.

• **Long-range planning.** It is obvious that proper direction of a research and development program requires long-range planning in the 10- and 20-year brackets.

A Long-Range Planning Section has been established in ARDC headquarters, headed by Col. J. W. Carpenter III, and six technical committees covering the following broad fields:

• **Aircraft, headed by Brig. Gen. Howell Estes.**

• **Missiles and space vehicles, headed by Maj. Gen. D. N. Yates.**

• **Electronics, headed by Brig. Gen. Thomas L. Bryan.**

• **Aero-sciences, including guidance, control, armament, nuclear, bio-sciences and human factors and headed by Maj. Gen. Edward P. Mechling.**

• **Propulsion, headed by Maj. Gen. Donald J. Keirn.**

• **Materials, headed by Brig. Gen. Marvin C. Demler.**

These long-range planning technical committees are staffed by the top military and civilian experts in ARDC in their respective fields. Their job is to determine the probable technical advances in each field over a 10-20-year time span with each specific development time tagged as closely as possible and then draw up an ARDC operational plan to provide the necessary resources to foster these new technical achievements and turn them into useful USAF inventory equipment.

Each of these committees has been given six months to make its first report and most of them are scheduled to fall due next month.

At that time they will present detailed charts of potential and probable technical progress over the next two generations and what resources in funds, manpower, facilities and management ARDC will need to handle them properly.

Functional Commanders

ARDC headquarters is now organized under three functional deputy commanders:

• **Research and Development**—Brig. Gen. Marvin C. Demler holds this post and supervises the directorates of engineering, development and research. Primary concern of the groups operating under Gen. Demler is the USAF of tomorrow. Their work ranges from purely exploratory research aimed at generating new concepts to technical development aimed at proving the feasibility of utilizing these new concepts in weapon systems development and developing actual performance design criteria for new types of hardware that can be applied in new systems.

• **Weapon Systems**—Maj. Gen. Albert Boyd is deputy commander in this field.

Lt. Gen. Donald L. Putt, Deputy Chief of Staff for Research and Development, USAF . . . Military Director of the Scientific Advisory Board . . . born Sugarcreek, Ohio, 1905 . . . learned to fly 1929 . . . engineering degrees from Carnegie Institute of Technology and California Institute of Technology . . . held engineering and intelligence posts with Air Materiel Command . . . served in Hq. USAF posts . . . joined ARDC in January 1952 . . . served as vice commander, ARDC, and commander, Wright Air Development Center . . . commanded ARDC, July 1953 to April 1954 . . . member Institute of Aeronautical Sciences, National Inventors Council, National Advisory Committee for Aeronautics, Society of Naval Architects, National Research Council, Marine Engineers.

Work by his groups at ARDC headquarters and at the Weapon Systems Project Offices at Wright Air Development Center concerns USAF today—providing new combat-ready weapon systems ready to be added to the active inventory at specific dates.

• **Resources**—Brig. Gen. Kurt M. Landon supervises the groups that are responsible for supporting the main technical missions of ARDC by planning and providing the major resources required such as manpower, special development and test facilities, special aircraft and financing programs.

ARDC also has two special deputy commanders who organized special management structures pushing high priority projects at top speed. They are the deputy commander for ballistic missiles, Maj. Gen. B. A. Schriever, who also commands the Western Development Division in a unique management effort to speed ballistic missile development, and the deputy commander for nuclear systems, Brig. Gen. Ralph Wassell, who is sparking a similar high priority development push for nuclear powered aircraft.

One of the most significant things in recent ARDC history has been the clear cut separation of its long-range future developments from those devoted to immediate improvement of USAF weapon systems. This has laid the foundation for achieving major scientific breakthroughs in a wide variety of promising new fields and pushing state of the art development of new components and sub systems without retarding entire weapon systems.

Development Cycles

It involves a basically new approach to weapon system development. Formerly, the development philosophy was aimed at building a new weapon system from the ground up—developing new hardware for every facet of the system. This slowed development of the new system to the pace of its slowest and most complex component development and was a major factor in stretching out the development cycle.

ARDC ran a study on the development cycle of all weapon systems used by USAF since the beginning of World War II, comparing the contractor estimates of when a new weapon would be ready for service with the actual dates it was ready.

It was found that only one major equipment item had actually met its contractors delivery estimate during this period.

ARDC then analyzed the causes of the continual slippage in the development cycle of these weapons and developed new methods to avoid them in the future. Biggest problem involving a new weapon system was the use of equipment and sub-system developments that had no clear date of completion. As the availability of these developments receded into the future, the entire weapon system completion date slipped with them.

USAF RESEARCH & DEVELOPMENT PROGRAM FISCAL YEAR 1956

(In Millions)

BY DIRECT ALLOCATION TO ARDC	FY 56 Estimated Obligations
Research & Develop. Funds	
Aircraft & Related Equip.	176.0
Guided Missiles & Related Equip.	58.3
Ammunition & Related Equip.	10.5
Other Equipment	79.2
Military Sciences	62.9
Operations & Management	237.5
	624.4
Other Supporting Funds	
Military Construction	103.0
Hospitals	.86
Command Administration	6.5
Military Personnel	3.3
Reserve Personnel	.06
	113.72
PROCUREMENT & PRODUCTION FUNDS SUPPORTING R&D	
Aircraft	585.6
Missiles	1048.8
Components	549.0
Other Systems	17.5
	2,200.9
TOTAL	2,939.02

ARDC is now pursuing a philosophy of gearing its weapon system development only to components and sub-systems that have been brought to a state of feasibility and reliability sufficient to give them a definite availability timetag.

At the same time, ARDC is pushing state of the art development of new components and sub-systems harder and with a goal of taking bigger risks and biting off larger chunks of technical progress because of the freedom from time-tagged weapon systems. This philosophy is pushing state of the art development faster and will eventually provide a better flow of advanced subsystems and components that can be cranked into weapon system development.

High Risks, Big Gains

This state of the art development is aimed at taking high risks to achieve big technical gains, bringing a wide variety of programs along to the point where one or two indicate the technical gamble will pay off. These pay-off developments are then brought to a state of reliability sufficient to qualify for use in weapon systems. The other developments are either abandoned or kept going if they offer any hope of future pay-off. In the past, there has been too much of a tendency to push state of the art development too slowly trying to crank in reliability at the same time major technical progress was sought.

At the same time the high-risk, big pay-off philosophy dominates state of the art development programs, the high reliability factor dominates the weapon system development programs. Another major headache in past weapon system development has been the high degree of unreliability of certain components or sub-systems, mostly avionics, even after the weapon was in production and has been delivered to combat forces. By waiting until the component or subsystem reliability factor has been achieved before making it available for use in time-tagged weapon systems, it is hoped to avoid this pitfall of the past.

Pay-Off Promises

Among the vital areas in which a strong push on state of the art development promises major pay-offs are:

• **Materials.** The high speed ranges of both piloted aircraft and missiles make aerodynamic heating a major problem and require development of new heat resistant materials both externally for aircraft structures and internally for rocket, turbojet and nuclear powerplants.

• **Propulsion.** Although the turbojet revolution hasn't yet run its course, a wide variety of new propulsion methods have already appeared offering quantum jumps in improved performance. These include ramjets, rockets, nuclear powerplants and new combinations of these types such as the nuclear reactor driving a gas turbine or the dual cycle ramjet-turbojet. Development of new high energy fuels that may eventually replace the conventional hydrocarbons is also a promising line of investigation that should be pushed hard.

• **Guidance.** Revolutionary new techniques are required both for offensive and defensive long-range weapons. This is one of the critical fields where dependence on guidance developments pitched too far in the future has critically delayed delivery of reliable new weapon systems to the combat inventory.

• **Space.** A whole new reservoir of basic scientific information in this area is needed in addition to the active development of exploratory hardware for manned and unmanned space vehicles and research tools. Utilization of solar energy is another field where a major breakthrough is possible.

Although ARDC has integrated and expanded all of the former USAF research, development and test facilities into a team working together toward common goals, the pace of technological development has been so fast that development and construction of new facilities to do these jobs has become critical. Present legislative and budgetary procedures on authorization and funding of new research, development and test facilities can't keep pace with actual needs. New procedures are urgently needed so that the results of ARDC long-range planning groups can be implemented to provide these new type facilities at the time they will be needed.

New Facilities

Among the new type of facilities that technological progress now demands are captive missile test devices including both supersonic sleds capable of full-scale environmental missile testing and captive tests stands capable of full-scale missile system testing. Solar furnaces to produce the high temperatures necessary for missile and aircraft component testing, special facilities for testing high energy fuels, nuclear materials test reactors, equipment required to ground test nuclear aircraft powerplants and hypersonic test facilities are just some of the other major new facility jobs that ARDC is tackling in order to keep abreast of its development problems.

Another major problem facing ARDC in maintaining a technological pace sufficient to assure qualitative superiority of USAF weapons is financing. The USAF research and development program has been rolling along for the past three years at about a constant budget level despite some bookkeeping changes that have increased the amount now credited to the USAF Series 600 research and development account. These bookkeeping changes merely transferred maintenance and housekeeping funds required for research and development operations from scattered accounts to the Series 600 category. This constant level research and development budget has been imposed on USAF by the Defense Department. Unfortunately the pace of scientific progress has not remained constant to match this budget level. Instead, it has been increasing by geometric proportions that have so far outstripped this budgetary concept that the USAF development effort is actually losing ground in its effort to maintain the superiority pace.

Budget Handicap

The most serious effect of this artificial budget limitation on research and development effort is that it saddles USAF with a handicap in the international race with the Soviet competition which is operating with a blank check in atomic-airpower research and development areas. It also prevents ARDC and USAF from pushing hard in the promising new areas where major scientific breakthroughs and wide margins of technical superiority could be gained.

Richard E. Horner, acting Assistant Secretary of the Air Force for Research and Development since February of this year . . . Deputy for Requirements in that office, May 1955 to February . . . born Wrenshall, Minn., 1917 . . . aeronautical engineering degree, University of Minnesota, 1940 . . . master of science degree, Princeton University, 1947 . . . USAF pilot from 1940 to 1949, leaving service as a colonel . . . holds Silver Star, Air Medal with four Oak Leaf clusters, Presidential Unit Citation . . . general engineer and technical director at ARDC's Air Force Flight Test Center, Edwards AFB, Calif., from 1949 until 1955 . . . associated with aeronautical research and development since 1944.

One major effort of ARDC to keep up the pace despite this artificial budget handicap is to encourage private industry and research groups to exert more initiative and spend more of their own funds in this effort. Some progress is being made as a result of ARDC's effort to keep industry and scientific groups well informed on USAF future goals and current progress.

ARDC also confines its construction program to the type of facility that is too expensive to be financed by private industry and will be required by a large number of industrial contractors to test the development hardware.

Another problem area in which ARDC is showing better progress, is in development and retention of trained scientific personnel. Of the 38,000 people now in ARDC—this is 3½% of the total USAF manpower—about 30,000 are support personnel and only 8,000 technically trained personnel. As a result of Operation Bootstrap begun shortly after World War II to provide scientific training to combat proved young USAF officers, ARDC now has a good foundation of technicians in uniform but it has had to revise its personnel policies to hold them in the service in the face of lucrative offers from private industry.

ARDC recognizes that it faces a kaleidoscope of new organizational and management problems in trying to ride the surging tide of the technological revolution in atomic airpower. It recognizes that tradition will provide no solutions to problems of the future and is working hard to retain its organizational flexibility, fresh technical outlook and enthusiasm for its future tasks. ■

ARDC Research Program Titles

1. **Research on Conversion of Solar Energy**
   Research on conversion of solar energy for useful military purpose.
2. **Research on Sources, Extraction and Use of Chemical Energy**
   Efforts leading to new sources and new ways of extraction and use of chemical energy.
3. **High Energy Nuclear Research**
   Research on nuclear energy with concentration on study of high energy nuclear reactions.
4. **Research on New Energy Sources**
   Efforts to find and use new energy sources yet undiscovered.
5. **Research on the Electromagnetic Spectrum**
   Research on the electromagnetic spectrum for new ideas and usefulness of those already discovered.
6. **Research on Dynamics of Fluid Flow**
   Concentration on dynamics of fluid flow under extreme conditions.
7. **Research on Human Effectiveness**
   Research on the human and his reactions and environmental relationships.
8. **Research on Basic Materials**
   Efforts to find new basic materials having desirable properties and new uses for known materials.
9. **Research on Information Handling and Analysis**
   Studies on storage, retrieval, handling and analysis of information for useful military purposes.
10. **Research on Terrestrial and Extra-terrestrial Phenomena**
    Efforts to find new basic materials having desirable properties and new uses for known and their relationships.

HEADQUARTERS, AIR RESEARCH AND DEVELOPMENT COMMAND

COMMANDER
Lt.Gen.T.S.Power

VICE COMMANDER
Maj Gen. J.W.Sessums, Jr.

Col J.T.WINSTEAD
EXECUTIVE

STAFF JUDGE ADVOCATE
Col.G.Cechmanek

ADJUTANT
Col.W.J.Atkins

CHAPLAIN
Col.G.S.Wilson

DEPUTY COMMANDER RESOURCES
Brig.Gen.K.M.London

DIRECTORATE OF
INSTALLATIONS
Col.D.H.Miller

DIRECTORATE OF
PERSONNEL
Col.M.Duffy

DIRECTORATE OF
MANPOWER & ORGANIZATION
Col.R.M.Grek

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Col.M.E.Godfrey

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MATERIEL
Col.A.D.McEwen

DIRECTORATE OF
OPERATIONS
Col.W.R.Jackson

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PROCUREMENT
Col.L.W.Fulton

6590th SUPPORT
GROUP (HQ)
Col.W.G. Bowyer

DEPUTY COMMANDER
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Brig.Gen.M.C.Demler

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ENGINEERING
Col.L.M.Taylor

DIRECTORATE OF
RESEARCH
Col.L.B.Williams

DIRECTORATE OF
DEVELOPMENT
Col.J.R.V.Dickson

DEPUTY COMMANDER
WEAPONS SYSTEMS
Maj.Gen.A.Boyd

ASSITANT FOR AIRCRAFT
SYSTEMS
Col.M.F.McNickle

ASSISTANT FOR GUIDED
MISSILE SYSTEMS
Brig.Gen.D.R.Ostrander

ASSITANT FOR ELECTRONIC
SUPPORTING SYSTEMS
Brig.Gen.I.L.Farman

DIRECTORATE OF
NUCLEAR SYSTEMS
Brig.Gen.R.W.Wossell

DIRECTORATE OF
SYSTEMS MANAGEMENT
Brig.Gen.H.M.Estes, Jr.

DIRECTORATE OF
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Col.A.M.Prentiss, Jr.

ASSISTANT FOR AIRCRAFT
NUCLEAR PROPULSION
Maj Gen. D.J.KEIRN

ASSISTANT FOR WESTERN
DEVELOPMENT DIVISION
Maj.Gen.B.A.Schriever

PLANS AND PROGRAMMING OFFICE
Col.J.W.Carpenter,III

OFFICE OF INFORMATION SERVICES
Col.A.A.Arnhym

ANALYSIS AND
EVALUATION OFFICE
Mr.E.R.Melton

PROGRAMS DIVISION
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INSPECTOR GENERAL
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TECHNICAL INDUSTRIAL
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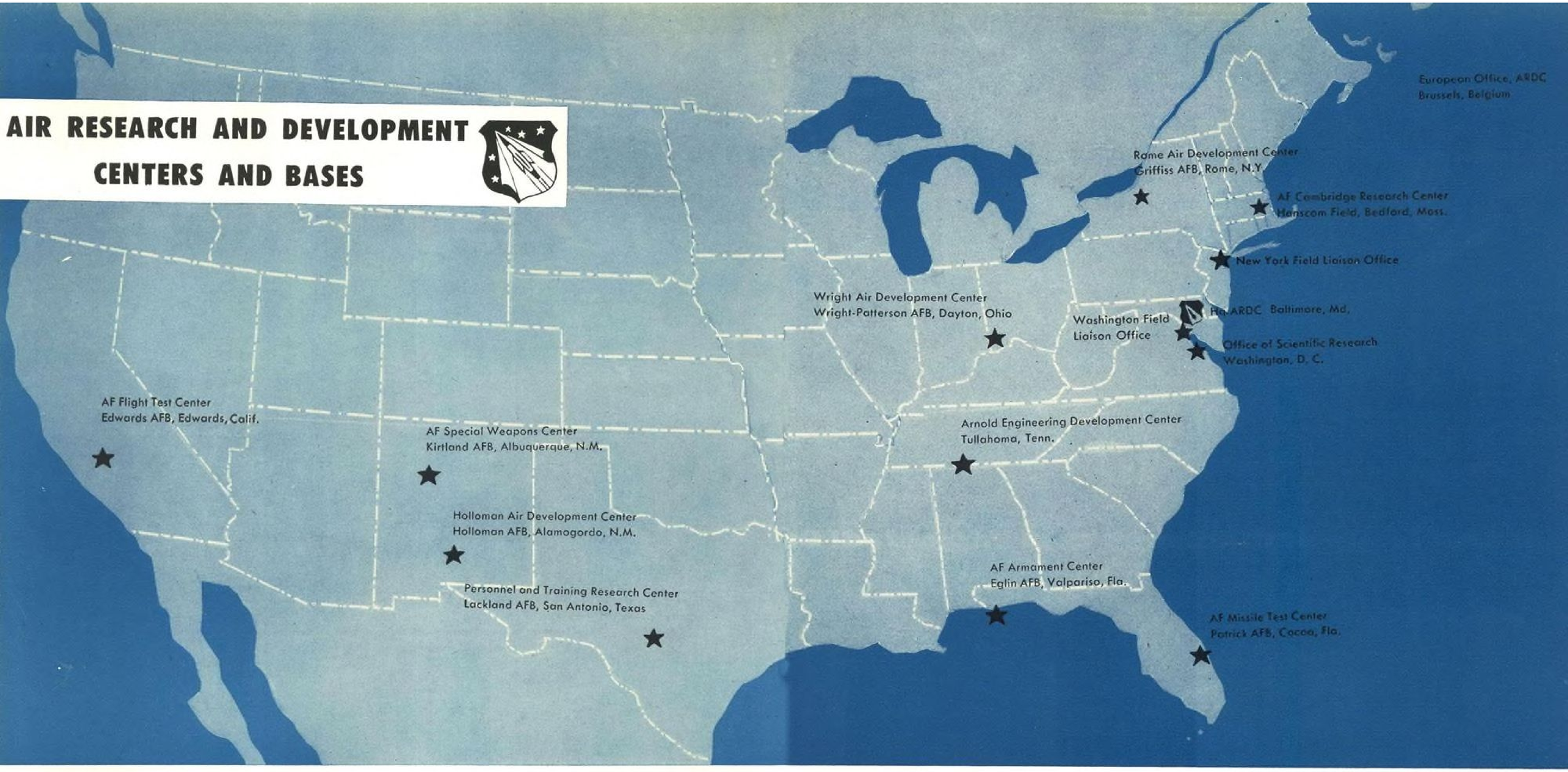
Lt.Col.S.E.Ernst

SURGEON
Col.A.L.Streeter

WESTERN DEVELOPMENT
DIVISION
Maj.Gen.B.A.Schriever



ARDC Procures Scientific and Technical Competence

Baltimore, Md.—In the Air Research and Development Command, procurement means the buying of technical competence—the key factor in ARDC's formula for producing qualitative superiority in USAF's men and machines.

Contracts are written for research and development work rather than hardware, and they are written against the capacities of people rather than the capacities of production lines.

Like all good buyers, ARDC searches constantly for new sellers. This search is one of the primary jobs of the Directorate of Procurement in Command Headquarters, which also oversees other phases of research and development contracting. It is headed by Col. L. W. Fulton.

Finding new sources is a difficult task. When the command was new it drew heavily on the experience of project engineers. But, like all shoppers, they tend to want to go back to the same store and purchase a brand that has served them well in the past.

While this has advantages, it also has its drawbacks:

• **The base for procurement** remains narrow. In new sources there may be new capabilities, a better quality of work, or comparable work at a lower cost. The part of USAF's budget identified as research and development has not increased fast enough since World War II to stay ahead of industry's growth in research and development capacity.

The Procurement Directorate operates on the philosophy that there always is a producer around to fill its needs, but the producer must be found and his capability investigated.

• **ARDC cannot guarantee** the many specialists it deals with a constant level of work. Consequently it sometimes finds itself going to a man whose work it knows and needs only to find that others have bought all his time. The problems that arise as technology progresses are not predictable, and it is not possible to reserve a scientist's time in advance. A specialist tends to get lost if he is filed only in a project officer's mind and is not used for several years because there is no work for him or he was not available when he was needed.

To meet this problem the Directorate is studying ways to improve the source files at ARDC centers and to maintain a comprehensive, accurate, up-to-date master source file at headquarters—one which always would be open for additions.

Finding New Sources

Possible feed-ins for this file would be:

• **Contractors suggested** by project officers and engineers—still a primary source of information on who sells the best in research and development, since

they are supposed to keep abreast of technical progress in their fields.

• **Contractors contacted** through the many symposia, weapon systems requirement conferences and technical planning program meetings which ARDC has with industry.

• **Contractors who come** to headquarters or to an ARDC center suggesting or looking for areas in which they have a capability that USAF needs. Wright Air Development Center, for instance, interviews 15 or 20 contractors' representatives a day who come to Dayton on just such missions.

• **Contractors who write** to headquarters or centers exploring the possibilities of contracting with ARDC. The command has a form questionnaire and a list of USAF's areas of scientific interest (reproduced on page 385) which may be obtained from the Contractor Relations Office at any center, from the Office of Industrial Relations in Baltimore, or by writing to Commander, ARDC Headquarters, Box 1395, Baltimore 3, Md., Attention: RDSKM.

• **The Industrial Sources Branch** of the Directorate's Facilities and Management Division. This branch was created within the past year in an effort to find more sources.

Selling to ARDC

A research and development contractor who wants to do business with ARDC does best to contact the center or centers engaged in the type of work he feels he can do. Few contracts are written at headquarters.

The contractor can visit or write to headquarters for general information on areas of USAF interest or specific information on which centers do what, but eventually he must deal with the center itself.

The quality of the work which ARDC buys must of course be weighed against its cost and the amount of time required to accomplish it.

So that ARDC can know what it is likely to get when it goes back a second or a third time, the Directorate is exploring methods of keeping experience records—how well a contractor did before, what went wrong if anything did, whether that is likely to happen again, what improvements in the contractor's capabilities have been made since the last time he was dealt with, where the people are now who have done superior work in the past. Like the source file, this file would serve only as a guideline to future procurement and not as an exclusive list.

The Command and the Directorate give great consideration to a contractor's proposed approach to a technical problem. Competition among research and development contractors in fact is one of approach and apparent technical competence—since the product that ARDC buys is never visible until the contract is completed.

ARDC's primary end-product is a specification, written so that USAF knows it is procuring aircraft or missiles or training men, with the optimum amount of quality.

Beneath these specifications must be a solid foundation not only of finding the right sources for high-quality research and development work, but of negotiating and administering contracts.

Procurement Cycle

All service procurement stems from Public Law 413, which gives the Secretaries authority to buy. The part of this authority affecting ARDC is redelegated down through an assistant secretary, the chief of staff, his deputy for materiel, and several levels of the Air Materiel Command.

All research and development contracts above $250,000, however, are subject to review by the Procurement Review Committee at AMC. ARDC in turn delegates to its centers the authority to do all "local purchase" contracting (housekeeping services, construction, etc.) and to write research and development contracts. The Procurement Directorate reviews all local purchase contracts over $50,000, and those above $100,000 also must go on to AMC for review and approval.

The centers, in their turn, review their own contract officers on contracts from $30,000 up before forwarding them to the Directorate. This is done through base review committees, replacing the old compliance divisions.

ARDC spends from $750 to $800 million on research and development contracts a year. In the past year ARDC has signed some 3,900 new contracts. It has an average of 4,000 to 4,200 on hand and active at any one time.

In a fiscal year, 30 per cent (representing some 20 per cent of the total dollar value) of the 3,900 contracts are placed with non-profit and not-for-profit research organizations. The balance is placed with industrial firms.

Types of Contracts

Non-profit organizations ordinarily get cost reimbursement contracts, with no fee involved. Not-for-profit groups (RAND, Inc., Armour Research Institute, etc.), which pay no dividends, usually receive cost reimbursement plus a nominal fee. The fee is invested in the institution, indirectly benefitting USAF.

Commercial organizations receive some form of cost reimbursement plus fixed fee contract (with the fee stated in dollars, not percentage) or one of two types of fixed price contracts.

Once a USAF program has been funded and the money for it is in ARDC's hands, project officers are advised. They initiate Purchase Requests and recommend sources for the work. The comptroller approves the request as being within the financial plan, and the request is then considered initiated.

It goes next to procurement, where the project officer's source list is checked against the larger source file and the number of sources to be asked for proposals is determined. It varies from one to 50 or more.

This is the point at which the contractor enters the picture. He is sent a statement of the work to be done and asked to submit a proposal as to how and for how much he would do the job.

Proposals come back in a ratio of 8 to 12 for 50 requests. They go then to the technical project office originating the request—but without any mention of the prices quoted, to insure that they will be evaluated only with regard to the technical value. It will be rated Very Satisfactory, Satisfactory, or Not Acceptable.

Next a contract officer compares the technical rating with a cost rating. If the cost is way out of line, the contract officer discusses the proposal with a project officer to decide if it is worth USAF's while to pay a premium for the work.

This is a question of judgment, one of the many that leave procurement personnel open to criticism with USAF, Congress and the public looking over their shoulders.

The contract officer next negotiates with the source selected, and the project is underway.

Managing Contracts

Management of the contract can be as difficult if not more so than negotiating it. A project officer reviews progress reports periodically, deciding each time whether the contract should be continued, if the direction of the work should be changed, if ARDC should continue the contract or terminate it.

Schedules for completion of the work in a research and development contract almost always are estimates, at best, and not infrequently they turn out to have been unrealistic.

When a project suddenly needs an extra funding of several million dollars because it was calculated unrealistically to begin with, not monitored carefully enough, or because a breakthrough may appear to warrant the increase, a decision must be made quickly. If the decision is to put more money into the contract, other contracts—existing and future—must suffer.

Contracts have run over by as much as $20 to $25 million— enough to affect other research and development work materially.

Industry Role in New Weapons Increased

By Claude Witze

In the past year, the Air Research and Development Command has effected a revolution in its use of planning and management skills in an attempt to shorten the development cycle for new weapons. It is monitoring industry's effort with the goal of getting the maximum return from America's inventory of talent and facilities.

Emphasis on planning and management has been introduced at a time when the aircraft industry is faced with an engineer famine and the menace of Russian technology is growing by leaps and bounds.

ARDC is leaving responsibility for the design, development and production of better hardware in the hands of the contractors.

As a fundamental, however, it has recognized USAF's obligation to ease industry's task in the crucial field where new ideas are needed to meet the challenge of the day. Since the start of 1956, ARDC has taken contractors into its confidence to such a degree that a manufacturer of certified capability and integrity would have to be laggard not to be looking ahead and preparing for the weapons of tomorrow.

Gen. Power's Approach

One direct result of the May, 1955, Moscow air show, where the Reds unveiled some amazing and threatening new aircraft, was the establishment last autumn of a new ARDC Deputy Commander for Weapon Systems. The job is filled by Maj. Gen. Albert Boyd, former commander of both Wright Air Development Center and the Flight Test Center at Edwards AFB, Calif.

In creating a new deputy, ARDC's Commander, Lt. Gen. Thomas S. Power, took a vital step toward achieving what he calls "big jumps" in the advance of weapons technology. Like the Air Materiel Command, ARDC recognizes that USAF lacks the facilities and talent to achieve these jumps alone.

Through proper planning and management it intends to help industry provide these and use them at peak efficiency. At no time in history has there been closer co-operation between industry and government, with the former holding so much crucial responsibility.

At the same time, USAF today is taking a necessarily tough attitude as a customer. Industry's performance in utilizing its facilities and talents is the key factor in competition. If past complaints that industry was shouldered with responsibility but hampered by ignorance of long-range USAF needs, by the state of the development art and by inability to get a decision out of a complex uniformed bureaucracy were justified, these grumblings now should die.

Systems Management's Role

Gen. Boyd is the top man in the weapon systems effort so far as management is concerned, while ARDC holds executive responsibility for any particular project.

In the task of establishing the Command's planning and management policies for specific types of hardware, Gen. Boyd has three assistants:

- **Brig. Gen. Don R. Ostrander** on guided missiles.
- **Brig. Gen. Ivan L. Farman** on electronic supporting systems.
- **Col. Melvin F. McNickle** on aircraft systems.

High priority given to development of USAF's nuclear-powered aircraft is reflected in a special Directorate for Nuclear Systems. Headed by Brig. Gen. Ralph L. Wassell, this office in effect is the highest rated Weapon System Project Office. Charged first with management of Weapon System 125A, it also will guide development of other nuclear powered aircraft systems to insure "technical and operational excellence" throughout their service life.

Gen. Boyd's alter ego in his vital relationship with industry, the using commands and USAF Headquarters is Brig. Gen. Howell M. Estes, Jr., the Director of Systems Management.

Gen. Estes' office is at Wright-Patterson AFB, outside Dayton, Ohio, but it is a component of ARDC's headquarters in Baltimore. Dayton was chosen to put Gen. Estes' staff right next door to the Weapon System Project Offices (WSPOs) in Dayton, and probably is the most important factor in speeding decisions for industry engineers, once a project is under way.

In the history of a new weapon system, however, there is another office—this one in Baltimore—that plays an earlier and farsighted role.

Secrets Shared With Industry

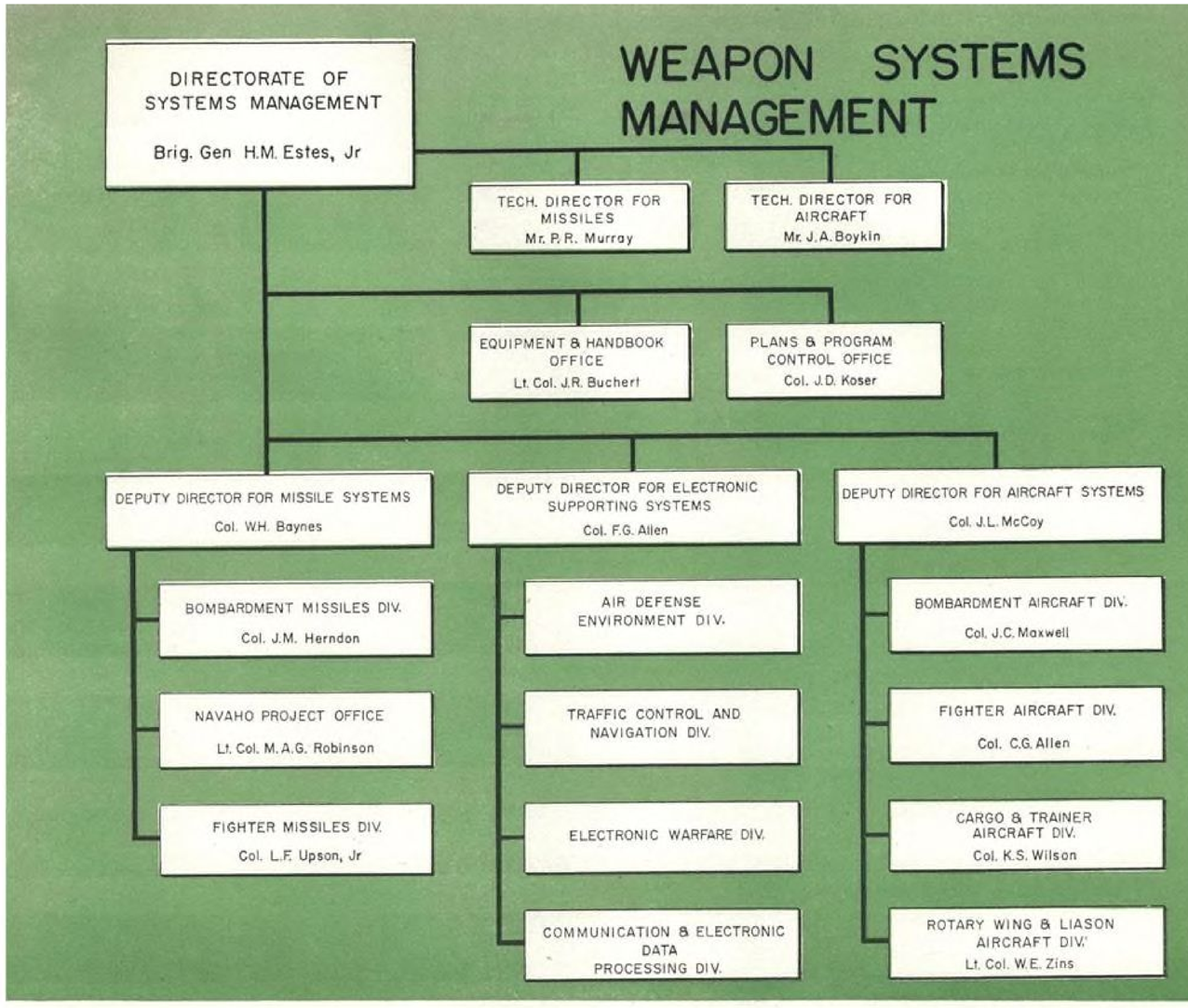
It is Gen. Boyd's Directorate of Systems Plans, headed until very recently by Col. Ernest N. Ljunggren. New chief is Col. Augustin M. Prentiss, Jr. It is here that one of the major revolutions in USAF-industry relations has taken place in the last eight months.

The revolution is simple. Within the framework of existing security regulations, the Directorate has found it possible to let industry in on what used to be ARDC secrets.

It is releasing System Requirements to qualified contractors, encouraging them to start voluntary studies, to invest their own money in the search for information that will help ARDC decide which way it is going.

It is no secret that the program is a selfish one from USAF's viewpoint. A year ago, Trevor Gardner, then Assistant Secretary of the Air Force for Research and Development, protested loudly against what he considered the reluctance of the aircraft industry to invest some of its profits in development. There was some effort, he acknowledged, but not on the scale he felt the size of the industry and its dependence on USAF contracts justified.

Maj. Gen. Albert Boyd, Deputy Commander for Weapon Systems, ARDC . . . former commander, Wright Air Development Center and Air Force Flight Test Center . . . veteran USAF test pilot . . . one of the first USAF pilots to fly faster than sound in the Bell X-1 . . . born Rankin, Tenn., 1906, grew up in Asheville, N. C. . . . learned to fly at Kelly Field, 1929 . . . held engineering jobs in Air Service Command . . . went to Europe as Deputy Commander 8th Air Force Service Command, supporting Gen. Jimmy Doolittle's 8th Air Force combat units . . . returned to U. S. as chief of Flight Test Division, Air Materiel Command, at Wright Field . . . holds Distinguished Flying Cross.



No More 'Paper Curtain'

Col. Ljunggren approached the situation from a different but equally practical point of view. Until this year, he pointed out, there existed a sort of "paper curtain" between the Air Force and the major facilities and talent on which it depends.

"It was something approaching the chicken and the egg situation," he said. "A manufacturer needed a contract to get information and he needed information in order to get a contract. This resulted in too many stalemates.

"It also resulted in the waste of a great deal of valuable time and engineering talent, devoted to studies that the Air Force did not want."

Col. Ljunggren cited the case of one company which was forced to resort to the old spy system. This provided scattered pieces of inaccurate information mixed with hearsay. The company put great effort into a design study and came up with something that was three years out of date. Its information was no good; it was not aware of the state of the art.

The fault was USAF's because of its strict interpretation of the "need to know" shibboleth that has governed the distribution of knowledge.

'Open Door' Policy

It is well known that USAF just a year ago eliminated preliminary design studies as a waste of engineering manpower that stretched instead of compressing the development cycle. Rather than pay a dozen firms to compete with each other in the production of $3 million worth of paper, the Air Force now gives Phase I contracts to two or three firms which it has determined to have a capability in the area of interest.

This, too, is related closely to ARDC's release of System Requirements to industry. Full knowledge of the requirements—an "open door" allowing the potential contractor to go ahead on the basis of authentic information—is the only thing that makes Phase I work practical without a preliminary design study.

ARDC says it is releasing System Requirements to:

- **Give contractors adequate guidance** in their preliminary work on product design, new design and innovations.
- **Conserve national engineering** capacity by channeling it along lines which promise the best payoff to USAF, and by providing a focal point for details on what is desired, to prevent misdirected effort.
- **Encourage independent research** and development work on the part of the contractors.
- **Shorten the development cycle** by get-

ting the contractor interested as early as possible.

• **Initiate and stimulate new ideas** as well as increasing operational capability significantly.

Transfer of Information

It also is important to have an adequate transfer center to pass information on future concepts from USAF to industry. Data from operational units has to be translated, or interpreted, so it can be understood by technical people.

The System Requirement attempts to explain what the Air Force wants to know. It calls for a study that will produce information, and sometimes a relatively specific design. There are cases where all that is needed from industry is data that will help USAF decide what approach should be taken. In all cases, the requirement tries to make it clear why USAF wants the information.

Further, the Directorate of Systems Plans can insure that industry knows fully what USAF headquarters wants. This is important because there are cases where even the using command, such as SAC, TAC or ADC, does not know what modifications have been made on the original Qualitative Operational Requirement. The Baltimore office has an obligation to give industry the balanced story and keep it up to date. When a contractor finds a conflict, he can get the right answer from a single source.

Technical Race With Russia

Gen. Power ties the new policy directly to the technological race with Russia.

He told industry at the outset that it is essential to intensify the team effort.

"Industry in general," he said, "has indicated a willingness to expend effort toward defining possible solutions to Air Force problems. It is the intent of the program to identify areas for study which will significantly improve our operational capability, thus permitting contractors to channel engineering efforts into the most profitable fields."

Procedure for Contractors

Procedure for obtaining copies of System Requirements is simple.

The contractor's vice-president for engineering or his equivalent is invited to visit ARDC headquarters for a review of all potential future weapon system study areas.

A conference may be arranged by writing to the Program Plans and Policies Office of the Directorate of Systems Plans (RDZPP) at ARDC Headquarters in Baltimore.

This office cannot distribute the System Requirements indiscriminately. Security regulations give the "need to know" as a standard under which such secrets can be shared. "Need to know" is defined by ARDC as integrity, plus a capability to participate in the research and development effort.

Naturally, the Director of Systems Plans must be convinced of this capability.

He will determine it on the basis of company interest, facilities and personnel. Past performance is important, but not the only factor involved.

Contractor Picks Work Area

At the first conference an effort is made to hold down the size of the group, usually to three or four men. Most essential is that the group include someone familiar with the company workloads, who can discuss company policy.

ARDC first presents a general picture of all study requirements by mission area.

The contractor then selects the specific area in which he thinks he can make the greatest contribution. He must verify that he has the technical capability and that personnel are available for the job.

At this point some company representatives face temptations like those of a boy at the candy counter, but they are forced to limit themselves to the two or three areas where they have the greatest capability.

Separate meetings are set up at which the contractor's preliminary design group can confer with experts from the appropriate division of the Directorate of Systems Plans. At this session the contractor is given complete data and the system requirement.

Origin of Requirement

The System Requirement grows out of such standard USAF documents as the Development Planning Objective (DPO), Qualitative Operational Requirement (QOR), General Operational Requirement (GOR), other studies or technological advances and general USAF intelligence.

These sources cover such key fields as strategic, air defense, reconnaissance, tactical, logistic and electronic supporting systems.

It is important that the System Requirement provide the contractor with the key to all relevant ARDC centers. Possession of the document entitles his engineers to visit appropriate centers in search of further information. On-the-spot consultation with experts frequently speeds industry results.

As for the contractor's obligation, he must:

• **Sign an agreement** to safeguard classified documents and maintain security controls.

• **Return the documents** on demand from ARDC.

• **Acknowledge that the** documents are not a request for a proposal, or a commitment by the government that can be used as the basis for a financial claim.

On its side of the bargain, ARDC accepts obligations to:

• **Maintain a master control** of study effort by mission areas and prevent unwarranted studies, prevent overloading of contractors and insure proper coverage of all areas.

• **Safeguard proprietary information.** USAF will not agree that a development is of a proprietary nature before evaluation, but it promises to recognize bona fide rights when they appear.

• **Provide continued guidance** and clarification when the contractor needs it, keep him informed of changes in requirements, review his efforts during the study and guarantee that all contractors get equal treatment.

As a general rule, the study will be conducted with the contractor's own money, although some System Requirements call for funded studies. These are augmented with a purchase request and work statement.

In the more common case of voluntary studies, there is a "Statement of Desired Work" that is less stern than a formal contract. It includes the work desired, probable USAF action dates, suggested reporting forms and procedures.

Proprietary Data

To submit results, the contractors usually will be asked to split his report into two segments. The first will include general information, written for wide distribution to other companies or government agencies. The second should include the company's interpretation of the first segment. It will contain proprietary information and will be treated as such.

Another document given to the contractor at the outset is a "Technical Brief." This is a resume of the work known to have been done in the field—a report on the state of the art and the agencies engaged in work germane to the problem.

An example cited by ARDC is a proposed study for an air-to-surface rocket. The Technical Brief in this case would tell why existing rockets are not satisfactory, what guidance systems exist or are under development and what is known about propulsion systems that could be applicable.

For obvious reasons, it is impossible to discuss the program at this time in terms of any specific weapon system, mission, area of technological interest, or contractor.

Industry Responds

In about six months ARDC's Directorate of Systems Plans has rounded up 95 industry working groups representing more than 30 contractors out of 91 who were invited to attend the initial briefings on 54 separate studies.

The average contractor from the 30 already has three studies under way. At least one contractor has 13 projects.

There have been some concrete results from a trial exercise inaugurated a few months before first mass invitations were issued. In this run, six contractors undertook studies. Two dropped out quickly because they were unable to carry the work load. The others have completed their studies and submitted data which ARDC already has put to work.

Col. Ljunggren estimated the value of their contribution at more than $1 million.

Looking at these products and contemplating what will come out of the 95 studies now under way, the Directorate has become convinced that the release of System Requirements helps industry as much as the Air Force.

Long-Range Benefit

Because the studies help orient ARDC toward a firm GOR on a new weapon system, the contractor who contributes cannot escape attention when early history of the project is considered, the Directorate points out. For this reason, the command feels that a good job at this early stage contributes heavily to a later decision by AMC-ARDC's Source Selectio Board that will help determine which firms are chosen for Phase I contracts.

"Here we knock down the trees and prepare the field for planting by Systems Management," one ARDC officer said.

He feels that if industry grabs suitable opportunities when they are offered by headquarters it will help insure consideration of the most competent teams when the time arrives to select contractors for prime and subsystem consideration. Possibly the most important contribution of this routine is what it does to shorten the development cycle.

The secret is that the System Requirements study program should improve industry's capability before the final weapon system requirement becomes urgent. Technical knowledge, placed on the shelf as it sometimes will

Brig. Gen. Howell M. Estes Jr., Director, Weapon Systems Management . . . born Ft. Oglethorpe, Ga., 1914 . . . graduate U. S. Military Academy, 1936 . . . learned to fly and transferred from Cavalry to Air Corps, 1940 . . . held posts at Brooks Field . . . commander, Lubbock, Tex. . . . served with USAFE 1946 to 1948 . . . Air War College . . . served with 22nd Bomb Wing in U. S. and United Kingdom . . . commanded First Air Base Group, 44th Bomb Wing . . . vice commander, FEAF Bomber Command March 1951 to July 1951, flying 25 combat missions over Korea in B-29s . . . commanded 106th Bomb Wing and 12th Air Division at March AFB, Calif. . . . commanded Air Task Group 7.4, Special Weapons Center, Kirtland AFB.

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be, will shorten the engineering learning curve when the project gets hot. The same holds true for USAF: with better material upon which to base decisions, the decisions should come more quickly and have more merit.

Managing a System

Making many of these key decisions is up to Gen. Estes' Directorate of Systems Management at Dayton, which has responsibility for preparing detailed System Development Plans. The directorate also must implement them, monitor contracts and provide liaison with Air Materiel Command, the using agency and ARDC centers.

This office, according to Gen. Boyd's mission statement, must "insure technical and operational excellence throughout the service life of the weapon system.

"On all assigned systems and projects, this directorate is the focal point for both industry and the Air Force where co-ordination is effected and where mutual problems are resolved."

The gateway to management for all parties concerned, and the key point for industry's contact, is the Weapon System Project Office, (WSPO). There is one for every system and it is under ARDC's executive responsibility during the development stage. Later, when AMC takes over and procurement of inventory hardware proceeds on the assumption that technical and operational excellence is within reach, that command provides executive responsibility for WSPO.

ARDC never loses contact with the project.

It always has a functional responsibility—one that operates in high gear when a "fix" or modification is necessary—and serves only as a technological monitor as long as the weapon system operates up to standard.

Some of the missions of the Directorate of Systems Management are to:

- **Co-ordinate its System Development** Plans with internal ARDC centers and major air commands. (This does not include headquarters USAF.)
- **Establish WSPO's** in conjunction with AMC.
- **Prepare work statements** and purchase requests, expedite the awarding of development contracts and then monitor them.
- **Establish and maintain** a reporting system that will uncover bottlenecks and help insure that development of sub-systems and supporting systems, proceed according to a timetable that will in turn prevent delays due to lags in any single area.
- **Supply AMC with engineering** approval on all systems during development and on changes during production.
- **Handle procurement scheduling,** maintenance and storage of all experimental Government Furnished Equipment (GFE), Contractor Furnished Equipment (CFE) and spare parts for systems under development. There is an equipment and handbook office for this job.
- **Monitor correction** of those Unsatisfactory Report projects which affect the performance, mission and/or development and production schedules of weapon systems.

'Big Jumps' Mean Risk

Aside from the urgent necessity to cut time from the development cycle, there is one other simple fact behind centralization of these key jobs—that the "big jumps" in development demanded by Gen. Power almost invariably involve big risk.

It probably is significant that ARDC's reorganization, with formation of directorates of plans and systems management under Gen. Boyd, took place last year shortly before Trevor Gardner resigned his Pentagon post.

As Assistant Secretary in charge of USAF's research and development, one of Gardner's main frustrations was the inability to get reasonably quick decisions in matters involving big jumps —and big risks.

ARDC clearly has recognized the problem and realizes that sound management and technological advice must precede action. At the same time, these raw materials are best provided from the shelf—with sufficient backlog and proper organization fast and more accurate decisions can be reached.

'Fixing' a System

In the Directorate of Systems Management, this idea goes beyond development of new weapon systems and finds application in the equally important activity that surrounds a "fix." When a bug develops in an aircraft, missile or supporting system, money is being spent at a fast clip, while the trouble is analyzed and a decision made on the correction.

Successful day-by-day relationship between the WSPO and industry and the using command is a prerequisite in these cases. Time and money can flow rapidly while the alternatives are pondered:

Shall we continue production and set up a modification line to incorporate the fix after it has been determined?

Shall we continue production and send a fix kit to the field for modification by the using command?

Shall we slow down the production rate to incorporate the fix on the line as soon as possible?

Shall we stop production for a "quick fix" that may require further adjustment or changes in the field?

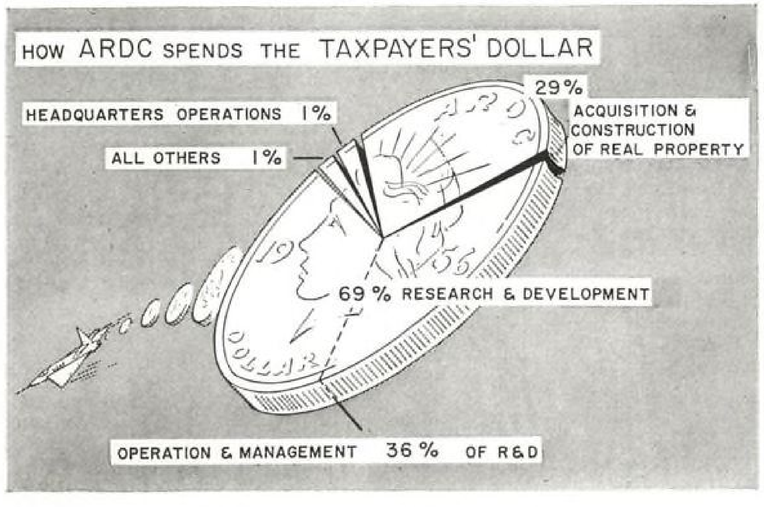
Shall we stop production for as long as it takes to incorporate a permanent fix?

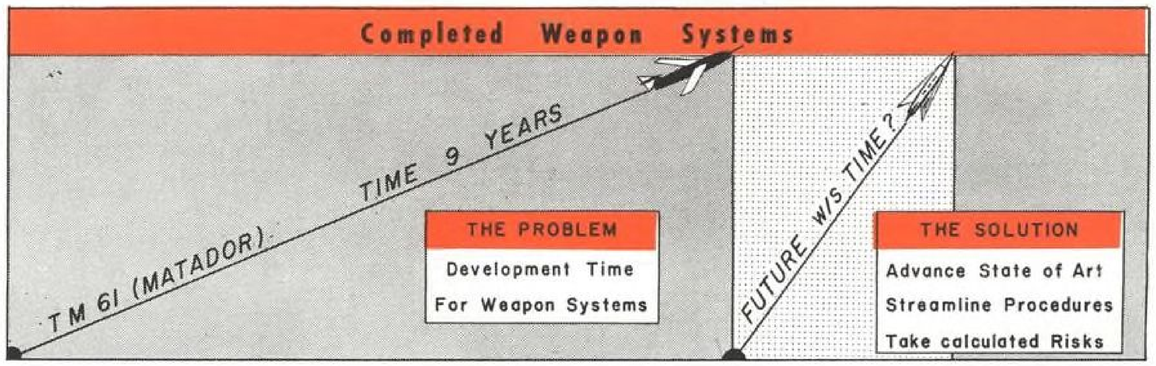
Factors that come to WSPO from all sources concerned must be considered. These include the using command and AMC, and prime and subsystem contractors, who will have problems involving labor, facilities and overhead. The world situation is a factor, weighed at USAF headquarters. Sometimes dominant is the simple question: How much will it cost?

Gen. Estes and WSPO

Under Gen. Estes WSPO has achieved the prestige it needs to act swiftly in these circumstances; it has a direct line to the top because Systems Management speaks and acts as part of ARDC headquarters.

Along with the improved WSPO





effectiveness that comes with marshaling information from industry, ARDC centers and other military sources, there is the additional advantage—not yet fully realized—of improved personnel standards.

The Systems Management Directorate is making an effort to build a staff out of USAF's best-qualified ranks. Present members give Gen. Estes credit for praising a good job well done and citing these accomplishments to Gen. Power as part of his campaign to obtain top personnel.

In the directorate, there are three deputy directors. Two of them are in full operation. They are:

- **Aircraft Systems,** under Col. J. L. McCoy. He has divisions covering bombardment, fighters, cargo and trainers, rotary wing and liaison.
- **Missile Systems,** under Col. W. H. Baynes. There are two divisions covering bombardment and fighter missiles. A separate office was created to handle the North American SM-64 Navaho. This, in effect, is a glorified WSPO set up to insure top-priority action.

New Electronics Office

Newest deputy directorship is for the field of Electronic Supporting Systems, headed by Col. F. G. Allen. Organization of the unit was started Apr. 1 and probably will take a year to complete. For each development contract in the field, it will introduce a new unit and another addition to ARDC's alphabetical maze: The ESSPO, for Electronic Supporting Systems Project Office.

Col. Allen's problems and what he plans to do about them form a case history that illustrates the entire Systems Management approach.

Electronic Supporting Systems are not airborne; they are part of the ground environment in which weapon systems operate.

Responsibility for their development, improvement and procurement has been a relatively haphazard operation involving some ARDC centers, USAF, ARDC and the manufacturers. Growth has been Topsy-like and there has been dissatisfaction at high levels with the slow rate of development.

One distinctive thing about electronic supporting systems is that they do not as a rule contain any single piece of major hardware, such as an airframe. They are a complex of buildings, telephone lines, black boxes, computers, real estate and external fittings. This miscellany of components for the most part comes from shelf items that are in being, although improvements and a few key developments may be needed to achieve a desired result.

How Contractors Benefit

Col. Allen points out that a General Operational Requirement in his field generally is tied to a date well in the future, with more development time allowed than in the case of the average weapon system. This has been necessary because in the past there has been no way to link the bits and pieces properly. This has delayed decisions for a proper co-ordination of information, most of it from manufacturers and scattered ARDC centers.

For the contractor, creation of the ESSPO's will simplify his relations with ARDC, ending the interminable travel from center to center in search of information. It will resolve and coordinate data and make decisions based on all the facets of the problem that must be considered.

It may take as long as two years for Col. Allen's part of the organization to become fully operative. He is hampered by the hunt for personnel to staff its four divisions and to man a dozen or more system project offices that will be needed in the electronics management field.

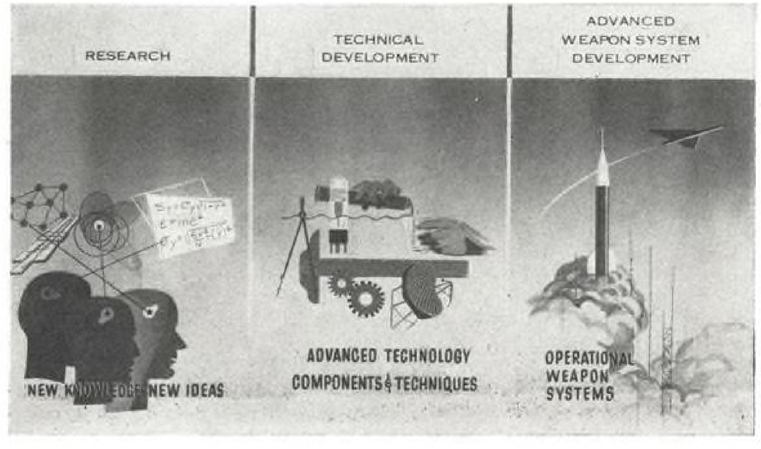
They will cover air defense, traffic control, electronic warfare, communication and high-speed electronic data processing systems.

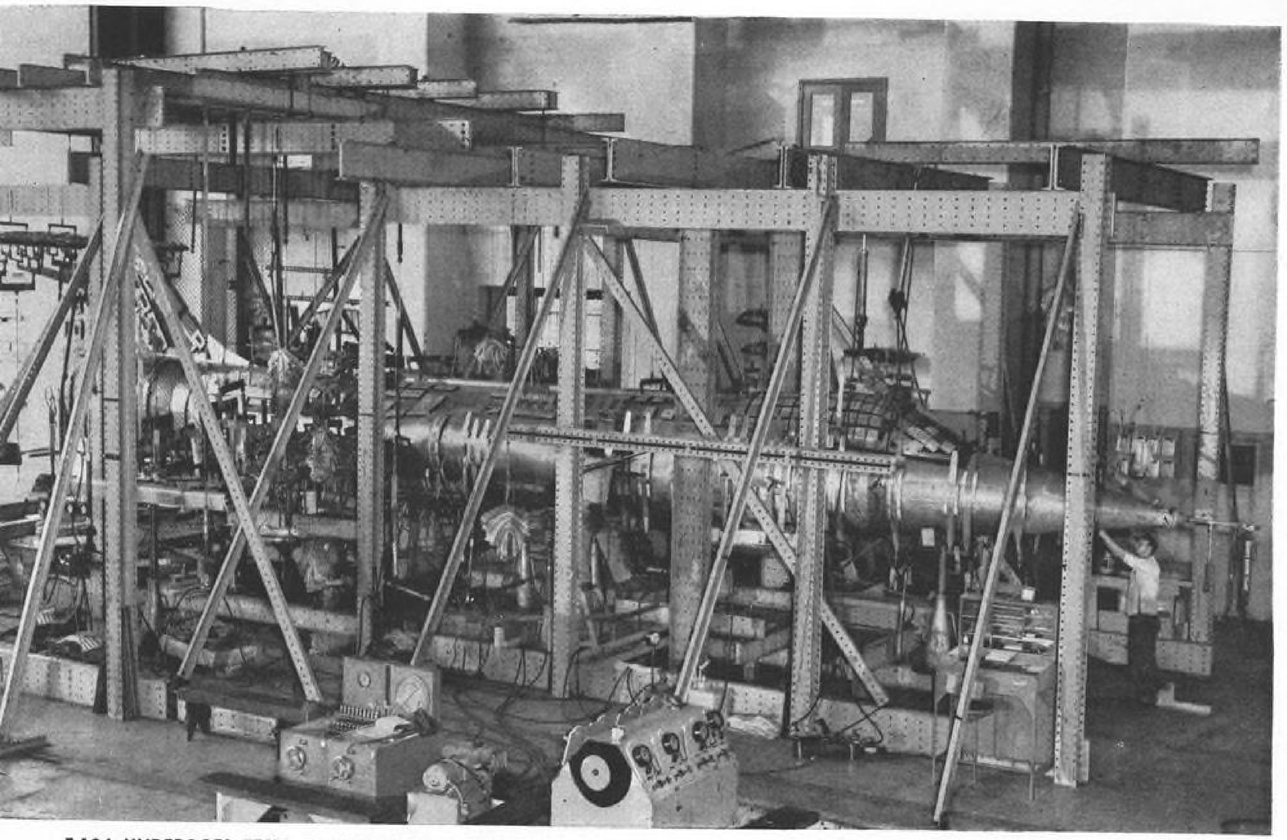
ARDC's reorganization of last year and the renewed effort to meet the Soviet challenge are part of the overall USAF program to stimulate the industry.

Basic doctrine that must be accepted by the contractor in order to benefit from these policies is simple and direct:

- **Be qualified** and have a record to prove it.
- **Want to do the job.**
- **Make contributions** to the state of the art.

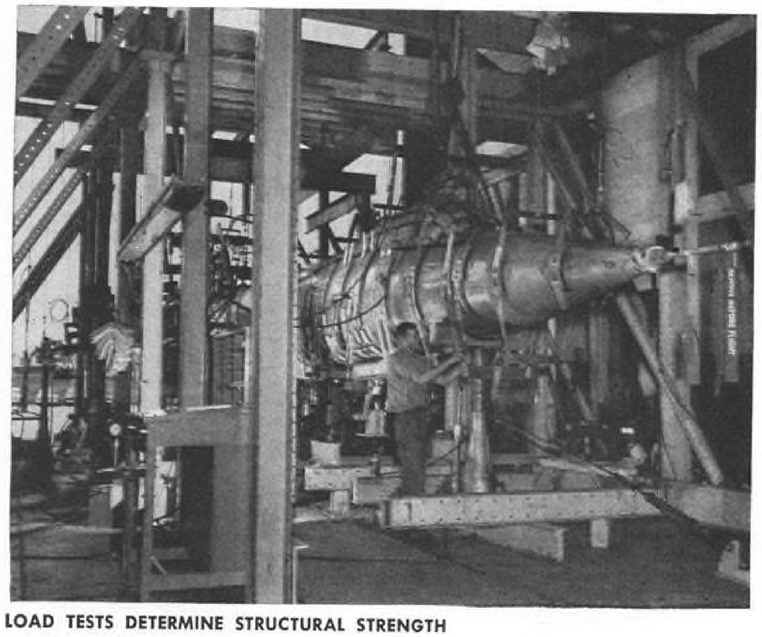
Improvements in ARDC's weapon systems management are based on the assumption that industry has accepted the job and will do it. ■





F-104 UNDERGOES TESTS IN AIRCRAFT LABORATORY

Wright Supports Weapon Systems With Technological Know-How



LOAD TESTS DETERMINE STRUCTURAL STRENGTH

Wright-Patterson AFB, Ohio—Wright Air Development Center, first home of the Air Research and Development Command, today is a principal supplier for USAF's Weapon System Project Offices. WADC's product is technological know-how. There are two other customers:

• **Air Materiel Command,** which depends on WADC for technical information needed for procurement. This applies both to weapon systems and in other areas of USAF purchasing.

• **USAF's using commands,** which need technical data for maintenance of the air fleet and modification of weapon systems in operation.

Basically, WADC's job is to sponsor applied research and exploratory development for the purpose of improving the state of the art. The Center produces the basic knowledge vital to the development of hardware, then monitors the technological aspects of development, evaluation and production. .

The assignment runs from the cradle to the grave in the life cycle of a weapon system.

Because support of weapon systems is the biggest challenge to WADC, the organization has been geared to that task since the concept first was introduced. As weapon systems have grown in complexity and USAF has learned more about managing them (see preceding article), WADC has undergone a steady series of changes.

Laboratories Reorganized

More than a year ago, WADC's dozen laboratories were split up between the directorates of research and development to permit their organization along lines parallel to those of weapon system sub-systems.

In this shift some new and significant laboratory titles appeared, emphasizing such things as weapons guidance, flight control and aerial reconnaissance. What comes out of them contributes to the overall packages needed in new systems.

In the Flight Control Laboratory, for example, diverse elements formerly scattered through several fields of technical interest were combined to meet the challenge of high-speed combat. New concepts of flight control have resulted.

Brig. Gen. Thomas L. Bryan Jr., WADC commander, now expects additional changes to be made over the next eight months. Within each of the two top directorates and 12 laboratories, staff responsibilities will be broken into two parts:

• **Technical development,** which will focus on techniques in such fields as aeronautics, guidance, powerplants and flight control. This staff will give full time to exploration and advancement of the state of the art. Much of the material that results will feed into the System Requirements studies carried out by industry under ARDC sponsorship through the office of Col. A. M. Prentiss Jr. at Baltimore.

• **Operational development,** concerned with specific hardware for weapon systems. This staff will look at all problems with the weapon system concept in mind, employing existing know-how to help finalize specific sub-systems. There will be a minimum of question marks and maximum dependency on "what we know we can do."

WSPOS & ESSPOS

To the production contractor, the operational area is the immediate one, where the Weapon System Project Office (WSPO) and the Electronic Supporting Systems Project Office (ESSPO) will go to get day-to-day co-operation from WADC's laboratories. Technical responsibility for each sub-system will be sub-contracted to the Operational Development staff of the appropriate laboratory.

Contribution of this staff will be to speed and improve the scheduling and control of contracts, the detection and correction of defects when they appear, and the dovetailing of sub-systems into the weapon system.

This monitoring will help insure the simultaneous passing of milestones as various sub-systems go through development. One laggard component can keep a weapon system grounded when it is vitally needed.

Helping the Operational Development staff will be a Systems Analysis Group, skilled men capable of taking a

PROPELLER GYRO STAND TESTS VIBRATORY STRESSES

Brig. Gen. Thomas Ludwell Bryan, Jr., Commander, Wright Air Development Center . . . born Tyler, Tex., 1908 . . . graduate U. S. Military Academy, 1929 . . . learned to fly at Brooks and Kelly Fields . . . served with tactical units and as flying instructor . . . commanded Army Air Corps Communications School . . . went to England in 1941 to gather radar data . . . planned and operated first USAF airborne radar school . . . staff communications officer 5th Air Force in South Pacific, World War II . . . observer Bikini bomb tests, 1946, and staff member, Eniwetok tests, 1948 . . . served with Alaskan Air Command . . . commanded 10th Air Division (defense) in Alaska and 1800th Airways and Air Communications Service Wing in Oklahoma.

Brig. Gen. V. Haugen Deputy Commander for Development

Col. C. Gasser Deputy Commander for Research

J. Keto Technical Director

E. Kotcher Technical Director, Development

look at each element of a weapon system to help determine what kind of performance can be expected and what impact shortcomings will have on the system as a whole.

The Contractor's Role

Essential to all this is a realization by the contractor that he has not lost fundamental responsibility for project management. WADC contends there is no easy way to speed up development. It still depends on industry's capability, decisiveness by USAF and good management planning. As planning effectiveness improves under ARDC's insistence, AMC's job should become less complicated.

This in turn should lead to easier relations between contractors and AMC's Procurement Directorate.

Ezra Kotcher, Technical Director of WADC's Directorate of Development and a veteran of long service at the Center, puts particular emphasis on this industry factor.

He believes the evolving WADC setup is leading to better communication between the laboratories and within them, that the synthesis of sub-systems is improving and that the big payoff will come from improved relations with industry. USAF depends on industry for the results.

Defining WADC as a center for integrating experience from industry, Kotcher cites an example from the Powerplant Laboratory, where a compressor stall problem might call for joint action by an engine manufacturer and an airframe builder. This would be true, for example, if a new problem in stability and control were uncovered in isolating a solution to the engine problem.

Value of Research Plane

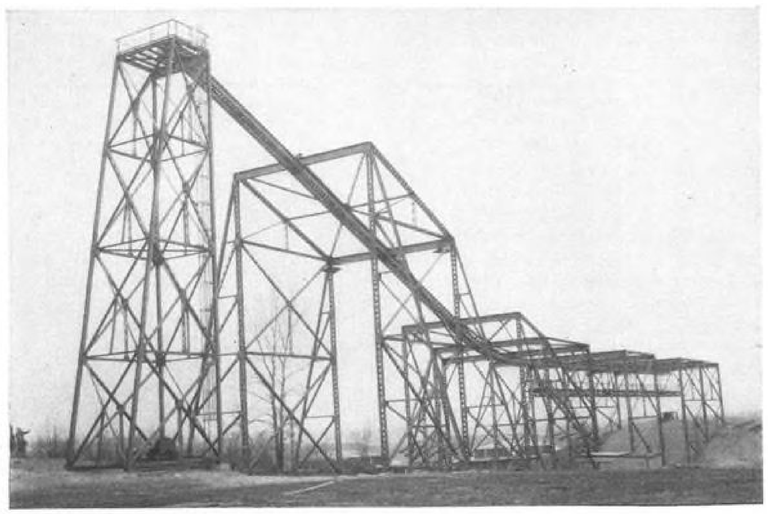
Kotcher, an enthusiast for the research airplane and sponsor of it as a development tool, points out that the more work done on advanced sub-systems before the prime contractor enters the picture, the fewer problems will arise when real development starts.

In this connection, the research airplane is important because it can get data not available from ground facilities for the simple reason that the ground facilities are inadequate or don't exist.

Frequently in this age of fast-moving technological advances the state of the art moves far ahead of the adjustment possible in laboratories. As missiles come in with a rush this will be even more true.

All of these things have an obvious relation to the concern of Lt. Gen. Thomas S. Power, ARDC commander, over the need for "big jumps" and the relationship between the state of the art and actual weapons in production.

John E. Keto, Technical Director of WADC, feels that the newer WADC organization, with a split into separate monitorship of technical and operational development, has a special merit for the WADC contractor. It will give him a previously impossible opportunity to calculate the size of his risk when he undertakes a job.



NEW STRUCTURE TESTS ARMY CARGO PARACHUTES

ARDC's Largest Center

WADC is the largest installation maintained by ARDC. There are 200 buildings at Wright-Patterson AFB, scattered over 4.5 million square feet of land. There are 8,000 military and civilian employes.

Eight of the 12 laboratories are under the Directorate of Development, headed by Brig. Gen. Victor R. Haugen. They are concerned with Aircraft, Aerial Reconnaissance, Communication and Navigation, Equipment, Flight Control, Propellers, Powerplants and Weapon Guidance.

The remaining four laboratories—Aero Medical, Aeronautical Research, Electronic Components and Materials—comprise the Directorate of Research under Col. Clyde D. Gasser.

There are four other directorates, covering Flight and All-Weather Test, Procurement, Support and Engineering Standards. The first of these conducts Phase V all-weather tests on new weapons systems.

In addition to flying at Wright-Patterson AFB, some of this work is conducted in Alaska and at the climatic hangar at Eglin AFB in Florida.

Phase V tests cover adverse weather, climatics and cockpit standardization. During development of the system, components—such as jet engines—are exposed to icing conditions at WADC's facility on top of Mt. Washington, N. H., where the contractor and USAF can experiment with natural phenomena.

Aircraft Laboratory

Basic problems of airframe structures and aerodynamic shapes are studied in the Aircraft Laboratory's six wind tunnels, which range from six in. to 20 ft. in diameter. Spin characteristics and the stability of parachutes and bombs are determined in a vertical tunnel, one of two in the United States. In the Laboratory's structure test building, probably the only one of its kind in the world, airframes undergo load testing to determine strength before they are flown extensively.

In addition to aircraft, the laboratory is concerned with some types of equipment, usually items that could have an effect on aerodynamic capability. An example is the emergency, inflatable pontoon developed for helicopters servicing Texas Tower radar stations off the Atlantic Coast.

Developed by Vertol Aircraft Corp., the pontoon is carried externally on the H-21 tandem helicopter, can be inflated in eight seconds and will keep the aircraft afloat long enough for the crew to man life rafts.

The laboratory also considers problems of escape in the case of supersonic fighters. Typical of this is Project Smart, the laboratory's high-speed rocket sled track atop Hurricane Mesa in Utah.

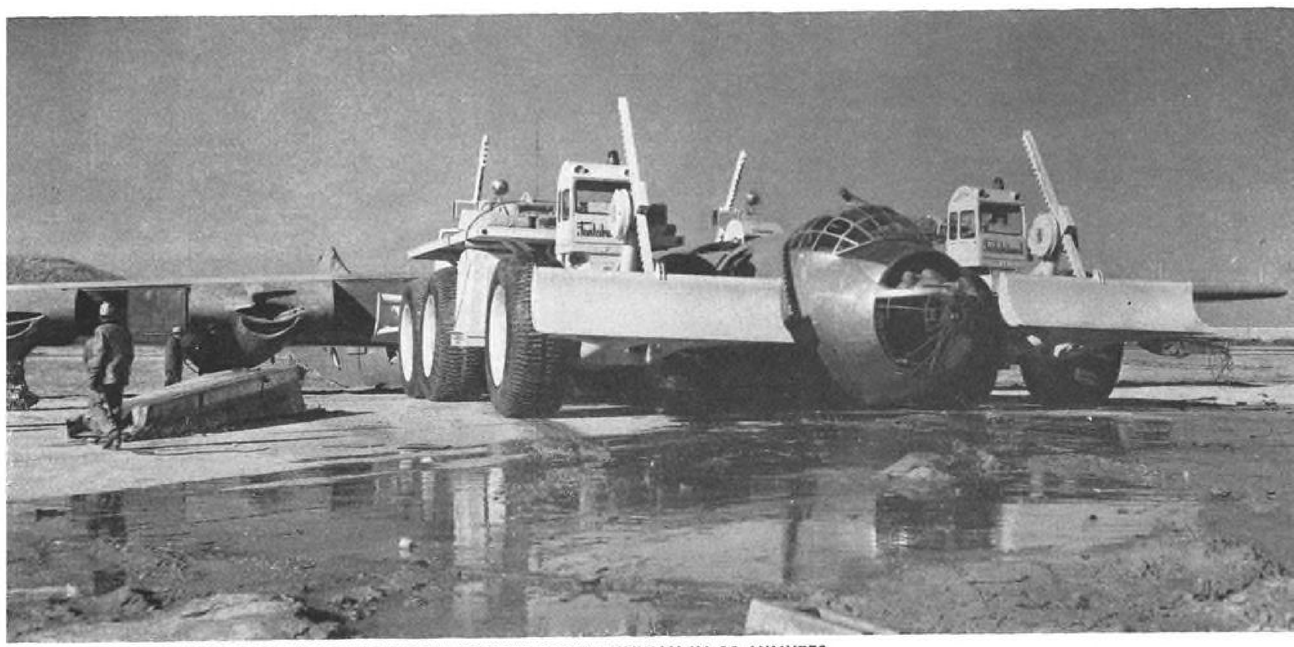
An instrumented dummy is catapulted out of a sled capable of speeds between Mach 1 and Mach 2. The information is used in development of ejection capsules.

The Laboratory's assignment is divided into design, mechanical, aerodynamics and special project branches. Thus special attention is provided for everything from preliminary design studies to such components as landing gears, hydraulic systems, camera doors and bearings.

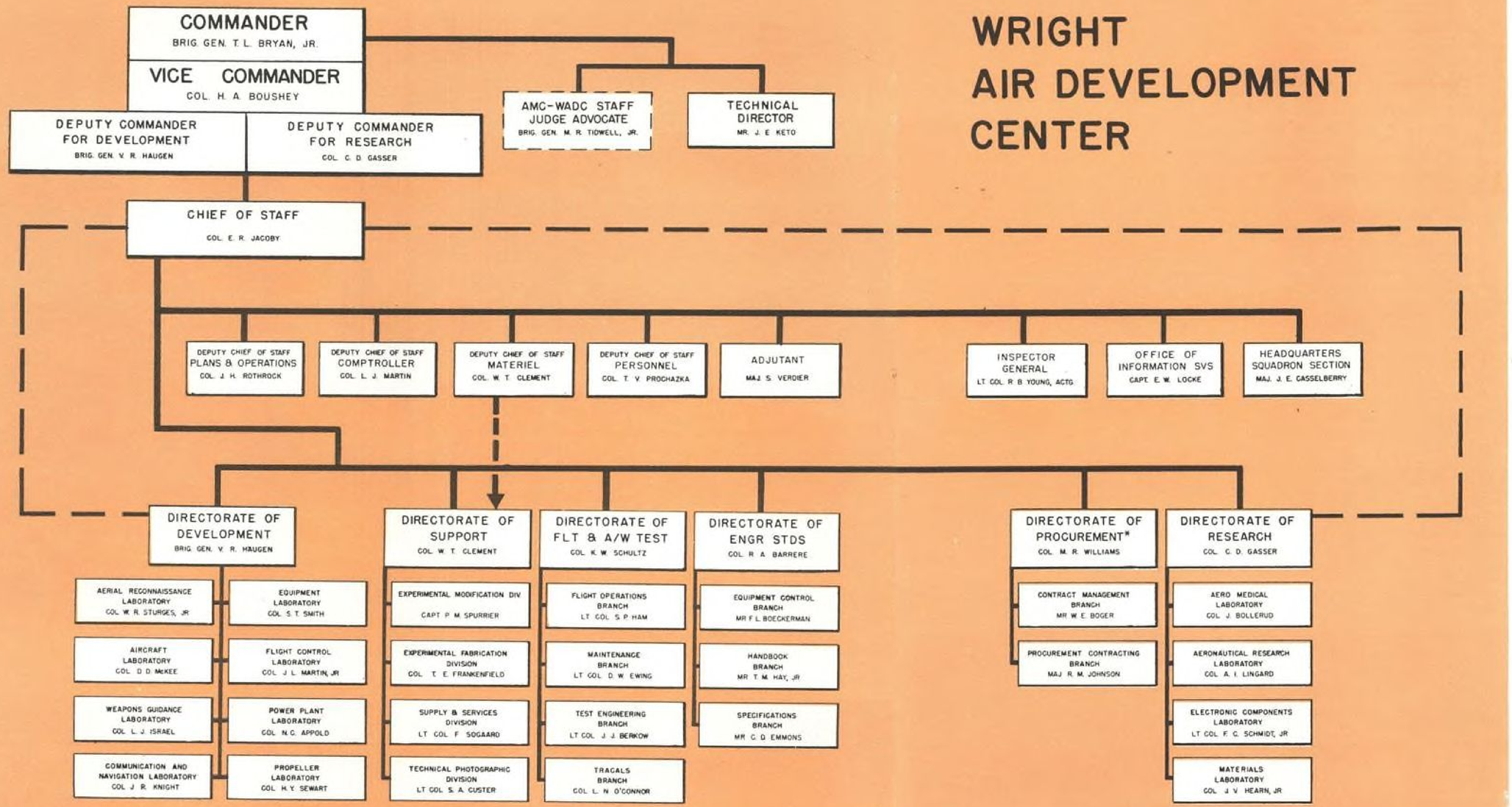
Powerplant Laboratory

WADC's propulsion program is conducted by the Powerplant Laboratory

POWERPLANT LABORATORY TESTS A ROCKET



CRASH PUSHERS CAN CLEAR 400,000-LB. BOMBER FROM RUNWAY IN 20 MINUTES.



through continuing studies of turboprop, turbojet, ramjet, pulsejet, liquid and solid propellant rocket engines, reciprocating engines and the application of nuclear power. Its turbojet test stands can take power units up to 40,000 lb. of thrust at sea level.

Special sections are set up to deal with each major engine manufacturer, such as General Electric, Allison and Pratt & Whitney—a recognition of the fact that industry is best qualified to design and develop aircraft propulsion. The lab guides and evaluates the manufacturers efforts.

A typical current project is reverse thrust to decelerate landing jet aircraft. Another, which resulted in the start of a production program last year, was the reinforced plastic droppable fuel tank. This was developed to replace the more expensive aluminum tank, which can be salvaged and reused by the enemy.

Propeller Laboratory

Both subsonic and supersonic propellers and helicopter rotors are tested by the Propeller Laboratory. The prop whirl stands are powered by motors up to 30,000 hp. and capable of speeds up to 12,000 rpm.

Helicopter rotor whirl stands can handle rotors up to 95 ft. in diameter at 140 to 600 rpm. There is other equipment to test the fatigue limits of rotor blade sections.

Newest facility is a gyroscopic test stand capable of rotating a prop on both horizontal and vertical axes to simulate the stresses met by large airplane propellers in flight. It is a cylinder 22 feet in diameter. With a propeller speeding inside, the cylinder can be rotated on an axis perpendicular to the ground at speeds up to 25 rpm. This produces vibratory stresses similar to those met in flight by equipment on large transports with heavy loads. The cylinder can be drained of air to simulate an altitude of 165,000 ft., making it possible to spin a 20 ft. prop with a 60-hp. motor.

Aeronautical Research

The Aeronautical Research Laboratory is a primary installation, cutting across traditional divisions of science to seek solutions to problems in a number of areas.

These include aerodynamic heating, structural materials, flutter analysis bombing computers, fire control and equations of motion in aircraft maneuvers. The lab has several electronic computers to solve problems in mathematics.

Branches include Chemistry, Fluid Dynamics, Mechanics, Metallurgy, Mathematics, Engineering Physics, Mechanical Physics and System Dynamics.

"Cat Eye," a device to enable an airman to see in the dark, is a typical project. It is an electronic system which amplifies light from the ground. It is 1,000 times more sensitive than the human eye. Other projects are as commonplace as the shimmy in a nose wheel or as remote as a study of solar generators that can convert sunshine into electrical energy.

Materials Laboratory

Development of new and improved materials and creation of substitutes for critical items is the task of the Materials Laboratory, which establishes quality standards for all materials used by USAF. Vast new field of activity has been opened in this area by the introduction of thermal and nuclear radiation as a factor in combat considerations.

Recent example of the lab's activity is the development of a cold extrusion process for titanium. So far, pure titanium has been used in the manufacture of simple round bars. In the future, alloys may be used, and the items manufactured may grow larger as experience is added, along with improved tools and the utilization of higher pressures.

Other projects involve the effect of rain on radomes, use of atomic energy to vulcanize rubber and studies of atomic radiation in a "hot cell."

Electronic Components

WADC's Electronic Components Laboratory conducts research and development on airborne electronic equipment, the fastest-growing field of aeronautical activity.

This equipment may represent half the total cost of a modern fighter or jet bomber. The list of parts includes transistors, connectors, capacitors, inductors, conductors, electron tubes, radomes and related items.

About two months ago the lab announced completion of a new test range to study the effects of radomes on aircraft radar performance. Instrumentation of the facility has begun. The $500,000 facility will help solve problems in transmission-reflection, beam distortion and bore sight error.

Communications & Navigation

New and improved communication, identification and navigation equipment and systems—for aircraft and guided missiles—are handled by the Communications & Naviagation Laboratory.

Interest here ranges all the way from traffic control to anti-jamming and security techniques. Included are ground reference navigation, instrument landing systems, frequency standards, rescue devices, antennas and other items.

The lab also maintains climatic chambers and other test devices.

Typical project is a 15-ounce radio that takes up only 20 cubic in. It is designed to call aid to a stranded airman.

Small enough to fit in the seat survival kit of a fighter pilot, it will permit two-way conversation between the man and rescue plane. Another is the Sperry AN/APN-59 airborne radar, a 150-lb. device with a 5-inch screen, capable of search and surveillance, beacon interrogation, navigation, storm detection and collision warning.

Flight Control Laboratory

Development of improved flight instruments and manual and automatic flight controls is the mission of the Flight Control Laboratory. A new approach now under consideration is "control stick steering," in which the pilot has constant control over the

aircraft when flying manual or automatic and can put corrections into his course without shutting off the automatic pilot.

Aerial Reconnaissance

The Aerial Reconaissance Laboratory covers not only the routine photographic and radar equipment in this area and is studying wave propagation.

Once called the Photo Reconnaissance Laboratory before this title became too limited for the activity, it still works on cameras to operate at altitudes of 100,000 ft. and others that will be used at low heights while speeding at 1,000 mph. Electronics are utilized to do things with this equipment that cannot be done by human beings.

The lab also is working on stereoscopic photography, radar recording cameras, spark flash photography, night photography and photo installations in rockets and missiles.

The new KB-5 camera, which automatically adjusts its lens opening to control the amount of light hitting the film, is a product of this lab. A gun type camera that can be used on fighter aircraft, the KB-5 will cut down on the amount of improperly exposed film.

Weapons Guidance

The problems of fire control, self-contained navigation systems, bombing and gunnery devices and weapon guidance are handled in the Weapons Guidance Laboratory. This effort runs into such scientific interests as electronic jamming, "chaff," manual navigation aids and special test equipment. One of the largest labs, it is divided into branches covering Interceptor Systems, Guidance Development, Weapons Defense, Analysis and Design, Navigation, Strategic Bombing, Tactical and Services.

Aero Medical Laboratory

Improvement of aircraft equipment so that man, who is obsolete in the world of high speed flight, can survive, is the role of the Aero Medical Laboratory.

It determines man's tolerance to the forces of modern flight, anticipates his future demands and extends his capabilities. A new test chamber, announced early this year, can simulate altitudes in excess of 150,000 ft. and the decompression that follows if a plane's canopy is blown off at that height.

Equipment Laboratory

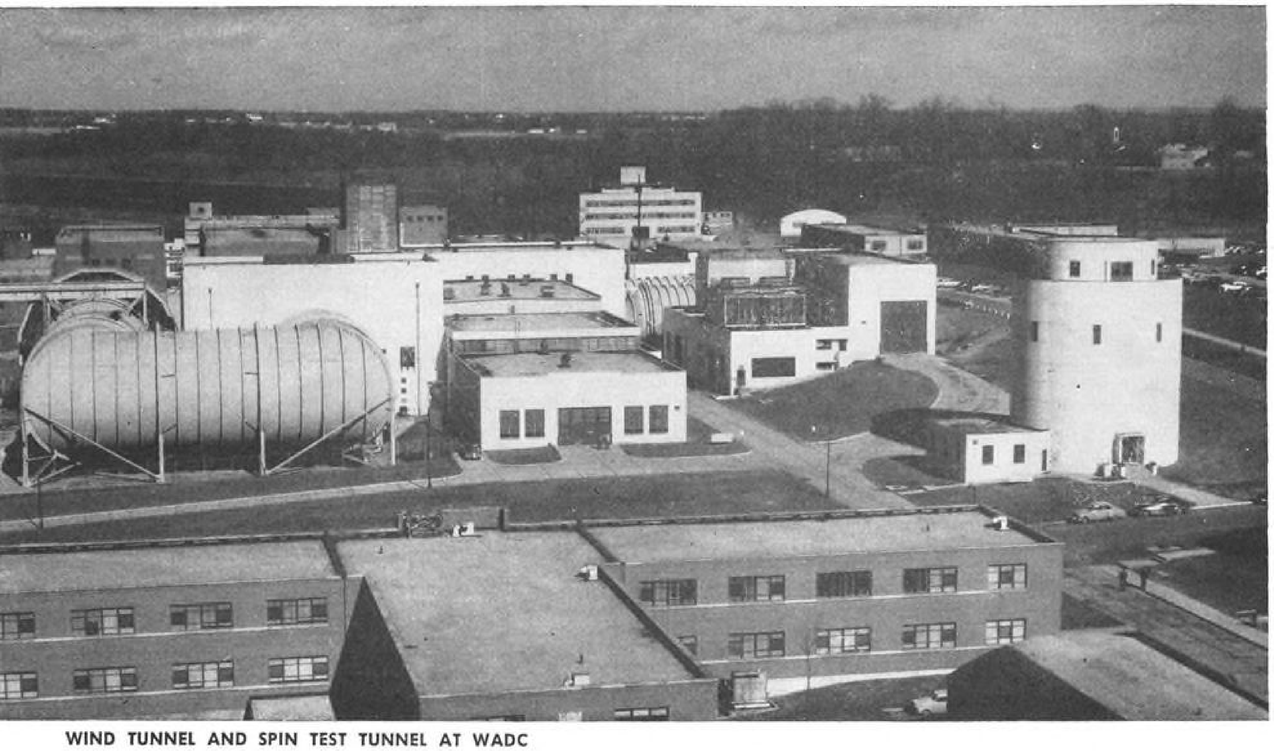
Incorporation of all ground and airborne equipment into the weapon system to make the modern aircraft a more effective combat tool has increased the importance of WADC's Equipment Laboratory. Everything from tiny filters to mammoth hangars is developed and tested by this unit. Fields of interest are depot equipment, electrical accessories, servicing of aircraft and missiles, support equipment, parachutes and air installations. Specific projects cover such items as crushers, auxiliary power vehicles, crash fire vehicles, air conditioning, heating, lighting, flight simulators and trainers. Climatic chambers are an important tool in the work.

One recent development provides a new sound warning device to tell a pilot when he is about to land without lowering the landing gear. Instead of a horn in the cockpit, which may not be heard, the new device puts a tone in the pilot's headset.

It is turned on when the throttle setting, airspeed or altitude of the aircraft indicate that a landing is about to be made.

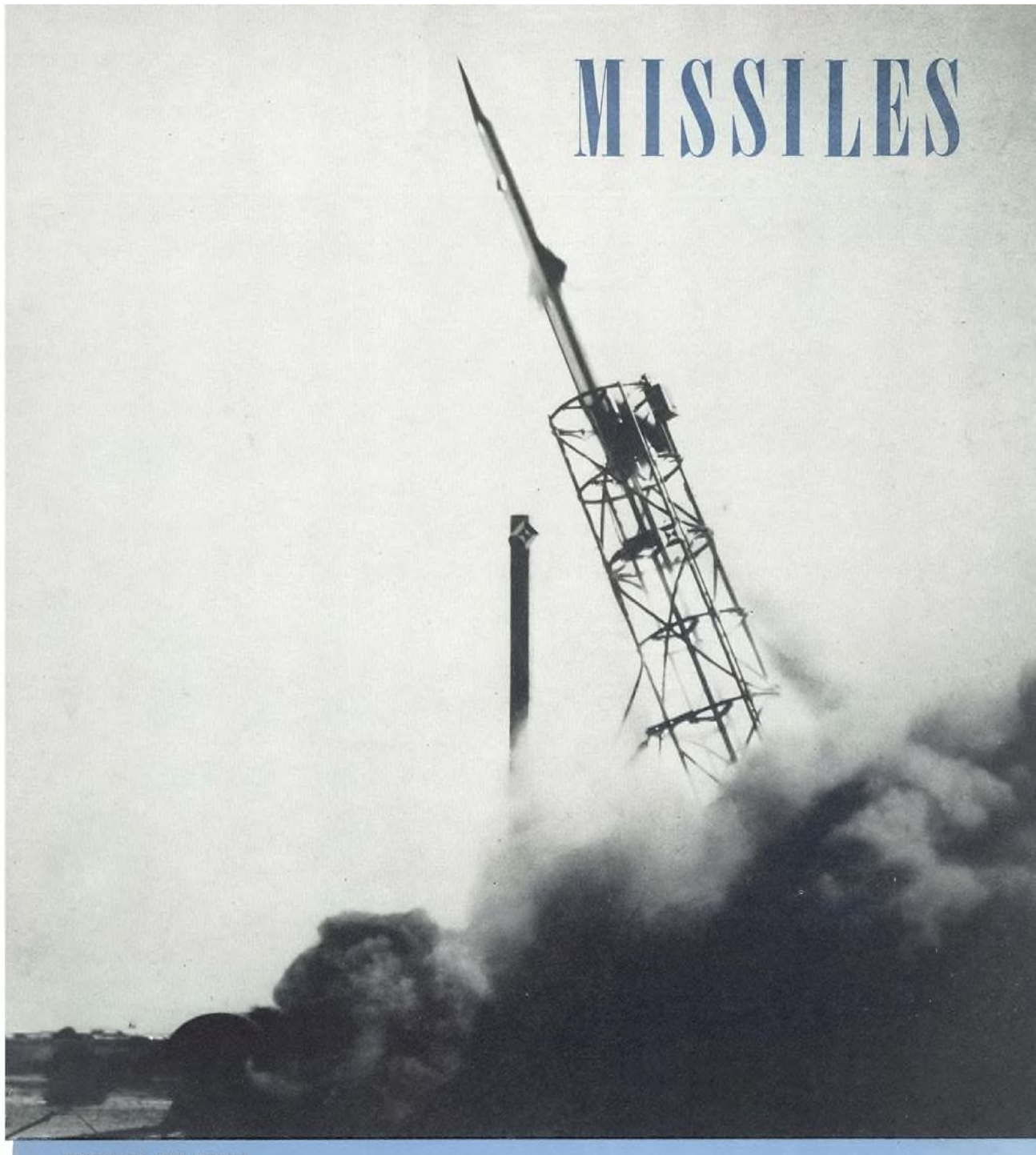
A new type trainer permits simulated flying with navigation by Shoran radar.

It will permit synthetic action for bombing, photo reconnaissance and aerial mapping missions. Another recent addition is a steel drop test facility designed to study parachute delivery of military equipment. A giant "ski jump," 365 feet long, it is expected to bring about improved shock absorbers, anti-toppling devices and aerial delivery platforms.



WIND TUNNEL AND SPIN TEST TUNNEL AT WADC

MISSILES



HYPERSONIC TEST VEHICLE

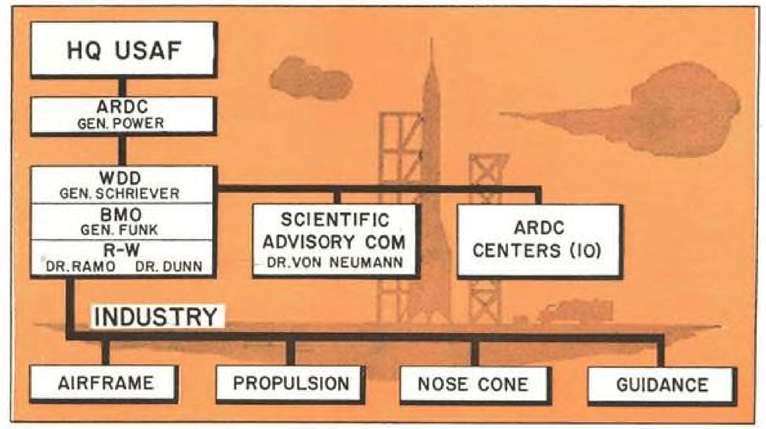
WDD Guides Nation's Top-Priority Missile Programs

Patrick Expands to Meet Long-Range Missile Challenge

Holloman Adds Facilities for New Missile Test Tasks

Edwards Rocket Base Tests Sophisticated Powerplants

WDD Directs ICBM, IRBM Development



Los Angeles—The nation's highest-priority program—development of a family of strategic ballistic missiles to an operational status—is being managed here by three organizations under the leadership of ARDC's Western Development Division, commanded by Maj. Gen. B. A. Schriever.

WDD's job is to plan and develop the long-range ballistic missile and create a task group for tomorrow's Air Force. The assignment goes far beyond routine monitoring of a weapon systems contract. It requires WDD to lead USAF's strategic ballistic missiles program through research, development, production and early operations, and includes responsibility for the task group's initial operational capability.

In this WDD is aided by the specialized talents of the Ballistic Missiles Office of the Air Materiel Command and the Guided Missile Research Division of the Ramo-Wooldridge Corp.

These three groups, operating as an entity, bear the final awesome responsibility for the success or failure of all of the Air Force's ballistic missiles: The Convair Atlas, Martin Titan and Douglas Thor.

Organization Is Unique

This unique organization, which outsiders have called everything from the Holy Trinity to a three-headed monster, was specifically built two years ago to allow the Air Force to do the systems engineering of these new weapons.

Before that, systems engineering of long-range missiles was the responsibility of the prime contractor. At that time, the only U. S. intercontinental ballistic missile under way was the Atlas, with Convair Division of General Dynamics Corp. acting as prime contractor for the complete system.

Convair had more than an ordinary interest in the field. One of the first companies to start long-range missile studies, Convair had nursed the project through the post-war boom and bust in the aircraft business and had sheltered it after an economy review stopped any further official funding, providing a home for an infant who gave every prospect of growing up to be a bruiser.

Shortly after the nuclear breakthroughs of 1952 and 1953, which produced a lightweight high-yield thermonuclear warhead, the Air Force began a major study to determine the direction in which weapons technologies were going. In 1953, Air Force established a Strategic Missiles Evaluation Committee under Dr. John von Neumann.

Von Neumann's group recommended the creation of a development-management group to monitor all strategic missiles and the Air Force implemented the recommendation in 1954. Once that decision was made—for better or worse—it meant that USAF had to set up a specialized staff to handle the technical direction and systems engineering. It did not have, nor could it get, the necessary talent within the Air Force, so it hired the Ramo-Wooldridge Corp. to do the job.

The action took the Atlas project management away from under Convair, and in effect made the firm what the Air Force calls a "principal associate" contractor to WDD. Convair's howl was loud and instantaneous. It was echoed by other contractors who shared Convair's belief that technical competence could be found in their own organizations.

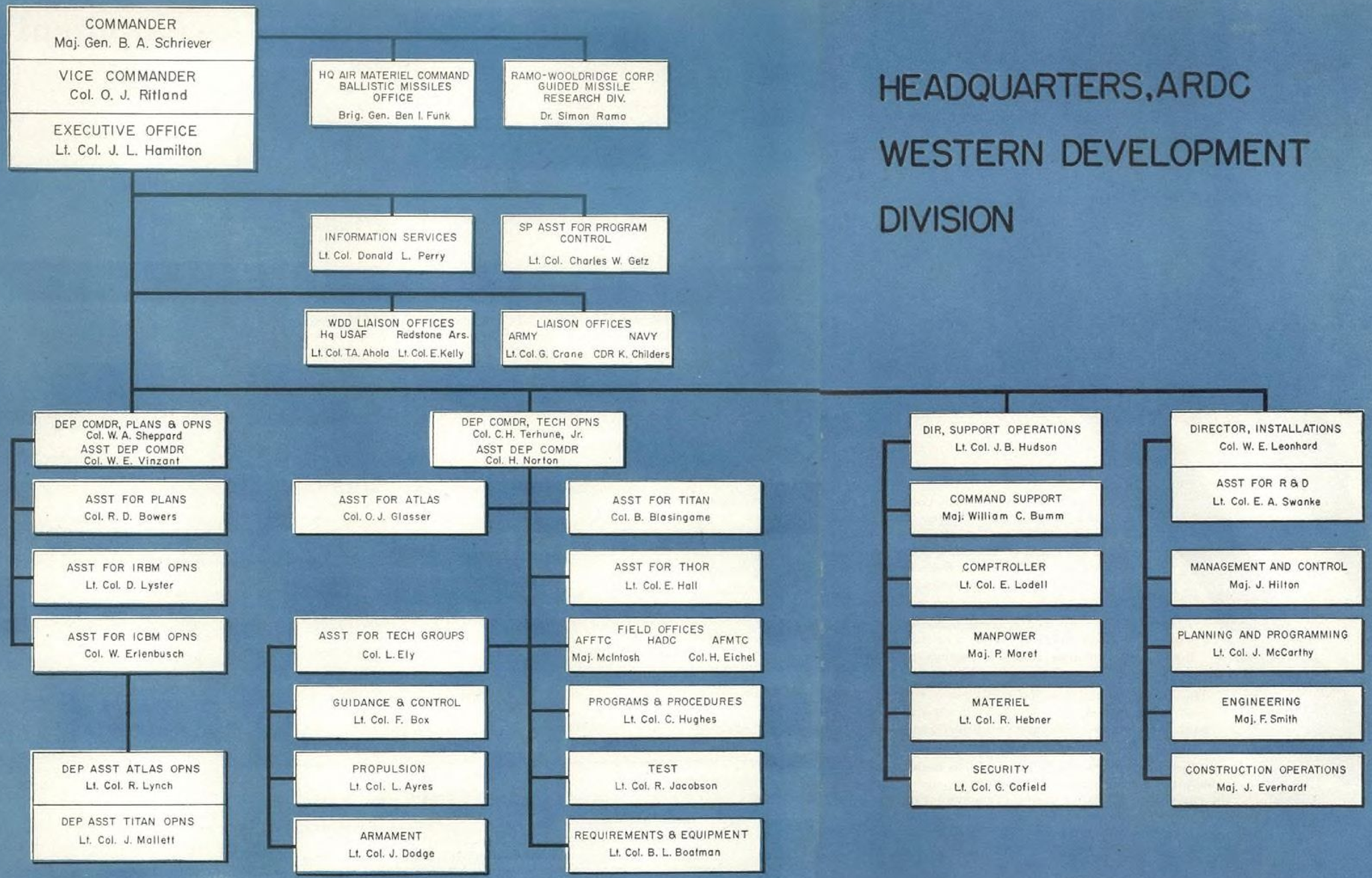
AMC's Part

Air Materiel Command strengthened its own part of the task by setting up a Special Aircraft Project Office in the same buildings occupied by WDD and Ramo-Wooldridge. SAPO's job was to monitor the contractual and procurement procedures, and to bear the major responsibility for production, quality control, supply, maintenance and transportation.

But no matter how efficient, an organization as complex as WDD can get bogged down in the multi-leveled structure of responsibility and authority above its head. Most of these levels were removed when the strategic missile program was realigned early this year.

That realignment raised the intercontinental and intermediate-range ballistic missile programs from highest USAF priority to highest national priority. At the same time it freed the programs from the routine channels of the missile maze that bedevil lesser projects. Only two special missile committees have the power of review over WDD:

Maj. Gen. Bernard Adolph Schriever, Commander, Western Development Division . . . born Bremen, Germany, 1910 . . . graduate Texas A&M, 1931 . . . two master's degrees from Stanford University . . . learned to fly Kelly Field . . . test pilot, Wright Field, 1939 . . . with 19th Bomb Group, 5th Air Force Service Command, and commander, Advanced Headquarters, Far East Air Service Command in South Pacific in World War II . . . scientific liaison post at AAF Hq. . . . assistant for evaluation and later for development, USAF Hq. . . . assistant to the commander, ARDC from May to August, 1954 . . . commander of WDD since, with immediate control and supervision over all aspects of USAF's ballistic missile program.



the USAF Ballistic Missile Committee headed by USAF Secretary Donald A. Quarles, and the Missile Advisory Committee headed by Eger V. Murphree in the Office of the Secretary of Defense.

With the organization completed, the next task lay ahead: A study and review of the strategic missile program.

It was this first program review that kicked off the bitterest and longest series of complaints against the organization from the outside. Ramo-Wooldridge, in its capacity as technical director and systems engineer for the programs, needed complete and detailed scientific information on all of the missiles in order to evaluate them properly.

Contractors didn't like this. Their chief argument was that they had developed this technical data at considerable effort, in some cases with their own money when there was no other support forthcoming. Ramo-Wooldridge was in a position to compete with them for future missile contracts. The contractors' first reaction was that they'd be damned if they'd turn over their hard-won data to make it easier for R-W to compete.

This was not what was supposed to happen, and WDD had a lot more explaining to do. R-W said its job was to provide technical direction and overall systems engineering—not production of the systems. R-W would build some experimental units probably, but this would be done only to help in their understanding of the systems problems.

These soft answers turned away the wrath of the contractors to a large degree, and the review went on relatively unhampered. But now and then a disgruntled rumble still can be heard, and this sore point may never heal to the complete satisfaction of both doctor and patient.

Development Philosophy

Two basic philosophies governed that first study and review by WDD:

• **A different kind** of test program designed to reduce flight testing and losses in flight. Because reliability is the key to successful weapon systems, reliability testing was planned for the earliest stages instead of waiting for complete systems or sub-systems. Facilities for the unique tasks were not in existence and had to be improvised or invented and built for the component and sub-system testing.

• **A multiple design approach** with back-up provisions. The scheme was to provide two major contractors per sub-system except for the guidance package, for which several were to be selected to do the development job. If one contractor fails, the alternate contractor's system must be available for substitution. This does not preclude different approaches to the same subsystem, but instead encourages different technical paths.

The overall weapon system job for strategic missiles is broken down into sub-system areas for technical and contractual reasons. Four major sub-systems are the building blocks for these missiles: airframe, propulsion, guidance and nose cone.

Principal contractors for the strategic missiles program, and the sub-systems they are responsible for, include:

• **Airframe:** Convair Division of General Dynamics; Martin, Denver; Douglas Aircraft Co.

• **Propulsion:** Aerojet-General Corp.; Rocketdyne Division of North American Aviation, Inc.

• **Guidance:** AC Spark Plug Division of General Motors Corp.; American Bosch Arma Corp.; Burroughs Corp.; General Electric Heavy Military Electronics Division at Syracuse; Massachusetts Institute of Technology; Sperry Rand Corp.; Western Electric Co.

• **Nose Cone:** Avco Manufacturing Corp.; Lockheed Aircraft Corp.'s Missile Systems Division; General Electric Co.'s Special Defense Projects Dept.

Ramo-Wooldridge's Role

Less than one year after its founding by Drs. Simon Ramo and Dean Wooldridge, R-W became one-third of the management of a project that even today occasionally staggers the scientific mind.

Its nucleus was a group of disenchanted employes of Howard Hughes; today it numbers 2,000 personnel, predominantly scientists and engineers. It was founded to do research, development and manufacturing in the field of avionic systems and guided missiles. It now occupies eight buildings totalling 350,000 sq. ft., has another 900,000 sq. ft. under construction as a research and development center on a 40 acre tract, and is building a new avionics plant just south of Denver.

This phenomenal growth can be attributed in part to the enormity of the task assigned to R-W by the WDD.

"Our major requirement is to under-

Ballistic Missile Chronology

About 15 years will have elapsed between the first flight of the Atlas and that of its distant relative, the German A4 (V-2) ballistic missile. But this time lapse is not as important as the 10-year gap between the first studies leading to Atlas and the experimental missile's first flight.

Ten years is a long time on the calendar of weapons progress. A decade separated the start of the German experimental rocket program from the first good flight of a V-2 in October 1942. A decade will separate the first study contract for the precursor of Atlas from the first major tests of sub-systems and—with luck—the first flight of an Atlas test vehicle.

There are more than time parallels between the German program and that of USAF. For both, part of the long lead time can be attributed to the technical magnitude of the job to be done.

But too big a part can be charged against false economies, low priorities and incomplete understanding of its potentialities at high military and government levels.

The chronology:

- 1942: First V-2 flights; two unsuccessful rounds in June and August were followed by the first completely successful firing in October.
- 1944-1945: Approximately 6,000 V-2 rockets were built and about 3,600 were launched against London, Antwerp, and other European targets.
- 1946: First study contract on MX-774 long-range ballistic missile let to Consolidated-Vultee (now Convair division of General Dynamics Corp.).
- 1947: Economy review by Defense Department under Louis Johnson cancelled the MX-774 project.
- 1951: Second study contract let to Convair for MX-1593 long-range missile. This study carried a low priority aimed at realizing a missile in one or two decades.
- 1952-1953: Break through in thermonuclear technology reduced the multi-thousand pound bomb to a light-weight warhead with a high yield, making possible a tremendous reduction in weight and size of the ICBM.
- 1952: A major study projecting weapons technology was made to see in what direction future weapons systems go. Part of the study was concerned with concepts and technology of the ICBM.
- 1953: Strategic Missile Evaluation Committee was established by the Air Force with Dr. John von Neumann as chairman, sparked by Trevor Gardner, then USAF assistant secretary for research and development.
- 1954: In February, the von Neumann committee recommended establishment of a development-management group for strategic missile programs. The Air Council and the Secretary of the Air Force approved and the project received highest USAF priority.
- 1954: In June, the Air Research and Development Command was directed to establish a field office to monitor strategic missile development.
- 1954: Western Development Division assumed its responsibility in August, bringing in under the same roof the Air Materiel Command's Special Aircraft Project Office (now Ballistic Missiles Office) and the Ramo-Wooldridge Corp.'s guided missile research division. WDD was to act as overall monitor; SAPO was to look after the contractual angles, and R-W was responsible for systems engineering and technical direction.

stand the relation between military requirements and the state of the art," said Dr. Simon Ramo. "For this we must have people with experience in complex weapons systems as well as the pure scientist with no responsibility for any particular part of the missile but who understands the concept of a weapon. These people must judge what industry can accomplish, knowing the organizations of industry. They must be capable of creating a research and development plan possible of attaining and based on the facilities available and to become available."

Average age of the key personnel at R-W is around 40, and there are about 40 of them. Their backgrounds include academic, governmental and private research laboratories and industry. In addition the company can call on the services of part-time consultants in many specialized fields.

R-W had a guided missile research division available before it got the ICBM-IRBM jobs, but not under that name. A group of company personnel were doing missile systems studies for the von Neumann committee at the time that that committee was doing its strategic missile evaluation. Part of the von Neumann committee's final report was the recommendation that a development-management group be created to run the strategic missile program.

The new division of R-W was created to match the systems responsibility given it by the Air Force a few months after the von Neumann group's final report.

Ballistic Missiles Office

The formation of Western Development Division was followed through by the Air Materiel Command with the appointment of Brig. Gen. Benjamin I. Funk as Deputy Director for Ballistic Missiles. Gen. Funk was assigned to head the Special Aircraft Project Office (now the Ballistic Missile Office) of AMC in Los Angeles.

BMO authority covers procurement, production, quality control, supply, maintenance and transportation for the ICBM-IRBM programs.

Its personnel contribute to all group activities that recommend qualified contractors, solicit proposals and evaluate them to choose the contract winners.

Approximately 30 ICBM-IRBM contracts are monitored by the BMO.

Selecting Contractors

The routine for selecting contractors to contribute their specialized knowledge to the strategic missile programs begins with a requirement prepared by ARDC's Western Development Division. A team made up of AMC and ARDC personnel recommend the best qualified contractors for the job, based on past performance, present workload, technical capability, available facilities and similar factors.

Requests for proposals are sent to these contractors by the Ballistic Missiles Office jointly with WDD. These requests are followed by a pre-proposal briefing at which details of the requirement are discussed with the prospective contractors and any necessary revisions or changes are made.

Evaluation Board

Next step is the establishment by WDD of an evaluation board with members from WDD and BMO with R-W advising. The board's job is to prepare criteria for evaluation of the proposals and then to review the proposals. Evaluation of the various phases of the individual proposals by specialists and further conferences with the contractors follow.

Choice of the contractor is made by the evaluation board, which names a sole source or a prime and backup sources. The board's recommendation is forwarded by WDD and BMO to the three Headquarters of ARDC, AMC and USAF.

So far, 17 major contractors and a host of minor ones have been selected by this method. Not every selection has met with complete acceptance by the bidders, but the batting average is very high. ■

SPECIAL RADOME ON F-94C TESTS AND EVALUATES MISSILE COMPONENTS

Patrick Prepares for Ballistic Missiles

By David A. Anderton

Patrick AFB, Fla.—The IRBM and ICBM test programs have triggered an explosive expansion at the Air Force Missile Test Center.

During the next two years the center must approximately triple its present program capability to meet test requirements for hypersonic weapon systems with intercontinental ranges and to launch increasing numbers of shorter-range missiles. The list of active projects then will include missiles of all the services and of several types and ranges.

To handle this workload, the range is being extended to lonely Ascension Island, 5,000 mi. away from the Cape Canaveral launch pads. New instrumentation is being developed and bought to see optically and electronically for greater distances than ever before.

More buildings and other facilities are programmed and under construction. Personnel increase in the USAF organization is estimated at 30%; range and missile contractor personnel may quadruple.

This planned growth indicates more than any other factor that the missile program, for long years a political and technical football, has been kicked around for the last time. The future growth and stability of AFMTC now seems assured.

Look to the Future

Credit for a major portion of the planning incentive is given by military and civilian employes to Maj. Gen. D. N. Yates, AFMTC's commander. Said one civilian: "He's just what you need in this business: a bear on planning ahead."

Future growth will be built on a large, strong base: the present state of the range. During the six years of operation, the programmed work load has grown astronomically. These are the highlights of current operations:

• **Active missile programs** underway—the Boeing Bomarc, Martin Matador, North American Navaho, Chrysler Jupiter-A (formerly Redstone) and the Northrop Snark.

• **Eleven contractors are on the site** working with missiles or missile subsystems. This does not include the joint range operators, Pan American World Airways and the Radio Corp. of America.

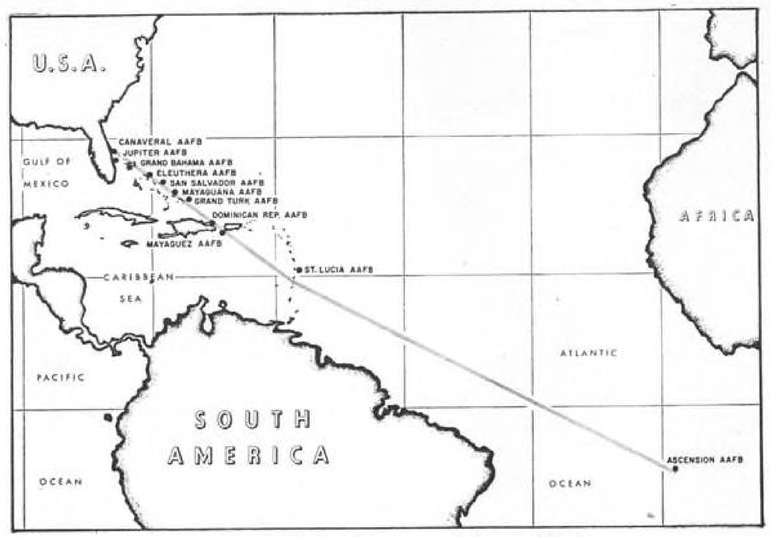
• **Work load is about 250 tests** per month, of which only a very small percentage are live rounds. The rest are simulated missile flights using USAF aircraft flown by contractors.

• **Operating costs are at about** a $4 million level per month.

• **Personnel total about 9,500.** Approximately 4,000 are the range contractors', 2,200 are military, 1,600 are civil servants and 1,600 are missile contractor employes.

• **New construction is everywhere.** A new technical systems building will open soon. Downrange stations are getting additional facilities. At the Cape Canaveral launching sites, half a dozen additional pads are being built, singly and in complexes.

Maj. Gen. Donald N. Yates, Commander, Air Force Missile Test Center . . . born Bangor, Me., 1909 . . . graduate of U. S. Military Academy, 1931, and California Institute of Technology, 1939 . . . learned to fly at Kelly Field . . . spent five months in Russia in 1942 as member of a military mission . . . directed Strategic Air Forces Weather Service in Europe in World War II . . . Chief, Air Weather Service, 1945-1950 . . . assistant deputy chief of staff for development and later director of research and development, USAF Hq. before taking command of AFMTC in July, 1954 . . . former president American Meteorological Society . . . member Institute of Aeronautical Sciences and American Rocket Society.



PRESENT 1,500-mi. missile test range is being extended to 5,000-mi.

But now the sudden surge to grasp the technical subtleties of the intercontinental ballistic missile has reoriented the thinking and planning of the military and civilian scientists here. To the carefully built foundation of their present range they now must add a superstructure to meet the new and peculiar requirements of the IRBM and ICBM.

Range Extension

The proximity of the test program for at least one strategic missile, the Convair Atlas WS-107A, has spurred extension and expansion of the range. On Cape Canaveral, launching point for all test missiles, concrete is curing in a complex of blockhouses and launch pads for the ballistic missile family. Survey and construction crews have begun work on Ascension Island, the scientific outpost and present terminal point.

Monopulse radars that can see a missile at distances of several hundred miles have been developed and are being procured for the specialized tracking problems of high-altitude trajectories.

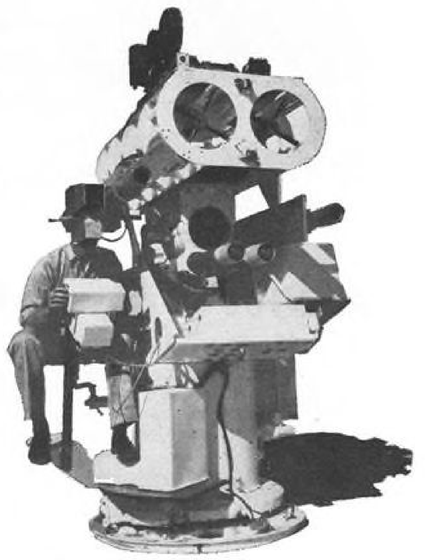
Advanced optical systems based on astronomical telescopes slaved to radars will yield visual data on missile attitude, stage separation and re-entry tumbling at distances well over 100 mi. away.

All this expansion is chargeable directly to the long-range ballistic missile programs, but more than distance and new instrumentation is planned for future growth.

Increasing numbers of Army, Navy, and Air Force missiles will outgrow the limitations of other service ranges at White Sands, Inyokern, Pt. Mugu, China Lake and Holloman AFB.

The biggest problem facing AFMTC will be to expand the range rapidly and

MITCHELL 35-mm. attitude camera.



SANDIA tracking telescope.

FULL SKY recording camera takes picture every 15 min. of complete sky as reflected in a 12-in. glass sphere.

still maintain the high utilization rate.

First complaints of range saturation already have been heard. "It isn't saturation, it's restriction," said Col. H. J. Sands Jr., AFMTC Deputy for Test. "This is a problem right now, but good planning can solve it. It's going to mean tight scheduling, and firing when the schedule says to go."

Quadrupling of the firing schedule over the past three years has forced a change from the first leisurely pace. Then, if a missile crew needed four or five hours or more to calibrate the telemetry, time was available. The entire range could go off the air while one missile transmitter and receiver were checked.

In the future, telemetering calibration will be done on closed coaxial cable loops and the range will stay open. Plans are that there will be no radiation during an entire ICBM test round check until perhaps 90 minutes before launch.

All this, Col. Sands believes, will cure any symptoms of range restrictions. Of them, meeting schedules is the most important.

Future Potential

Dividing line between present and future range capabilities is the island of St. Lucia, about 1,500 mi. from the launching sites on a course splitting the Mona Passage between the islands of Puerto Rico and Hispaniola.

Below St. Lucia the range takes on an entirely different character, born of the unique problems of a trajectory that reaches far into the ionosphere and stretches over 5,000 mi. Col. Claire E. Ewing, Director of Range Development, explained the tie between the trajectory and the range:

A ballistic trajectory can be divided into three areas of interest:

• **Launch to burnout,** covering the period from the time the missile lifts off the pad until all its stages have burned and separated.

• **Mid-course,** during which the missile coasts to the zenith on the kinetic energy of its speed at burnout, and falls down the other side towards the earth.

• **Re-entry,** when the missile plunges through the atmosphere, weathervanes, and arrows downward to the impact point.

Covering the first phase will be the island stations between the Cape and St. Lucia.

Down to St. Lucia, the range was built for aerodynamic missiles. Telemetry, tracking radars and command destruction equipment were developed to watch missiles in level flight within the atmosphere at altitudes not exceeding about 20 miles, and slant ranges probably under 100 miles.

But the Great Circle route between Cape Canaveral and Ascension is off the island chain by a considerable dis-

tance; in some cases one missile will never be closer than 100 miles from a tracking station.

Tracking Farther

This distance has forced the extension of current radar and optical tracking equipment to cover ever greater ranges. Convair's Azusa C-W system and the COTAR (Correlation Tracking and Ranging) system are being developed for ballistic missile tests. Azusa is under consideration as an input to impact point predictors; it has been tested successfully during several ballistic missile launchings. COTAR will be of primary use at remote sites for tracking the re-entry phase.

One significant problem underlined by Col. Ewing is caused by the attenuation of transmission from the missile by the free electrons in the path of the flame of the rocket motors. Some tests on the Army's Jupiter A have shown that the problem is not as severe as expected, but the tests are not believed to be completely conclusive.

At burnout the engineers expect to be able to pinpoint the missile within a distance comparable to the missile's size and to measure its speed within a few feet per second. The latter accuracy is about one part in 10,000; this is precision measurement.

Below St. Lucia, ballistic missile trajectory data are of relatively little importance; the critical phases of the flight are from takeoff to burnout and from re-entry to impact, so missile position and velocity are not required to the extremes of accuracy needed at burnout.

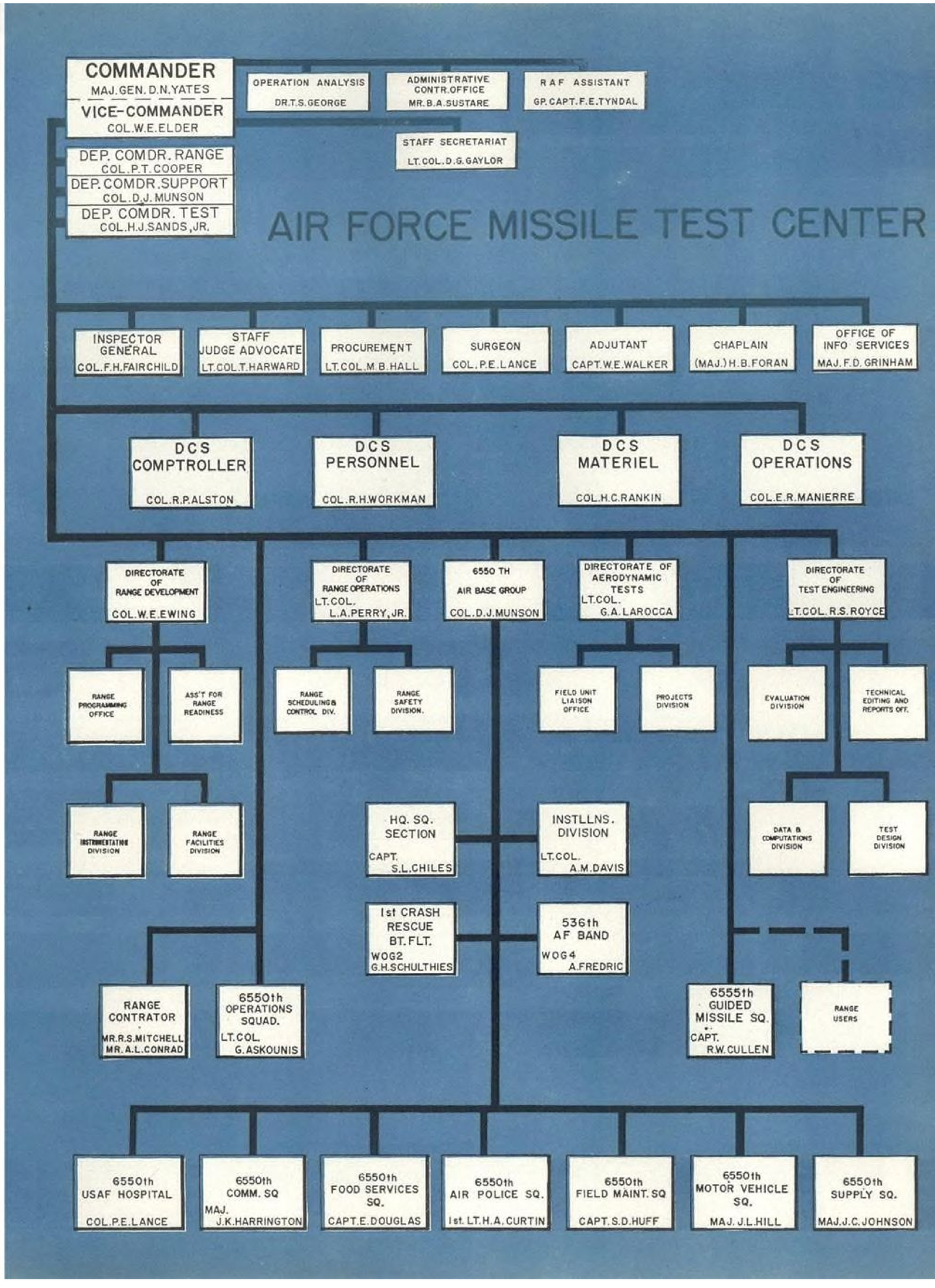
This less-precise telemetry data doesn't require knowing the position of the ground station to the same precision as the uprange stations covering the path to burnout. Those stations, surveyed by radar navigation systems, are spotted within a few feet of their true position.

Telemetry stations below St. Lucia will be ships, strung out in a line parallel to the coast of Brazil. Their position will be known within several hundred feet, which will be accurate enough for the purposes of the mid-course phase. No islands are available.

'If We Miss Ascension . . .'

The end of the 5,000-mile line now is Ascension Island, the guano-covered home of gooney birds and a way station on the route to Africa in World War II. Into the waters off this volcanic island will splash the ICBM test rounds after their searing ride through the atmosphere.

The last few hundred miles before Ascension measures the re-entry of the ICBM. The kinds of information needed during the critical portion of the flight means that precision track-



ing radars and command destruction must be available.

One anticipated difficulty during the re-entry phase of the ballistic trajectories will be created by ionization caused by the high compression and temperatures behind the shock wave. Transmission from the missile will be very difficult through the ionized layer.

Two ways have been suggested to avoid this—use high-gain telemetry antennas in a quartering position behind the nose cone, and therefore out of the extreme ionization pattern, or skin-track the nose with long-range monopulse radars until ionization ceases.

Impact points of these long-range missiles can be located quite precisely by listening techniques, comparable to underwater sound systems used in anti-submarine warfare. These techniques are being explored now.

Range errors as high as 10 miles over the complete trajectory of an ICBM could result from variations in the local acceleration of gravity. The earth's crust is neither uniformly thick nor dense; those variations mean changes in G force with geographical position as well as with altitude.

Gravity surveys are being made from Ascension Island back up to the Cape. These surveys will yield more accurate values for acceleration due to gravity.

Range Safety

Development of safety equipment has moved along with the growth of the range itself. Originally the range safety officer watched the missile rise against a vertical reference of a plumb line. Now the safety system has reached a degree of sophistication matching other instrumentation.

Safety systems cover two time periods during a missile-firing:

- **Zero to three seconds,** during which the missile is lifting vertically and any variation from course, means instant cutoff and a crash back on the pad.
- **Three seconds to burnout,** during which any cutoff must be predicated on the impact point of the aborted missile.

The first system was the personal observation technique, called an open sky screen; second was an optical sky screen, with the human eye aided by a scope with internal references. Next came monopulse radars to measure deviations from vertical. Fourth system was Elsie (ELSSE: electronic sky screen equipment) which uses a phase comparator on two pairs of radar sets at right angles, one pair watching the azimuth and the other the programming turn downrange. This is the current system.

Heart of the system for the second time period is an impact predicator consisting of three units: a C-W radar

for tracking, a computer and a display device, which comprises both plotting boards and cathode ray tubes. It shows the range safety officer where the missile is and where it would fall if the power were to be cut at that particular instant. This system will be completed shortly and is waiting for a building now.

Joint Operators

The combined operation of the range by Pan American World Airways and Radio Corp. of America has been in effect only about three years. "During that time," said A. L. Conrad, manager of RCA's Missile Test Project, "Very few rounds have been delayed or aborted due to range operations. This is good, because the time scale of the programs forces us to take range equipment from development straight into field operations without any time for shakedown."

Relations between Pan American, RCA and USAF are formally clear. Pan American is charged with administration, support, maintenance and housekeeping of the range; RCA does the techniqual work of data gathering, reduction, photo processing, report writing. Both report to the center commander through his Deputy Commander for Range, Col. Paul W. Cooper.

RCA engineers begin work shortly after a contractor's test proposal arrives at the center, collaborating with the missile project officers under Col. Sands and the engineers in Col. Cooper's organization, developing instrumentation requirements, figuring budgets and plans for the tests and evaluating the proposals from a technical view. RCA monitors the tests and delivers the reduced data to the Air Force; the end product of RCA activities on the range is a final flight test data report.

When the combined operations of the range began, some test flights took weeks to get reported; in one extreme case the delay was 135 days. Average time to produce a final data report now is between 10 and 12 days, according to Conrad.

Improved Maintenance

Maintenance of the instrumentation is under control, Conrad reported, even though it is complicated by the combined humidity and salt water corrosion at the stations. Better supply systems and better programming have contributed to maintenance improvement.

RCA keeps several teams of maintenance inspectors roving the range, checking on station techniques for repair and overhaul.

One difficulty was that RCA found no as-built drawings of the equipment when it took over. There were drawings showing what the original designers had in mind, but there was little relation between that and the piece of equipment as it stood on the concrete. So one of the major projects was to prepare a complete set of as-built drawings; that has been done. Drawing standards, conspicuous by their absence in the center blueprint and Ozalid files, have since been set up to the RCA system.

Missile Test Program

A contractor with a missile test program in mind approaches the center with a formal, thick document delineating the program requirements. This blue-covered Test Requirements Handbook serves the contractor both as a guide to the center capabilities and an outline for his test series.

In its pages are complete descriptions of the range, instrumentation, operations, data gathering and reduction, and everything else he needs to know to plan adequately. The back of the handbook contains a sheaf of blank forms in standardized layout which the contractor uses to explain and justify his test plan.

Sands, his project officer and test engineering group review the completed handbook, and as the test requirements become firm, pass them to

the Deputies for Range and Support.

The Central's formal answer to the contractor's proposal is the Test Support Plan, a fat folder of detailed test operations.

With the formalities and scheduling completed, the contractor tests begin. Preliminary data evaluation is done under Sands' control, because in this way, early feedback of the data can be used to check the adequacy of the test plan and indicate what might be added or deleted from the operation.

6555th GM Squadron

About 150 officers and enlisted airmen make up the 6555th Guided Missile Squadron, a combination of a training and support operation.

Under Capt. R. W. Cullen, the Squadron reports to Col. Sands as a part of the Center's test operations.

Primary function of the squadron is research and development testing; however, it will train initial cadres for USAF missile squadrons. It does not form "package" missile outfits comparable to the Army system.

Major contributions to missile projects have been made by this squadron. For one missile now operational with USAF, the 6555th modified in one way or another all the ground handling equipment, half the checkout equipment, and the test program. For example, all vacuum tubes were removed from the field checkout gear to eliminate the uncertainties of their operation.

Before a USAF missile is released for production, the 6555th has run through the complete field sequence with the bird and its equipment from receipt of the disassembled unit to a firing.

After the missile gets into field use, the squadron still may be active when field troubles develop. Missile improvements by the contractor, either on his own or spurred by Unsatisfactory Reports from the field, mean a further firing program. This is generally assigned to the 6555th.

Shakedown of the contractor manuals for missile erection and maintenance is another important function.

Lt. Col. Gust Askounis' 6550th Operational Squadron chases missiles, operates an airline, carries the mail, simulates missiles, monitors radiation interference, keeps an eye on the range for safety, and drives drones.

Askounis and his pilots fly jets, transports, cargo planes, helicopters, amphibians and old bombers, a total of about 50 airplanes of around a dozen different types.

A typical month finds the squadron's C-54s ferrying a half-million pounds of special cargo downrange, and flying about three-quarters of a million passenger-miles.

Downrange Life Is Work and Hobbies

Grand Bahama Island, BWI—A dozen scientific outposts on as many islands mark the downrange stations of the Air Force Missile Test Center.

On them work an order of scientific hermits, employes of Pan American World Airways and the Radio Corporation of America, joint operators of the range.

These technicians man and maintain the complex optical and radar tracking systems, cameras and telemetry ground stations that gather and record the myriad test points during a missile flight.

This island is a typical station. You land on an airstrip hacked out of coral rock by the Aviation Engineers and drive a few hundred yards to the base. A handful of low white buildings spreads around a parched plot with a flagstaff at whose head fly the American and British flags.

Inside the buildings, the life of a post-shoot day drones quietly. Technicians, up until early morning with a sick missile, sit through the coffee break on the shaded porch of the mess hall, reliving the firing and unwinding the tension of last night.

The Quick Tow

A tour of the base takes five minutes —longer if you stop to look at the housing and talk with the men who are awake at this hour. The dormitories are laid out with a long corridor-porch along one side. Double rooms lead off the corridor, with a bath between each pair of rooms.

In one room are the twisted wiring and pyramided boxes of a hi-fi system. An easel with an unfinished oil decorates one corner of the next room; airplane and other models brighten a third.

Work and sleep and eat, hobbies and athletics: that about sums up the life at one of these downrange stations. But that's a dull summation. The work can be as exciting as it is necessary to the success of half a dozen missile programs.

Sleep is sleep, anywhere, and food is unusually good. Coffee is on tap 24 hours a day; box lunches—with the thickest sandwiches yet seen—go out to the tracking sites after hours. Pan American's commissary runs the mess hall and produces 650 meals each day from an efficient kitchen.

Island Hobbies

There is a skin-divers' club, and a flying club—which at one time had five planes on a homemade strip—tools of the base carpentry and machine shops. Fishing is typical of the Bahama Banks

area; when they bite, there are big ones and lots of them. There are movies seven nights a week.

With all this, the men are paid salaries comparable to industry rates back home. They also get a 30% overseas bonus, extra vacation time (one month after two years' service with RCA), home leaves on Fridays and Mondays to straddle and include the weekend. After 18 months out of the U.S., they can get a refund of all the income tax paid during that time. Board and room are free.

There is not much to spend the money for, either. There is a Club Rendezvous, where liquor is cheap, but in a closed community like this one the hard drinker is soon returned to the mainland for reason. So men stay sober; tomorrow might be a tough day.

There's no stipulated work week; the men have to be ready for duty at any time. If they work for RCA, they have a minimum assignment of one year downrange. If they are Pan American employes, the assignment is considered permanent.

Managing the Base

Manager of the base is Russell Reed of Pan American. His responsibilities include housing, feeding and supporting all personnel, administering the base, heading up the data gathering crews, and monitoring the work of the technicians. Russell used to fly for Pan American. After being assigned here, he flew his own plane to the mainland on weekends or days off, but recently he gave that up.

Base commander is Capt. Arthur G. Miller who formerly was a chase pilot with the 6550th Support Squadron at Patrick. Like his counterparts at every downrange station, he has no troops to command, no planes to operate, no logistics to provide. Range safety during a firing is his overriding responsibility. His other tasks include meeting emergencies of illness, evacuation, or fires; monitoring the use and care of the Air Force-owned instrumentation, and as the official representative of the United States Government in a British colony, liaison visits with the Crown Commissioner.

Permanent population of this station is about 220, with transients occasionally bringing the total to 250.

There are two women on the base, wives of technicians. Women can come only to a very few of the downrange sites, and then only with special reason. All natives are off-limits to the men. But down at the West End, there is a resort where occasional plane loads of school teachers and secretaries land for vacations. The resort is not off-limits. ■

Holloman Evaluates Missile Systems

By Irving Stone

Holloman AFB, N. M.—A battery of new test facilities aimed at meeting exacting development requirements of missiles scheduled for the Air Force arsenal is being acquired by ARDC's Holloman Air Development Center.

These new facilities will give Holloman a key role in missile development:

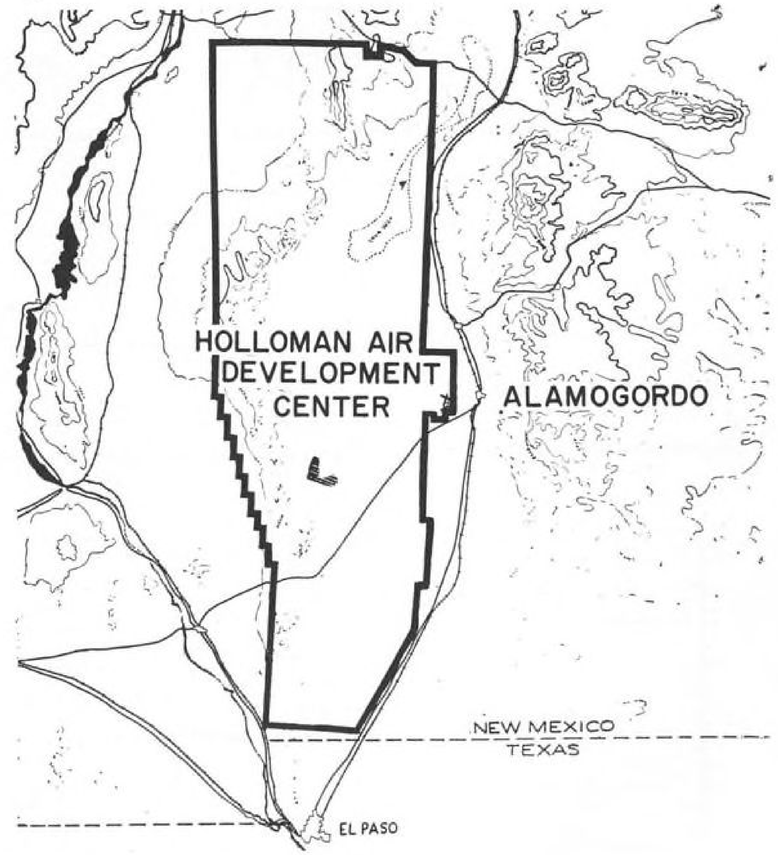
• **A closed-shop in-flight** performance analysis system which will automatically compute and send immediate corrective responses to operational signals from a missile so flight may continue under new test conditions. This precise test control will cut down the number of proving flights required for a missile.

• **A 35,000-ft. captive-missile test track** on which missiles and missile components can be sled-carried to discover and eliminate "bugs" before actual firings. The growing complexity and high cost of missiles will demand increasing reliance on this type of pre-proving facility to save both money and time.

• **Captive-missile test stands** which will accommodate the largest missiles being built today. Operation in these static stands will reveal system defects in a relatively inexpensive procedure which does not expend the missile.

• **A solar furnace** to create very high temperature conditions for realistic study with basic materials and other factors related to missiles.

Other facilities are under study.



How HADC Helps Industry

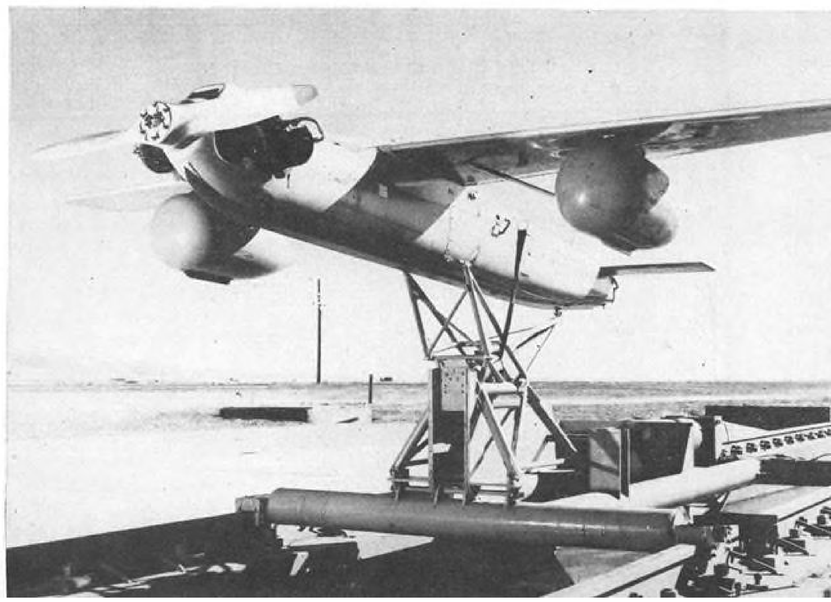
Despite the projected growth and the accumulation of knowledge which will accompany it, Holloman will not become an independent developer of missiles. The center will continue to rely on industry for design and fabrication of the missile, using its facilities only to test and evaluate. Holloman's management talent will be directed at assisting the contractor in the interpretation of military requirements and projecting requirements of future weapon systems.

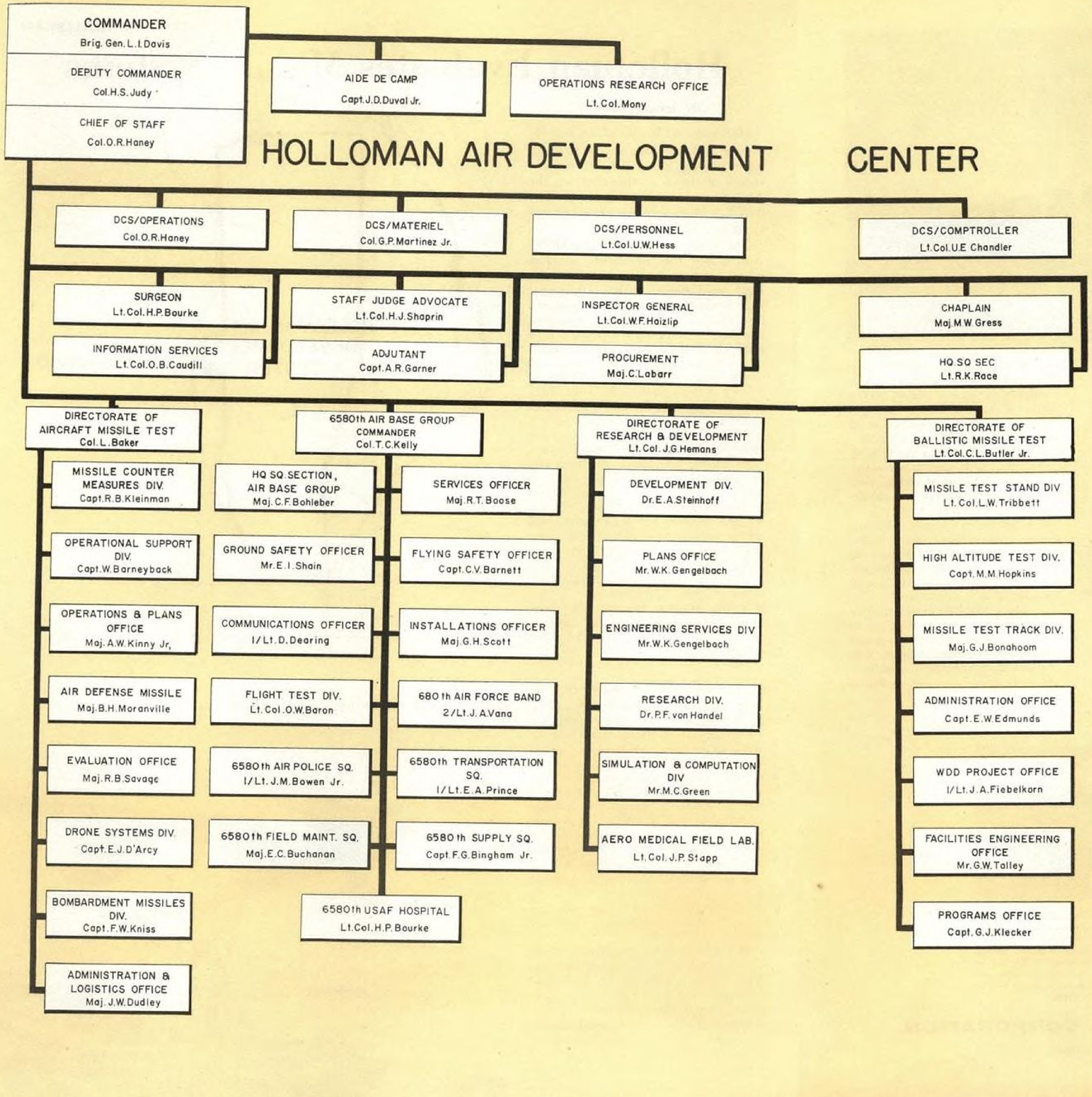
Some 26 major contractors now are testing here. They include Bell, Lockheed, Douglas, Ryan, McDonnell, Convair, Hughes, Radioplane, Goodyear, Martin and Aerojet.

HADC's Directorate of Research and Development was established only last May. It is headed by Lt. Col. John Hemans. Its function is to sponsor research and development in missile systems. It also lends scientific support to contractors whose missiles are being tested at Holloman.

Big item in the directorate's projected

CAPTIVE OQ-19 TARGET DRONE ON 3,600-FT. TRACK





Brig. Gen. Leighton Ira Davis, Commander, Holloman Air Development Center . . . ARDC's first armament director . . . ARDC Hq. posts from 1951 until he took command of HADC in September 1954 . . . graduate of U. S. Military Academy, 1931 . . . Director of Army Air Force Ground School there in 1942 . . . holds Institute of Aeronautical Sciences' Thurman H. Bane Award for work in developing jet fighter fire control equipment . . . held engineering, bombing, armament and research posts at Wright Field and commanded Office of Air Research there in 1949 . . . became Deputy Commandant and later Commandant of the Air Force Institute of Technology . . . holds Legion of Merit with Oak Leaf Cluster.

plans is the improvement in missile flight testing techniques through the use of a novel "real-time" closed-loop performance analysis system. Expected to be in operation in 1958, the installation will cost approximately $8 million.

The system will reduce the number of flight tests required to obtain desired engineering information and permit extension of missile flights into regions of uncertainty without immediate loss of the weapon. As a testing procedure, it is aimed at providing corrective design data, rather than detection of gross, basic errors, such as in assembly.

Under the command of Brig. Gen. Leighton I. Davis, three principal organizational elements conduct missile tests:

- **Directorate of Research and Development.**
- **Directorate of Ballistic Missile Test.**
- **Directorate of Aircraft Missile Test.**

'Man in the Missile'

The "real-time" feature of the system is that computer analysis of missile performance is conducted rapidly while the missile is in flight. This feature, plus the closed-loop capability, is equivalent to "putting a man in the missile."

New test conditions, based on the computer's analysis, can be established and test variables changed while the missile is in the air, much the same as a test pilot would control flight parameters.

It is estimated that time for a closed-loop analysis of one element of missile performance will be of the order of ½ sec.

This approach to missile testing will require test engineers to devote much greater effort to test planning. Preflight test requirements also will be increased to provide the more accurate and extensive data needed for flight test planning.

The real-time, closed-loop performance analysis system will receive flight test information from missile telemetering equipment and ground instrumentation such as radar and other tracking devices. This will be converted and transformed by computer equipment.

Equipment will consist of telemetry receivers, analog-to-digital converters and other electronic units which will assemble the information and feed it to two high-speed digital computers—the heart of the installation.

One computer will reduce data while the other does the performance analysis in conjunction with analog computers and simulation equipment.

When performance characteristics are being analyzed, signals will go to the missile through a transmitter so test parameters can be changed immediately.

Until the new system is ready, the directorate is using an elaborate analog computer system and flight simulation equipment for support of missile testing in the preliminary ground phase. Design studies are checked by analog computer and actual hardware is checked by physical simulation equipment.

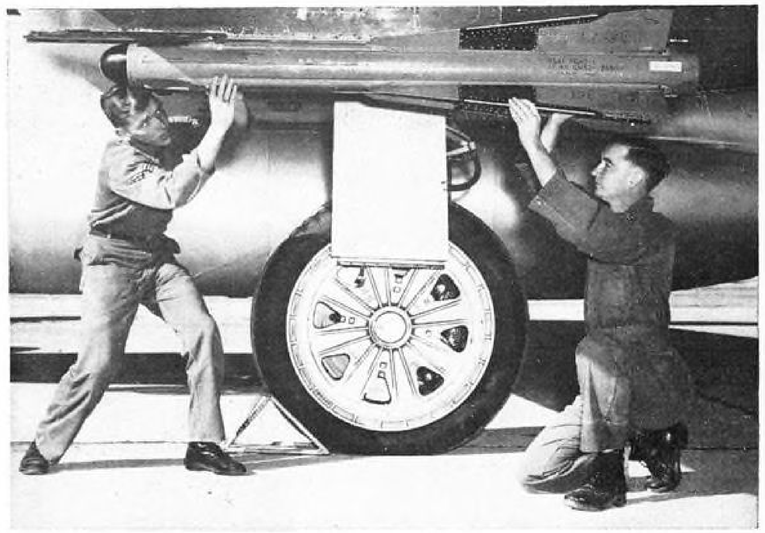
Rocket Test Vehicles

Big part of the directorate's work is development of rocket-powered test vehicles for checking guided missile components under conditions of acceleration, vibration, temperature and pressure similar to those which would be encountered in flight.

In effect, vehicles are themselves missiles especially designed to carry test instrumentation. Geometry of the test vehicle resembles that of the guided missile whose components are to be checked.

Two types of test vehicles are used—free flight types and captive units for mounting on a track sled.

Duration of test vehicle operation is less than that of the normal flight time of an actual missile but of sufficient



HOLLOMAN PERSONNEL attach Falcon air-to-air guided missile to its launch aircraft.

length to give results that are desired.

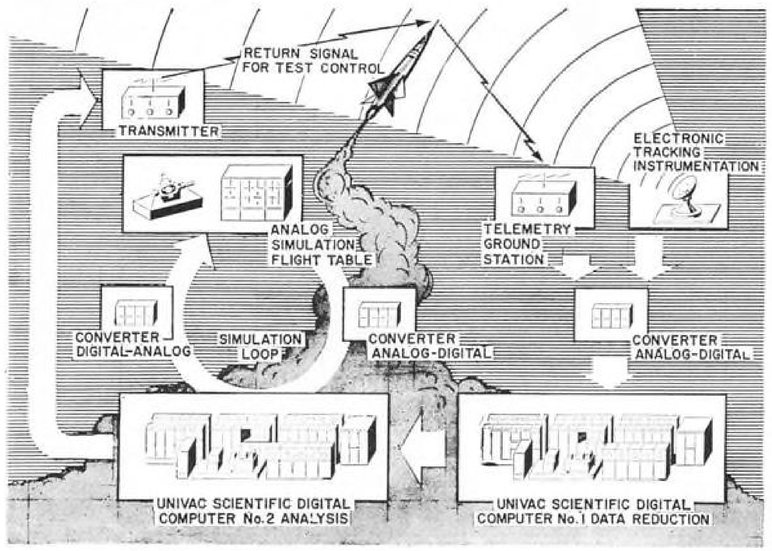
Some of the directorate's work is concerned with Air Force feasibility studies for future missiles. If also supplies consulting services to the Air Force for advanced scientific programs.

The directorate now has a staff of about 60 scientists. That number is expected to be more than double within the next two years. The staff now includes many former German scientists who were associated with the V-2 program during World War II. Fifteen staff members have PhDs.

Because of its unique geographical location and the new facilities it will operate, HADC will see increased work on ballistic missiles coming into the Air Force inventory. Most of this work will fall under the jurisdiction of the Directorate of Ballistic Missile Test, headed by Col. C. L. Butler.

One of the directorate's key installations will be the 35,000-ft. captive-missile test track, scheduled for completion in September 1957. It will be an extension of Holloman's 3,500-ft. track and will be located on terrain which will allow it to be extended to over 100,000 ft. if longer stretches become necessary.

The track will be a test tool on which shock and accelerations experienced in actual launchings and velocities attained in free flight can be duplicated by sled



MISSILE PERFORMANCE ANALYSIS SYSTEM

runs, eliminating the costly and time-consuming firing of individual missiles. The 35,000-ft. stretch will permit longer periods of data recording at speeds considerably higher than those attainable on shorter tracks.

Speeds Up to Mach 4

Initially it is expected that speeds between Mach 3 and 4 will be attained, and accelerations up to 50Gs. Studies of effects of decelerations in excess of 200Gs are planned.

Components of ballistic and other types of missiles, including guidance systems, fuel pumps and tanks, will be sled-mounted to determine how they resist the forces imposed by simulated launching and flight.

For simulating aerodynamic heating, the skin and structure can be preheated before the sled is launched to see if the assembly holds together during the sled run.

The track sled will be able to accommodate complete small missiles. Conceivably it would be possible to mount a large missile, too, but this is not included in the immediate planning.

Captive Firings

Initially the track will not be used for firing sled-mounted missiles but captive firings are planned for the future.

To minimize clicking effects of track joints on sled instrumentation, track lengths will be welded and ground smooth to make 10,000-ft. sections, joined by bolting. Track gage will be 7 ft. and weight of rails will be 171 lb. per yard. The sled will be stopped by water braking.

Static Test Stands

Four static test stands will be constructed at Holloman to test large ballistic missiles. The missile, held captive in the test stand, will be operated as if it were being launched for free flight.

In this way test results will be obtained with the missile held intact for inspection, replacement of components and continued testing.

Every item of equipment on the missile can be checked in such a static firing. Rocket engines could be checked for thrust, fuel system operation observed, guidance system and other electronic components operated under conditions of firing shock and vibration. Even structure could be checked for resistance to shock.

Considering the great cost and complexity of large ballistic missiles such as the ICBM and IRBM, repetitive preproving in the static stand will bring tremendous economies and save valuable time before the missile type is approved for flight status.

A powerful new tool which probably will be used by the Ballistic Missile Test

• HOLLOMAN

Directorate in tackling high temperature problems associated with future ballistic missile flight is a huge solar furnace generating temperatures in the range of 6,000-8,000 degrees F.

Reported to be the largest of its type yet planned, the solar furnace probably will be a joint Air Force–Army-Navy project, managed by HADC.

Among other things, the furnace will be used for this vital research:

• **Investigating behavior** of potential missile materials subjected to extremely high temperatures. Exposure to heat will be controlled to prevent immediate vaporization of materials.

• **Studying missile structures** under high rates of heat transfer.

• **Duplicating thermal effects** of nuclear weapons, as far as is possible.

A good solar furnace site has been located in mountains about 9,000 ft. high some six miles north of Cloudcroft, which is near HADC.

The heliostat, a flat mirror measuring about 40 by 100 ft., will revolve and follow the sun to reflect its rays to a parabolic mirror about 150 ft. in diameter. The parabolic mirror will concentrate the rays onto a relatively small area to generate the intense heat.

Research by Balloon

Another phase of the directorate's work is maintaining facilities for launching large high altitude balloons for use in upper air research done by Wright Air Development Center, Air Force Cambridge Research Center, and HADC's Aero Medical Field Laboratory.

Already the activity has launched more than 400 balloons ranging up to 172 ft. in diameter. The 172-ft. balloon will carry a 350-lb. payload to 117,000 ft., or a 2,000-lb. payload to 90,000 ft.

Next November, it is planned to launch a 128-ft.-diameter balloon which will carry a man to 90,000 ft. where he will bail out and fall free to 60,000 ft. before his parachute is opened. This will be done in support of human factors studies being conducted by WADC.

Guided Missiles Testing

Development testing of guided missiles is carried out by HADC's Directorate of Aircraft Missile Test, headed by Col. L. Baker. Most of these missiles are types carried by aircraft, although other types also are tested.

Related activities which the directorate conducts include missile countermeasure studies, recovery system development, propulsion services and photographic services.

• **Missile countermeasure activity** evaluates the missile's vulnerability to countermeasure techniques and reports on jamming susceptibility to the Wea-

Valve Talk

FOR WM. R. WHITTAKER CO., LTD.
BY MARVIN MILES

The Air Research and Development Command undoubtedly has a formal motto, but its mission could be told in two words:

"Keep Ahead!"

I use the exclaimer deliberately, for ARDC's goal cannot be stated in a matter-of-fact manner. The driving urgency of its mission must be emphasized as strongly as possible.

Nor is the vast field of the Command's responsibility difficult to designate. One word suffices:

"Quality!"

For too many years quality was subservient to quantity, with an improper balance between research and development on one hand and production on the other.

Lt. Gen. Donald L. Putt, Deputy Chief of Staff for Development, former ARDC commander, and one of the foremost proponents of special emphasis on research and development years ago, voiced the need succinctly:

"I would be the last to argue that one (quality or quantity) is more important than the other. You have to have both. The Air Force is based on quality times quantity."

In the late 1940's, General Putt and a group of far-sighted officers realized that research and development were being submerged within the Air Materiel Command because of AMC's great size, the ever-present demand for an Air Force in-being and scattered responsibility for basic scientific and technical achievement.

They advocated reorganization under which equal consideration would be given both quality and quantity aspects, a separation of research and development from procurement – to the end that technological supremacy over any potential enemy could be achieved and maintained.

A confluence of thinking, including support by the Scientific Advisory Board, won the historic struggle for research and development independence, and ARDC was formally established as a separate major command on January 23, 1950.

The results of this decision have been remarkable – brilliant is a more accurate word – and while many of them remain secret, the long list of announced achievements under the Command's carefully-considered program cover the gamut of aircraft, missiles, equipment, electronics, basic research, atomic energy, aerodynamics, aircraft design, materials, propulsion, human engineering, aviation medicine, geophysics, ordnance and armament and a variety of miscellaneous programs directly related to quality and the goal: "Keep Ahead!"

And in these achievements hundreds of non-Air Force agencies have played – and continue to play – a predominant role: Airframe and engine manufacturers, equipment concerns, independent research groups, industrial companies of many types, plus nonprofit organizations, universities, etc., and numerous government agencies such as Naval and Army Ordnance and the Civil Aeronautics Administration.

The vast bulk of USAF research and development funds is used to sponsor research and development programs within these agencies under the three primary missions of ARDC: The quest for new basic knowledge through analysis, observation and experimentation; the development of new and improved devices, processes and techniques to provide maximum effectiveness at minimum cost; and maintenance of qualitative superiority of materiel for the successful accomplishment of assigned missions.

From his headquarters in Baltimore, Lt. Gen. Thomas S. Power directs these myriad operations through ten major centers, and each center has authority to procure research falling within its field of interest.

Thus the ever-searching Air Research and Development Command, in far-flung coordination with industry and other outside agencies, assures superior new equipment for the Air Force of tomorrow.

Its programs encourage industrial achievements and scientific inquiries that over the years will not only help keep American air power in world leadership, but contribute to the welfare of every American.

As a small but zealous shareholder in aviation progress and this nation's future, the Wm. R. Whittaker Co., Ltd. pays tribute to the Command for its outstanding achievements and for its superb blending of science and technology in continuing exploration of new aerial frontiers.

pon System Project Office at WADC.

• **Recovery system activity** develops techniques and equipment for recovery of airborne recording units or even complete missiles, so that vital flight data may be obtained or missiles reflown.

• **Propulsion services** stores and handles unconventional rocket fuels, services and inspects solid and liquid missile propellant systems.

• **Photographic services** furnishes a documentary record of the missile, in the form of still and motion pictures taken on the ground and from aircraft when the missile is in flight.

The directorate's main workload is carried by three divisions:

• **Air Defense Missiles Division.**
• **Bombardment Missiles Division.**
• **Drone Systems Division.**

Talos, Sidewinder, Rascal

The Falcon air-to-air missile is the only weapon now being tested in the Air Defense Missiles Division, although other missiles are being phased in. These include the Navy-sponsored surface-to-air Talos and the air-to-air Sidewinder. The Sidewinder will be tested with the Air Force aircraft scheduled to mount it in service.

Bombardment Missiles Division has testing responsibility for both air-breathing and rocket-powered bombardment-type missiles. Under test now are the surface-to-surface TM-61B, a higher performance version of the Martin Matador, and a new guidance system for this missile.

The division also is testing the air-to-surface Bell Rascal, whose launching, guidance and propulsion systems are being checked.

Several Lockheed research test vehicles also are undergoing tests.

Air-dropped unconventional bombs with unusual trajectories are being tested also. Most of this work is done for other ARDC activities because of Holloman's specially suitable range and instrumentation facilities.

'Hustler' Components Tested

Work being done for other ARDC installations includes component testing for new aircraft, such as the Convair XB-58 "Hustler" weapons system. Some of this testing is done in the air, some on the track.

Several supersonic experimental target drones are being tested by the Drone Systems Division.

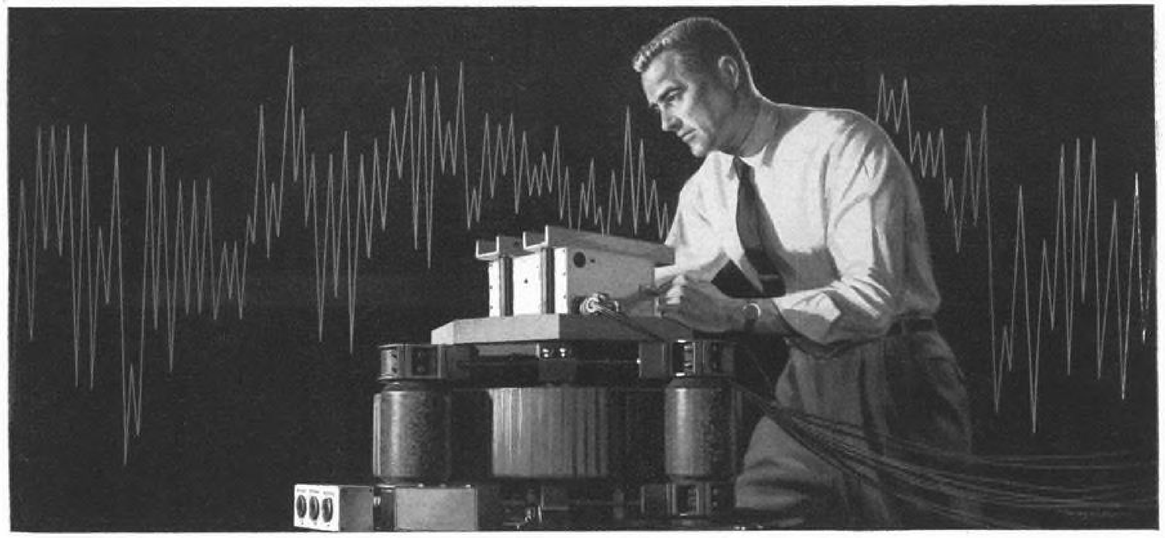
Testing also is scheduled for the XQ-2B drone, a modified version of the operational Ryan Q-2A Firebee. Refinements in the XQ-2B include more wing area, improved control system and a higher altitude capability.

Holloman's location in a vast desert area surrounded by mountains makes

Notable Achievements at JPL

REALISM IN VIBRATION... Recognizing that it was necessary to provide a simulated missile-flight vibration environment far more realistic than heretofore available the Laboratory developed high power, wide-band, complex waveshape vibration testing equipment.

This has made possible the development of components and packages of greatly improved reliability.



New Techniques for Component Reliability

Wide-band, complex waveshape vibration testing using electromagnetic shakers driven by large audio amplifiers, is a valuable new tool for evaluating guided missile components. Input information can be in-flight vibration data which has been obtained via telemetering or it can be artificial vibration records sythensized from noise, pulses, sine waves, etc., to suit specialized needs.

Design and test for survival in adverse environment is fundamental in producing guided missile components with reliability adequate for modern weapons system requirements At JPL, a constant search is being conducted for better design and packaging techniques, and for more significant laboratory test methods. Development of the "complex wave" vibration test philosophy, and of apparatus to exploit it, are but two results of this program. In the area of component design, new packaging techniques have been developed, involving control of local internal resonances and nonlinearities, which permit electronic circuits to withstand many times the vibration level which would destroy a conventional package.

Engineers and scientists are working at JPL in nearly all of the physical sciences. Here they are supported not only by outstanding laboratory facilities, but by a continuing series of experimental rocket firings which provide an invaluable tool for research and development.

The combination of a broad base of fundamental research, active development effort, and strong test and flight program has made the Lab a place of achievement. Perhaps you would like to participate in the many new, exciting programs now under way here. Your inquiry is invited.

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it an ideal site for missile testing. The high percentage of cloud-free days and clear dry air make precision observation easy. This is especially important in the early stages of missile development, because data can be gathered rapidly. The mountains around Holloman's missile range afford ideal sites for optical and electronic instrumentation.

Location Ideal for Testing

The very low population density of Holloman's general location decreases the chances of catastrophe in the event a missile goes astray. The area also is ideal because the loud noise and toxic byproducts of large missile engines require that they be tested far from habitation.

The integrated White Sands range, used jointly by HADC and White Sands Proving Ground, extends 100 mi. north and south and 40 mi. east and west. Army and Navy projects are at White Sands, Air Force projects at Holloman.

HADC's Dual Role

HADC uses a logical approach in the performance evaluation of missiles under development test. Holloman is confronted with two roles. In one, it is vitally interested in speeding development of the missile and "selling" it to the operational command. In the second, it must take a critical view of the missile and its value as a military weapon.

This somewhat contradictory situation has been handled by relieving the project officer of the responsibility for writing evaluation reports on missile progress. The project officer works closely with the contractor and is expected to be a strong protagonist for his project. He submits routine factual test reports to the Weapon Systems Project Office at Wright-Patterson AFB.

Evaluation responsibility is discharged by another organizational element made up of more experienced officers who gather progress data from the contractor and project officer. At significant points in the development cycle they write critical evaluation reports emphasizing such factors as reliability, accuracy and sufficiency of support equipment. These reports are submitted to Hq., ARDC, and to the Weapon System Project Officers.

Another important phase of Holloman's work is the study of human factors in aviation. This research is conducted by the Aero Medical Field Laboratory, which functions under the Directorate of Research and Development. The laboratory is headed by Lt. Col. John P. Stapp, famous for his participation in high speed sled runs.

One of the lab's projects, under the supervision of Maj. D. G. Simons, con-

cerns human factors in space flight. Three aspects of space flight currently are under study:

• **Evaluation of the hazards** of primary cosmic ray particles. Biological specimens varying from bacteria to monkeys have been taken by balloon to altitudes as high as 130,000 ft. in sealed capsules especially designed to maintain laboratory environment.

Emphasis has been placed on possible cosmic radiation damage to genetic material, skin, nerve tissue, eyes and blood cells.

• **Subgravity effects.** This program is designed to study the effects on human performance of the absence of gravity, which will result from flight in space. Purpose is to determine if it is necessary to provide artificial gravity to maintain adequate performance.

In present tests a two-place (pilot and subject) jet aircraft is being used. Periods of zero gravity up to a maximum of about 30 sec. are obtained by flying special trajectories.

Other subgravity tests are planned to extend the duration of exposure to weightlessness.

• **Environmental control.** Purpose is to provide information concerning protective equipment for, and human tolerance to, 24-hr. flights at high altitude.

Initial flights to 80,000 ft. in a balloon are planned with the subject protected by a sealed capsule. This study is being coordinated with a WADC project which involves bailout from the capsule.

Physical Forces Vs. Humans

Another project under study in the laboratory is concerned with the biodynamics of human factors—the effects of physical forces on human tissues.

The study will provide information on human tolerance to wind blast, acceleration and deceleration, tumbling forces, shock waves and buffeting relating to supersonic flight. Data obtained will be available to designers of high-performance-aircraft cockpits and escape systems.

Two test track systems are available for simulating these various physical forces.

One is the 5,000-ft. track (Holloman's 3,500-ft. track, which has just been extended 1,500 ft.) and its rocket-powered sled.

The other is a 120-ft. track using a catapult-powered sled.

Capabilities with the 5,000-ft. track include accelerations up to 40Gs, velocities of 2,000 fps., and decelerations up to 150Gs.

On the short track, accelerations up to 25Gs will be available, velocities up to 200 fps., and decelerations up to 200 Gs. ■

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With automation putting more and more information on magnetic tape, the tape equipment itself has become a fit subject for automation. Which is why we developed automatically programmed tape equipment. The transport starts, stops, and rewinds automatically . . scans any track or combination of tracks once or any number of times . . . automatically matches tape speed to requirements over a wide range . . . permits fast search and slow read-out . . . and all without human attention. It can also be programmed for continuous recording over hundreds of hours, recording on one track, rewinding, restarting, recording on the next track, etc., without attention.

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Our dead time simulator is particularly appreciated by analog computers in need of a variable time delay. In heat exchanger problems, for example, it can be rigged to accept a voltage simulating pump speed, and voltages representing temperatures at various points in the exchanger, from the computer. After delaying the temperature analogs for a time inversely proportional to the pump speed analog, back they go to a much relieved computer.

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A thorough analysis of process failures can considerably reduce the chance of future failures. Thus the market for continuous logging devices in the process industries. But continuous logging facilities are extremely expensive if the information they print is only important as it applies to events immediately preceding an abnormal condition. For the job of closing the barn door only when a robbery is in the offing, we propose our Casualty Recorder, which works like this: Conditions at critical process points are continuously recorded on the many tracks of a loop of magnetic tape, with loop length determined by the amount of hindsight desired. In normal operation, information is recorded on the tape, passes around the loop, is erased, and new readings are recorded. When an off-normal situation develops, information is fed to suitable read-out devices before erasure for later examination. While this system gives you only the data you need, that's all you have to *pay* for.

COMPLETE DETAILS on the systems covered are available. But it's difficult in booklet form to give any adequate idea of the seemingly limitless applicability of magnetic tape systems in data handling. We'll be happy to pass on what literature *is* available, but we'd rather discuss your data accumulation, storage, or reduction problem with you directly. Just name the time and place.

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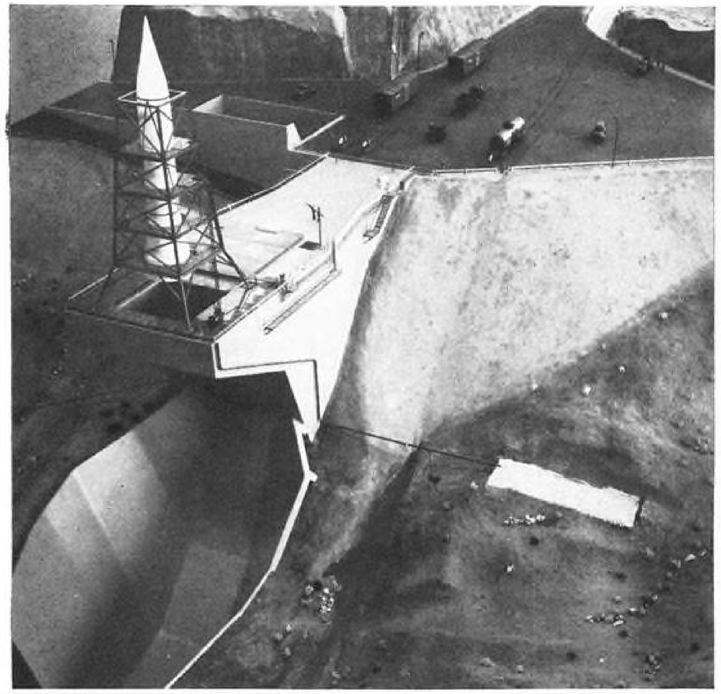

MOCKUP of rocket in launch position at proposed Edwards Rocket Base site.

Edwards Rocket Base to Test Captive Ballistic Powerplants

Edwards AFB, Calif.—The roar of high thrust liquid propellant rocket engines is being heard more frequently at the Air Force Flight Test Center here as ballistic missiles grow nearer to becoming a part of USAF's retaliatory capability.

To facilitate testing these sophisticated weapon systems, some $35 million already has been invested in AFFTC's Rocket Engine Test Laboratory, where first sub-systems and components and later complete ICBMs and IRBMs will undergo captive flight tests.

The laboratory, known as the Rocket Base, is located on Leuhman Ridge across Rogers Dry Lake from the main Edwards base, where heavy steel skeletons capable of holding down 50,000 lb. thrust powerplants can be anchored in bedrock and exhausts can blast harmlessly down the sides of high cliffs.

Navajo, Atlas and Thor

Three test stands are being operated at Rocket Base now by North American Aviation Inc., Convair Division of General Dynamics Corp. and Douglas Aircraft Co., Inc., who hold contracts for powerplants for the rocket-boosted Navajo cruise missile, the Atlas ICBM and Thor IRBM respectively.

All three stands have been or are in the process of being mocked up to simulate a particular missile system. This way contractors can test their completed missile components in simulated captive flight conditions, using approximately the same plumbing, shape of tankage and vertical flight attitude that the finished missile will have.

Support and backup facilities include a missile assembly building, machine and metal-working shop, warehouses, propellant and liquid oxygen storage, hydrodynamics (hydraulics) laboratory, engineering-administration building and personnel facilities including bachelor officer quarters, a cafeteria and a flight strip where contractors' small personal planes can land.

Under construction are:

- One vary large test stand capable of captive flight testing any complete missile envisioned for some years.
- A test stand "package" consisting of two test stands for completed missiles and one control center for both.
- Another missile assembly building.
- Additional warehouses and sub-assembly buildings.
- More fuel storage for the new test stands.
- A liquid oxygen plant to supply the

base's needs. This avoids having lox trucked in and stored which results in a loss from evaporation.

Proposed new construction to round out the final base configuration includes four more test stand packages—one in an isolated area where toxic propellants can be tested—three more missile assembly buildings, and additional warehouse and storage facilities.

There are 450 AFFTC personnel at Rocket Base, plus those employed by the contractors who operate the Air Force-owned stands. Of the Edwards personnel, 300 are civilians and 150 are military. Of the 40 Edwards engineers engaged primarily in support, facilities and instrumentation design for the base, three out of four are civilians. Several Air Force engineers are using the "over the shoulder" technique to learn stand operation from contractor personnel. They are looking toward the day when Rocket Base engineers will take part in running the complete missile system captive flight test stands now under construction.

Chief of the Rocket Engine Test Laboratory is Richard Gompertz. Assistant chief is Richard Schmidt.

Illustrative of the high costs of rocketry, the Edwards lab currently needs from $5 to $8 million a year to operate, exclusive of contractor-paid personnel and contractor hardware. The new large missile test stand alone, with backup, will cost more than $5 million.

Sixteen Firings Weekly

Rocket Base construction began in 1950 and the first firing was conducted in February 1953. Today, the base averages 16 firings weekly.

Philosophy behind Rocket Base is:

- **Contractor test facilities** will work chiefly with items still in research and development stage.
- **Contractors do not have space** or money for facilities to test systems at various stages, or subsystems or components involving partly their own and other contractors' hardware.
- **The necessary testing of systems** and components brought together for the first time, but not yet completed into an overall weapons system, will be done by Rocket Base.
- **Testing of complete weapon systems** before air launching (which is done at Patrick AFB, Fla.) will be accomplished at Edwards.
- **Reliability testing,** in which components, sub-systems and complete weapons systems are run to failure, can be conducted and fixes made.
- **New systems under development** but lacking their original promise, can be stage tested and when it is indicated that they definitely are not worth pursuing, they can be junked and new approaches to the problem can begin.

Dr. S. H. Browne (left), Assistant Director of Research, J. H. Carter, Associate Director of Research and Staff Scientists P. L. Taulbee and E. V. Stearns discuss weapon requirements for defense of continental United States.

SYSTEMS PLANNING

▲ ▲ ▲

the basic approach to missile development

The concept of systems planning has many degrees of interpretation and application. At Lockheed Missile Systems Division it is a primary field of endeavor that is emphasized as the optimum method of missile development.

As applied at Lockheed, it begins with operational requirements and covers every phase of the development of a complete system through preliminary design. Coordinated creative effort is required among scientists and engineers in virtually all fields.

A number of highly significant new activities will appeal to those possessing keen interest in systems planning. Inquiries are invited.

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NEW THIOKOL ROCKET MOTOR PLANT TO BE BUILT IN NORTHERN UTAH

12,000-acre plant site acquired for rocket motor development center

Near the north shore of Utah's Great Salt Lake a new Thiokol plant will soon rise. This latest expansion by the Thiokol Chemical Corporation will bring to four the total number of Thiokol plants devoted exclusively to the development and production of solid propellant rocket motors.

Just 84 miles northwest of Salt Lake City, the new site is centrally located with regard to all major western cities. It is convenient to both rail and air transportation, yet sufficiently isolated to permit the testing of the largest rocket motors.

Thiokol chose this location in order to service the growing missile and rocket industry in the West. It will become Thiokol's western center for all guided missile engines and rocket motor development and production.

Engineers and Chemists – *become a member of Thiokol's rocket development and manufacturing team. We welcome inquiries from mechanical engineers, chemical engineers and chemists interested in the rocket field.*

If you would like more information about the Thiokol Chemical Corporation, write on your business letterhead for our booklet, "From Rubber to Rockets"— the story of Thiokol, as a synthetic rubber and rocket propellant pioneer.

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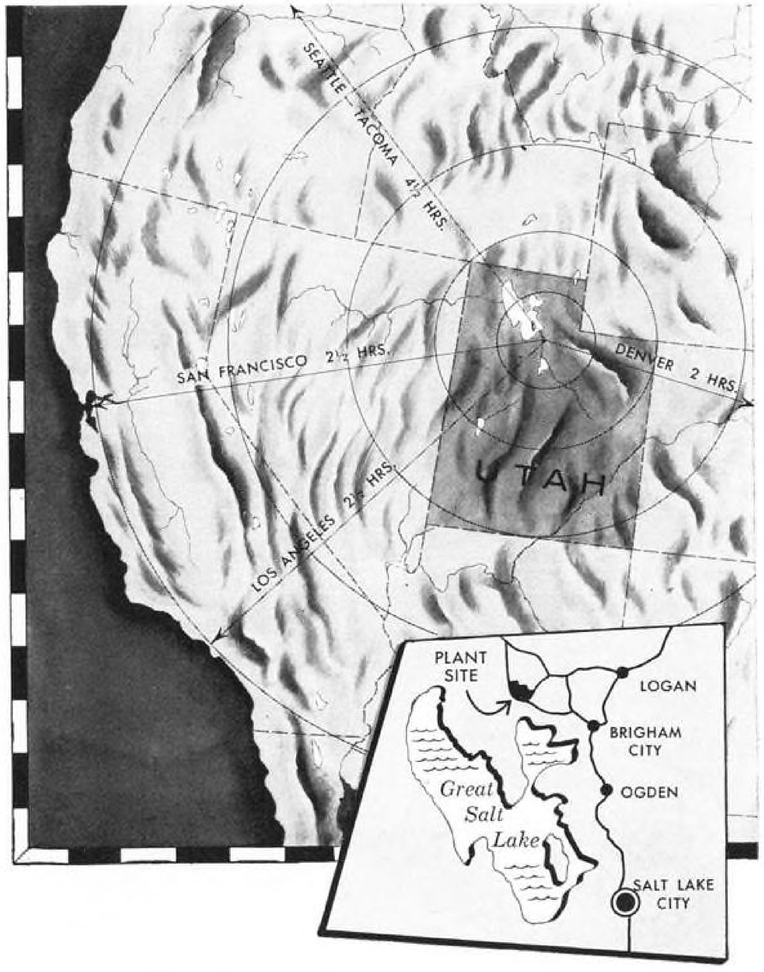

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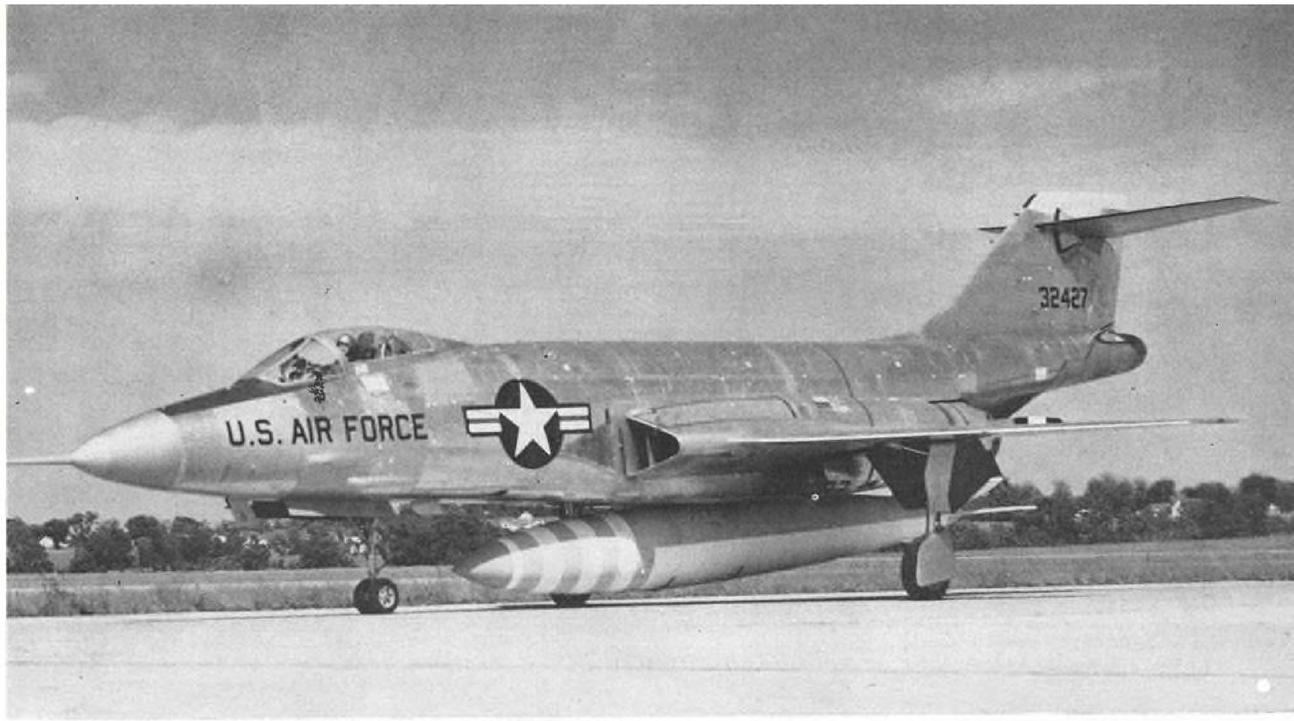
Nuclear-Powered Bomber Is Moving Nearer to Reality
First USAF Reactor Due to Operate Within Two Years
Convair's XB-36H Checks Out First Airborne Reactor



McDONNELL F-101 WITH EXPERIMENTAL BOMB-FUEL CONFIGURATION

Kirtland Gives USAF Nuclear Delivery

By Robert Hotz

Albuquerque, N. M.—Every first line fighter, bomber and offensive missile in the active USAF inventory today has the capability of delivering one or more types of nuclear weapons as a direct result of work done by the Air Force Special Weapons Center at Kirtland AFB.

First-line aircraft that are now delivery systems for nuclear weapons include the Boeing B-52 and Convair B-36 heavy bombers, the Boeing B-47 medium bomber, the Martin B-57 light bomber, the Republic F-84 and North American F-86 fighters and the Martin TM-61 missile.

Every new supersonic aircraft and bombardment missile now under development by the USAF will have a nuclear-weapon delivery capability because of work now in progress at the Special Weapons Center. This includes the Century series supersonic fighters such as the North American F-100 and the McDonnell F-101, as well as new bombers like the Convair B-58 Hustler and ballistic missiles such as the Martin Titan, Convair Atlas and Douglas Thor.

The primary job of the Special Weapons Center is mating the expanding new families of nuclear and thermonuclear weapons to the wide variety of aerial delivery systems being developed for the USAF combat forces. During the past three years, the center's mission has expanded into new research and development areas required by the vast technical progress of the nuclear weapons development program.

AFSWC Organization

The Special Weapons Center consists of three organizations devoted to its primary mission:

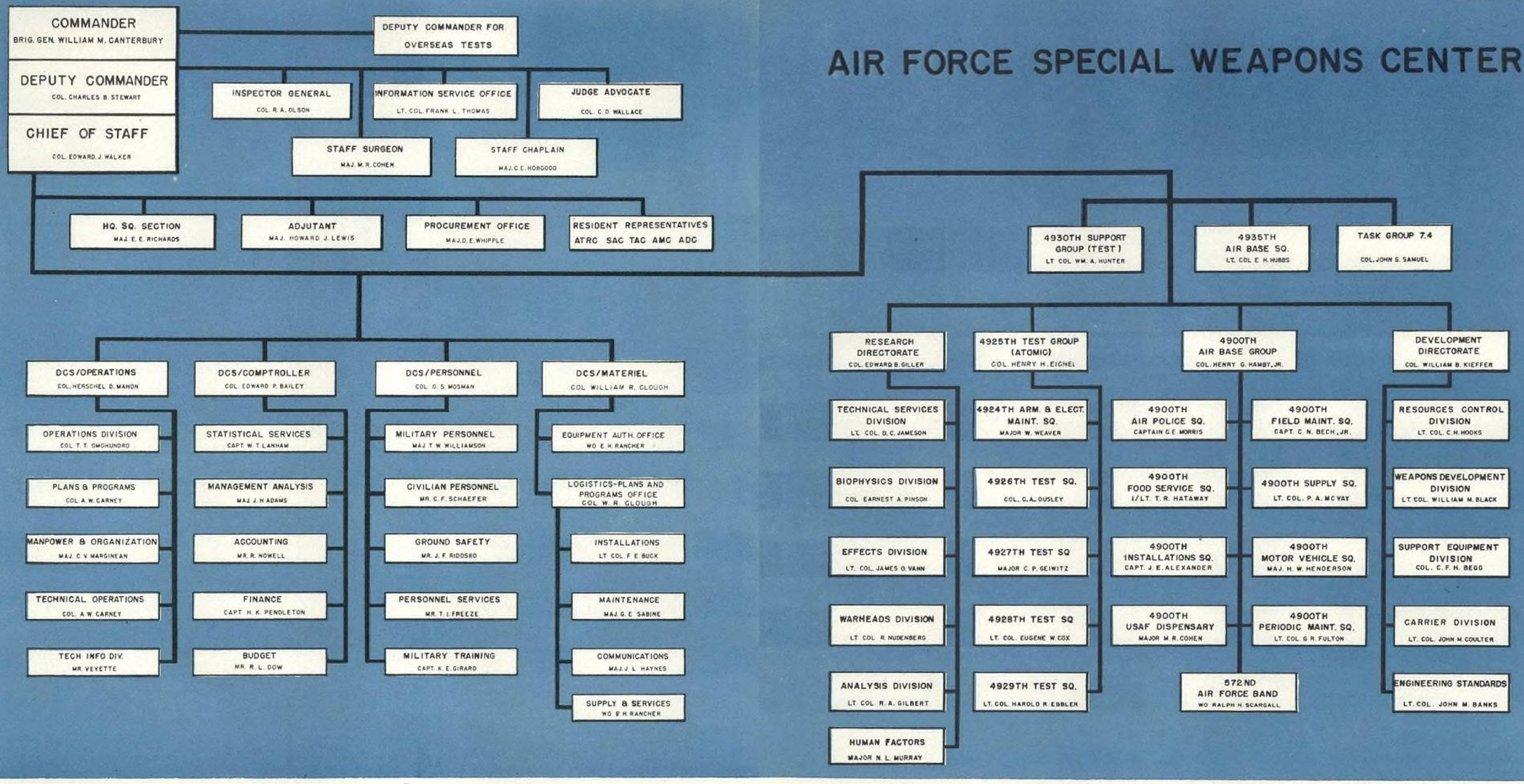
• **Research Directorate** headed by Col. Edward Giller, whose main job is concerned with analysis rather than laboratory research. Its work is aimed at future designs of atomic weapons, effects and employment of these weapons. It also functions as the principle USAF technical liaison agency on the future progress of atomic weaponry.

• **Development Directorate** headed by Col. John T. Dishuck, whose main job is the marriage of atomic weapons to aerial delivery systems. This is considered the "bread and butter" mission of the center.

• **4925th Test Group** commanded by Col. Fred H. Newman, whose

Brig. Gen. William Monte Canterbury, Commander, Air Force Special Weapons Center . . . born Muskogee, Okla., 1910 . . . graduate of U. S. Military Academy, 1934 . . . has held radar, research and development and atomic energy posts at USAF Hq. . . . served with 2nd and 8th Air Forces in World War II . . . participated in 1946 Bikini atomic bomb tests . . . director research and development at Sandia Base, 1947 to 1950 . . . joined ARDC in June, 1950 and served as acting deputy chief of staff for development, director of development, and assistant operations director . . . commanded 1009th Special Weapons Squadron before coming to AFSWC in June, 1954.

AIR FORCE SPECIAL WEAPONS CENTER



mission is to provide test support for the research and development activities of the center, the Sandia Corp. and air support for the weapons testing program of the Atomic Energy Commission.

The Special Weapons Center, now commanded by Brig. Gen. William M. Canterbury, is a key link between the nuclear weapons development program of the Atomic Energy Commission and the aerial-delivery-system development program of the Air Force. As a key link, its position in the entire nuclear weapons development complex requires clear definition.

At the top of the nuclear weapons organizational heap is the Defense Department Military Liaison Committee. This group bridges the gap between the Atomic Energy Commission that makes nuclear weapons and the Defense Department that is charged with delivering them.

The military liaison committee is headed by Herbert B. Loper, assistant to the Secretary of Defense for atomic energy, and has two military members from each of the three services. The military liaison committee transmits high level guidance between AEC and the Pentagon. A specific service is sometimes assigned cognizance for development of particular types of nuclear weapon delivery systems. For example, cognizance over large nuclear-bomb development has been assigned to the USAF, the atomic artillery shell to the Army and the atomic depth charge to the Navy. In addition, there are joint development projects that can be used by more than one service, such as missile warheads of a specific size.

These joint projects are handled by the Armed Forces Special Weapons Project.

The project has a headquarters organization in the Pentagon for policy guidance and a field command in Albuquerque which works with the AEC through Sandia Corp. under contract to AEC by Western Electric.

Liaison for USAF

AEC also has a development agency at the Los Alamos Scientific Laboratory of the University of California in the New Mexican nuclear triangle—plus a similar organization in the University of California Radiation Laboratories at Livermore, Calif. Both Los Alamos and Livermore are concerned with designing and producing the nuclear "guts" of weapons for all the armed forces. The Sandia Corp. concerns itself with developing and manufacturing the hardware that is combined with the nuclear "guts" to form a specific weapon. For example, Sandia Corp. makes the weapon casing and electronic gear required to fuse and fire the weapon.

Within this basic framework, each of the three services has a special technical operating agency to handle specific developments for which the service has been given cognizance and to supply guidance so that AEC and AFSWP activity produces hardware tailored to meet specific service requirements.

For USAF, this agency is the Special Weapons Center, one of the twelve major centers of the Air Research and Development Command.

This is the complex organizational and technical framework within which the Special Weapons Center operates. Because of the nature of this network, a large part of its responsibility involves functioning as the principle liaison agency for the USAF with all of the other agencies involved in the nuclear-weapons development and delivery programs. To facilitate this liaison, Special Weapons Center officers are regularly rotated for terms in AEC laboratories

and Sandia Corp. Despite all formal official channels of liaison, the center finds that personal contact between men working in various fields provides the fastest and most efficient form of keeping in touch with the rapid technological progress in atomic weaponry.

Nuclear Trends

The expansion of the Special Weapons activities and the increasing importance of its operation have been influenced by the principal trends in atomic weapons during the past three years.

These include:

- **Nuclear weapons have increased** their yield for any given size.
- **Nuclear weapons have grown** in variety as smaller and smaller weapons have become technically feasible.
- **Atomic weapons have expanded** their application to almost every type of USAF air delivery system and to almost every USAF combat problem.
- **Nuclear weapons are becoming** simpler to assemble, handle, store and use.
- **Complexity and magnitude** of the USAF logistics problem for the nuclear weapons program has grown proportionately as the number of weapons and types of carriers has increased.
- **Widespread use** of nuclear weapons by the USAF and potential enemies has increased the scope and importance of research on human factors involved in operating combat units during nuclear war.
- **Increased variety of weapons** and larger yield makes necessary continuing research on what actually happens when nuclear devices explode and what their effects are on various types of targets.
- **Shorter development cycle** for nuclear weapons in contrast to the longer time required to develop modern supersonic delivery systems still poses a major problem in providing operational compatibility between the weapon and its carrier.

Special Weapons Center Mission

The official mission of the Special Weapons Center at Kirtland AFB is:

"To accomplish the necessary development, testing and engineering support within the responsibility of the United States Air Force of atomic weapons, systems components, associated equipment (including weapon and weapon carrier compatibility determinations and feasibility studies) and evaluation of personnel hazards associated with the development tests and operational use of atomic weapons.

"To provide support to the Atomic Energy Commission and other governmental agencies as required in conducting both continental and overseas atomic energy tests.

"To provide support as required for certain other special weapons.

"To provide support for Atomic Energy Commission and Department of Defense agencies as required in the execution of wartime operations and attainment of related peacetime preparedness.

"To perform such other research as may be required of the Special Weapons Center by Headquarters, ARDC."

Research Directorate

The most important product of the Special Weapons Research Directorate is paper. These paper products are studies, analyses and ideas on future development of atomic weapon systems and future problems that will arise from their use. Special Weapons Center has an unusually high educational level among its personnel. This trend reaches its peak in the Research Directorate where more than 25% of the 120 military scientists working under Col. Giller have doctor's degrees.

Mission of the research directorate includes:

- **Studies and recommendations** on future designs of nuclear weapon systems and new, improved methods of using them.
- **Measure, evaluate and interpret** personnel hazards in handling nuclear weapons and recommend protective equipment and techniques necessary for both offensive and defensive operations in nuclear war.
- **Conduct human engineering** research and development applied to the design of equipment required by the Special

DECONTAMINATING A 'HOT' B-57

Weapons Center operations.

• **Disseminate information** to operational commands such as the Strategic Air Command, Tactical Air Command, Air Defense Command and ARDC headquarters on nuclear weapon development. Research Directorate also is charged with obtaining and evaluating this information prior to USAF distribution.

• **Provide focal point** of contact with AEC field agencies at Los Alamos and Livermore and the AFSWP Field Command at Sandia on nuclear weapon development and applications within USAF operational requirements.

• **Maintain administrative supervision** over USAF personnel assigned to AEC contractor installations at Los Alamos, Livermore, Sandia Corp. and elsewhere.

Research Organization

To do this job the research directorate is organized into five divisions:

• **Analysis Division** headed by Lt. Col. R. Nudenberg.

• **Bio-Physics Division** headed by Col. Ernest Pinson.

• **Effects Division** headed by Lt. Col. MacPherson Morgan.

• **Human Factors Division** headed by Maj. N. L. Murray.

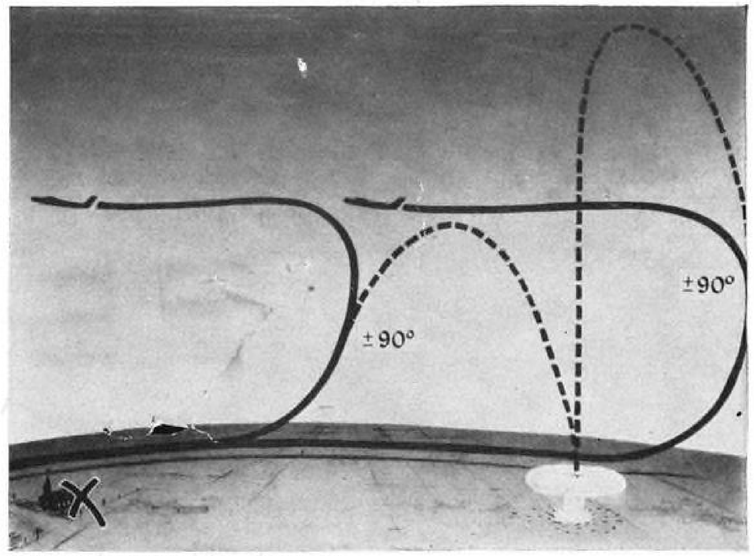
• **Warheads Division** headed by Lt. Col. D. C. Jameson.

The Research Directorate splits its work level between the Special Weapons Center and outside agencies with about 50% conducted at Kirtland and the other half done by other ARDC Centers, universities and industry. The Directorate has a $1 million annual budget which is divided into a variety of $50,000 to $75,000 projects.

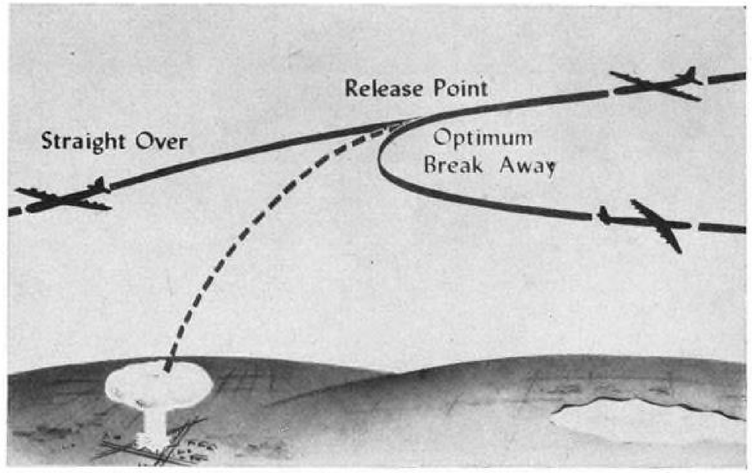
Main job of Analysis Division is to study continually new concepts for the employment of nuclear weapons and to analyze the future needs for nuclear warhead development to be used by USAF delivery systems. This division studies all possible types, weights, sizes, costs and yields of future nuclear weapons and analyzes how they can possibly fit into the USAF combat mission and how they could be used by future USAF delivery systems against what kind of targets. The Analysis Division is responsible for matching future nuclear weapons against future USAF targets with a variety extending from an infantry company in foxholes to an industrial city or a supersonic missile.

One of the major results from the Analysis Division work was development of the low-altitude-bombing (LAB) delivery technique for atomic weapons sometimes known as toss bombing (see diagram).

This was originally developed as an accurate method of delivery for fighter-bombers that would still permit the delivery aircraft to escape the lethal effects of its atomic weapon. Perfected by the Air Proving Ground Command at Eglin AFB, Fla., this technique has now been extended to bomber aircraft at a wide variety of altitudes and special instrumentation has been developed to make the technique automatic and give it an all-weather capability.



LOW ALTITUDE BOMBING TECHNIQUE



OPTIMUM BREAK AWAY MANEUVER FOR B-36

Nuclear Defense Systems

Another major contribution was the Analysis Division study of the feasibility of using nuclear weapons in air defense.

The research analysts looked into every aspect of employing a nuclear rocket for air defense such as:

How far from the target can a detonation occur and still kill the target? How far away from the detonation must the delivery aircraft be to avoid excessive radiation for interceptor pilots? What is the optimum yield for the nuclear rocket warhead? What is the effectiveness of such a nuclear defensive rocket?

Indication of the Analysis Division's success in answering these questions came in the detonation of an airborne "nuclear test device" during the 1955 Nevada AEC test series and the statement by Gen. Earle Partridge, commander of Air Defense Command, at a jet age symposium in Washington last spring that new USAF interceptors would be using nuclear weapons for air defense.

As the Analysis Division studies new nuclear weapons, it is coming to grips —as is everybody else in military aviation—with the effects of extreme altitudes and high Mach numbers on both weapons and delivery systems.

Another job of the Analysis Division is to analyze all potential USAF targets

CARTRIDGE START OF B-57s

in terms of future nuclear weapons. An example of this is relating probable circular error of bomb delivery to the weapon's yield and the characteristics of specific types of targets.

Gathering data on a variety of safe escape methods for pilots and crews delivering atomic weapons is also an analysis division task. With extreme altitudes, crews face not only the problem of escaping radiation from the nuclear weapon detonation but also from cosmic radiation. In any nuclear war, the allowable dosage level would have to be an operational command decision but the analysis division's job is to furnish the USAF commands with a wide variety of methods to reduce or avoid radiation dosage for aircrews.

The Effects Division aims at gathering data on exactly what happens when nuclear weapons are detonated, what yield they produce and what the radiation and fall-out effects will be.

The USAF is naturally concerned primarily with high-altitude nuclear blasts as the air war continues to move upward. The air defense problem already has moved above 50,000 ft. It will soon be on the edge of the atmosphere and eventually will move into space. USAF is already deeply concerned with a defense against a hypersonic intercontinental ballistic missile. Some day it may even be shooting at space satellites.

High-Altitude Problems

What are the effects of a nuclear explosion outside the atmosphere? No one knows yet, but the Effects Division is busy trying to find out. A start was made last year during the Teapot tests in Nevada with a drop from a B-36 detonated high in the air. But there is urgent need to go much higher as soon as possible. Dr. Alvin Graves, scientific adviser to the AEC Nevada test manager, said during Teapot that balloons were being considered for carrying nuclear test devices to desired altitudes. Rockets are another good possibility for getting the nuclear explosion at the extreme altitudes required.

Bio-Physics Division is concerned with measuring, evaluating and devising counter-measures for personnel hazards of nuclear warfare. It was transferred to Kirtland from the Cambridge Research Center.

An example of how the Bio-Physics Division operates is its program on the airborne and ground problems encountered by operational units employing nuclear weapons. Obviously, this information is vitally needed by commands such as the Strategic Air Command, Tactical Air Command and Air Defense Command to plan tactics for using nuclear weapons on specific missions.

Working in the laboratory, the biophysics division developed methods of predicting radiation dosage under a wide variety of situations encountered in nuclear warfare and methods of extrapolating these dosages up to near lethal levels. Initial tests were made with actual atomic blasts by monkeys and mice penetrating blast clouds in remotely-controlled QF-80 drones. Last year, the first human penetrations of kiloton yield bomb blasts were made as early as 15 minutes after detonation during the Teapot tests over Nevada.

Human Guinea Pigs

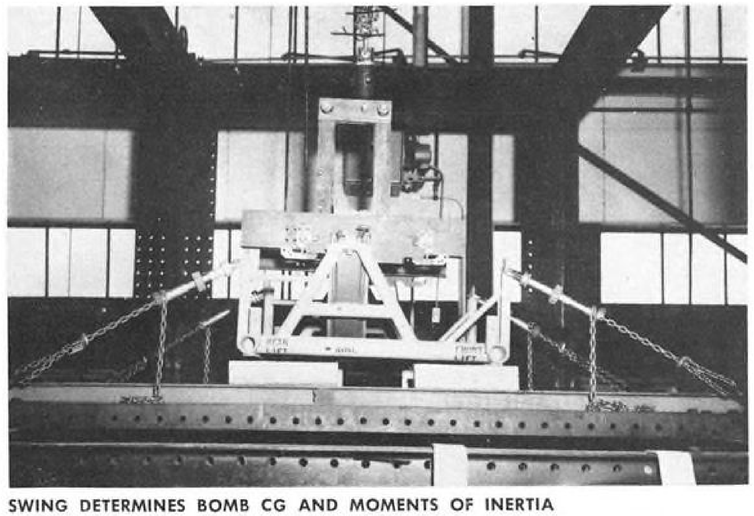
These initial early penetrations were made in specially instrumented T-33 jets with Col. Pinson and Capt. Charles Oldfield riding as specially instrumented human guinea pigs in the rear seat. Pilots wore protective gear, but Col. Pinson and Capt. Oldfield had only normal flying gear.

They were looking for the answers for SAC, TAC and ADC to questions such as:

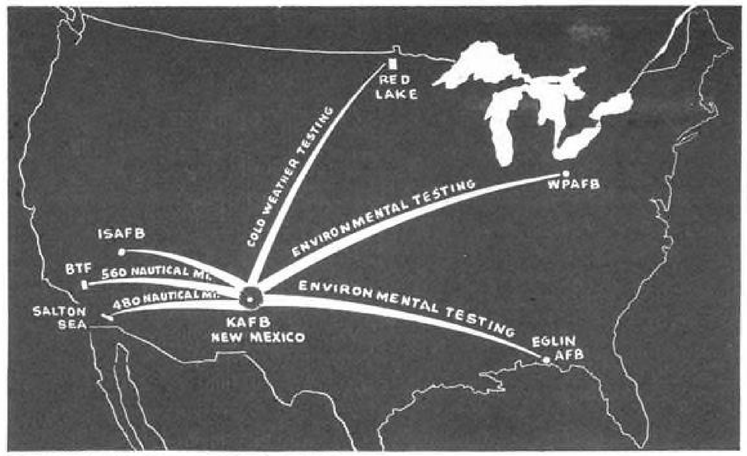
- **How long after detonation** does an atomic bomb blast present a hazard to pilots in a jet interceptor or fighter-bomber?
- **How much radiation dosage** will a pilot receive on his trip to base after a cloud penetration from his contaminated aircraft?
- **Can ground crews** service a "hot" plane for more missions the same day after an early penetration?
- **Exactly what parts** of an aircraft pick up radiation particles and how long do they stay?

The early penetrations of Col. Pinson and Capt. Oldfield over Nevada provided definite answers to these questions and also proved the laboratory prediction methods developed by the division.

Pilots received tolerable radiation dosage during penetration of the atomic cloud and return flights. Leading edge impact areas of the aircraft plus cracks and crevices in the external structure picked up the highest density



SWING DETERMINES BOMB CG AND MOMENTS OF INERTIA



WHERE SIMULATED MISSIONS ARE FLOWN

of radioactive particles, but the engine was the "hottest" radioactive portion of the plane.

It was found that decontamination of combat planes after flying through atomic clouds would not be necessary under wartime conditions. Ground crews could refuel, re-arm and maintain them with only the addition of gloves to normal work clothes. Dosage resulting from this type of work would be no more than that of several chest X-rays. For peacetime operations, a decontamination procedure has been developed. "Hot" aircraft are washed with "gunk," a special cleaning fluid originally developed to dissolve grease and dirt on aircraft structures and rinsed with a water spray.

Bio-physics division personnel were engaged this summer in attempting to find answers to the same type of questions under conditions generated by megaton yield blasts during Operation Redwing at the Eniwetok Proving Ground.

Radiation Measurements

Another responsibility of the division is development of radiation measuring instruments. The Armed Forces Special Weapons Project is responsible for the inter-service co-ordination on radiation measuring instruments. The bio-physics division is concerned primarily with special USAF applications or problems such as modification for standard radiation instruments for airborne use and developing airborne radiation measuring instruments for an atomic powered aircraft.

The division also works on the problem of reducing radiation hazards for both aircraft and personnel during such operational situations as operating an airbase during a period of heavy radioactive fall-out. It offers operational commands a wide variety of shielding and de-contamination methods and writes manuals on handling these problems for the operation commands.

The job of the warheads division is to keep abreast of the future state of the art possibilities in the development of new nuclear weapons and to be the principle source of USAF information on this subject. Personnel of the warheads division maintain an extremely close liaison with the AEC laboratories at Los Alamos and Livermore and the Sandia Corp. Many of them have actually worked in these organizations and, consequently, have a wide range of contacts with scientists involved in warhead development and packaging.

USAF looks to the warheads division to obtain realistic data on what type of yield will be available from what size nuclear devices for a period from five to 10 years ahead. This information is needed by the USAF in planning its aerial delivery systems of the future.

Warheads division also must provide data on the relative vulnerability of nuclear weapons to countermeasures, crash, fire and other disasters both while aboard a carrier or in the air between the carrier and the target, and plan protective measures. It also has a responsibility to make studies on the compatibility of proposed new aerial delivery systems and future nuclear weapons to make certain that AEC is developing the type weapons USAF will need. Although the warheads division makes this type of study, formal liaison between USAF and AEC on the compatibility of future weapons and their carriers is handled through the Military Liaison Committee at top level Defense Department and AEC levels.

The human factors division is another new function of the research directorate. Its job is to reduce the possibility for human error in the operation of nuclear weapons and their delivery systems. It includes human engineering on ground support equipment for the nuclear

weapon systems; the weapon operations equipment installed in the carrier aircraft, and weapons storage and assembly procedures.

Development Directorate

Happy marriage of the USAF aerial delivery systems and the AEC nuclear weapons is the primary job of the development directorate and the "bread and butter" mission of the Special Weapons Center. This directorate provides a management link between the aircraft industry contractors who are developing new delivery systems and the AEC laboratories where new weapons are under development. It is also charged with developing special supplementary equipment required for the complete nuclear weapons delivery system and with providing engineering services to USAF organizations which procure, maintain and use nuclear weapons.

The problem of compatability has grown much more complex since the early use of atomic weapons in 1945 when the main problem was getting the bomb to fit inside a B-29. Physical compatability between the weapon and carrier is a continuing problem. Despite the development of the new families of smaller weapons, some of the megaton yield weapons still pose size and weight problems for bombers.

But other factors of compatibility now equally important are:

• **Electrical**—Nuclear weapons require considerable airborne equipment in a carrier to monitor and control the bomb. These must all be carefully planned to fit into the carrier and match its auxiliary electrical power output and other sub-system electrical requirements.

• **Environmental**—This includes vibration and the negative and positive G loading the nuclear weapon must take both inside the carrier and after release, and the wide variations of temperature it must absorb between the ground and high altitude operations.

• **Aerodynamic**—This includes the problems imposed by external carriage of nuclear weapons as on fighter-bombers, and the release into a high-speed air stream of nuclear weapons carried internally by larger aircraft.

• **Operational**—Installation, arming, fusing and firing systems for various nuclear weapons also must be compatible with the delivery tactics and operational concepts of the user commands such as SAC, TAC and ADC.

Functional Missions

On a fuctional basis the development directorate mission includes the following jobs:

• **Guide AEC weapon design.** This job has a dual aspect. First the development directorate participates in USAF's formulation of desired military characteristics for future nuclear weapons. These characteristics are transmitted through channels to the Military Liaison Committee where they are approved and transmitted to AEC. When this AEC program begins, the development directorate keeps in close touch to monitor the compatibility requirements outlined earlier.

• **Guide USAF carrier design.** This is the opposite face of the compatibility problem and is carried out through the ARDC agencies that have prime responsibility for the development of particular nuclear weapon delivery systems such as the Western Development Division for ballistic missiles, the directorate of nuclear systems for atomic powered vehicles and the directorate of weapon systems for manned aircraft and non-ballistic missiles.

• **Develop components** for nuclear weapons arming and fusing systems. Responsibility for developing arming and fusing systems for AEC-developed bombs rests with AEC. But for practically all USAF missiles, the arming and fusing system responsibility rests with USAF. The development directorate monitors these programs with the contractors concerned through the appropriate ARDC weapon systems project office. Most of the current bomb arming and fusing systems can be easily adapted for missile use. However, in radical new weapons, new components for the arming and fusing system are required.

• **Develop components** for nuclear weapons testing, control and monitoring systems. This is an area in which the trend towards simplicity and handling ease has been successful. Early atomic bombs required scientific personnel for each mission to assemble, arm and monitor the weapon in flight. By 1950, development effort had reduced the complexity of this operation so that a specially-trained air weaponeer could handle this job in flight. New developments in simplified airborne T-boxes have reduced the requirement for airborne monitoring even more.

• **Develop handling equipment** for nuclear weapons. USAF has a major problem in handling nuclear weapons after they are manufactured by AEC. They must be stored under fairly specific conditions, transported to airfields and loaded aboard delivery systems. Operational commands want fast transport and loading facilities since their time on the ground is a period of maximum vulnerability. Most aircraft delivery systems have special problems that require design and development of special equipment to cope with problems such as the nose wheel struts on the B-47, the low belly on the B-47 and the wing spar arrangement on the B-45. There is an urgent need to develop new and

better equipment for both transport and loading of nuclear weapons.

• **Develop suspension and release** system components. This includes bomb shackles, sway braces, slings, retraction devices, hoists and weapon ejectors.

• **Develop special bombs and** rockets for use with nuclear warheads. USAF often needs special configurations of nuclear bombs or rockets for specific missions or carriers. For certain cases such as development of bomb shapes and other particular USAF applications, the Special Weapons Center is assigned responsibility.

• **Co-ordinate USAF development** of drogue devices for nuclear weapons. These drogue devices are normally developed by Wright Air Development Center, but Special Weapons Center's job is to establish the need for such devices, develop their operational characteristics, arrange to establish specific development programs at WADC and co-ordinate this development with AEC.

• **Develop nuclear practice bombs.** USAF has a big requirement for ballistically-true nuclear practice bombs since operational training with live bombs would be too expensive and politically impractical. This is particularly important for fighter-bomber delivery where pilots must become accustomed to asymmetrical control forces while flying a bomb to the target and during delivery maneuvers.

• **Co-ordinate development** of nuclear weapons simulators. WADC equipment laboratory actually develops these devices that permit crew training in operation of control and monitoring systems for nuclear weapons.

• **Develop nuclear weapon attack** planning data. Some delivery methods for nuclear weapons require extremely detailed pre-flight planning to include such data as fuse settings, attack entry conditions, altitude, speed, wind conditions, ballistic data, escape methods and other factors.

• **Support other ARDC centers** and USAF commands in engineering standards and field engineering service problems on nuclear weapons and related equipment. Special Weapons Center supplied Air Materiel Command with specifications for procurement on AEC and USAF-developed nuclear weapons and related equipment.

Atomic Test Group

The organization now known as 4925th Test Group (atomic) has delivered all of the air-dropped atomic bombs in AEC tests since the end of World War II and last May made the first air drop of a thermo-nuclear bomb with a megaton yield over the Eniwetok Proving Ground.

The 4925th Test Group operates a fleet of 55 aircraft valued at $90 million and ranging from the latest USAF bombers and fighters such as the B-52, F-100 and F-101 to specially equipped C-47s and helicopters. It currently has 109 active test programs and uses facilities valued at $10 million with $15 million in support and test equipment.

The group consists of five squadrons:

• **4924th Squadron** is the armament electronics equipment test organization.

• **4926th Squadron** is the atomic cloud sampling squadron operating F-84 jet fighters and B-57 jet bombers.

• **4927th Squadron** does atomic weapon testing with fighters and medium bombers and is equipped with the F-100, F-101, F-84F, F-86, B-47 and T-33.

• **4928th Squadron** is a composite test squadron including the heavy bombers such as the B-52 and B-36 light bombers such as the B-66 and B-57 and laboratory aircraft such as specially instrumented C-47s, and H-19 helicopters.

• **4929th Squadron** is a development test organization concerned with providing technical support for the other missions.

Nuclear Drops

Two biggest test operations of the 4925th Group are in support of the AEC testing of nuclear devices and new weapons at the Nevada Proving Grounds north of Las Vegas and the Eniwetok Proving Ground in mid-Pacific. The 4925th Group drops any nuclear weapons or test devices that are required by AEC and provides a wide variety of specially instrumented aircraft to perform specific missions in support of full-scale tests. It also tracks the radioactive cloud and monitors fall-out. Until the four-mile error in dropping a megaton yield weapon was made in the current operation Redwing at Eniwetok, the 4925th had a record of delivering their atomic bombs with a circular probable error of less than 700 ft. and within seven seconds of predetermined time.

The test group also does the first testing of nuclear weapons with each new aerial delivery system as it comes off the aircraft industry production lines and trains the first USAF instructors in the combined use of the weapon-aircraft combination. For example, the test group first tested the B-52 as a delivery vehicle for both kiloton and megaton-yield bombs and nuclear-weapon delivery capabilities of the F-100 and F-101 fighters and the B-66.

In addition, the test group does engineering evaluation of prototype nuclear weapons and their associated equipment and runs test programs on terrain surveys, cloud tracking, cloud sampling and other miscellaneous procedures related to nuclear weapons testing. ■

WS-125A Will Measure Range in Days

By David A. Anderton

Weapon System Number 125A is a bomber with supersonic dash performance, powered by the terrible energy that has devastated two cities, vaporized a fleet and swallowed an island.

It is the first of a long line of aircraft whose engines will be turned by the heat from nuclear fission. The bomber, with range measured in days instead of miles, will be joined by early warning aircraft, logistics carriers and mother planes bearing fighters armed with air-to-air missiles.

These are the first generation, now growing through embryonic stages for a birth not too distant. Still unborn are the fleets of nuclear-propelled transports, missiles and the vehicles that will take man beyond the limits of his knowledge and sight.

The job of creating dreams, solving problems and measuring men for the myriad aspects of nuclear propulsion is largely the responsibility of the Air Research and Development Command.

Two Programs Under Way

Two parallel programs are under way on the 125A, with a possible third in the offing. Convair division of General Dynamics Corp. is teamed with General Electric Co. on one concept. A second kind of powerplant plus airplane is being worked out by Lockheed Aircraft Corp. and Pratt & Whitney Division of United Aircraft Corp.

Final choice of powerplant and configuration is uncertain. It's on an "and-or" basis; either or both might be chosen for following through to the production model. It is certain that the WS-125A program will call for a number of experimental aircraft, probably all identical externally. An early test vehicle definitely not of prototype configuration is the Convair XB-36H, a modified B-36 with a small test reactor aboard.

Sub-Systems Already Tested

The WS-125A bomber system is closer to reality than is generally realized. Many of its sub-systems and components have been built and tested in the peculiar environment in which they will work.

The list of tangible accomplishments is a formidable one. Progress to date includes:

• **Tests of representative systems** of typical aircraft. Designers now can find out what happens to all parts of a landing gear, including the tires (they get spongy) and the hydraulic fluid. Similar data is available for standard radars and associated systems. These results are based on the "go, no-go" philosophy.

• **Knowledge of the behavior** of conventional structural materials under conditions of elevated temperatures plus radiation.

• **Useful life data for many components.** Transistor life, to cite one example, has been established quite precisely.

• **Heat exchanger system tests.** The first sub-system experiments at very high temperatures have been concluded long ago. During one of these, a centrifugal pump ran at yellow heat while boosting molten metal through its spinning interior. There was not even a gas leak.

Much remains to be done before any of these systems can be considered completely understood. Most of the data has been gathered with the idea of establishing limits; either the unit worked or it didn't. Either it was accepted for the airplane or it was rejected.

Many Centers Involved

Like human factors, another growing field of science and engineering that cuts across the scheduling boards of ARDC, nuclear propulsion problems are shared by many groups within the Command, geographically spread all around the country. Considerations of the peculiarities of propulsion by atomic energy are dominating factors in the future plans of every center.

• **The search for** fundamental knowledge of the atom itself is aided by studies sponsored by the Office of Scientific Research.

• **At Cambridge and Rome,** engineers worry about the effects of nuclear radiation on communication, radar and countermeasures equipment.

• **Laboratories at Wright** Air Development Center must oversee the design of systems planned to operate in the searing rays of a reactor.

• **Parts of the powerplant** will be tested at AEDC.

• **A crew from the Flight Test Center** will evaluate the flight performance of the prototype.

• **The destructive power** of the weapons born at Special Weapons Center will yield constructive data that can help save the lives of the crew in the 125A.

• **Establishing the human tolerance** to radiation is a special responsibility of the Aero Medical Laboratory, where many kinds of data are being correlated.

• **The Nuclear Engineering** Test Facility, scheduled for completion at WADC in 1958, will take a large load of the technical support of WS-125A from the crowded reactors of the AEC, where many tests have been and are being run.

ARDC's Partners?

But the job is not completely the Command's show. Relations between ARDC and the Atomic Energy Commission are close, necessary and mutually productive. At top level, Maj. Gen. Donald J. Keirn acts as special assistant for nuclear propulsion to ARDC's commander, Lt. Gen. Thomas S. Power. Gen. Keirn also is chief of the Aircraft Reactor Branch of the AEC's Reactor Development Division.

By agreement between the Defense Department and the Atomic Energy Commission, AEC holds responsibility for a reactor design until it is in the prototype—or what the AEC calls a "replica"—form. Consequently the aircraft nuclear powerplant contracts are joint AEC-USAF contracts with General Electric and Pratt & Whitney. Airframe contracts with Lockheed and Convair name only the U. S. Air Force as the buyer.

Much work supporting WS-125A has been done by AEC's Argonne National Laboratory, the Nuclear Reactor Testing Station at Idaho Falls, Idaho, and the Oak Ridge National Laboratory. Oak Ridge, in fact, conceived one of the nuclear propulsion systems now being built.

Contractors are major contributors to the WS-125A program. Lockheed and Convair airframes must carry P&W and GE engines. The School of Aviation Medicine under the Surgeon General of the Air Force is making most vital contributions to the WS-125A (and programs to follow) by its work with human dosage tolerances. The Medical Advisory Group, made up of internationally known authorities reporting through the school, is lending great help.

The Dominating Red Thread

Through the entire fabric of progress being woven for nuclear-propelled aircraft runs a single red thread: radiation. It dominates the pattern from start to finish.

Onto the troubles caused by the high temperatures of contemporary flight must be piled entirely new troubles, triggered by the invisible rays from the atomic heart of the aircraft powerplant.

Radiation can kill or injure men. It can alter materials, making structural changes in the metallurgy of alloys, making rubber tires and seals and lines spongy, and making radars inoperative. It contaminates the crew's clothing,

charts and computers, the pencils in their coveralls, their food and their waste.

A few years ago, these problems were just questions, their answers unknown because of the lack of data. But now there are answers to many of them, obtained from tests of everything from tiny material coupons to complete aircraft systems dunked in a swimming pool reactor.

Gradually the knowledge of radiation effects on things grows. But the big unknown is the effect on humans—on the crew that must fly the airplane, the ground technicians who maintain and repair it and its systems, the contractor representatives who live with their aircraft or powerplant or pumps or valves in the field and work alongside the mechanics.

Inside the Engine

The basic element of a nuclear powerplant is the reactor. Here in a small volume is generated the enormous amount of heat to be converted into mechanical power by the engines. But the atomic fire burns with the energy taken from the binding forces that hold the atom together; with that force removed, the atom flies apart. Its fragments are hot and dangerous. These invisible bullets can injure, maim and kill. They can cause something like a summer sunburn, or a disfiguring death.

These sub-atomic missiles can't be avoided, but they can be stopped by shielding. Some will balk at a sheet of paper or aluminum; others will demand a defense of a thick wall of lead or concrete.

There are two ways to shield an aircraft reactor:

• **Near-unit shielding,** where the total amount of shielding material is placed around the reactor itself.

• **Highly divided shielding,** where the total amount of shield is proportioned between the reactor and and the crew compartment.

Technical trends suggest that the highly divided concept is the better way. It keeps the cross-section of the fuselage at a minimum, which means high performance. But it induces radiation problems; stray particles can escape from the lightly-shielded sides and be bounced back by collisions with air molecules to increase radiation densities in the crew compartment. The same particles can damage structure, avionic gear and the aircraft systems.

A completely shielded reactor, designed with present-day long-term safety requirements in mind, would be so massive that no reasonable aircraft could lift it off the ground. Such a reactor would be completely safe; the conservative radiation levels that have been established by the AEC would not be exceeded and operators could then stand by the reactor on continuous duty.

But a short military mission is played to a different set of rules than a long-term laboratory operation. There is a compromise somewhere between life and death, a calculated risk made worthwhile by the tremendous payoff of the military mission.

But where is that dividing line? Neither the white of long life nor the black of instant death is acceptable; how gray can the mixture be?

Balance of Life

To find out, you must know the damage done by radiation. The four horsemen of the atomic Apocalypse—alpha and beta particles, gamma rays and neutrons—can cause cataracts, leukemia, genetic changes and shortening of the life span.

The probabilities of any or all of these effects have to be weighed against the value of the mission to be performed by the atomic airplane. The final decisions on shielding—which will determine the amount of radiation reaching the crew—have to be made from that fine balancing of values.

The acute aspects of radiation effects —those that occur within a short time after exposure—are well known. But the chronic aspects that reach their full effect with time are not so well defined. There has not been enough time yet to determine them.

So there are no criteria for unsafe exposures. The AEC level of 300 milliroentgens per week was determined as a conservative value for long-term exposure. A chest X-ray gives a dose 17 times that value. But the data from which to draw damage conclusions is scarce. Some indications can be obtained, but there is imperfect correlation.

One-Shot Crews

Right now the tendency is to be overcautious. One generally accepted concept is that of the one-shot crew. The idea would be to single out special crews for missions in the atomic airplane, much as lead and select crews are chosen by Strategic Air Command. These crews would train for a single mission with a single target and alternates.

If war came, this crew would perform its mission and retire.

The reason is a conservative one, because the exposure limits are not known to any degree of certainty. Rather than take a chance with the chronic problems, some atomic scientists feel that a crew should have only one mission's exposure to radiation.

But what about an emergency? Suppose the plane were hit by enemy fire and its powerplant controls were knocked out. The reactor runs away, becoming a seething mass of molten

fuel and transfer medium, pumps and lines. Shielding is no good any more. The crew might eject; but they would be irradiated with a massive dose.

Must the designer provide enough shielding around the jettisonable parts of the cockpit to get a crew through the runaway reactor flux without injury?

Landing Problems

How about battle damage not sufficient to prevent the plane from getting back to base? Its landing gear or flap systems might be shot out and the pilot forced to make a belly landing. Suppose the plane broke up, spilling its reactor over the runway?

Or suppose it didn't quite make the field and landed short, or broke up in mid-air during the approach.

These latter considerations are the easiest to deal with because the range of a nuclear aircraft makes it possible to choose a base remote from population masses.

Even the safe return from a mission poses king-size problems. The aircraft is contaminated by radiation from the blast of its own nuclear weapons, possibly from the near-miss or fallout of an atomic anti-aircraft missile, and certainly from its self-generated radiation. How can a ground crew handle it.

Perhaps remotely controlled cranes could lift out the reactor and dump it into a shielded pit. Another crane might remove the crew compartment and trundle it away on a radio-controlled truck. A robot tractor might tow the empty airframe to a decontamination building.

The training of a crew to fly a nuclear aircraft means that crewmen must receive some actual radiation unless they train only in simulators. There is some feeling that even the most accurate simulation of flight does not train sufficiently for a complex mission.

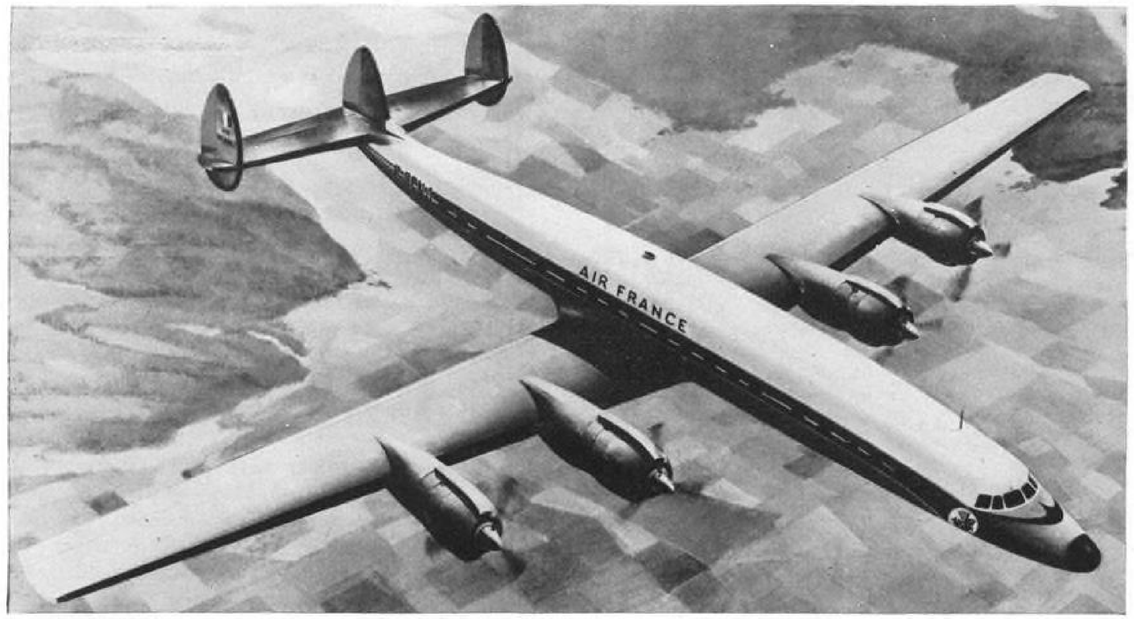
Maintenance and repair of nuclear aircraft means radiation hazards for ground crews and the contractor field service representatives.

Finally the airplane has outlived its usefulness; it is war-weary and normally it would be broken up for scrap. But not this plane—it must be treated almost like a spent fuel element and prepared for disposal at some remote site where atomic ashes still burn. How do you handle a large mass of hot material at one time?

"Working on these kinds of problems," said Col. Clyde R. Gasser, WADC's Director of Research, "makes you feel like you're trying to do everything behind your back with mirrors.

"We've been working on WS-125A for 11 years," he said. "There is a lot to be done, but we're already working on the next ones.

"This WS-125A is just the first step, and there's a long road ahead." ■



The new 1649A Super Constellation spreads its wings! Major wing and propeller improvements planned for the new, longer-range Lockheed Super Constellation aircraft due in 1957 mean important changes in intercontinental flight. Carrying up to 9600 gallons of fuel, the new Super Constellation at ranges beyond 4200 miles will fly point-to-point 70 mph faster than other piston-powered airliners. By moving its four powerful turbo-compound engines farther outboard, along its 150-foot wingspan, Lockheed promotes additional quietness in passenger cabins.

First USAF Reactor Due in Two Years

Wright-Patterson AFB, Ohio—The Air Force's first big nuclear reactor, the 10-megawatt heart of the Nuclear Engineering Test Facility at Wright Air Development Center, is scheduled to begin initial operations within two years.

A major task for NETF will be technical test support for the nuclear-propelled WS-125A weapon system. Everything from tiny samples of materials to completely operational major systems will be tested.

Availability of this new reactor and its test areas will relieve greatly the WS-125A workload now programmed into the overloaded reactors of the Atomic Energy Commission.

Present plans call for NETF to be fully staffed, with calibration and shakedown runs behind it, by mid-1958. Construction began last month on a site near the south boundary of WADC.

Five Test Areas

Basic layout of the reactor building will provide five different testing facilities:

• **"Swimming pool,"** a large water container where a complete crew compartment or other large prototype aircraft system can be subjected to controlled levels of radiation.

• **Two bare reactor faces,** with adjacent test cells where a complete engine or other component can be tested in the presence of intense radiation.

• **A thermal column,** which provides thermal neutrons for test purposes. Thermal neutrons are atomic particles slowed down by a moderator until their average energy is about that of the atoms of the medium that is being tested.

They are associated with the fuel elements of a reactor.

• **A gamma source,** which actually is a storage dump for spent fuel elements. Gamma radiation comes from the fission process and is given off by the fuel ash after fission has begun.

• **A "rabbit"** for testing materials during a brief exposure to extremely high radiation. This unit gets its name from the electric rabbit of the dog tracks, and is like a car running on a circular track.

The sample to be tested is placed in the car, which rushes through the reactor core.

Test Object's Route

These test installations are laid out in a cruciform pattern projecting from the reactor faces.

After exposure in one or more of these areas, the object being tested will be moved to the High-Level Radiation Building adjoining the reactor building, where the extent of radiation damage will be determined.

With the tests and analysis completed, the irradiated object has to be moved again to a waste disposal storage and treatment plant. There it will be readied for shipment and final disposal at one of the Atomic Energy Commission sites.

A laboratory building nearby will contain facilities for low-level radiation work in metallurgy, chemistry, physics and other fields.

Plans for Staffing

The NETF staff will combine military and civilian technicians who have spent from six months to a year in special training at one or more of the Atomic Energy Commission's reactor stations.

In addition, there will be specialists familiar with the particular problems of the nuclear systems assigned to each WADC laboratory. They will prepare the complete rigs they want to test, analyze test results and determine the courses of action suggested by the analysis.

Service Group

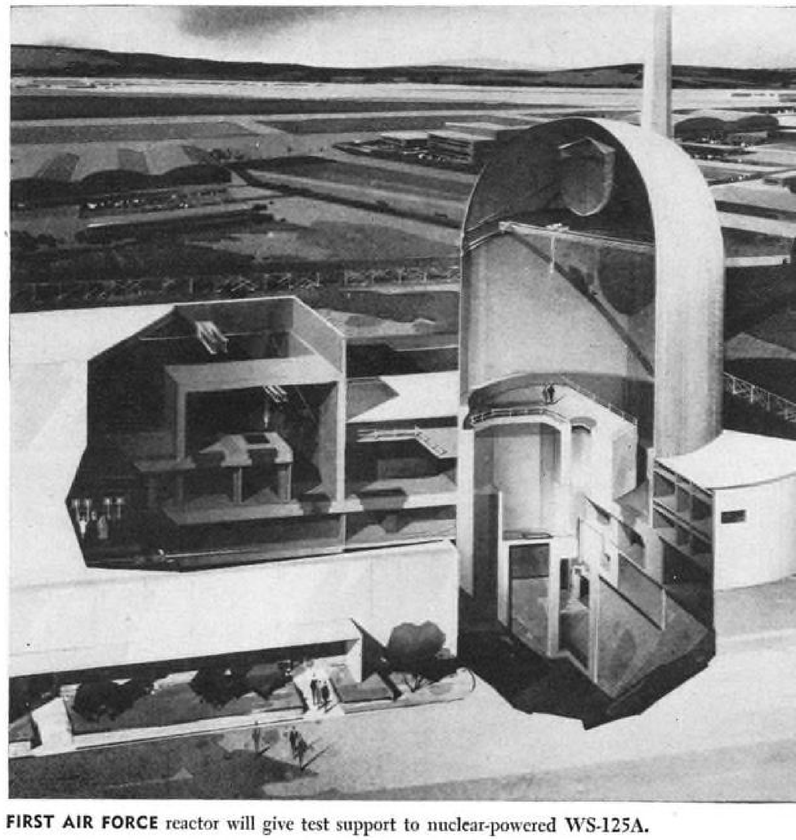
There also will be a service group set up within the Aeronautical Research Laboratory of WADC's Research Directorate to handle special analytical work.

Contractors are expected to supply professional personnel, trained in nuclear problems, for their scheduled tests in NETF.

NETF is one of the first steps toward establishing an ARDC atomic center. Said one officer: "We'll need an atomic center some day for the advanced manned nuclear systems, nuclear rockets and the things that lead out to space.

"The nuclear bomber is just the very crude beginning of a long line of these vehicles.

"You can't make progress without the tools." ■



FIRST AIR FORCE reactor will give test support to nuclear-powered WS-125A.

ENLARGED nose of modified B-36 contains shielding. Official radiation symbol decorates tail.

XB-36H Tests First Airborne Reactor

XB-36H crew on first flight: A. S. Witchell, Jr., pilot; J. C. Nance, nuclear test engineer; L. C. Brandvig, copilot; S. M. Andrich, flight test engineer; J. D. McEachern, flight engineer.

Ft. Worth, Tex.—The first airborne nuclear reactor tests are being made now under dynamic conditions in the Convair XB-36H, modified B-36 airframe.

This airborne reactor, designated ASTR, is one of two nuclear facilities operated by Convair Division of General Dynamics Corp. to get background data for the development of the company's nuclear-propelled weapon system. The ASTR is a low-power unit, rated at one megawatt, about equivalent to 150 lb. of thrust if it were part of a propulsion system.

The major purposes of these airborne tests are to reaffirm ground reactor data, to gain experience in reactor handling and equipment functioning, and to study crew shielding and overall effects on the airframe.

Ground Test Reactor

Convair's other reactor is the GTR (Ground Test Reactor), and is used in connection with a small "swimming pool." Its rating is also one megawatt. Both reactors are part of the overall WS-125A program directed by the people in the Air Research and Development Command connected with the many aspects of nuclear propulsion.

Flying the XB-36H

The colorful XB-36H, with its strangely shaped nose and the three-vaned radiation symbol bright on its vertical tail, flys from a long runway at Convair's facilities here. Blue paint on the nose streaks along the fuselage. Red flashes set off the wingtip jet engine pods.

The nose resembles the stepped-windshield design of current transports. Inside, shielded from radiation, are the flight crew and the reactor operators.

The reactor itself is back in the fuselage, its position marked by a large airscoop on each side near the rear scanners' stations. These scoops supply air for the reactor's heat exchangers inside.

Only the pilots and the reactor crew are aboard this aircraft. The scanners have been replaced by closed-circuit television, which also performs the vital task of monitoring the reactor controls.

The other technical personnel necessary to the test are in a B-50 flying formation at a discreet distance. Among the B-50 crew are 10 engineers trained as parachutists. They are a part of the safety precautions surrounding these tests.

If there is a disaster involving the XB-36H, it will be their job to jump near the disaster area and cordon it off, working with local law enforcement groups.

All flights are conducted over isolated areas of the Southwest to cut to the minimum the risk of endangering the public.

Tests in the Air

The ASTR is unique; it can provide variable shielding of its core by means of movable shields of different materials.

This is to determine the shielding capabilities of a whole spectrum of materials, alone and in combination with others.

Special types of miniaturized, ruggedized nuclear instrumentation had to be developed for this task, in addition to meeting the tricky requirements of the television system.

So far tests have confirmed early predictions that the crew would be quite safe from radiation hazards. The tests also have confirmed other shielding parameters for airborne reactors.

Right now, this program is an all-Convair show, by the company's request. Gradually USAF personnel are being brought into the test program so that its personnel also will benefit from the training and experience being gained in this unusual aircraft. ■

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AIRCRAFT & PROPULSION

ROCKET ENGINES IN ROCKETDYNE TEST STANDS

Flight Test Center Makes or Breaks Air Force Planes
Test Pilots Evaluate New Systems, Explore Frontiers
USAF Contractors Keep Arnold's Test Tunnels Filled

F-104 in Tests at AFFTC

Edwards Makes or Breaks USAF Planes

By Richard Sweeney

Edwards AFB, Calif.—The Air Force Flight Test Center is the "make or break" station for USAF's aircraft. Complete evaluation of a new weapon system here determines clearly how well manufacturers, subcontractors and other Air Research and Development Centers have done their jobs.

At Edwards all parts of a new system come together for the first time, to be checked out as an entity rather than as separate units by an imposing array of technical talent.

AFFTC, commanded by Brig. Gen. J. Stanley Holtoner, sprawls over 300,000 acres of California's Mojave Desert, surrounding a dry lake bed 13 miles long and five miles wide.

The lake bed, smooth as a billiard table and able to withstand the landing loads of the heaviest bombers, is the prime reason for the center's location here.

As USAF conducts research seeking basic aeronautical knowledge, planes like the X-1 series and the X-2 use the lake bed for their deadstick landings, while the X-3 needs three of its miles to become airborne and again when it makes a landing

AFFTC officers estimate the lake bed so far has "saved" $400 million worth of damage to planes, not counting complete washouts or time to build new aircraft

YP-59A Tested at Rogers

AFFTC is not the only organization taking advantage of Rogers Dry Lake. National Advisory Committee for Aeronautics maintains a $4 million high speed research station here, and USAF's Flight Test School takes advantage of other facets of Edwards' capabilities, including the 350 days of flying weather per year.

Sometimes the lake is incorrectly called Muroc. Teenagers raced cars here during the 1930s, and over the years many planes made maiden flights from it. Sir Hubert Wilkins tested his Lockheed Vega here in 1924 prior to his polar flight.

In 1943, the Army Air Forces set up a base on the north side of the lake to test the YP-59A, the nation's first jet aircraft. Already operating on the south side of the lake was a school for P-38, B-24 and B-25 crews. As the war ended, expansion occurred in the North Base section where test teams from Wright Field came out to take advantage of the lake bed and the better weather.

ARDC Takes Over

Finally training and test bases were consolidated, ARDC came into being and Muroc became one of the first six centers.

It was renamed Edwards in 1950 after Capt. Glen Edwards, who was killed in 1948 testing a Northrop YB-49 "Flying Wing" jet bomber.

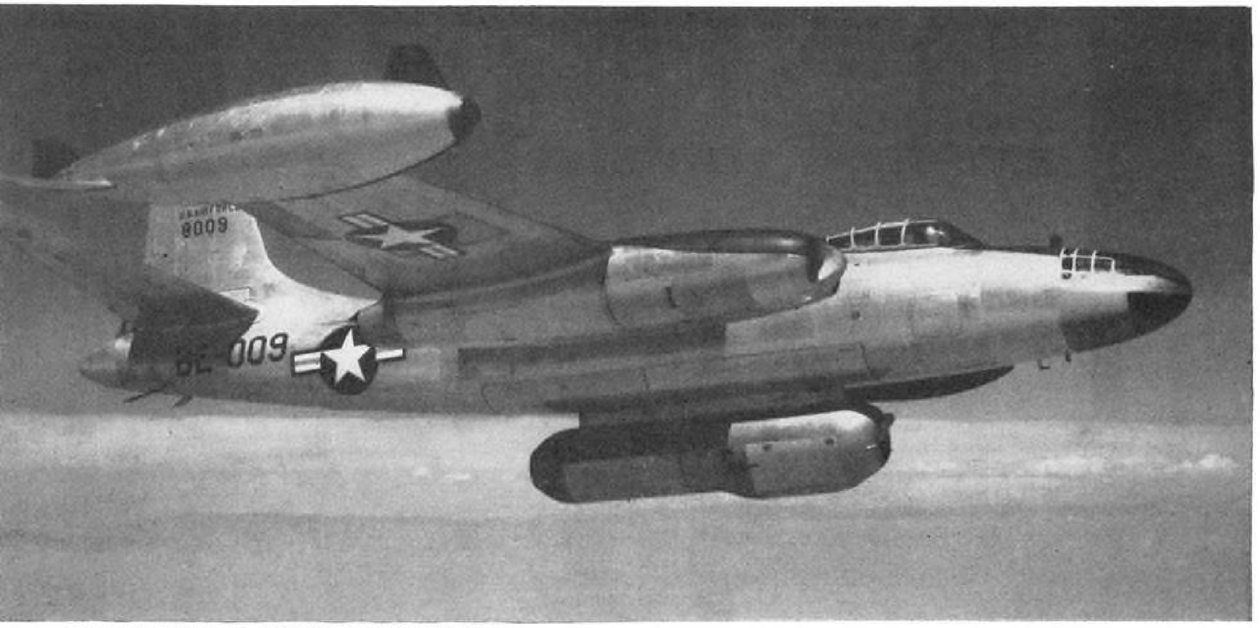
The center now is well into a $120 million construction program. Completed parts of this master expansion plan are:

- **A 15,000 ft. runway** which extends to the edge of the dry lake bed, making a continuous landing roll of 8 mi. possible in one direction.
- **New maintenance hangars,** including the largest USAF has.
- **New buildings for base headquarters,** the various divisions and branches supporting flight test, personnel quarters and quarters for base tenants including contractors.
- **Wherry housing for base personnel** with dependents, which created a new city of 13,000—Edwards, Calif., adjacent to the base.
- **General base buildings** such as chapel, gymnasium, and clubs for officers, civilians, NCOs and airmen.

The geographical sections of Edwards today are:

- **South Base,** where the original consolidation of Air Force activity took place. It is fast being eroded by the harsh

Brig. Gen. J. Stanley Holtoner, Commander, Air Force Flight Test Center . . . has flown every type of USAF fighter from P-1 to F-104; the B-36, B-45, B-47, XB-51, B-52, B-57 and B-66 bombers; helicopters and cargo aircraft and the X-1 rocket research plane . . . set world speed record of 690.118 mph over 100-km. course in F-86D and won Thompson Trophy race in 1953 . . . born New York City, 1911 . . . graduate of New York University . . . commanded 82nd Fighter Group in World War II . . . served at USAF Hq. in Directorate of Research and Development . . . Assistant Deputy for Development when ARDC was formed in 1951 . . . commanded Flight Test Center since January 1952.



B-45A TORNADO IS TESTBED FOR JET ENGINES

desert weather and there is a race to requarter contractor and AFFTC activities in new, permanent structures at Main Base.

• **North Base,** original flight test area. Several contractors, the deceleration track and a number of AFFTC activities still are located here.

• **Main Base,** center of the new construction, adjacent to the new 15,000-ft. runway. Location is about a mile north of South Base.

• **Rocket Base,** located several miles away across the dry lake and on a ridge to accommodate its work with high-thrust liquid propellant rocket engines and the missiles they power.

Heart of AFFTC is the Directorate of Flight Test, headed by Col. Horace Hanes.

Supporting the directorate are Flight Test Operations Division, headed by Lt. Col. Frank K. (Pete) Everest; Flight Test Engineering Division, headed by Lt. Col. J. J. Berkow; Technical Services Division, headed by Lt. Col. J. H. Battle, and Technical Facilities Division, headed by Frank Ross, a civilian specialist.

Under each division are highly specialized branches contributing their part to evaluating a new aircraft's capabilities and requirements. The Project Control Office, headed by Lt. Col. Ralph Martin, coordinates the whole directorate.

Based at Edwards, in addition to Flight Test Center and the Test Pilot School are:

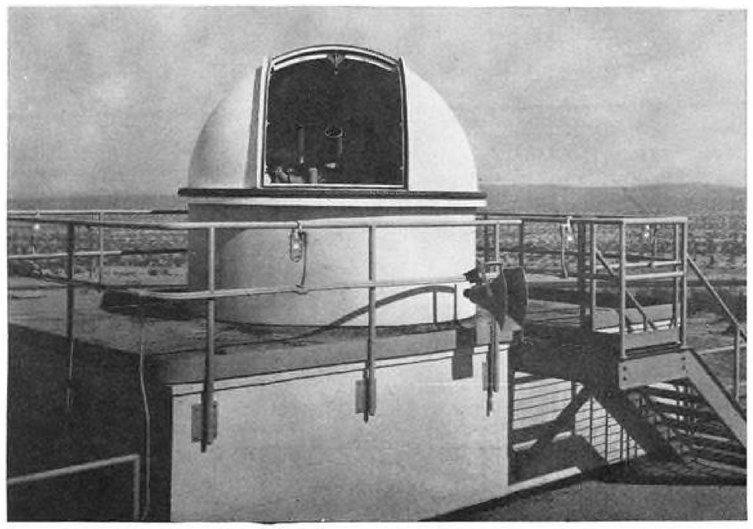
• **6511th Test Group (Parachute)** which, while administered by AFFTC, is physically located at the Defense Department Joint Parachute Test Facility, Naval Auxiliary Air Station, El Centro, Calif. Group Commander is Lt. Col. H. A. Orban.

• **6515th Maintenance Group,** commanded by Col. Franklin S. Allen, which handles upkeep of the test airplanes.

• **6510th Air Base Group,** commanded by Col. F. J. Collins, the housekeeping unit for Edwards.

• **Rocket Engine Test Laboratory,** Richard Gompertz, chief; known as Rocket Base or Rocket Engine Lab.

• **Ballistics Test Facility.** While not part of Edwards in one sense, is adjacent to Edwards. Formerly operated by the Aberdeen Bombing Mission of Army Ordnance, it has been transferred to ARDC's Armament Center.



ASKANIA CAMERA TURRET

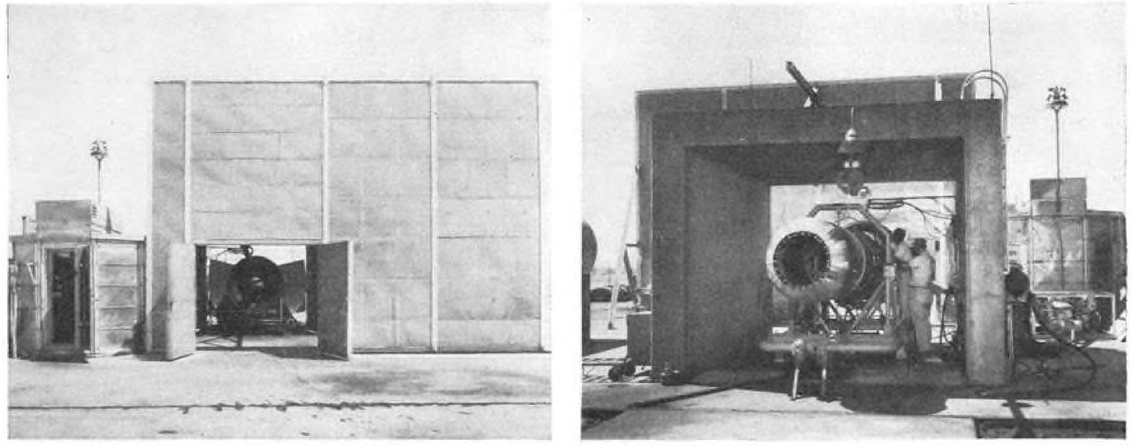
Testing New Aircraft

AFFTC enters the life of a new weapon system early, officially and unofficially.

AFFTC men sit in on design evaluations, mockup boards and other judging groups. AFFTC pilots frequently are asked for advice on cockpit layout and other matters affecting pilots while a plane still is in the design stage.

USAF tests an airplane weapon system in eight phases:

• **Phase I—Contractor compliance,** or



POWERPLANT BRANCH TEST ENGINE IN SHAW-ESTES CELL. LEFT PICTURE SHOWS FRONT, RIGHT SHOWS REAR

essentially, will it fly? In about 20 hrs. testing, the aircraft is held to 80% of design limits.

• **Phase II—Initial performance,** usually Phase I done again by USAF test pilots. AFFTC fliers already have flown the new plane unofficially once or twice, but Phase II is USAF test which goes on the record. In this phase, USAF gets an idea if this will be a smooth one or if troubles are on the horizon.

• **Phase III—Contractor development,** where the company and AFFTC test pilots' squawks are taken care of and major bugs ironed out. Fixes continue to be made during the entire service life of the aircraft, but the majority are to be eliminated here.

• **Phase IV—Performance and stability,** in which the thoroughly instrumented prototype investigates the entire performance regime. In some 200 hrs., data is obtained from which the aircraft handbooks are later written.

• **Phase V—All weather testing,** done at Wright Air Development Center, Eglin AFB, Fla., and Ladd AFB in Alaska.

• **Phase VI—Functional development,** using production models. All systems must work. Every necessary part of the weapon system must be operative. During each flight, everything in the weapon's repertoire is accomplished—guns fire, bombs drop, radar tracks and is jammed, cameras shoot, tanker hookups are completed, intercepts are made.

Using agency pilots enter the picture here, helping fly the phase, which uses three to six airplanes for approximately 150 hrs. per airplane. Users also get a line on overall operation of the weapon system, its support requirements and special techniques, training and equipment needed.

• **Phase VII—Operational suitability,** accomplished by the using agencies at the Air Proving Ground.

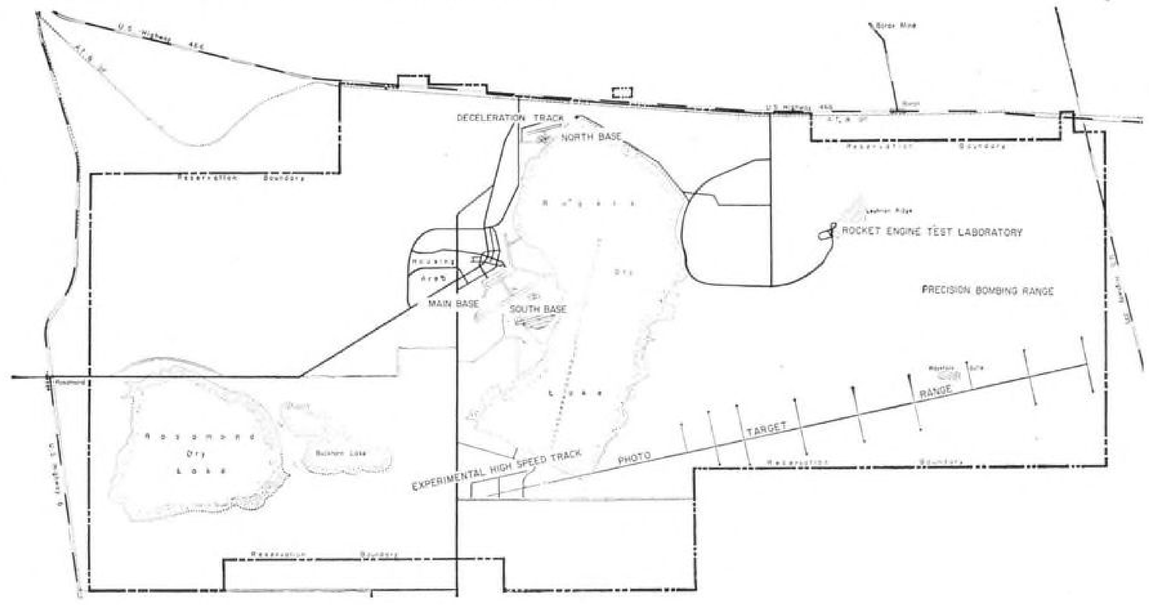
• **Phase VIII. Unit operational** employment testing. Accomplished by the using commands under Air Proving Ground supervision.

AFFTC conducts Phases II, IV and VI at Edwards, and frequently, contractors from Southern California fly Phase I and III there as well.

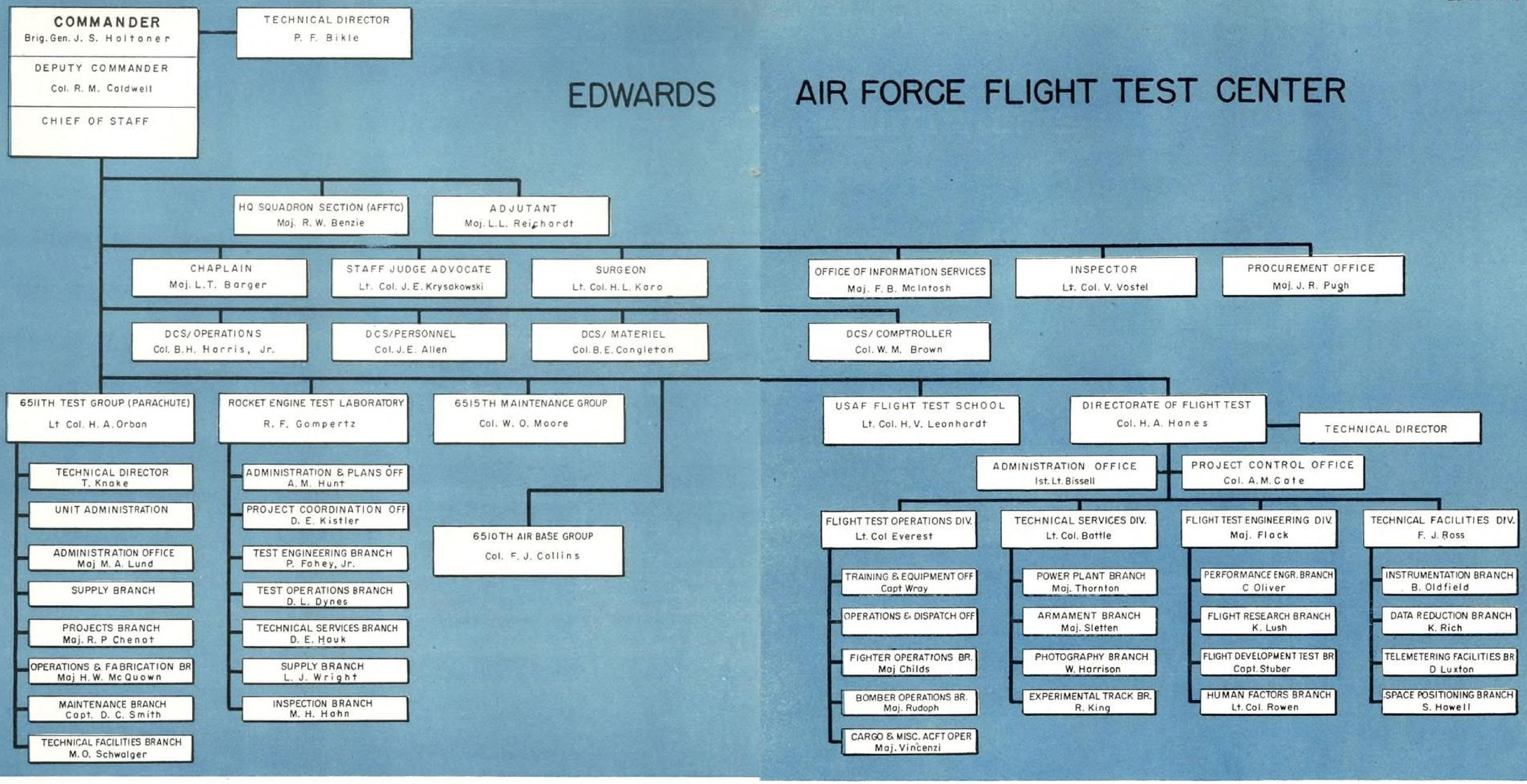
Test Engineering Division

But long before a new project is ready for flight test at Edwards, a project engineer has been designated from

NEW CONSTRUCTION IS AT MAIN BASE (CENTER OF MAP)



EDWARDS AIR FORCE FLIGHT TEST CENTER



AFFTC's Flight Test Engineering Division. He is the key man in the flight test program, making up the cards the pilot flies each time. The other divisions and branches work in close coordination with him when their activities enter the test picture of his particular project.

Composing the Flight Test Engineering Division are:

• **Performance Engineering Branch,** concerned with all aspects of the plane's flying characteristics.

• **Flight Research Branch,** which determines how best to gather data as it pertains to new developments in this aircraft.

• **Flight Development Test Branch,** which works mostly in Phase VI, planning more and better ways to utilize this particular weapon system.

• **Human Factors Branch,** concerned with all aspects of the man-machine relationship, seeking to improve the machine to insure greater compatability with the man to the end of better accomplishing this mission. Not only aircrews figure in these investigations and recommendations. Ground crews and other support personnel are considered as well. The recommendations have even brought changes in HIAD (Handbook of Instructions to Airplane Designers, official guide on designing USAF planes).

Test Operation Division

In the Flight Test Operations Division are:

• **Training and Equipment Office.** (One for each plane type.)

• **Operations and Dispatch Office.**

• **Fighter Operations Branch.**

• **Bomber Operations Branch.**

• **Cargo and Miscellaneous Branch** (which also tests Army planes).

Technical Services Division

Other supporting groups within the directorate, their branches and functions are the Technical Services Division, including:

• **Powerplant Branch,** which does analytical evaluation of engines involved in test programs—either new engines or established engines in new installations.

• **Armament Branch,** concerned with guns, rockets, bombs of all types and with the avionic gear necessary to their function. In combination navigation-bombing systems, Armament retains cognizance while conventional electronics and communications equipment comes within the scope of the 6515th Maintenance Group.

• **Photography Branch,** which does all photographic work in support of the AFFTC test mission as well as assessing new aerial photo systems which are parts of new weapon systems.

• **Experimental Track Branch,** testing many components and systems on a high speed track, as well as initiating (through WADC) its own investigations.

Technical Facilities Division

In Technical Facilities Division are:

• **Instrumentation Branch,** charged with providing and installing the equipment needed to gather data required by the project engineer.

• **Data Reduction Branch,** where data is translated into useful information. It is known as "Project Datum".

• **Telemetering Facilities,** handling this operation for both AFFTC and contractors working at the test center.

• **Space Positioning Range,** an organization of people and equipment, called

"Project Range," which tracks the vehicle's path and position throughout the various test flights.

Several of the branches within the directorate are high specialized and somewhat unique.

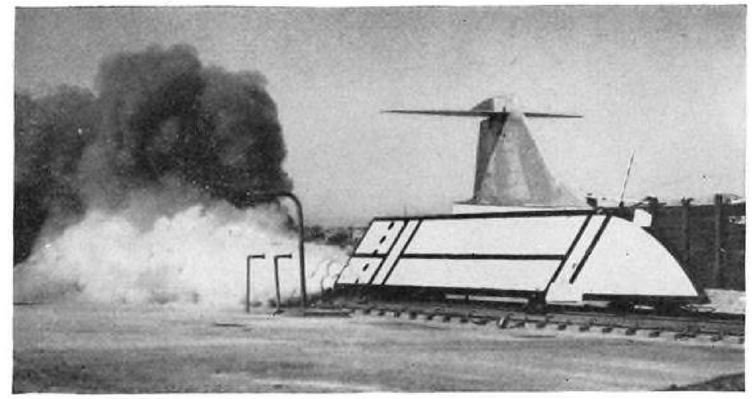
High Speed Track

At the 10,000-ft. high speed track, where a Convair test vehicle exceeds Mach 2 regularly, tests have been run on small models of planes; nose sections of supersonic aircraft have been rammed through simulated rainstorms; and full scale sections of various airplanes have been used in tests of tail flutter and ejection systems.

The track performs tests for contractors and can originate its own tests (through WADC). It is proving a highly useful tool with a wide, as yet untouched potential. The art of track testing is relatively new, and the possibilities are great for testing systems and sub-systems of all kinds of aerial hardware and even armament (in one case, a vehicle was slammed into an armament warhead at 1,500 fps. to check impact fuze timing).

Liquid or solid propellant rockets are used. Liquid rockets prove more versatile and less expensive, so the track has been using them for some time in smaller thrust brackets. However, now on order is an engine of upwards of 500,000-lb. thrust, capable of pushing a 10,000-lb. vehicle to a speed of Mach 2 and sustaining it for 2 sec. A second engine, with about half the capability of the larger one, also is being developed. These will be multiple thrust-chamber engines with pressure fuel systems.

Although the high speed track is best known, the 2,000-ft. deceleration track is the oldest in the nation. It was built by Northrop Aircraft in 1947-48. On this track, webbing to hold pilots has been tested in simulated crash conditions, as has belt material of all kinds.



TAIL GETS FLUTTER TEST RIDING ROCKET SLED THROUGH TRANSONIC RANGE

Lt. Col. John P. Stapp made a number of human deceleration tolerance runs here before the Holloman track was constructed.

In conjunction with the Parachute Test Group, the Edwards high speed track also plays a part in nylon pilot lifesaver development. Canopies for decelerations from very high velocities are track tested, as well as multiple canopy systems for stabilization, deceleration and vehicle recovery.

Edwards' 'Used Car Lot'

Test vehicles either are built by the contractor or the track. In either case, when the test series is completed, the vehicle becomes part of the track inventory, and joins its predecessors in a storage area known as the "used car lot," where pieces and bits of airplanes and several off-beat special purpose vehicles give the area a unique appearance. In most cases, vehicles are used for several series of tests during their lives, but some time may elapse between uses.

Instrumentation at the track, built of 115 lb. crane rails precisely aligned and mounted on concrete, includes telemetering, a coil-magnet speed recording system and a thorough camera installation—trackside high speed Eastmans and Fastexes, panning Eastmans and Fastexes and a Hoelscher camera.

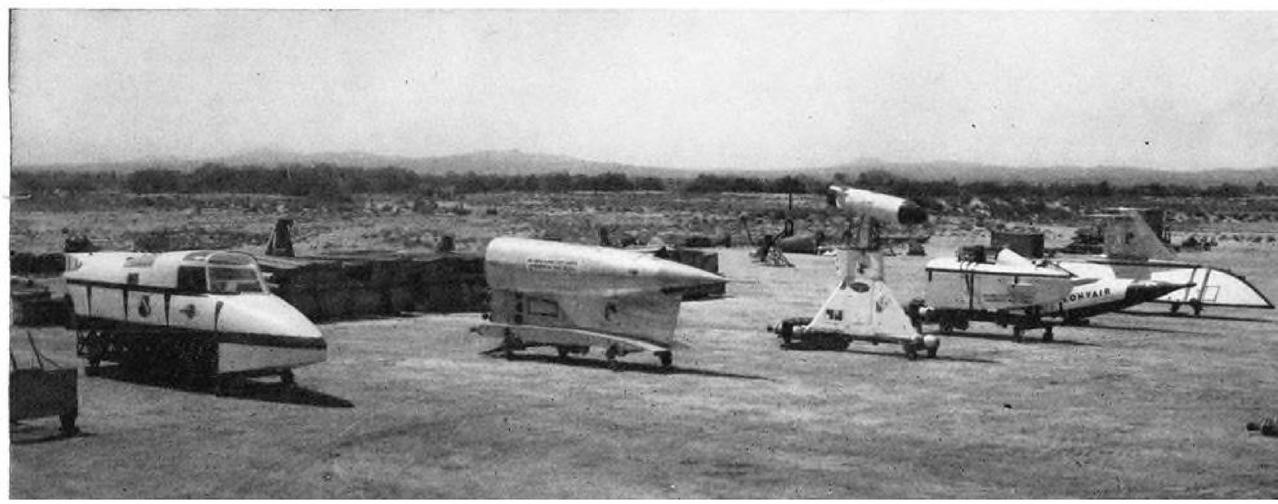
The track uses water brakes capable of withstanding upward of 100,000 lb. braking force. Brakes consist of scoops which deflect the water 165 deg. laterally an 15 deg. upward, gradually digging deeper into the water trough built into the last 2,000 ft. of the track. Newer brakes will be capable of withstanding up to about 500,000 lb. of braking force. R. R. King is chief of the track branch.

Powerplant Branch

The Powerplant Branch, with Capt. Gerald Jones as acting chief, enters the test picture of an engine still under development when a contractor requests its services. Otherwise, it becomes active when the powerplant enters USAF's phases of flight test.

The branch's main building of 42,000 sq. ft. has 10 bays for engine work, plus a machine shop and stands capable of completely testing any engine accessory or component. It represents a

AIRCRAFT PARTS FILL 'USED CAR LOT'



$2 million investment. Also available for expansion is a large warehouse.

In test stands, the branch operates two jet and two turboprop setups on South Base. At the branch's new building is a Shaw-Estes stand capable of handling engines up to 30,000-lb. thrust.

Four new test stands are under construction. They are due for completion in October, 1957. Cost will be $4 million. Three are for turbojets and one is a combination turbojet-turboprop setup. They will hold engines of up to 50,000 lb. thrust.

The 131 people (five USAF engineer-officers and 28 airmen) in the branch can accomplish their part of flight test support in a very short time on a critical project. Their normal routine is engine teardown and repair to keep a flight test program going, analysis of problem areas and performing the required fixes.

No Routine Maintenance

The branch ordinarily takes a powerplant involved in a test program, works it over and returns it to the same airframe. It does not engage in routine maintenance where an engine is taken from a plane, a new one issued and the incoming one worked over on a production line basis.

Paul F. Bikle
Technical Director

Col. H. A. Hanes
Flight Test Director

The branches findings have been that in nearly all cases, engine problems arise in flight which never show up in the controlled circumstances of test cell development. In addition, installation in an airframe brings out a host of new aspects and problem areas.

In maintenance equipment, the branch has the latest and best inspection equipment—Magnaflux, Zyglo, portable X-ray and an ultrasonic test unit. The machine shop can make engine parts needed, and can fabricate special tools when these have not yet been developed or put into manufacturer's production. The shop has two machines for balancing gas turbine rotors.

Test cells take standard measurements—thrust, flows, pressures, temperatures and vibrations. In the stands under construction, data recording will be automatic and in analog tape form for use in AFFTC data reduction center.

In the fuel flow test setup, the branch can handle up to 100,000 lb. per hr., duplicate any set of circumstances desired, and accomplish recalibration and rescheduling. A special nozzle test stand is used to check spray patterns and recalibrate as necessary.

Engine Development

The branch has played a prominent part in the stories of several well known engines, notably the J65 and J73. Information gathered here is used to write engine Technical Orders, and in some cases these TOs are developed through the powerplant branch's efforts.

Although the majority of the branch's work is with turbojet engines, one bay is devoted to piloted aircraft liquid propellant rocket engines. There, 12 highly skilled technicians work with the several types of this powerplant now flying in research planes at AFFTC. Their work so far is with small thrust, pressure propellant types of systems rather than the large engines handled at Rocket Base.

On Reaction Motors Inc.'s XLR-11 which powers the X-1 series, the branch handles all overhaul and maintenance except when the powerplant is installed in the airframe at the NACA

• EDWARDS

High Speed Research Station at Edwards.

On the Aerojet LR-63, being tested in the F-84F as a short-term power boost, they handle all maintenance.

The branch assists on test stand work with Curtiss-Wright's XLR-25, a fully controllable rocket engine on the X-2.

Recording Test Data

As airplanes go through the flight test program's required maneuvers over Rogers Dry Lake, much data is recorded aboard the aircraft. But additional data is being obtained by the Space Positioning Branch's Project Range built around the dry lake area.

Backbone of the range is the Askania camera, theodolite tracking equipment, a master target acquisition and control system and a precise electronic timing system governing the operation.

The range operates as a branch of the Technical Facilities Division, with Stanley Howell as chief. It consists of nine Askania camera positions—a master control center and eight slave stations located about the dry lake bed.

The control center is a 4,000 sq. ft. building where targets are acquired, tracked and controlled, where electronic timing and camera operating commands originate and where all space positioning equipment maintenance, both optical and electronic, is done.

Construction began about a year ago, first equipment was installed last October, and presently four of the slave stations (in 16 by 24-ft. buildings) are completed. The remaining four are due to be finished by the end of August. Calibration will be accomplished and the range in full operation by Oct. 1. Completed, with backup and support, the range will have cost $2.5 million. Some 30 men, USAF and civilian, will operate it. The range already has seen service with spin tests run on the F-101.

The Askania camera, worth $25,000, can take up to four frames per second. Simultaneously with target photograph, an internal azimuth and elevation scale is shot (scale accuracy is five seconds of arc). The Askania system's accuracy makes mandatory a first order land survey for camera site and installation. Cameras are insulated from the buildings in which they are mounted to avoid transfer of any building tremor or machine vibration or other abberation. They are hand panned, using theodolite tracking, with 65 cm. lenses standard. Variable diaphragms are incorporated, and films range from Tri-X through color according to conditions and requirements.

Two systems developed by the Ralph M. Parsons Co., general contractors for the range, are PARTAC and PARSET. PARTAC is Precision Askania Range Target Acquisition and Control. PARSET is Precision Askania Range

System of Electronic Timing. Both operate on command channels from the control center to Askania stations and the airplane.

In PARTAC, targets are acquired by radar. Signals are relayed to a master map stand on which there is a map of the range with two overlays. On one, a pen traces the target's path across the range. The other is oriented to an altitude scale on the side of the map.

Currently, radar information is verbally transmitted to the map station and Askania sites. When PARTAC is completed, radar signals will go into a computer which will translate them in such a way that, without human intervention, tracking signals will show up on Askania theodolite eyepieces as wheat germ lights. Camera operators will pan toward the lights and acquire the target. Simultaneously, computer translated signals will automatically operate the tracing pens on the map board. Directions will be verbally transmitted to the target aircraft pilot, since steering a precise ground track from 40,000 ft. is somewhat difficult by ground reference alone.

The timing system, built around a conventional binary coded time signal, also will be carried on the command channel. It will carry relative time and time of day. With PARSET, frame-by-frame assessment of each camera's film separately will not be necessary to match film records since all pictures will have been taken at exactly the same time from all stations and will so indicate on each frame. Camera preparation for operation is done by operators at each station. But when operation begins, control is from the master center for each photograph.

While data is being recorded photographically, the magnetic tape for tie-in with Project Datum again will be used to recording information for later orientation in the data reduction center. Fourteen channels are available. Command data, PARTAC and PARSET will be recorded.

Although not a part of Project Range, Askania cameras are scheduled for mounting on 30-ft. towers at each end of the 15,000 ft. runway to record landing and takeoff data on test airplanes.

Project Datum

AFFTC activities revolves around gathering data. To reduce it all by hand would cost many more years than could be afforded, timewise and financially. To handle the mass of technical information gathered at Edwards, the Directorate of Flight Test has set up Project Datum under Technical Facilities, for integrated gathering, processing and reduction of data obtained by all base organizations.

Project Datum is built around the

1-in., 14-channel magnetic tape gathering system. Data is in analog form, which will give engineers a "quick look" so that they can select the portions they want for detailed reduction and computation. After the tape has been fed through the analog system, parts needed for complete reduction are fed into an analog-to-digital converter made by J. B. Rea Co. of Santa Monica, Calif. From the converter, data goes to the digital corrector, which produces a tape suitable for use with IBM computing equipment. At present, the Data Reduction Branch is thinking in terms of an IBM 702 computer.

Units at AFFTC which will participate in Project Datum are:

- **Flight Test,** where direct tape recordings will be made. These will include PARSET information from Project Range, to connect airborne data reduction to Askania range data.
- **Rocket Engine Test Laboratory.** This facility will have analog "quick look" equipment which will enable Rocket Base engineers to send edited tapes to Project Datum, ready for conversion, correction and detailed computation.
- **High Speed Research Track,** which now is converting its data acquisition insofar as possible, to integrate with Project Datum's 14-channel tape.
- **Project Range,** general data.
- **Askania Cameras** including PARTAC information.
- **Contractor and other telemeter** data acquisition organizations.

Equipment used in Project Datum includes that made by Applied Science Corp. of Princeton, N. J., Ampex Corp., Redwood City, Calif., and the Rea company.

The aims of Project Datum are to:

- **Eliminate manual handling** and reading of test data insofar as possible.
- **Make test data available** for further use within a few hours after completion of tests.
- **Increase the accuracy** of test data over that currently possible.

The Crowded Desert Air

Gen. Holtoner took command of the Flight Test Center in February, 1952, and has been in on the growth of the center and its web of support elements since the start of expansion. Originally the principal occupant of airspace over the desert region known as Antelope Valley, Edwards now shares the sky with an already large and expanding assembly plant complex at nearby Palmdale, where Convair, Lockheed and Northrop are flight testing high performance production airplanes. A Marine Air Station at Mojave, a few miles up the valley, also competes for the sky. The airspace problem is serious now and steps are being taken to prevent its becoming critical in the future.

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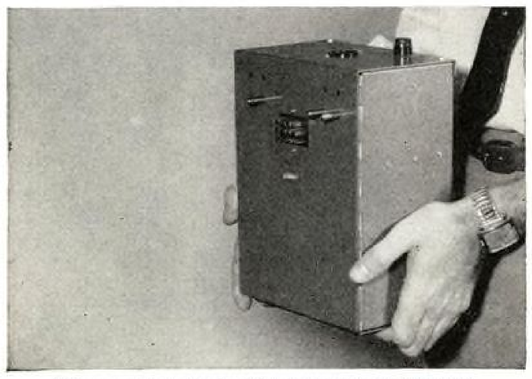
Without deviation, this new Sciaky control counts the cycles of power line frequency which is governed by the U. S. Naval Observatory. In predetermined absolute numbers the cycles and impulses of the various welder functions are simply counted by a Dekatron tube. A single tube is used to count both the respective cycles of succeeding functions, as well as the impulses of welding current. The positive adjustment snap switch control dials are logically calibrated in these same cycles and impulses.



Close up of a typical unitized, plug-in sub-assembly.

ABSOLUTE CONSISTENCY

Control settings are realized with exactness. No relays are necessary during the entire welding sequence. The unvarying accuracy of counting is maintained throughout the entire range for the longest run at the highest production rate, and is readily reproducible at any time.

Note the ease with which a plug-in new function unit can be added.

EASE OF MAINTENANCE OR ADDITION OF FUNCTIONS

The entire control is designed to permit the greatest possible ease and speed of maintenance or addition of functions through the use of separate plug-in subassembly units. Down time is minimized since it takes only minutes to install a spare or an additional function.

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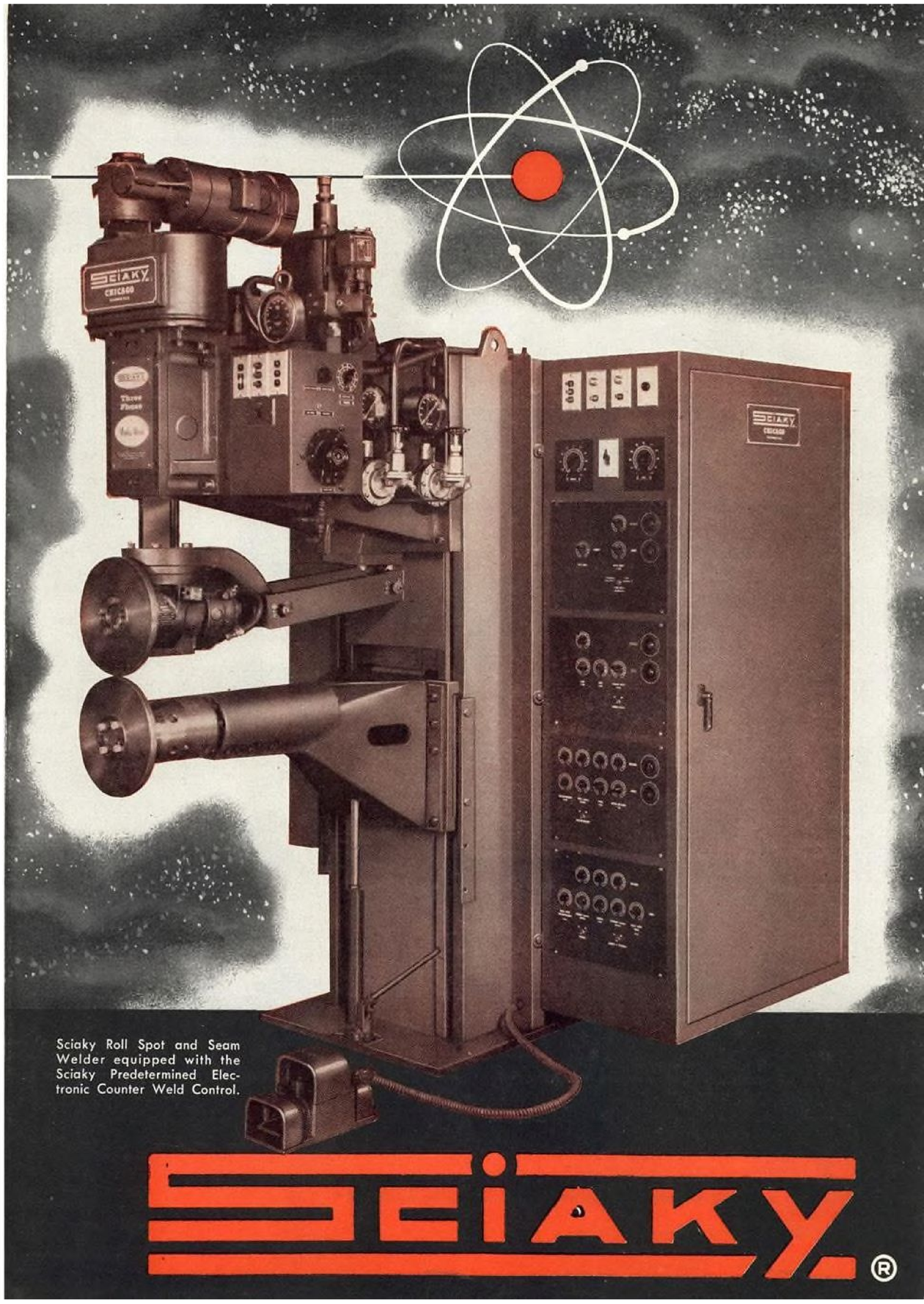

Sciaky Roll Spot and Seam Welder equipped with the Sciaky Predetermined Electronic Counter Weld Control.

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Test Pilots Are Evaluators, Explorers

Edwards AFB, Calif.—The official wording of the Air Force Flight Test School's mission is deceptively simple—"to train pilots to conduct flight tests of experimental and production aircraft."

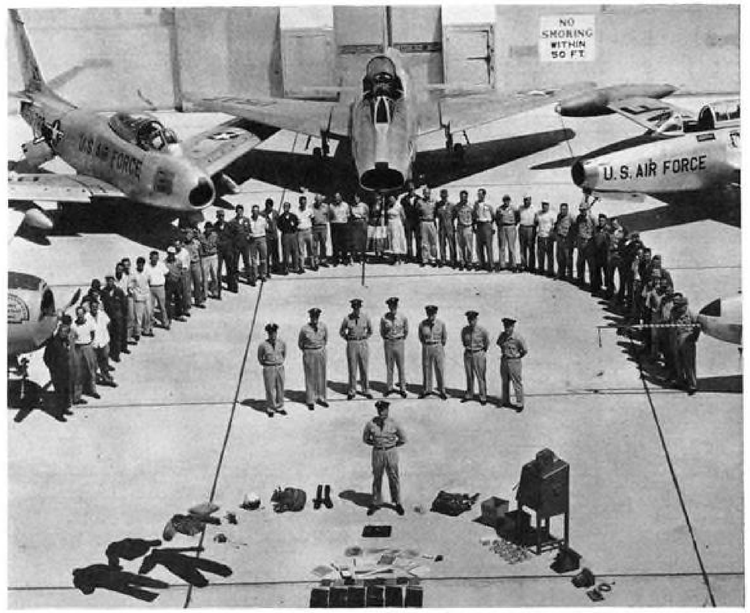
The real task of the school, located at the Air Force Flight Test Center here in California's Mojave Desert, is to turn out pilots fully capable of assessing weapon systems in Phase VI testing or of pushing back the frontiers of aeronautical knowledge by flying the unusual experimental series of test vehicles.

The school's commander is Lt. Col. Herbert Leonhardt, who holds a master's degree and did much of the test flying on the B-47 program. He took over from Lt. Col. John Amann, now at Wright Air Development Center, who was with the school off and on for nine years from its days as a pilot-to-pilot exchange to the present precise guide to USAF flight testing.

Chief of the Training and Operations Branch is Maj. Richard Lathrop, Ph.D., who gained fame for his research on inertial coupling several years ago.

The school's usual complement is 102 persons, including students. Of these, 47 civilians and 23 airmen maintain the school's aircraft. The school also has its own supply branch.

During the performance half of the course, students fly T-28s, F-84Es, a T-33 and the F-100C. Instructors are Capt. Harry Spillers, chief; and Capt. Robert Jacobson. To learn stability and control, students fly the TB-25J, three T-33s, and four F-86Es under the instruction of Capt. Harold Eberle, chief, and Capt. Ralph Matsen.



EQUIPMENT and personnel required to make Capt. A. G. Moore (front) a test pilot.

THOROUGH pre-flight briefing and cockpit checkout precede each student flight.

Modernization Plans

Currently the school teaches the photo panel method of data collection which utilizes Recordaks for frame-by-frame assessment. As the Flight Test Center converts to airborne magnetic tape data recording, the school will shift its data collecting and reduction training accordingly. The school also is collecting a comprehensive assembly of conventional training aids such as mockups, a film library and slides.

An effort is being made to have at least one of each of the latest types of planes being tested at Edwards assigned to the school on completion of Phase VI. On this basis the school now is slated to receive an F-102 and an F-104. It also hopes to phase out reciprocating engine aircraft and substitute turboprops soon.

During their stay at the school, students are given a comprehensive acquaintance with all activities at the Center. They see and sit in the latest aircraft and get thorough briefings from chiefs of all branches supporting the AFFTC mission.

"Graduation" comes in the form of a week's tour of contractor plants, with one class going to the East coast and the next to the West coast. There students get a complete picture of current problem and progress areas, and an appraisal of the contractors' work as background for their new duties.

The 60 graduates of the four classes a year may stay at Edwards, be assigned to another ARDC center, go to the Air Materiel Command or the Air Proving Ground Command, or be assigned

to any other slot in the Air Force where their training and background are needed.

To accomplish its mission, the school has at its command:

• **Seven instructors,** one with a Ph.D., four with master's degrees and two with bachelor's degrees. All are graduates of the school and they teach both in the classroom and in the air, giving authenticity to lectures by aerial illustration.

• **Nineteen aircraft**—one B-25, five T-28s, four T-33s, four F-84s, four F-86s and one F-100C, each instrumented for its work in teaching performance, or stability and control evaluation.

• **A curriculum** which includes in the six month's course (three months of performance and three of stability and control): 170 hrs. formal classroom work on mathematics, aerodynamics and related subjects, as well as the specific flight techniques appropriate to each type of flight testing; 70 hrs. flying time, accomplishing typical tests (students gather data, reduce it and write reports on it); 214 hrs. of data reduction and report writing and 96 hrs. of an activity common to all USAF schools—athletics.

• **Some 32,000 sq. ft.** of hangar space, a ramp area and a new 12,100 sq. ft. school building which has classrooms with calculators on students' desks, an instrument calibration laboratory of its own, an auditorium and a deluxe coffee room.

LT. COL. H. V. LEONHARDT

Entrance Requirements

A high-ranking five man board at Edwards screens all applicants to be sure they meet the school's entrance requirements:

• **At least 1,500 hrs.** diversified flying time.

• **Age from 25 to 33 years.**

• **Rank of second lieutenant** through major. (Most students at Edwards are captains.)

A bachelor's degree in engineering or one of the physical sciences is desirable, but applicants may prove a second-year college knowledge level by tests.

From Edwards, screened applications are sent to USAF where final selection is made. (The school is a USAF school, with operation responsibility delegated to ARDC and in turn to Commander, AFFTC.)

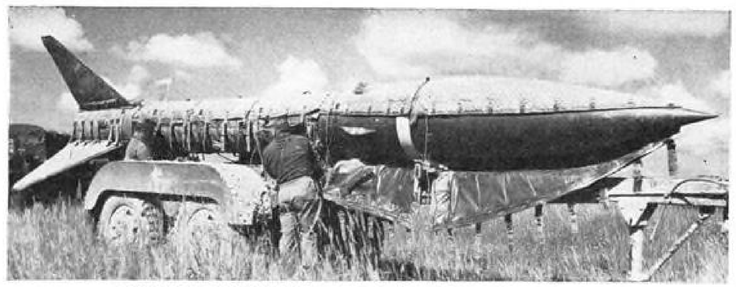
Aspects considered in the final screening include availability with respect to current duty, service experience, and record.

Reservists accepted for training must agree to serve at least three years' active duty after graduation.

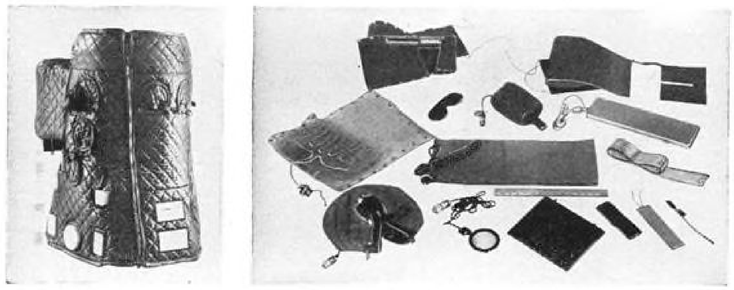
The 15-man classes usually include 14 USAF pilots and one "guest" from the Civil Aeronautics Administration, the Navy, the RAF, RCAF or a contractor.

School's Evolution

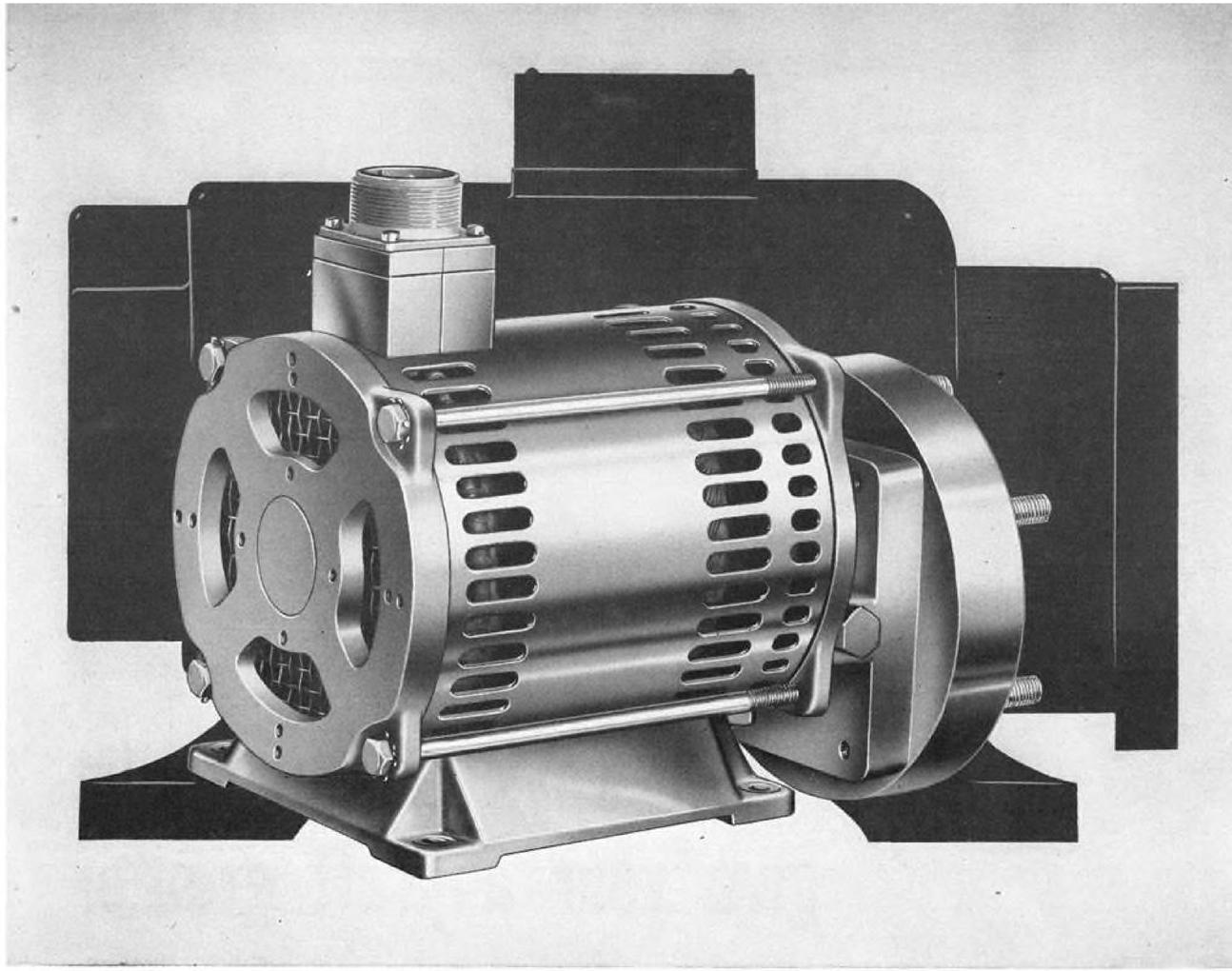
The school had its beginning late in World War II and immediately afterward, when USAF test pilot training consisted chiefly of experienced pilots passing along what they knew to men who were newly assigned. Semi-formal lectures evolved next and finally the full-fledged school emerged under ARDC. Three years ago it became a USAF school.

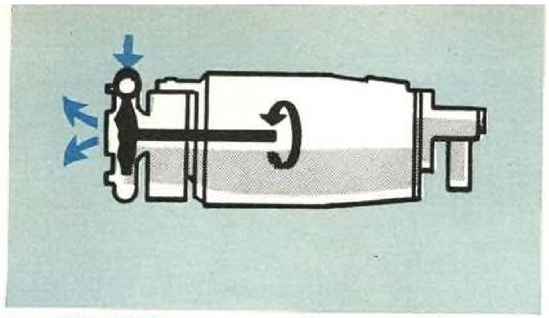


THERMAL CONDITIONING OF ROCKETS AND GUIDED MISSILES

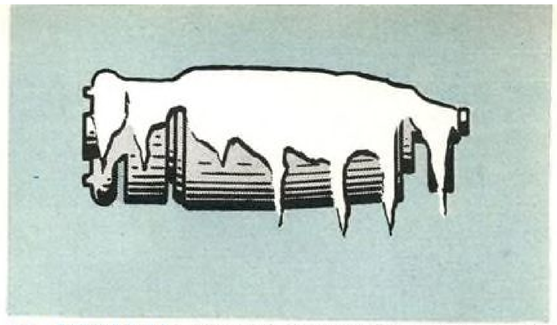


HEATING OPTICAL, ELECTRONIC, OR HYDRAULIC AIRBORNE EQUIPMENT



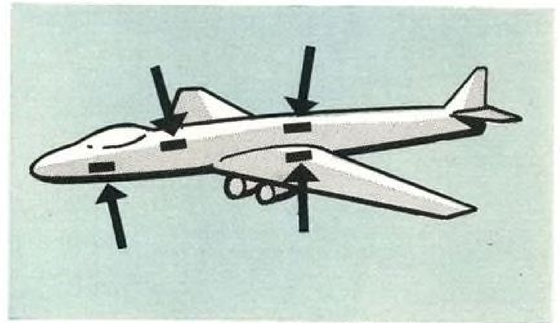


1. RELIABILITY: Fewer moving parts help assure more dependable operation.



2. FLEXIBILITY: The G-E Pump will operate up to 55,000 ft. altitudes.

5. NO PAD SPACE NEEDED: Reduced engine frontal area permits smaller nacelle size.

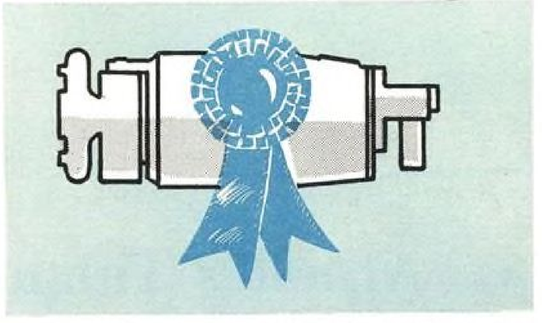


6. FUNCTIONAL LOCATION: G-E turbopumps can be located close to power requirement.

3. AUTOMATIC: Completely self contained, self lubricated and automatic in operation.

4. EASIER MAINTENANCE: Equipment changes can be made without removing the main engine.

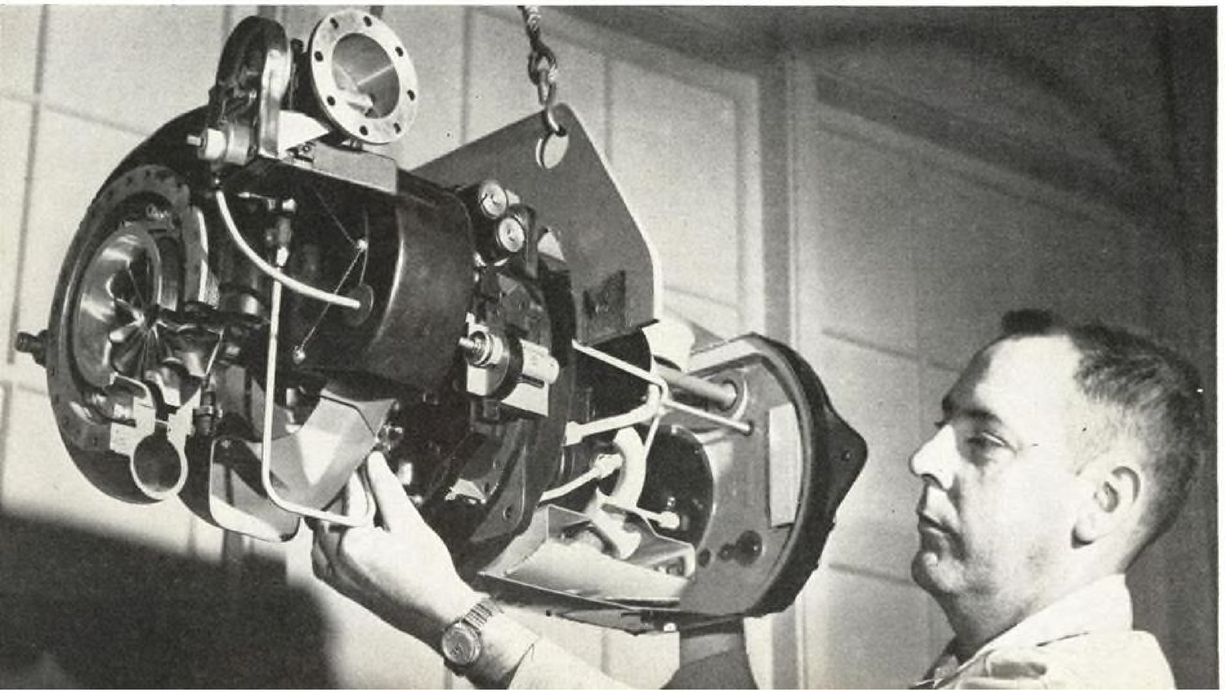
7. IMPROVED AIRCRAFT PERFORMANCE: System's light weight increases speed, climb rate, range.



8. PROVEN BY QUALIFICATION TESTING: Can meet requirements of your aircraft.

8 ways G-E Hydraulic Turbopumps can help give your aircraft greater availability, better performance

The G-E Pump is a completely self contained unit with its own control system and integral hydraulic reservoir. The inlet duct is assembled in three positions to permit air supply from three directions relative to a fixed reservoir position. This feature helps the Pump meet varied installation requirements.



General Electric's new Hydraulic Turbopumps are now available to give you the eight benefits illustrated above in furnishing auxiliary power for your aircraft. Designed to operate at almost any location within the plane's structure, the G-E Pump can be used to supply power for such hydraulic requirements as raising and lowering the landing gear, steering, opening and closing bomb-bay doors, maneuvering wing spoilers, and empennage surfaces.

Designed for efficiency—These G-E Pumps operate on the simplest of principles. Turbine wheels in each unit spin on streams of air extracted from the jet engines. The turbine wheel shafts then drive the constant speed variable displacement hydraulic pumps. This system eliminates the problems of bulk associated with direct drive systems. Expensive maintenance procedures are also unnecessary because a mechanic can easily get to each drive inside the plane. Their remote locations eliminate the weight of long transmission lines, and ground test operation is possible without operating the main engines.

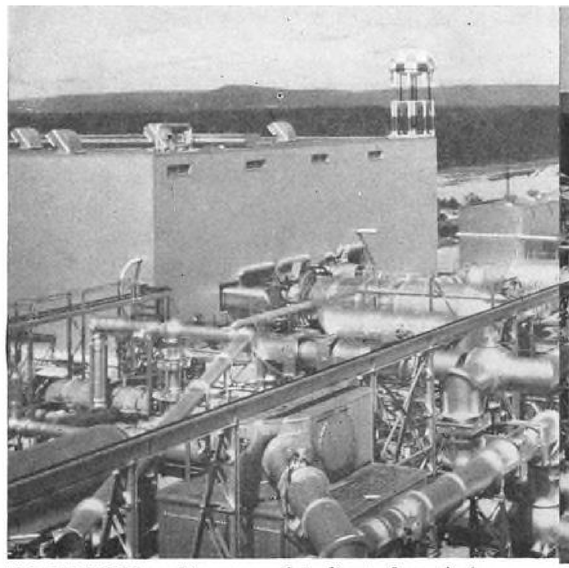
Greater aircraft availability: G.E.'s Hydraulic Turbopumps have been proven in operational testing. It has been designed for faster, easier installation, and greater accessibility in maintenance. These inherent features add up to greater availability for your aircraft.

Can meet your requirements—Designed to meet the toughest conditions that might be encountered in flight today, current models can operate up to 55,000 feet. Potential operational altitude is almost limitless. For more information on how General Electric can help you meet your auxiliary power demands, see your nearest G-E Apparatus Sales representative, or write for bulletin GEA-6333. General Electric Company, Section 231-4, Schenectady 5, N. Y.

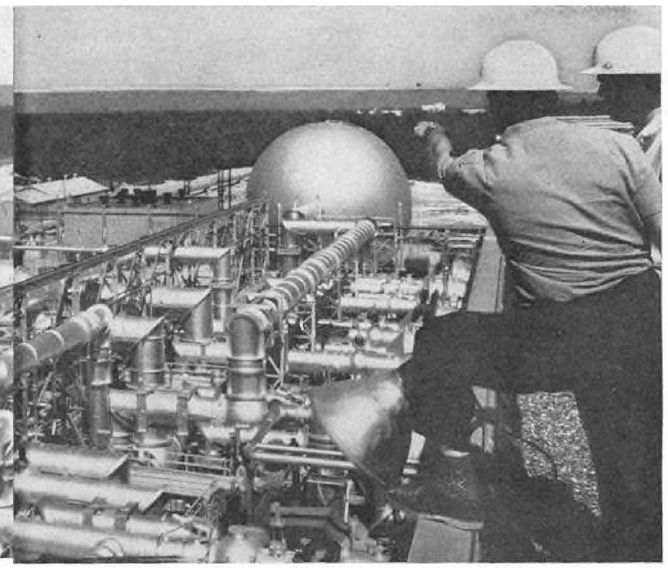
Progress Is Our Most Important Product

GENERAL ELECTRIC

CONTRACTOR discusses program with Bob Kamm and Maj. Gil Morehouse.



ARO ENGINEER explains maze that directs flow of air



through Gas Dynamics Facility's supersonic and hypersonic tunnels.

DR. B. DOETHERT, J. Ferrell show contractor model of ETF.

Arnold's Tunnels Test New Weapon

By Robert H. Cushman

Tullahoma, Tenn.—As each new wind tunnel is checked out at Arnold Engineering Development Center, aircraft contractors form a line, waiting to use it. Already the 70%-finished test center has contributed major aerodynamic and engine data to some of the country's most important weapon programs—the ICBM, the Century Series fighters and the B-58 Hustler supersonic bombing system.

Initially funded by Congress as part of the unitary wind tunnel plan in 1949, AEDC was tailored to keep US fighting aircraft internationally competitive.

Now, although AEDC's lead over the state of the art is perhaps less pronounced than expected, the center stands as the best of its kind known to be in existence.

Arnold is run by test men from management down. Many of the men who worked on the original tunnel designs with the parent company, Sverdrup and Parcel, have transferred to ARO, Inc. to operate the center and continue to improve it.

Utilization Record High

The present record of plant utilization is high.

Arnold's Engine Test Facility, which has been running long enough to have obtained usage statistics, has achieved 65% utilization based on a 24-hr. day. The best evidence of its usefulness to industry is that its customers keep coming back.

To appreciate the scope of Arnold's ability to help spawn a weapon system, imagine what the center could mean to a hypothetical weapon system's progress.

The following illustration is a fiction, not patterned after any actual system. This hypothetical example will start today in time and go to 1961, including the time needed for the completion of AEDC and giving the system somewhat over the minimum three years' development time.

Assume to start with that Midwest Aircraft's weapon system study group has come up with a system which they think is the answer to a vital defense need. Briefly, they plan a missile called "Slofast" as an ICBM predecessor. Like the Snark, it cruises subsonically at moderate altitudes. But unlike the Snark it has reserve performance so that as it nears an enemy off-shore radar warning line, it can gain speed and altitude, flying up and over enemy interception. Finally, when over the target, Slofast noses down and dives hypersonically to elude anti-missile missiles as it pinpoints its destructive effect.

Since much of the missile's performance is well outside the company's past experience, it feels it must try to check its assumptions before submitting an informal proposal to the Air Force. How will the missile behave in the final Mach 5 dive to the target? Will it overheat the warhead? Will it remain under control?

The company has a small Mach 5 tunnel but its Reynold's number is too low to give the engineers faith in the similarity of the model results to the full scale results.

Where to Test?

The number of existing wind tunnels which will simulate actual flight at Mach 5 is limited. In running down the list the Midwest test engineer calls AEDC to find out what help it could be.

He talks with Col. Bernard Marschner, military chief of the center's R & D Division. The engineer tells Col. Marschner his company does not have a contract at present but he has heard that under the unitary plan his company is eligible for some tunnel time on a proprietary project.

Col. Marschner encourages the engineer to visit AEDC. He begins by discussing his company's needs with Robert Kamm, Marschner's civilian counterpart and Maj. Gil Morehouse, chief of the division's Program Branch. They are part of the relatively small Air Force staff which oversees operation of AEDC. Their job is to screen new projects, but once that is done a contractor's representative is turned over to the operating contractor of the base, ARO, Inc.

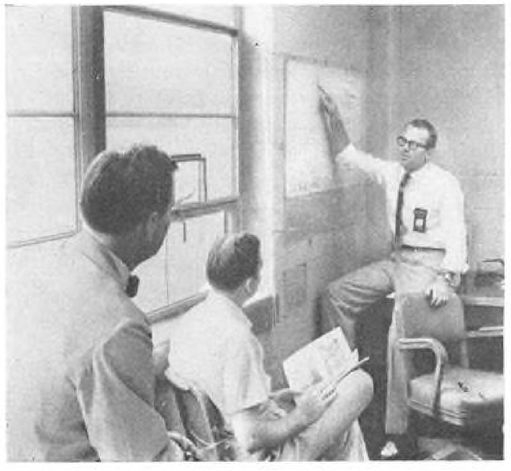
After a tour of the base, Kamm takes the engineer to the Gas Dynamics Facility (GDF) office where he meets Ronald Smelt, GDF director and former chief of Britain's highspeed flight research.

Smelt feels that GDF may be able to run tests in tunnel E-1 in a couple of months if, as seems likely, the program now in the tunnel runs into trouble and the next item on the priority list isn't ready.

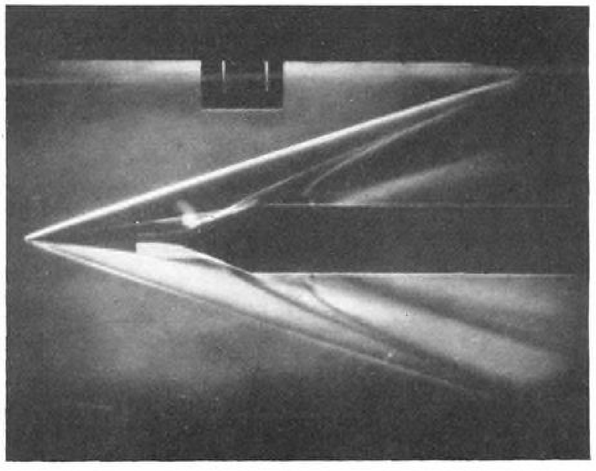
"Assuming AEDC's Air Force R & D division (Kamm and Marschner's group) okay your test, then if your model is ready we will be very happy to slip it in," Smelt says.

Kamm and Smelt estimate that they

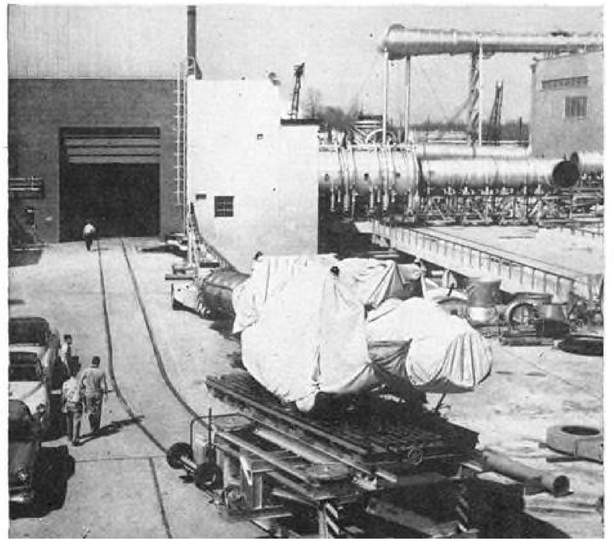
CONTRACTOR discusses scheduling with Ferrell, Lou Self.



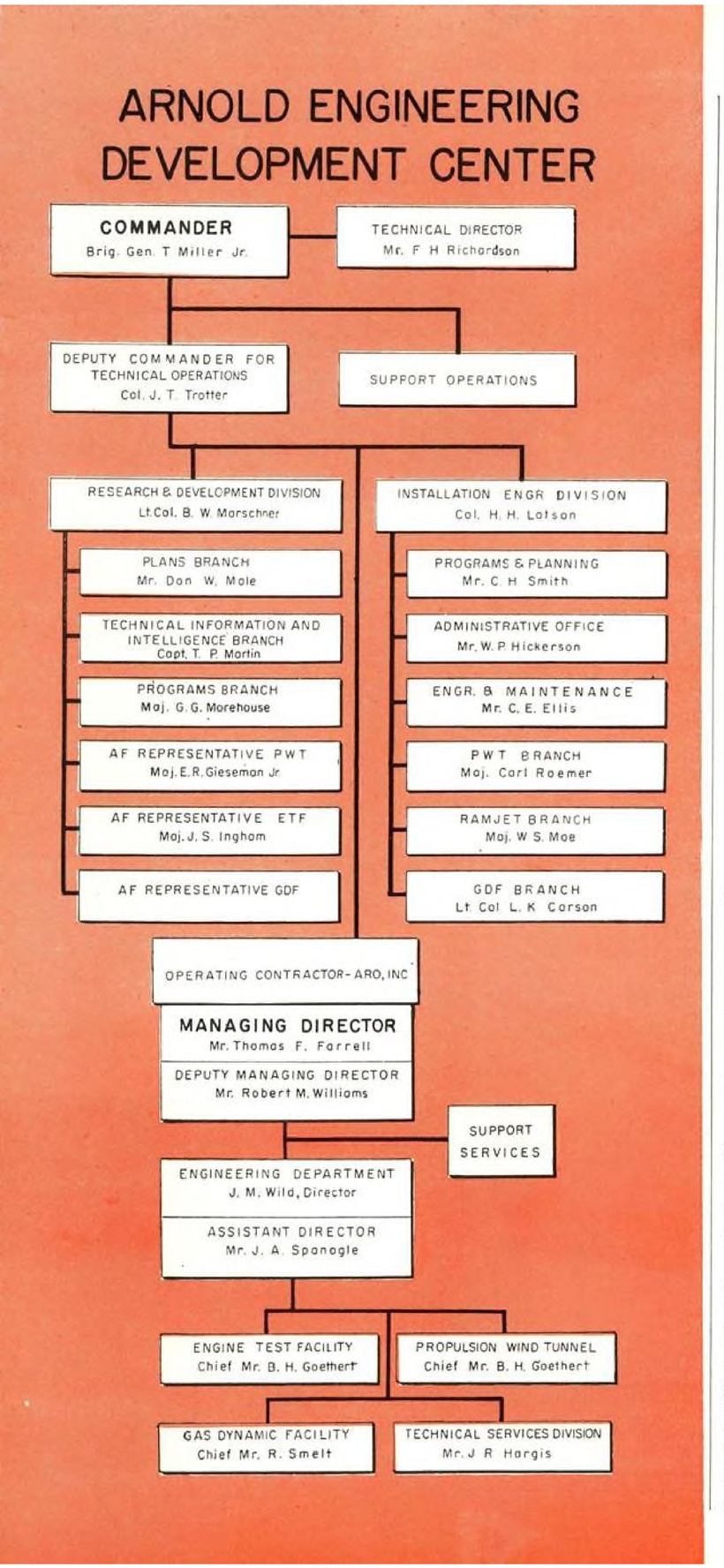
SHOCK WAVE PATTERN in GDF's Tunnel E-1 at Mach 5.



SHROUDS cover contractor's engine on its way to test cell.



CONTRACTOR discusses data reduction with Houston Hodges.



can get Midwest's program over in about two weeks at a cost of $8,000 per week. This includes operating costs and electrical power but not amortization of the facility.

Smelt gives his new customer a copy of the tunnel specifications and advises him to study the type of model mountings he wants and compute the data equations so they will be ready.

Smelt assigns a GDF engineer to the contractor's testing. While they wait for the vacancy in tunnel E-1, the ARO engineer makes certain that the contractor's model will be correct for the test and that the computer program is ready.

By fall of 1956 the expected break in the schedule arrives and the company test engineer brings an 18-in. Slofast model to the center. Working around the clock, ARO technicians install the model on the sting mount in E-1's 12-in. test chamber and connect the instrumentation. This tunnel is the oldest operating tunnel at Arnold. It already has proved valuable on the Raytheon Hawk missile and Republic F-103 and 105 aircraft.

For the company's model they run a series of one minute blow-downs at Mach 5, programming the altitude in steps from 100,000 ft. to sea level to simulate the warhead re-entry.

Data Handling

During the runs the company test engineer watches the schlieren of the shock waves to get a visual picture of the flow pattern around the missile and after each blow-down he steps over to Flexowriters and plotters which are automatically typing and point-graphing the advanced data in semi-corrected form as it is fed back from the ERA 1102 computers. The reduction system is capable of returning 250 inputs in 30 seconds.

Between tests, he discusses the test points for the next run with the ARO test project engineer.

At the end of each day's run he calls the home office and reads the day's results to the Slofast project engineer. For particularly pertinent runs he tears the punched tape from the Flexowriter and takes it to Arnold's communication center, where it is teletyped directly to his plant.

This combination of rapid reduction of data to usable form and constant intercommunication allows the project group at the home plant to utilize the tunnel results while the testing is going on. They call the test engineer at the end of the first week of testing and tell him that the results indicate a factor was overlooked in their original analysis and that it means a slight but important change must be made in the warhead's configuration if the missile system is to work at all. If possible they would like to have the change made and new runs to check it out.

The AEDC technical services shop makes the "fix" over the weekend, adding the additional instrumentation to check out the validity of the change. The runs in the final week verify that they have solved the problem. In fact, because of the completely automatic test set up, the test engineer finds that he is able to throw in two extra test runs to bracket the desired test points for further accuracy. It is just a matter of pushing the "take-data" button and then watching the results come off the recorders.

Powerplant Tests

While at AEDC the company engineer is cleared to visit the engineer from the company supplying the missile powerplant. The powerplant engineer invites the airframe engineer over to watch the engine on test in one of the ETF cells. Typical of the long development cycle on turbojets, the engine already has been under test at ETF for some time. The powerplant company also has been testing a boiler plate ramjet in ETF for almost two years. It hopes to combine its experience on these two engines for a dual-cycle power package for the missile.

The Midwest engineer leaves Arnold at the end of the second week with schlieren photos and the ARO project engineer's preliminary data report.

In about 60-90 days he will receive the final test report, after the ARO project engineer has had a chance to evaluate the results for completeness and accuracy. He is assured that it is AEDC's practice not to distribute the company's proprietary results either to the Air Force or industry. Arnold, however, will keep complete records of all tests made, using them to evaluate its own equipment.

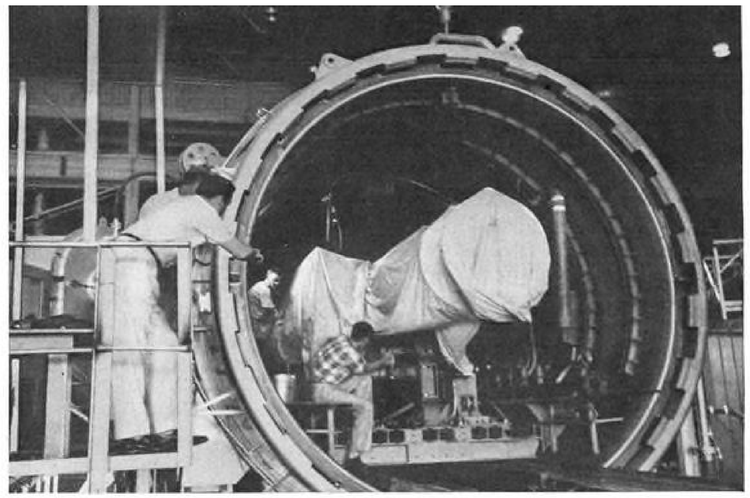
When ARDC receives the company's informal proposal late in the fall of 1956, it is sufficiently impressed to award Midwest and one other firm competing USAF Phase I contracts.

Coordinating the testing of these two contractors with each other and with the other systems competing for priority is no small problem for AEDC.

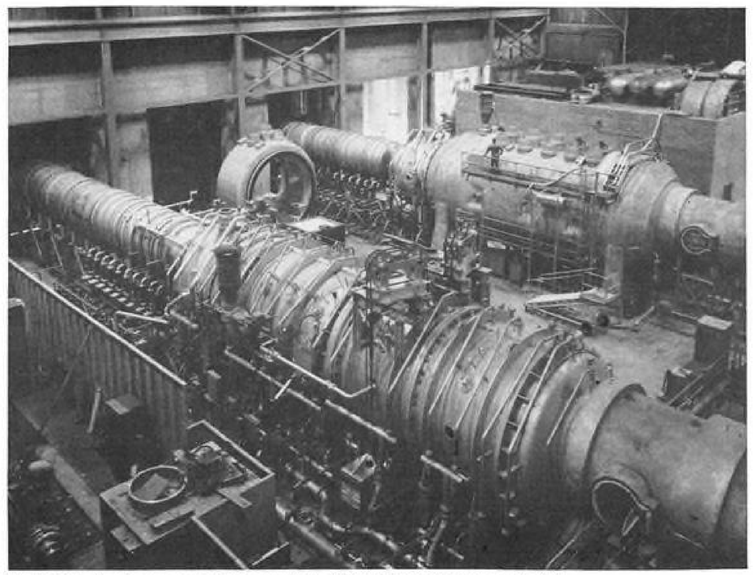
Priority for use of AEDC facilities is established by ARDC in conjunction with HQ USAF Headquarters.

The priority decisions are particularly difficult when an aircraft or powerplant that has already passed through AEDC and is operational suddenly is grounded because of "bugs." The panel then must take time in the tight schedule for "debugging" tests, sometimes postponing work on future systems.

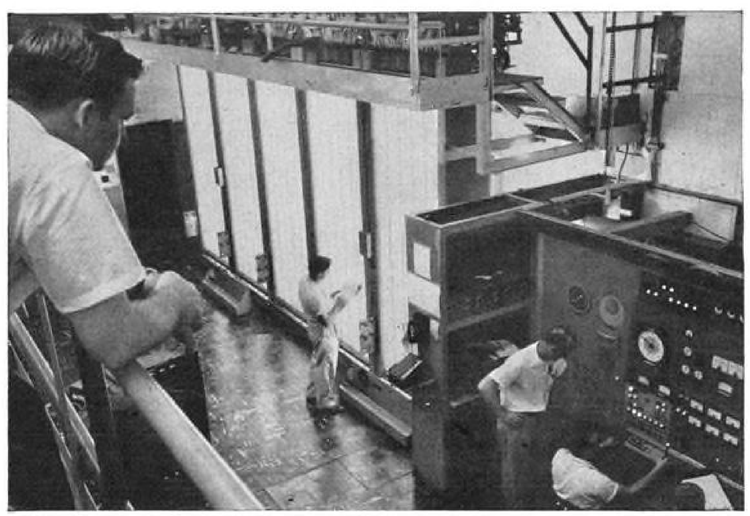
As far as the hypothetical weapon system's use of AEDC within the limitations set down by the priority board goes, the contractor, the Weapons Sys-



STILL IN SHROUDS, contractor's engine is moved into place in test tunnel.



T-4 CELL in foreground tests ramjets; T-1 cell (rear) tests turbojets.



CONTRACTOR watches control room activities as tests get under way.

tem Project Office concerned, and Arnold must thrash out the types of tests and the mechanics of getting them done.

In this case it is decided that adequate test support should consist of:

• **Investigating aerodynamic** behavior and powerplant inlet conditions with scale models in the best completed tunnel of GDF. As much of the lower performance testing as possible will be run in tunnels outside AEDC to free the unique AEDC facilities for more vital work.

Engine exhaust effects can be simulated on the models by piping in oxygen and hydrogen. The water which results from the combustion of these two chemicals will be removed by the tunnel dryers.

• **Taking the results** of the inlet investigations and providing these conditions at the inlet of the powerplant contractor's specially modified turbojet in the ETF.

• **Simulating the hypersonic re-entry** in GDF's E-2 or B-minor to a more refined degree than had been possible in the first E-1 proprietary test.

• **Running a power** plant-missile integration analysis with a "live" engine burning in a Slofast prototype mounted successively in the two circuits of the Propulsion Wind Tunnel. In this test the complicated cross-over from subsonic turbojet cruise to full ramjet penetration can be adjusted out under controlled observable conditions. This will be the climax of the contractor's test program.

ARD Liaison

At these meetings the Midwest project group meets the engineers which the GDF, ETF and PWT chiefs have assigned to the tests. These ARO men will live with the contractor's problems for the next few years—possibly longer if the system has to come back for fixes during operational use.

They and their staffs will make it their business to visit the Midwest plant and learn all they can about the system, keeping up with innovations and refinements as they develop. The ETF and PWT groups will visit the powerplant contractor's plant and learn all about his engine.

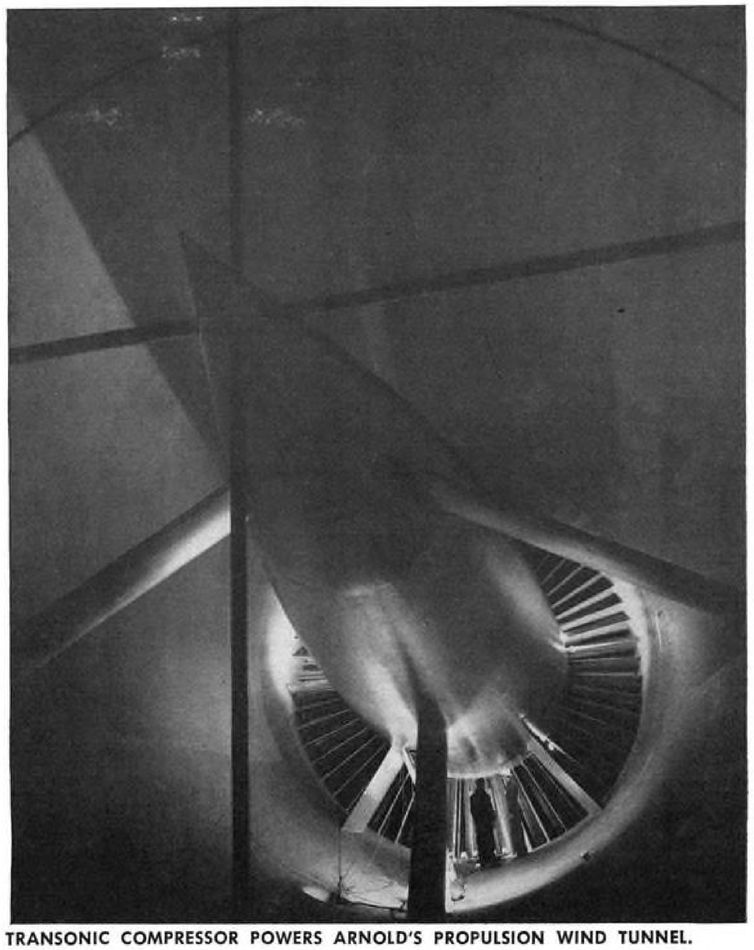
The ARO mechanics, for example, must know enough about the engine to tear it down and rebuild it in case extensive work is needed to continue a test.

The first test of the program is run in Tunnel A early in 1958. It is a much more elaborate version of the contractor's first proprietary test. The contractor and ARO agree that a semi-span or half-model of the missile should be mounted on the test section wall for this.

To give ARO adequate lead time the contractor delivers the model to AEDC four weeks ahead.

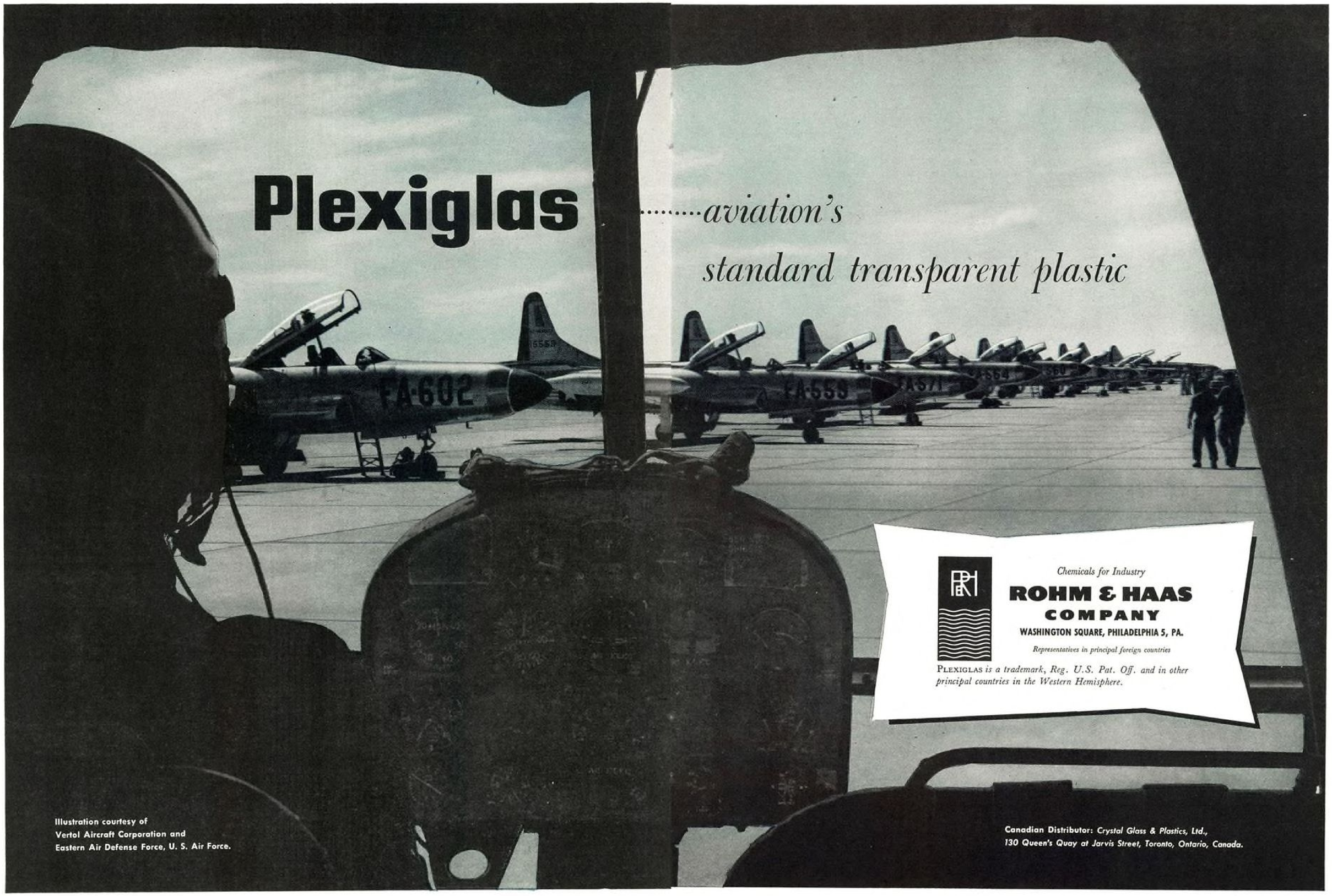
Because Tunnel A runs continuously, it is able to provide more convenient testing than the first test in blow down tunnel E-1. A flow of Mach 2.5 moves past the model constantly while the inlet configuration of the model is varied for optimum setting. The unusually high Reynolds number due to the high pressure of the tunnel means that results will be valid for the full scale missile.

The powerplant tests in ETF, which will come in 1958 and 1959, are the most extensive series of the whole program. Here the associate contractor takes first place as he attempts to



TRANSONIC COMPRESSOR POWERS ARNOLD'S PROPULSION WIND TUNNEL.

Brig Gen. Troop Miller, Jr., Commander, Arnold Engineering Development Center . . . born Omaha, Neb., 1908 . . . graduate U. S. Military Academy, 1930 . . . learned to fly at March and Kelly Fields . . . transferred to Air Corps, 1931 . . . served in flight and combat crew training posts . . . served in the Southwest Pacific in World War II with Fifth Air Force and Far East Air Forces, and as commander of the 59th Air Service Group and chief of staff and commander of the 13th Bomb Command . . . served at Air University and USAF Headquarters . . . commanded Northern Air Materiel Area (Europe) from July, 1953 until last Aug. 1 . . . holds the Legion of Merit and the Air Medal.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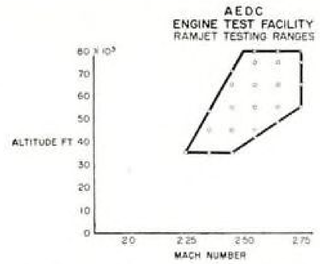
Eastern Air Defense Force, U. S. Air Force.
Canadian Distributor: Crystal Glass & Plastics, Ltd.,
130 Queen's Quay at Jarvis Street, Toronto, Ontario, Canada.

iron out the many problems of his dual-cycle powerplant.

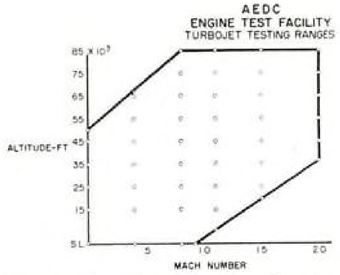
The test starts in ETF cell T-1, with the engine connected directly into the ETF air supply. This only provides internal engine conditions. For the all-important inlet conditions and the transition to full ramjet afterburning the test engine is moved into ETF cell T-4. There behind the special swiveling free-jet nozzle, realistic flight inlet conditions are produced. To a large extent the success or failure of the missile-powerplant combination is determined in these tests.

While these tests are going on in ETF's T-4, the competing system with its powerplant, is being tested in the nearby ETF Ramjet Addition (RJA). The proximity is at first felt to be too close, but both projects soon learn that AEDC's system of closed-off areas and special inter-facility badges can be trusted. They find that there are no leaks from one project to the other or to the three other tests going on in ETF at the same time.

So tight is the inter-contractor security, in fact, that the Midwest men do not even know their competitors have solved the same inlet position problem now stumping them. The ETF officials, of course, know this, and they see that the USAF staff knows enough about the situation to work out a solution compatable with the interests of both contractors and national defense.



THIS PLOT outlines general performance testing ranges available for ramjet propulsion unit test at Arnold's Engine Test Facility.



THIS PLOT outlines the general performance of testing ranges available for turbojet propulsion units. Size of air flow requirements determines envelope.

By 1960, with the GDF and ETF tests over, the contractors are ready to go ahead with the big test—a full-scale run in the PWT.

Sizing the portion of the Slofast to go into the two PWT circuits turns out to be no problem at all. The whole missile will fit inside the 16-ft. square test section.

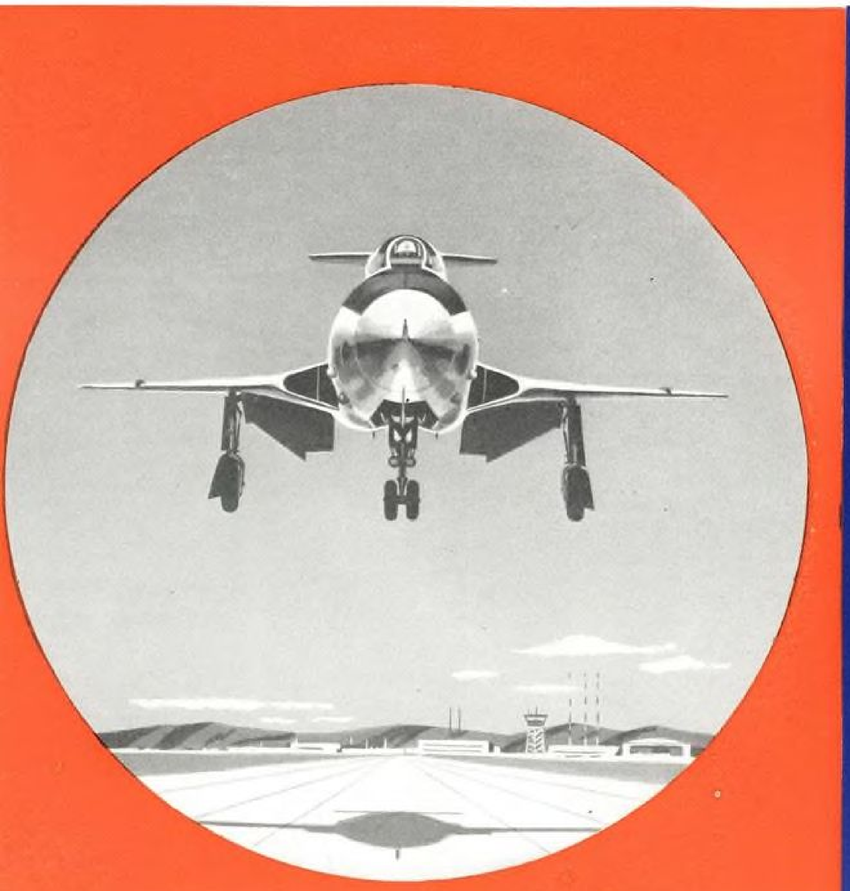
Complete Missile

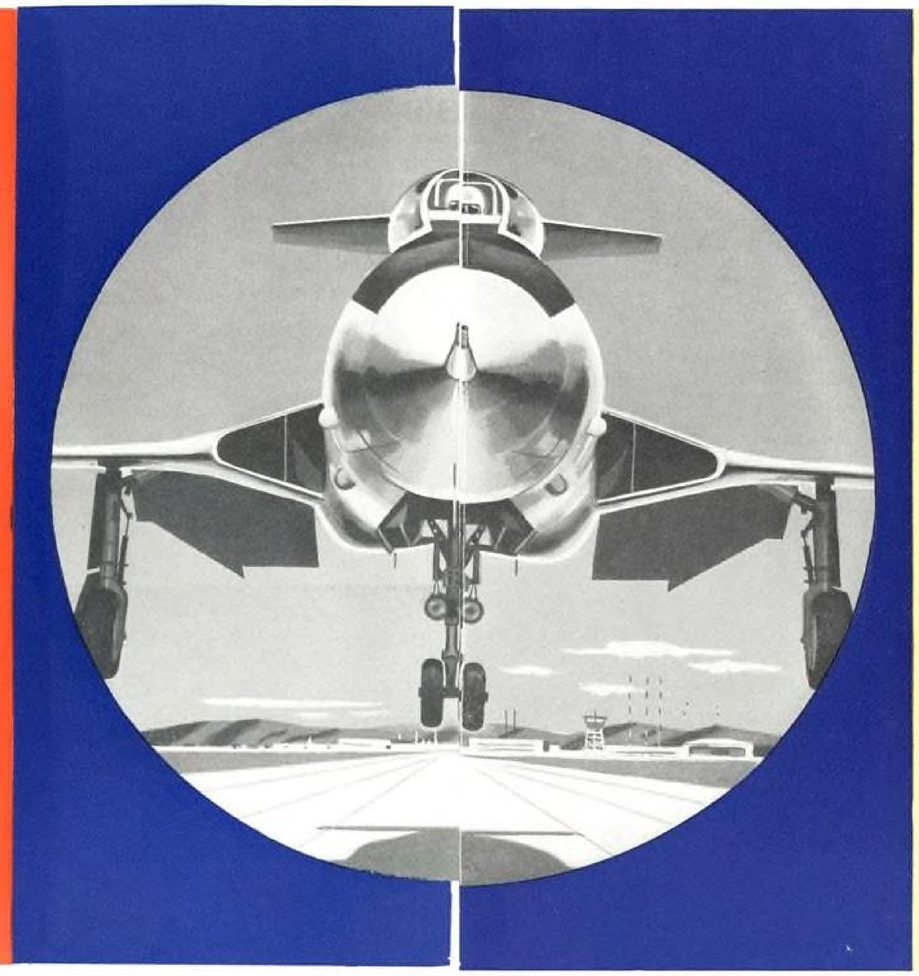
The prototype for this test, complete with engine, is delivered to AEDC two months before the scheduled tunnel occupancy data. It is carried to one of the four walled-off bays in the PWT model installation building.

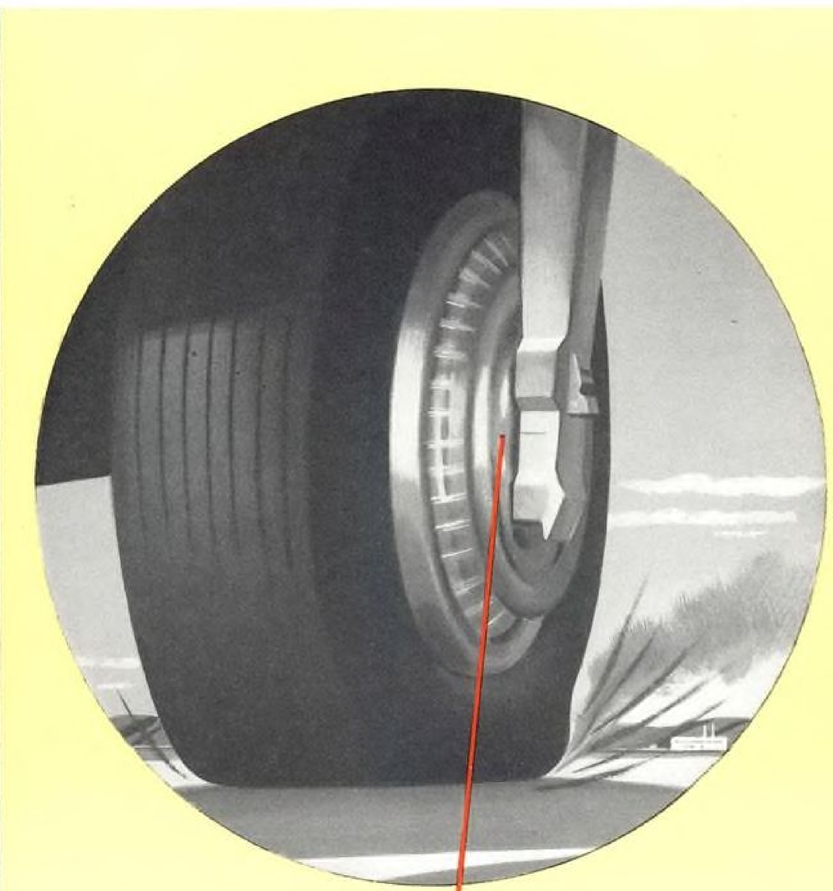
Here, in guarded privacy, technicians install the Midwest missile on one of PWT's three 450-ton portable test sections, using a specially designed mount. They connect the engine instrumentation, the hundreds of thermocoupled, strain gages, pressure transducers, flowmeters and vibration pick-ups.

To save time ARO has urged that Midwest's associate engine contractor install his own internal engine instrumentation, such as temperature and pressure pickups on the powerplant's rotating members. The associate contractor is able to do this while he builds

AT THIS MOMENT







WHEN PRECISION COUNTS MOST

YOU CAN DEPEND ON GRUEN PRECISION®

Flaps down...runway clear...speed 130 knots! This is the moment of touchdown! This is the moment when precision counts most!

MINISTOP by GRUEN—a precision part smaller in diameter than your fist—takes command at the instant of touchdown. Its precision electro-mechanical brain infallibly aids the pilot as he brings his aircraft to a smooth, gently rolling, skid-free stop. It's another example of Gruen precision you can depend on!

MINISTOP by GRUEN is no fair weather friend, either! It completely ignores blinding snow, slick rain, treacherous ice... performs with famous Gruen precision always! Stopping distance is reduced as much as 20%—automatically! The pilot is free to concentrate on other vital duties! Greater overall safety is assured!

MINISTOP by GRUEN is lower-priced, lighter and more compact than any other anti-skid device. Installation is easy and economical—maintenance practically nil. Tires take less punishment—last far longer. And the MINISTOP has been fully tested and proven under the most rugged conditions.

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...world's lowest-priced, lightest, smallest, easiest to install anti-skid device. Another product of famous Gruen precision.

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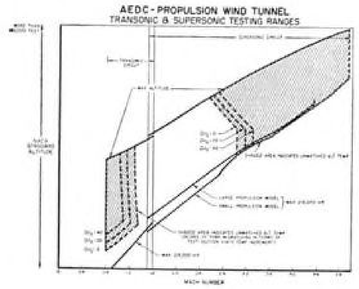
CONTRACTOR oversees test run.

the engine up for shipment but ARO would have to tear down the engine then rebalance the rotating parts before rebuilding.

As this test will cost AEDC roughly $5,000 per hour (best guess at this time), no expense is spared in making careful preparations. Each minute of air-on time must be productive. Not only will this test tie up the PWT, but parts of the ETF and RJA will have to shut down on the higher performance portions of the runs, since they provide power for scavenge and make-up air.



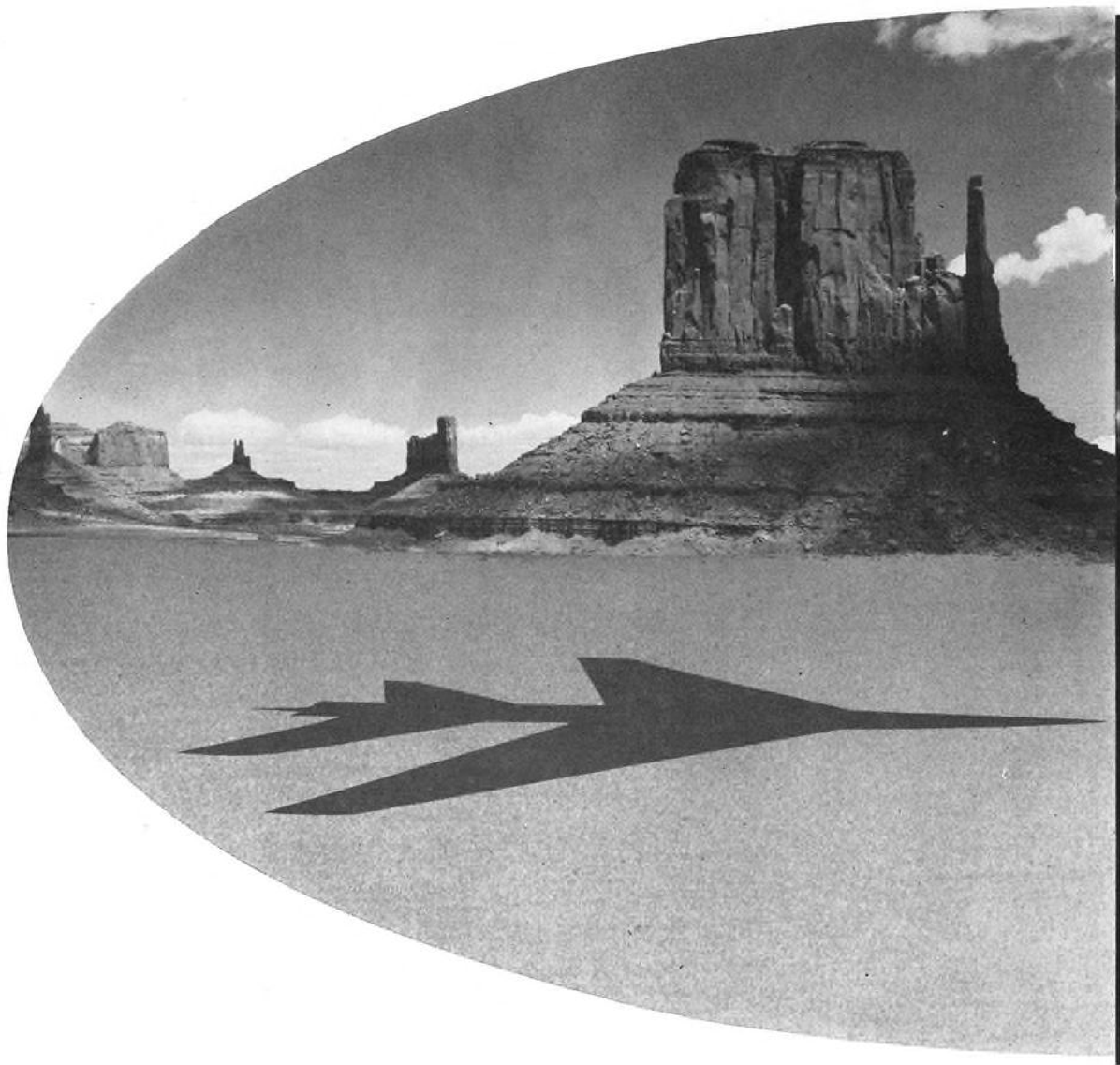
In mid-summer, 1960, the first day of PWT occupancy block time arrives. The PWT test section containing Midwest's Slofast missile is brought up to the transonic circuit on PWT's 125-ton transfer cart and rolled into place in the circuit. It is jacked into smooth alignment behind the variable throat nozzle and ahead of the exit diffuser, with its exhaust scoop.

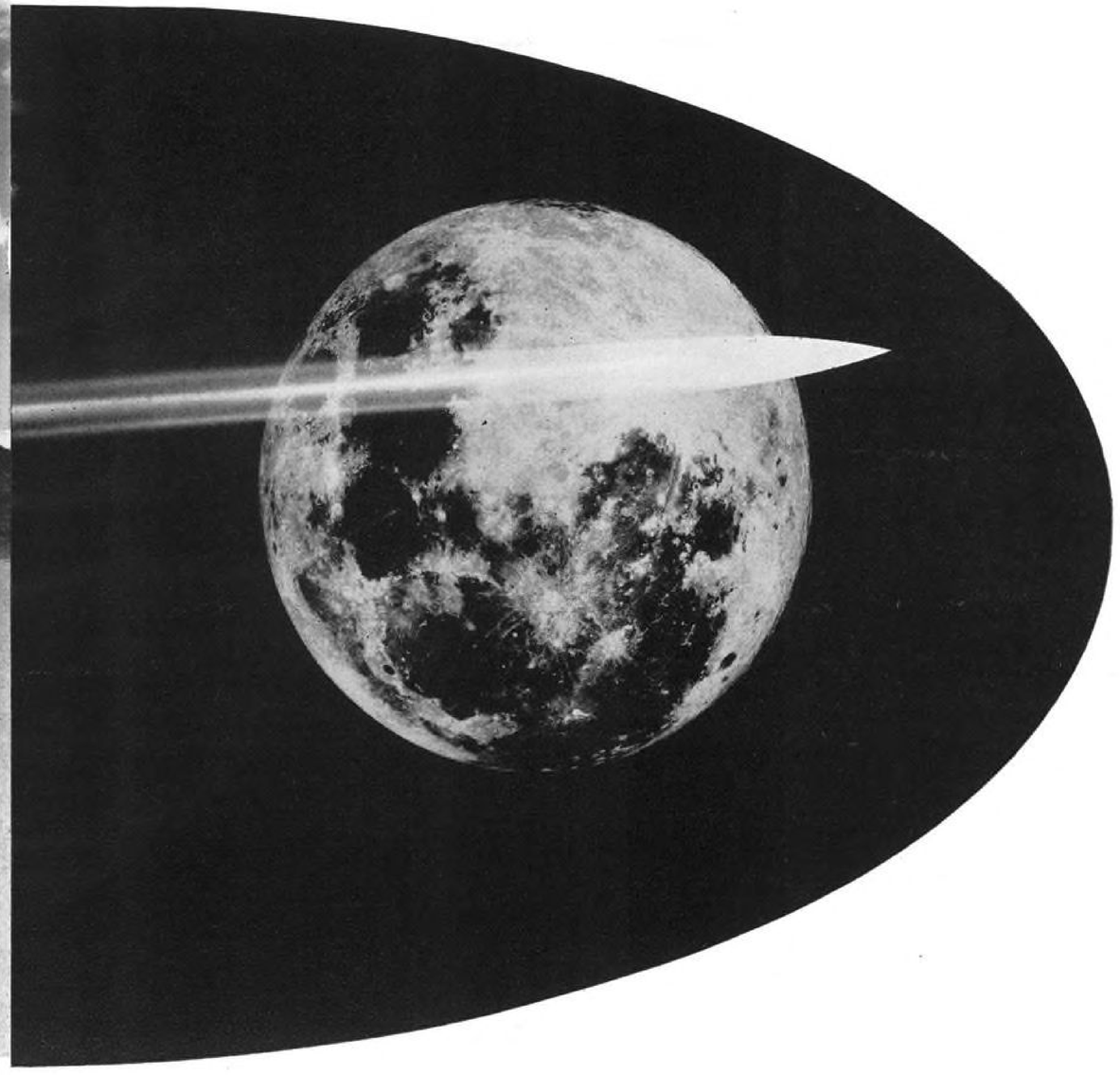
Start of Test

After one day of hook-up, the 216,000-hp. main tunnel compressors (which have been turning slowly to prevent a permanent sag from setting up in the 574-ft. drive shaft), are slowly accelerated up to speed—600 rpm.—and air begins to flow past the actual missile.

The 200,000-hp. ETF RJA powerplant stands by to scavenge the exhaust when the powerplant is lighted off; the

NORTH AMERICAN HAS BUILT MORE AIRPLANES THAN ANY OTHER COMPANY IN THE WORLD





SUPERSONIC SHADOW

Tomorrow's aircraft are casting their shadows before them. Details of their performance are incredible. Yet their most dramatic asset is still the fact that a human pilot will be at the controls. For there is no mechanism that possesses man's power of judgment . . . his ability to capitalize on opportunity. At North American—home of the U. S. Air Force F-100 SUPER SABRE, the free world's first operational supersonic fighter, and the Navy FJ-4 FURY—this is the order of the day: to make tomorrow's planes habitable by man, while they operate at speeds and altitudes which otherwise would be beyond his physical limitations.

SPACE SILHOUETTE

The shape of things to come in long range missiles looms ever clearer at North American. More than ten years ago, North American engineers started work in an almost unexplored technological world. This was the birth of the U. S. Air Force's SM-64 NAVAHO Intercontinental Missile. Today —though security restrictions prohibit any details—we can tell you that the automatically controlled NAVAHO is playing a vital role in the Air Force's program of missile development, so essential to our nation's security.

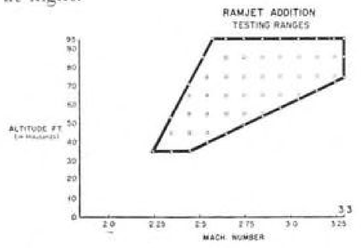
North American Aviation, Inc., Los Angeles, Downey, Canoga Park, Fresno, Calif.; Columbus, Ohio

NORTH AMERICAN AVIATION, INC.

Engineers: write for details regarding challenging positions now open.

• ARNOLD

ETF air supply is ready to make up the scavenged air with clean air, and the 180,000-hp. ventilated throat suction drive is readied. The vast cooling water flow—100,000 gpm.—is removing the heat churned in by the compressor. Because of the PWT drain on the ETF and RJA the running is scheduled at night.



After the check-out runs, serious flight simulation begins. Starting at launch conditions, the powerplant is "fired up" and the initial acceleration up to cruise is performed. A short run at cruise and 50,000 ft. is held—just long enough to see that the cruise will be satisfactory. The ratio of net thrust to specific fuel consumption is most important here—the cost of running this tunnel being too prohibitive to allow the luxury of an endurance run for Slofast.

Ventilated Throat

Then, for the transonic crossover, the tunnel throat is "ventilated" by pulling a suction through its porous walls (to absorb the shock waves from the missiles' nose and prevent them from bouncing off the throat test section walls and hitting the missile's tail) and the tunnel flow is further increased by adjusting both the compressor speed and curvature of the variable tunnel nozzle walls.

All this time the engine thrust output is kept matching the missile drag as it would in flight. When the turbojet powerplant is no longer able to overcome the missile drag the afterburner is lighted off and the engineers are able to continue the acceleration, slowly, as the response of the tunnel's huge machinery prevents actual time-matching of the acceleration.

This carries the missile right up to the Mach 1.2 limit of the transonic circuit's ability.

Sonic Drag

Since getting through the transonic drag hump is one of the most critical phases, this is run through a number of times.

With the large schlieren, test engineers check to be certain that the variable inlet shape is providing the correct location of the shock pattern for the all-important shock ram recovery which is to take the place of turbojet

Cessna T-37 designed for Jet Training

To meet jet age demands, the U. S. Air Force requires a jet trainer that makes it easy for cadet-pilots to master first line combat airplanes.

The Cessna developed T-37 introduces the cadet to all combat jet airplane characteristics while training on this safe, easy-to-fly jet trainer.

It is designed to provide the Air Force with a jet trainer that can be operated at substantial savings and cover the most important and longest phase of the cadet-pilot's jet training.

It is a privilege for us here at Cessna to team with the Air Force in its forward-thinking plans for the jet age. CESSNA AIRCRAFT COMPANY, Wichita, Kans.

Cessna

"Air Force T-37 . . . You are cleared for take-off"

Be an Aviation Cadet. Inquire today about the future your Air Force offers from your Air Force Recruiting Office.

New Low Hysteresis and Threshold in *HYDRAULIC RESEARCH'S*

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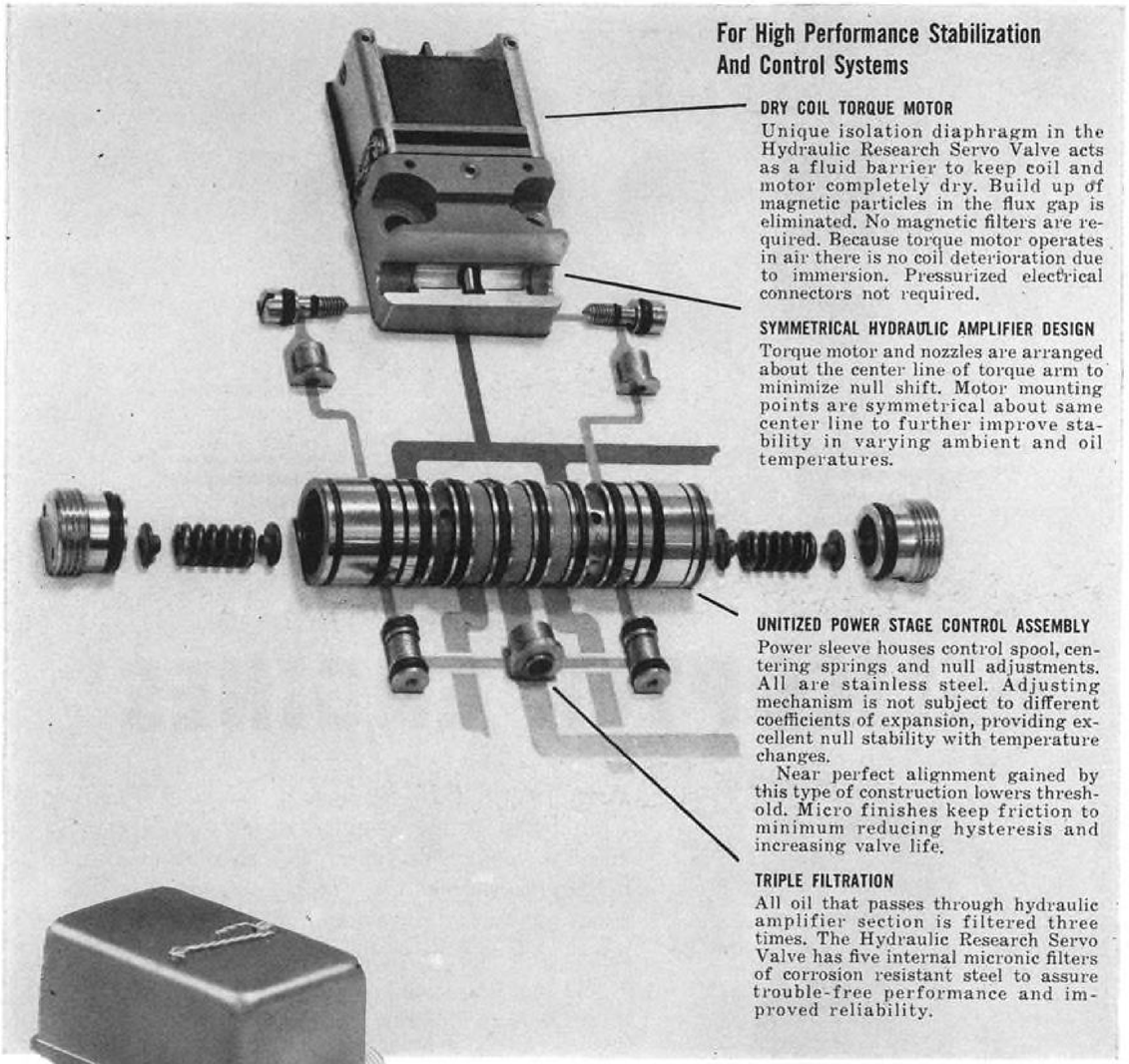

For High Performance Stabilization And Control Systems

DRY COIL TORQUE MOTOR

Unique isolation diaphragm in the Hydraulic Research Servo Valve acts as a fluid barrier to keep coil and motor completely dry. Build up of magnetic particles in the flux gap is eliminated. No magnetic filters are required. Because torque motor operates in air there is no coil deterioration due to immersion. Pressurized electrical connectors not required.

SYMMETRICAL HYDRAULIC AMPLIFIER DESIGN

Torque motor and nozzles are arranged about the center line of torque arm to minimize null shift. Motor mounting points are symmetrical about same center line to further improve stability in varying ambient and oil temperatures.

UNITIZED POWER STAGE CONTROL ASSEMBLY

Power sleeve houses control spool, centering springs and null adjustments. All are stainless steel. Adjusting mechanism is not subject to different coefficients of expansion, providing excellent null stability with temperature changes.

Near perfect alignment gained by this type of construction lowers threshold. Micro finishes keep friction to minimum reducing hysteresis and increasing valve life.

TRIPLE FILTRATION

All oil that passes through hydraulic amplifier section is filtered three times. The Hydraulic Research Servo Valve has five internal micronic filters of corrosion resistant steel to assure trouble-free performance and improved reliability.

The Hydraulic Research Dry Coil Servo Valve is available in quantity for high performance flight and control systems. ***Write for additional engineering information.***

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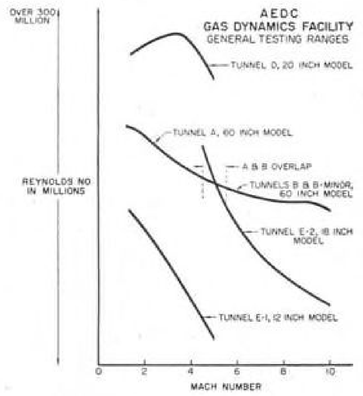
CHALLENGING ENGINEERING POSITIONS OPEN



compression in supersonic flight.

Then the cart carrying the missile is removed from the transonic circuit and rolled over to the parallel supersonic tunnel.

Supersonic Test

Here the missile starts where it left off in the transonic tunnel and is flown up to its maximum performance of 100,000-ft. and Mach 2.5. Though this is right on the edge of present ramjet state-of-the-art it by no means has tapped the extent of this facility, which could take the missile up to Mach 5 and well over 100,000 ft.

As the Mach number gets to 2, the engine compressor stages are cut out one by one, for the tunnel flow past the missile now is providing the compression, as it will in flight.

Finally at Mach 2.3 the entire compressor is bypassed and then ejected from the missile. A special barrier has been constructed in the tunnel to catch the compressor and prevent serious damage to PWT.

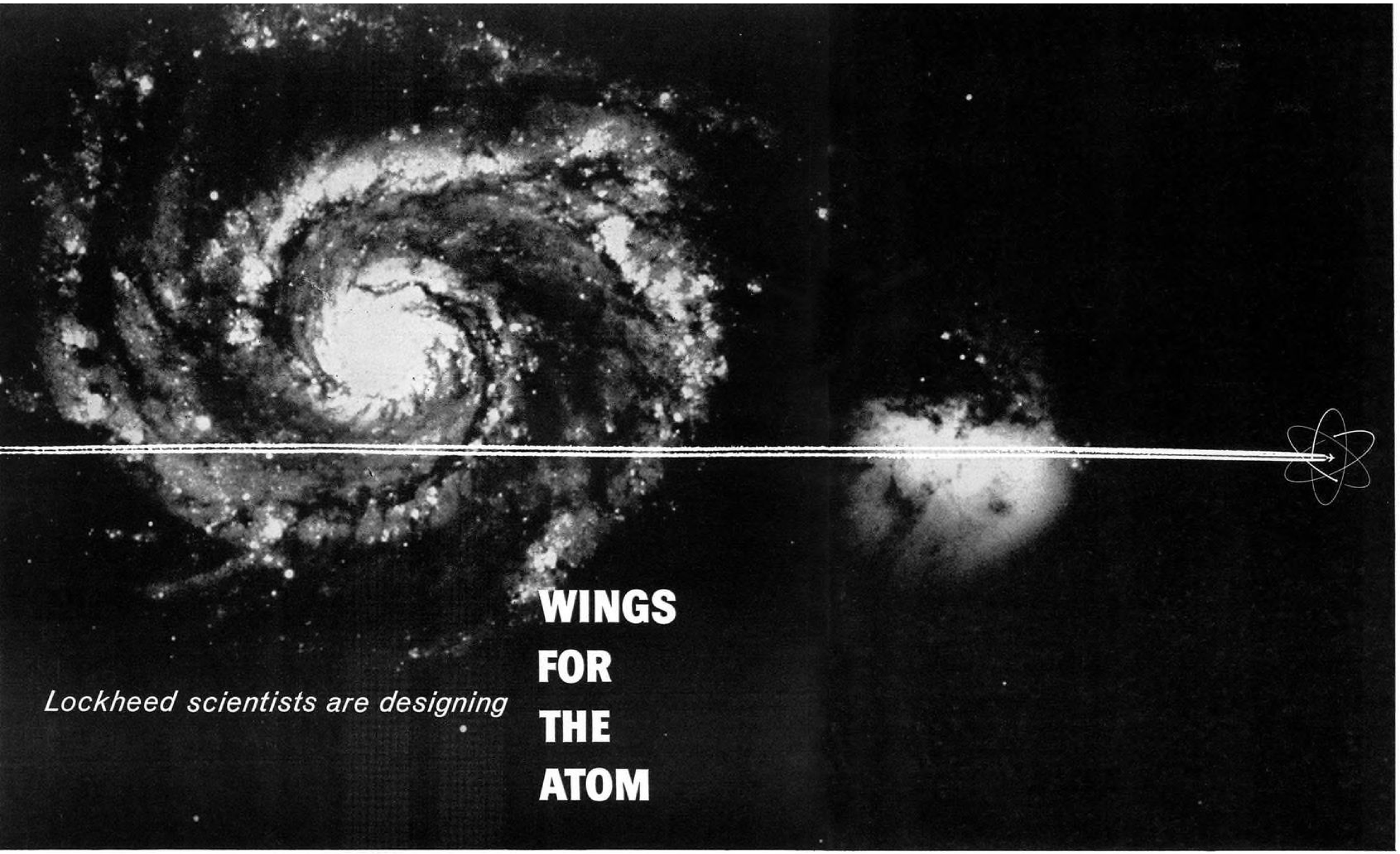
The Slofast now flies on its maximum speed, which turns out to be over the design point at Mach 2.73.

This run, made during a high-humidity spell of mid-summer, illustrates the virtue of the closed-circuit tunnel. Because the tunnel continuously recirculates its own air (except that which must be replenished to make up for the scavenged powerplant exhaust) it is able to maintain moisture free flow without relying on dryers which would become saturated after a few hours running time.

Ready for Flight

Because it has been through the mill at AEDC, the missile which leaves Arnold for flight test at Patrick Air Force Base is more reliable and basically better.

With most of the steady state missile and powerplant problems worked out in the "captive" tests at Tullahoma, the flight test program now can concentrate on the dynamic problems of



Lockheed scientists are designing

WINGS FOR THE ATOM

Domesticating the atom to serve mankind has intrigued science for over a decade. One top priority application, secretly under way for several years at Lockheed: developing a nuclear-powered plane as different from present types as a supersonic jet is from the first stick-and-wire biplane.

IMAGINE A GIANT AIRCRAFT SOARING ALOFT, NOT WITH TONS OF GASOLINE, BUT WITH A URANIUM FUEL SUPPLY NO BIGGER THAN A HANDFUL OF GRAVEL. EVENTUALLY, SUCH A PLANE-OF-THE-FUTURE—WITH THIS SCANT FUEL SUPPLY—WILL GIRDLE THE GLOBE NON-STOP BETWEEN SUNRISE AND SUNSET.

More than a dream, this incredible aircraft is now being developed by Lockheed for the U.S. Air Force despite problems of propulsion, structures and materials, thermodynamics, crew survival, producibility and maintenance unique in aviation.

Old concepts are being shelved, traditional solutions rejected. *The kind of aeronautical advances that once took a generation of research are now being telescoped into a few months, even weeks.*

Soon several hundred nuclear scientists and engineers from Lockheed's Georgia Division will move to the North Georgia mountain country. There on a vast site—some 40 miles from U.S. Air Force Plant No. 6 at Marietta, operated by Lockheed—will be built the nation's largest facility for the development of atomic-powered aircraft.

The exact status today of U. S. atomic plane development is still a military secret. But the strategic importance of the "A-plane" to our nation can hardly be exaggerated. It will be an aircraft with a new dimension—endurance unlimited. Its immense range and round-the-world patrol capabilities are certain to revolutionize air logistics—freeing military aircraft from shackles presently imposed by fuel capacity and air-base location.

THE DAY WHEN AMERICA'S FIRST NUCLEAR-POWERED AIRCRAFT BECOMES OPERATIONAL WILL BE ONE OF THE TRULY SIGNIFICANT DATES OF AVIATION HISTORY.

Look to Lockheed for Leadership

LOCKHEED

Aircraft Corporation

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Georgia Division, Marietta, Ga.
Missile Systems Division, Van Nuys, Palo Alto, and Sunnyvale, Calif.
Lockheed Air Terminal, Burbank, Calif.
Lockheed Aircraft Service, Ontario, Calif.

LOCKHEED'S NEWS COLUMN

Detection of Heart Disease—*our nation's #1 killer—is being speeded with aid of Lockheed's battery of super-fast electronic brains that are correlating the studies sponsored by the Nash Cardiovascular Foundation. Ten minutes' work sandwiched between computations at the Missile Systems Division gives the cardiologist complete and accurate harmonic analysis of electrocardiograms that speed his vital research immeasurably . . .*

Radiant heating, first time used in *any* airliner, will be one of the many new creature comforts of Lockheed's up-coming propjet Electra. Heating wires in walls and ceilings work like electric blankets to give no-draft, no-hot-spot comfort . . .

Atomic plane concept on a recent cover of Newsweek was *not* based in any way on Lockheed's Georgia Division ANP (Aircraft Nuclear Power) Project. That plane will *really* surprise you . . .

25,000 Lockheed stockholders in every state of the union will learn in mid-August that sales reached approximately $345 million for the first half of 1956. In a like period 20 years ago sales were less than *one* million . . .

Univac's newest cousin Si *(for Scientific) will be the'top quiz kid in the battery of analogue and digital brains at Lockheed's Missile Systems' Computer Center. Si, first Model 1103A Univac in use, "thinks" up to 100 times faster than other computers . . .*

A nationally-known Los Angeles physician, after periods of intense nerve strain, goes to the airport, buys a round-trip ticket to New York on a Super Constellation, spends a quiet day at the Waldorf-Astoria, and comes back on the next flight. Says: "It relaxes me". . .

Hercules C-130 performance data *just released show that the USAF strong-man can haul 20 tons of cargo right on the contrails of a fast jet tactical force. 100 mph faster than present combat transports. Hercules climbs fully loaded to 2500 feet altitude in just one minute.*

CONTRACTOR, signs out of Arnold and heads for flight tests at Patrick.

stability, control and guidance.

Arnold's future is hard to tie down. "AEDC has limitless expansion capabilities (space, power and cooling water) . . . it will be the leading aeronautical testing center in the world at some time in the future . . ." said retiring Gen. Harris as he handed the Center over to his successor, Gen. Troop Miller last month.

Straight Attitude

But the using engineers contacted by AVIATION WEEK seemed agreed upon one thing: The present straightforward attitude of service to industry must not change.

The fact that Arnold is staffed with "career" engineers with professional pride in their work and run by a private industry operating contractor is perhaps the best reason for hoping that it won't.

More so than at any other ARDC base one has the feeling that this is like any other part of industry, with the emphasis on the job to be done and not on organizational procedure.

As ARO Director of Engineering, John Wild said:

"Since most of us have been schooled in industry, we have industry's viewpoint—and I think this helps us to be more useful to industry."

'Hot Rod' Caliber

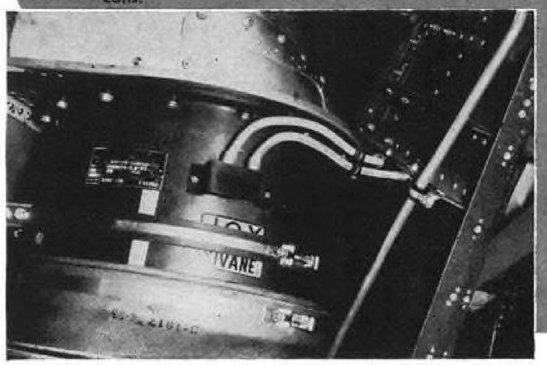
Arnold will not be content to do routine testing. "You cannot expect men of this caliber to be just service station attendants . . . primarily we are a service station, but we like to think that while we are giving service out front we are working on a hot-rod in back," says Smelt.

Arnold will put its stamp on the next century of aviation. Ironically, though, AEDC will have to scurry to keep up with the very progress it is fostering. ■

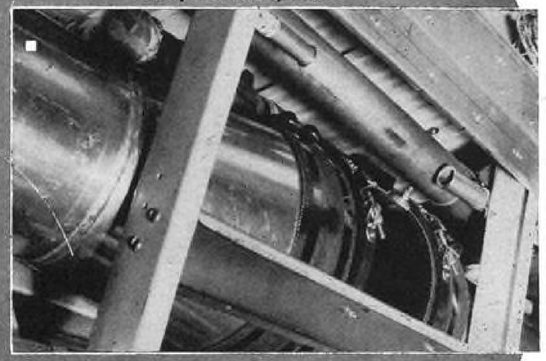
Douglas DC-7, one of America's fastest and most luxurious airliners.

IMAGINE FITTING A FAN IN HERE . . .

Looking up into right wing fillet at Joy Axivane Fan which pulls outside air in and blows it over cooling coils.



Cabin air blower in left tunnel of aft cargo compartment. Note extremely restricted quarters.



. . . or HERE

IN-LINE DESIGN OF A JOY AXIVANE FAN MAKES IT POSSIBLE

Cabin air blower used in DC-7. It produces 900 CFM at 8" pressure. Diameter is 9" and weight is 24 lbs.

JOY BUILDS A COMPLETE LINE OF FANS FOR ALL AVIATION AND ELECTRONIC APPLICATIONS.

In designing their new DC-7, Douglas engineers were determined to make it "America's most luxurious airliner." As a result, the DC-7 is air conditioned not only when in flight but also when on the ground!

The extra air system called for real maneuvering in and about all sorts of obstructions in some of the most restricted areas of the wings and fuselage. This necessitated sturdy, lightweight, thoroughly dependable fans that would use as little space as possible.

Joy Axivane Fans fit the bill completely. Their compact, in-line design permitted installation *right in the ducts,* with absolutely no lost space for fan housings!

The DC-7 fan system includes a condenser blower in the belly of the ship. Its job is to pull outside air in and over cooling coils. A second unit, called an evaporator fan, circulates the cool air throughout the cabin.

Douglas has found this system absolutely dependable and very efficient. They state, "At all times, the cabin temperature stays in the pleasant 70's." For complete details on Joy aviation and electronic fans, write to ***Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa.*** In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*

Consult a Joy Engineer

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Fastest Navy Fighter

Faster-than-sound *Crusader* Will Strengthen U. S. Fleet's Command of the Skies Above the Seas

Chance Vought's F8U-1 *Crusader* represents the next generation of Navy fighters. It combines supersonic level flight performance with exceptional combat ceiling, long endurance and ease of maintenance.

Agile and amazingly lethal, the *Crusader* meets the demands of shipboard operating requirements with no sacrifice in speed and striking power. It will give air superiority to the U. S. Navy wherever its task forces operate.

Behind this triumph in aviation achievement lay an intensive research and development program...and experience gained in 38 years of pioneering leadership. Like many other significant Vought advances, it emphasizes a tradition of engineering excellence.

In the field of high performance aircraft, as well as guided missiles, the creative spirit is strong at Vought. Because of this spirit, America can continue to expect superior new weapons from Chance Vought—as long as the need for them exists.

SCIENTISTS AND ENGINEERS: There is a challenging place for you on Vought's creative team now. For details write: Engineering Personnel, P. O. Box 5907, Dallas, Texas.

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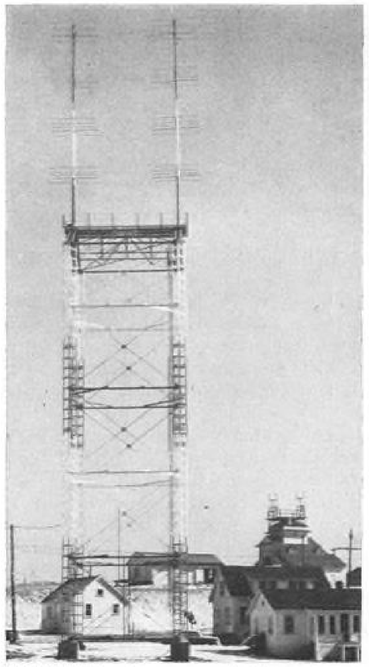
Rome Plans Integrated Global Communications System

WADC Seeks Radical New Flight Stabilization System

Heat, Radiation Revolutionizing Avionic Components



NEW YAGI scatter communications antenna.

HUGE new radar is part of experimental SAGE air defense sub-sector.

Reshaping Air Warfare, Traffic Control

By Philip J. Klass

Hanscom Field, Mass.—Exciting programs that promise to reshape the conduct of aerial warfare and air traffic control are under way at the Electronics Research Directorate (ERD) of the Air Force Cambridge Research Center (AFCRC). They fall into two broad categories:

• **Search for technological** breakthroughs in key research areas. These range from propagation studies which may provide an answer to the difficult problem of detecting intercontinental ballistic missiles at great distances and altitudes, to research in new semiconductor (transistor) materials and techniques.

• **Complex electronic** ground environments (systems), employing automatic data processing, computing, and control techniques for continental air defense (SAGE), overseas air defense, tactical air operations, and traffic control.

In 10 years ERD has grown from a small research station into a full-fledged Air Research and Development Command partner, responsible for some of the USAF's most important programs.

The explanation for ERD's fast-rising stature is simple. USAF hopes for giant strides in military technology ride on research, and electronic data processing appears to be the only means for enabling humans to cope with the pace and complexity of nuclear warfare.

ERD has specialized in both areas since it was created in 1945 as a "home" for scientists who wished to continue their wartime activities at the Massachusetts Institute of Technology's Radiation Laboratory and Harvard's Radio Research Laboratory.

Super-System Center

Air Force recognition of the importance of large "super-systems" led ARDC to set up Electronic Supporting System Project Offices (ESSPO), comparable to the Weapon System Project Offices (WSPO), to manage their development.

Because electronic data processing techniques form the heart of these systems, ARDC has picked ERD to manage many of the electronic ground environment systems developments needed by the Air Force.

ERD's first such assignment several years ago, was in connection with the development of SAGE, the most sophisticated of the systems.

The Air Force need for complex "super-systems" stems from the fact that military aircraft speeds and combat areas have more than tripled since World War II. The combat area has far outstripped increases in radar performance which is limited now to line-of-sight range by the curvature of the earth. Whereas one or two radars could cover a complete aerial combat area in World War II, a network of such radars is required to meet modern requirements.

Supersonic warfare will not tolerate a system which must rely upon human operators to read radar scopes, transmit what they see by voice communications, with more human operators plotting and integrating the data on a central display, according to Lt. Col. W. H. Vance, Jr., deputy director for systems at ERD.

Stale Situation

This approach not only runs the risk of human errors, but it prevents an air commander from ever having a completely up-to-the-second situation display upon which to base his decisions. The time delays between different bits of data are too variable. The plotted target position may be 15 minutes "old" while that of the interceptors may only 15 seconds late.

"The real advantage of integrated electronic supporting systems, employing automatic data processing and transmission," according to Vance, "is that it gives the true air situation over

a large enough area almost instantaneously—as it happens."

ERD's Systems Project Office and Special Systems Laboratory are handling the development of a number of such systems, including:

• **Tactical Air Control System (TACS),** a new mobile, air transportable system which will provide base air defense, interdiction and close support capabilities for Tactical Air Command operations.

• **Base Air Defense Ground Environment (BADGE),** for use at overseas air bases not equipped with TACS.

Development of the components for these systems is being handled by several laboratories, both in ERD and at other ARDC centers.

The air defense portion of TACS and BADGE might be termed a "little SAGE," although there are several important differences. Because of their use overseas, they must be designed to be less susceptible to sabotage and battle damage. In addition, TACS must be air transportable.

Tactical Flexibility

To give sufficient flexibility in tailoring individual TACS or BADGE systems to particular tactical requirements, the basic building block equipments are being designed to permit the construction of different system configurations.

A new TACS system being readied for production is designated TACS-II to distinguish it from an earlier system developed under Rome Air Development Center management and to which ERD contributed. Management of TACS-II was transferred from RADC to AFCRC last fall. RADC continues to be a heavy contributor.

TACS equipment is not yet as small, light or mobile as the Tactical Air Command would like. Airborne equipment miniaturization techniques may find their way into ground-based equipment to give it the desired size, weight and mobility.

SAGE Focal Point

ERD's Lincoln Project Office, headed by Lt. Col. R. S. LaMontagne, is ARDC's focal point for monitoring the activities of Lincoln Laboratory, most of whose efforts are devoted to the development of the SAGE air defense system. This covers a wide range of activities and includes:

• **Preparing for entry** into USAF inventory of all Lincoln Laboratory projects that show promise, such as scatter communications and Texas Towers. In addition to preparing specifications for prototype models, the project office advises the Air Materiel Command on procurement of SAGE equipment.

• **Advising weapon system** contractors so as to assure compatibility and suitability of their weapons with SAGE.

• **Developing test plans** and programs for evaluating SAGE's effectiveness.

LaMontagne points out that the SAGE tests are a continuing effort and will include simulated strategic bombing attacks.

On July 1, the Lincoln Project Office was transferred from ERD to ARDC Headquarters.

Navigation Laboratory

Bright hopes for solving Common System air traffic control problems can be found in the developments at ERD's Navigation Laboratory. The laboratory's High Performance Control Center (HPCC) goes into operation next spring at Ft. Dawes (near Boston). It will be the most advanced traffic control facility in the nation, equipped with novel automatic and semi-automatic traffic control equipment.

Headed by Benjamin F. Greene, Jr., the assigned task is to carry out USAF research and development in traffic control techniques and equipment, as part of the Air Force TRACALS (Traffic Control and Landing Systems) program. The laboratory in collaboration with CAA has taken on an Air Navigation Development Board project to investigate methods for remoting SAGE, TACS and BADGE to work Administration control centers.

The new HPCC will be tied in with SAGE, TACS and BADGE to work out techniques for smooth control transition between the terminal area traffic control system and the tactical control systems.

The Boston area, will serve as a high-density control area, with HPCC controlling flight test aircraft over a 200 mile radius and feeding them into a number of airports. Military aircraft will be controlled first. The laboratory hopes to bring in commercial aircraft in later phases of the program. Out of this program will come new ideas for improving equipment and control techniques.

Control Equipment

Under development at the laboratory are other automatic and semi-automatic equipment which could revolutionize present traffic control procedures. Examples:

• **Enroute Airspace Reservoir,** capable of storing a large number of flight plans for major airways, can be instantly interrogated to see if a new proposed flight plan conflicts with any portion of those on file. Display lights will show clear airspace or conflict for individual segments of the airway along the proposed route. The airspace Reservisor is being developed by Teleregister Corp., which designed the airline reservations Reservisor.

• **MAMIE** (Minimum Automatic Machine for Interpolation and Extrapolation), is a ground-based dead reckoning computer for keeping tab on the position of all aircraft, whether or not the area is under radar surveillance. MAMIE will continuously compute position of each airplane under control from flight plan data stored in the enroute airspace Reservisor, updating it with periodic position reports when the plane passes known fixes or is picked up by radar. Estimated positions of aircraft will be displayed on a cathode ray tube, probably by small circles whose diameters grow larger with time since last fix in order to show larger area of uncertainty as to actual airplane position. MAMIE is being developed for air defense applications as well as for TRACALS.

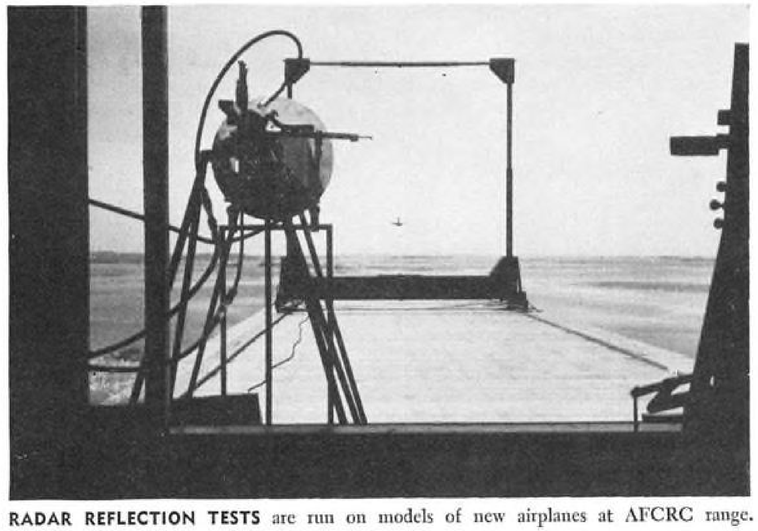
• **Automatic Data Routing System,** aims to eliminate human handling of aircraft flight data between controllers at different centers or within the same center. Greene admits this objective is an "ambitious undertaking." But a design study expected to result in experimental equipment is now under way at Cook Research Laboratories. Data that must now be written out on flight strip cards by each controller who handles an airplane, would be "filed" initially in a central storage drum. Based on each aircraft's flight plan, the equipment will determine what information each controller along the chain of control requires, when he will need it and then transmits and displays this information at the appropriate time.

The automatic data routing system also will determine when control should be transferred from one section to another, will notify each controller of the transfer and make a permanent record of the time when transfer occurred.

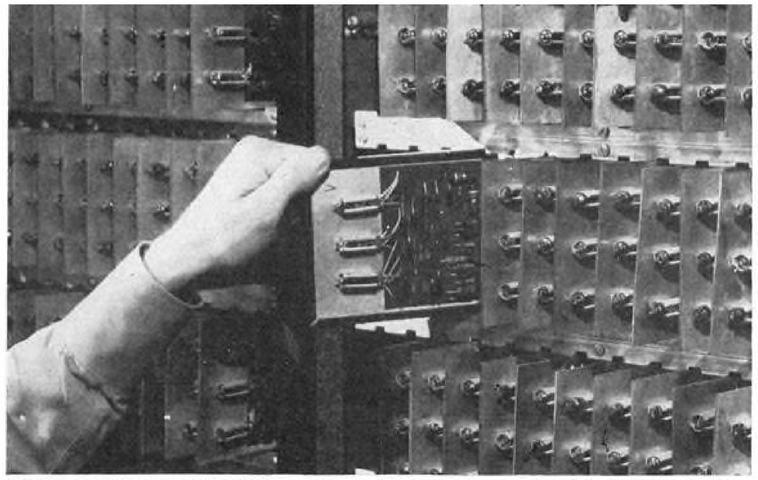
• **Radar Signal Enhancer** integrates successive radar pulses thereby increasing the useable automatic control range of radar by one-third. Greene emphasized that the Video Integrating Equipment, now being developed by Airborne Instruments Laboratory for delivery this year, does not increase the maximum theoretical detection range of the radar, but does build up all signals whose amplitude exceeds the noise level. The signal enhancing techniques are applicable to all surveillance radars.

• **Target Track Substitute** will assist the automatic tracking units now used in Volscan (AN/GSN-3 return-to-base computer). The trackers have a "velocity memory" which enables them to keep on providing data to the Volscan computer despite loss of radar information on airplane position. This velocity memory, however, assumes the airplane continues to fly in the same direction as it was at the moment the radar echo was lost, although the plane may be expected to fly a curved path according to its Volscan instructions. This causes the Volscan computer to "think" the plane is not following instructions and to call for unneeded corrections. The dynamic substitute target being developed by the Newton Co., will cause the synthetic target (during periods of loss of radar echo) to appear to be flying the heading and velocity called for by a Volscan, and being transmitted to the airplane. This will eliminate the spurious path-velocity correction which Volscan now computes during such radar-echo-loss periods. It should help the automatic tracker re-acquire the target by increasing the probability that the tracking gate will be centered on the airplane's expected position.

• **Automatic Voice Relay** will automatically relay Volscan control instructions to individual aircraft. The device,

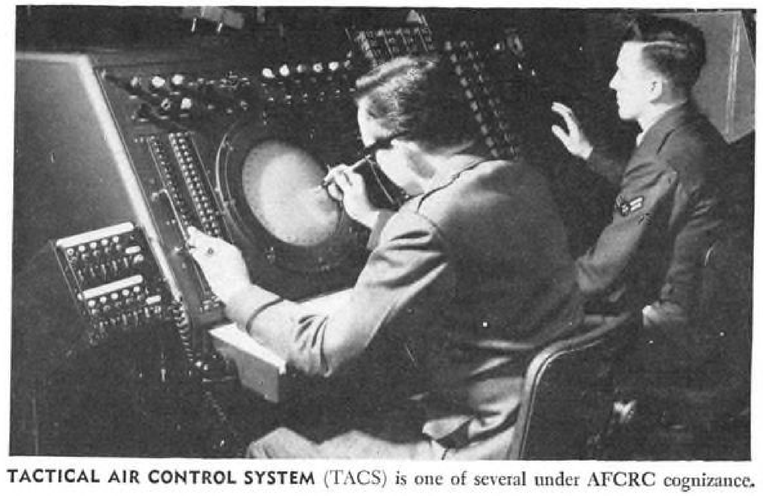


RADAR REFLECTION TESTS are run on models of new airplanes at AFCRC range.

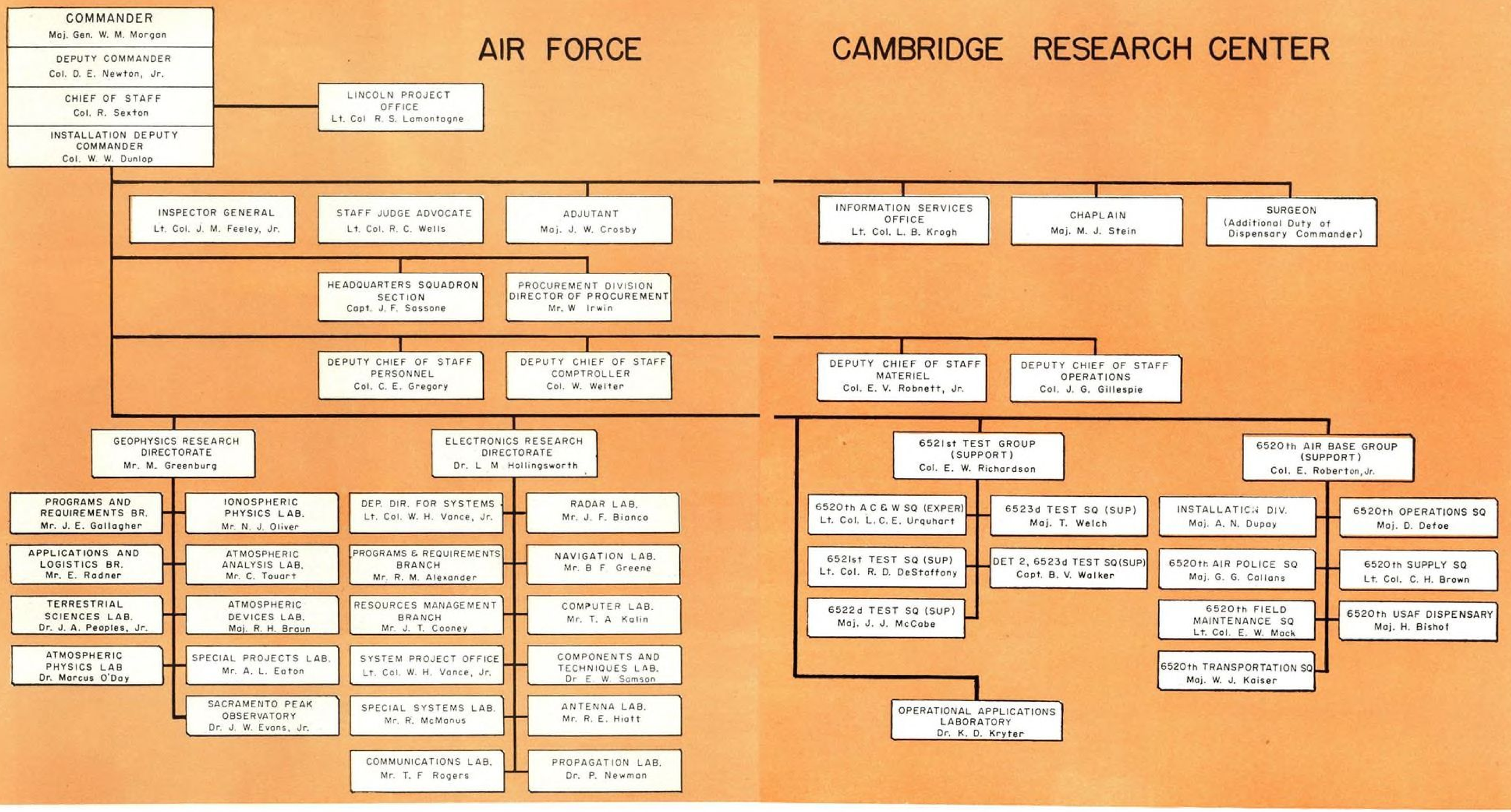


PROJECT "SMALL CHANGE" speeds construction of experimental digital computers.

400,000 DEGREE F temperatures have been achieved in experimental set-up shown.



TACTICAL AIR CONTROL SYSTEM (TACS) is one of several under AFCRC cognizance.



being designed and manufactured by Cook Research Laboratories, stores 85 voice commands on a magnetic drum. When Volscan wants to transmit new control instructions to an airplane, it will be able to automatically select the desired canned instructions from the magnetic drum, piece them together to form a complete message, and automatically transmit them by voice radio. To simplify the addressing of these instructions, each aircraft coming under Volscan control would be assigned an arbitrary code such as "White Three" or "Red Two." From pre-recorded standard instructions, Volscan might piece together a message like this: "Red Two, take heading 265 degrees, descend to 10,000 feet."

The device will have a built-in priority system which enables it to automatically transmit immediately any emergency instructions or commands to aircraft which are nearing the approach gate where more precise control is required. In addition to eliminating human errors and assuring standardized control commands, the automatic voice link will permit one human relay monitor to replace the four operators now required to convert Volscan instructions into voice commands. The equipment, to be delivered this summer, will be tested with the new prototype Volscan unit now being evaluated at Ft. Dawes. The Automatic Voice Relay is based on techniques originated by the Special Systems Laboratory which are being applied in slightly different form to TACS and BADGE.

• **High Quality Radar Remoting,** under development by General Electric Co., will consist of a 2,000-line, closed-loop, TV system. It will view a SAGE radarscope with its fine-detail Charactron tube presentation and display the same picture on three 27-inch TV type tubes at remote traffic control centers. Delivery is scheduled for late this year. In addition the Navigation Laboratory sponsors a long range study of more economical means for remoting SAGE data. This Selective Data Transmission study is under contract to the Technitrol Engineering Co.

• **Volscan Improvements.** Crosley (which built the three production prototypes to the laboratory's original design) has a contract to develop automatic monitoring equipment for Volscan which will enable it to detect its own malfunction. Crosley also is studying possible miniaturization of the Volscan system for greater air transportability.

As an adjunct to Volscan, a device

is under development to expedite the orderly flow of aircraft from a radius of 120 miles into the 60-mile Volscan control radius. Automatic trackers will be assigned to each aircraft entering the 120-mile radius. A computer will calculate the estimated arrival time for the airplane at the 60-mile radius, displaying this ETA for all aircraft by means of time markers around the periphery of the surveillance radar scope. This will give human controllers a visual indication of potential terminal area congestion (AW May 28, p. 65). This traffic flow computer will allow aircraft to take necessary delays while they are still at cruising altitudes and outside the crowded terminal area. The device could control traffic flow into a terminal area where there was no Volscan installed.

Most of the actual hardware design is contracted out, but the Navigation Laboratory does occasional prototype equipment design, as in the case of the original Volscan.

Propagation Laboratory

The activities of the Propagation Laboratory aims at better understanding of the fundamental medium in which electro-magnetic radiation works and how its properties influence the performance of radio and radar.

Any defense against intercontinental ballistic missiles is dependent on detecting and tracking their path through the ionosphere at ranges far beyond those now possible with conventional radar. Another problem is radio control and communication with our own missiles during initial phases of their trajectory.

Although security prevents Dr. Philip Newman, head of the laboratory from getting too specific, he acknowledges that some of the group's most important propagation studies are directed toward "application to high altitude, long-range weapon systems."

Newman says that "there are exciting possibilities and potentialities in some of our classified program areas."

Three years ago when AVIATION WEEK interviewed Dr. Newman for its ARDC issue he spoke with similar guarded optimism about the possibilities of scatter (beyond-the-horizon) communications at higher frequencies previously thought to be limited to line-of-sight ranges (AW Aug. 17, 1953, p. 308). Since then scatter communications has opened entirely new possibilities of long-range communications that are relatively unaffected by atmospheric disturbances which disrupt HF radio, the only previous long-distance communications technique.

Scatter communications already is a $20 million a year business and shows promise of strong future growth. The Air Force alone has installed $50 million worth of scatter communications equipment in the far north.

ERD's Propagation Laboratory is continuing studies of the basic mechanism responsible for scattering, generally credited to differences in the index of refraction of adjoining layers of the troposphere and ionosphere. For instance, ERD set up a tropospheric scatter communications link with three sites located approximately 150, 250 and 400 miles distant in order to determine the effects of refraction index on transmission over different path lengths. The index of refraction will be measured by airborne refractometers.

Upper Air Propagation

The ionospheric and atmospheric section, under Dr. Jules Aarons is investigating a variety of problems involving propagation in the upper atmosphere. Examples are:

• **Whistlers,** a little-understood phenomenon which produces low-frequency electro-magnetic whistling signals. The most accepted explanation is that whistlers are created by a lightning flash in one part of the earth which sets up an electro-magnetic disturbance which is reflected several hundred miles into the ionosphere. The energy then apparently travels along the earth's magnetic lines of force, hitting the earth half a hemisphere away and bouncing back and forth again along the lines of magnetic force. The fact so weak a signal can travel such tremendous distances without serious attenuation suggests that the same mechanism might offer attractive means for long-distance communications, Aarons says.

• **Radio astronomy,** the study of radio frequency "noise" generated by celestial bodies and its propagation through the ionosphere. Objectives are to determine the mean index of tropospheric and ionospheric refraction and to gain more knowledge of the inhomogeneity of the ionosphere's structure.

Maj. Gen. William M. Morgan, Commander, Air Force Cambridge Research Center . . . Director of Materiel, U. S. European Command Hdqtrs., from October, 1953 until he took command of AFCRC late last month . . . born Marshall, Mo., 1903 . . . learned to fly at March and Kelly Fields . . . flew experimental aircraft and held production engineering posts at Wright Field . . . served with Fifth Air Force and commanded its 310th Bomb Wing and 13th AF's 85th Fighter Wing in World War II . . . attended National War College . . . commanded Ogden (Utah) Air Materiel Area . . . vice commander Western Air Defense Force . . . commanded Western Air Procurement District from July, 1951 to October, 1953.

• **"Dawn Chorus,"** a scintillating type of noise from the ionosphere which normally occurs during intense magnetic storms and strong auroral borealis activity.

Some of these research programs are carried within ERD, others are contracted out to such research organizations as Stanford Research Institute, and to universities.

The Propagation Laboratory's curiosity about these and other unexplained phenomena is easy to understand: electro-magnetic radiation forms the nervous system of modern warfare. Better knowledge of the mechanisms behind some of these new phenomena could produce technological breakthroughs and make possible more effective utilization of existing equipment and techniques.

Communications Laboratory

ERD's recently formed Communications Laboratory works very closely with the Propagation Laboratory because of the intimate relationship between propagation knowledge and communications equipment techniques. Thomas F. Rogers, chief of Communications Laboratory, formerly was the assistant head of the Propagation Laboratory.

Within the new laboratory ERD centers a wide variety of activities, ranging from cryptography to digital communications, from IFF (identification, friend or foe) to various types of voice communications.

Despite apparent differences, all these activities have many things in common. Reliability and security (freedom from enemy jamming or interception) are major objectives for all types of communications so that techniques developed for one frequently find application in others.

In the search for more communications channels in the congested radio spectrum, the Communications Laboratory has been devoting sizeable ef-

fort to "compressed communications" "—in which speech bandwith is squeezed down prior to transmission. However, Rogers admits that "we are not now as close to effective speech compression as we had thought possible several years ago."

Bell Telephone Laboratories has devoted sizeable efforts in this area because of its obvious commercial pay-off in the Bell System. Despite speech compression for civil purposes being inherently easier because signals can be transmitted by wire or microwave link with good signal-to-noise ratios, and there being no enemy jamming to worry about, Bell scientists have not yet licked the problem.

Rogers doubts whether speech compression could be used, at least initially, at the highest command levels. (For instance, before General LeMay were to launch an all-out retaliatory raid, he would want to get the order from a voice that he instantly recognized as being one in authority. With speech compression, the loss of voice naturalness might make it difficult to make positive personal identification.)

SSB and Scatter

Single sideband techniques coupled with the new tropospheric scatter propagation mode holds great promise for easing and improving USAF communications. Because of its narrower bandwidth, and the fact that more useable power can be put into the single sideband, very high power transmission on SSB should provide reliable tropospheric scatter communications for distance of at least 400 miles, Rogers believes. He predicts that high power UHF scatter techniques will form the backbone of USAF communications.

"Significant strides have been made in the past year or two in the area of more effective and secure IFF equipment," Rogers told AVIATION WEEK. In addition to the requirements for security and reliability, an IFF system must be operationally feasible, a consideration which affects the first two.

Rogers is even more cryptic about another important phase of the Communication Laboratory activities—cryptography.

Efforts in this field are directed toward developing techniques for "secure" communications with special emphasis on flexibility. Research leans heavily on the most advanced mathematical techniques.

This work requires men with strong mathematics background and with "original and creative minds." Professionally qualified people are hard to find. Moreover, they must be willing to work in the atmosphere of supersecrecy which cryptography requires.

Speaking of data link systems, Rogers says, "We must be able to communicate with our interceptors until they gain airborne radar contact with the enemy despite his best countermeasures effort." A sizeable portion of the Communication Laboratory's efforts are now devoted to this objective.

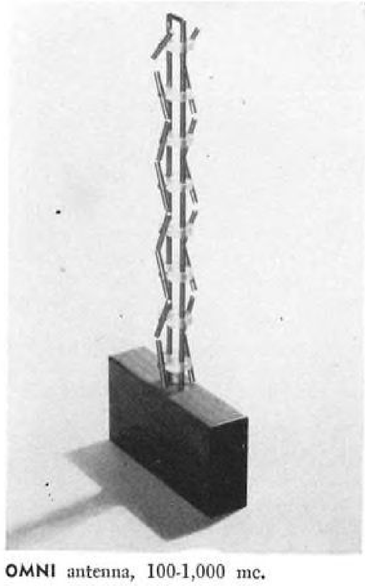
Radar Laboratory

Another group deeply involved in seeking ways to circumvent enemy counter-measures is the Radar Laboratory, headed by J. F. Bianco. Several years ago a study to determine the susceptibility of Air Force radar to ECM pinpointed a number of areas needing improvement. This work is being carried out by the Radar Laboratory as part of the Rome Air Development Center radar program.

AFCRC's Radar Laboratory concentrates on radar components and techniques. One way to make a radar less vulnerable to enemy jamming is to increase its frequency stability enabling it to discriminate between echo returns to its own transmissions and those generated by enemy ECM.

A 30-50 fold increase in frequency stability has resulted from the use of high-power klystrons to replace magnetrons. Developed under AFCRC sponsorship, the new klystrons are used in the Bendix AN/FPS-18 radar, with consequent improvement in anti-jam capability as well as in the performance of MTI (moving target indicator).

Although improved frequency stability produces better MTI performance, present MTI techniques have been pushed to the point of diminishing returns and new approaches are being investigated, according to Joseph Clark, chief of the laboratory's components and techniques section.



OMNI antenna, 100-1,000 mc.

Another major effort is pointed toward the development of three-dimensional radars, a project which leans heavily on the activities of AFCRC's Antenna Laboratory.

Antennas form the critical link between radar-communications equipments and the medium through which their electro-magnetic radiation travels. This binds the activities of ERD's Antenna Laboratory closely to its Radar, Communications and Propagation Laboratories.

USAF is seeking ways to extend the range of its radars and to improve their definition. One way to accomplish both objectives is to increase the size of the radar antenna. Some antennas under design measure 300 feet.

Rotating a huge antenna raises mechanical design problems. This has provided "tremendous incentive" to develop electronic scanning techniques which enable the antenna to remain stationary.

"We have discovered how to scan an antenna beam by varying the relative amplitude of the signal at each radiator of an array while maintaining its phase fixed," says R. E. Hiatt, chief of the laboratory. Previous electronic scanning techniques tried to vary the phase of the signal at each radiator, a more difficult function to control.

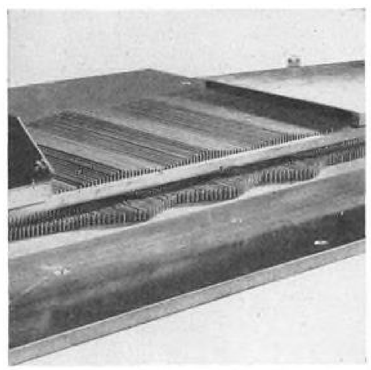
Another electronic scanning technique, employed in a Hughes Aircraft-developed 3-D combination surveillance and height finder radar, was originally sponsored by AFCRC. It employs "frequency scanning" in which variation of the radar's transmitting frequency produces a shift in the phase of the signal at the antenna feeds, causing the beam to scan vertically.

Ferrite Research

As part of its program for new antenna elements, materials and techniques, the Antenna Laboratory sponsors research and development at Harvard University in the field of ferrites. Their properties are extremely useful in antenna design. Purer ferrites with more closely controlled properties, Hiatt expects can be used for another type of scanning. Because of ferrite's ability to shift the phase of microwave energy, it can be placed at key points along a multiple antenna feed to introduce a known phase shift. The magnitude of this phase shift can be varied by the application of changing magnetic fields to the ferrite phase shifters, to produce electronic scanning, Hiatt indicates.

One objective is to develop ferrites with lower losses and capable of operating at lower frequencies and higher powers. Hiatt believes that "Harvard is making some of the best ferrites currently available."

To spread know-how through in-



SURFACE wave antenna for airborne use.

dustry, AFCRC and Harvard recently sponsored a three-day symposium on microwave properties and applications of ferrites.

The Antenna Laboratory also has been one of the pioneers in the development of printed microwave circuit techniques for making wave guides and microwave components. It currently is engaged in a cooperative program with Airborne Instruments Laboratory, Sanders Associates and others.

ERD runs pattern tests on large ground radar antennas at its Ipswich (Mass.) Antenna Range, 35 miles northeast of Bedford, with smaller antennas being tested at range facilities at Bedford. Radar reflection characteristics of new airframes and missiles are also measured in model ranges set up at Ipswich and Hanscom Field.

Communication Antennas

Application of an old technique to ionospheric scatter communications promises to ease a previous handicap to the military usefulness of ionospheric scatter. Costly and large rhombic antennas, requiring a "lot of real estate" have been required for ionospheric scatter.

Now it appears that this complex antenna can be replaced with a small, relatively inexpensive antenna, consisting of two banks of four "Yagis," each with five elements.

An installation at AFCRC's Scituate (Mass.) test site is operating experimentally at 38.6 mc., using single sideband voice transmission between Scituate and Cedar Rapids, Iowa, under contract with Collins Radio. To improve performance, space diversity is employed with two arrays located approximately 625 feet (25 wavelengths) apart.

One recent development is a new technique for coupling a two-wire transmission system to radiating dipoles. The technique, applicable over the frequency range of 100 to 1,000 mc., makes it possible to provide an omnidirectional radiation pattern in azimuth while the pattern of vertical coverage can be set as desired by changing coupling to individual dipole elements.

Airborne Antennas

Another major effort is devoted to airborne antennas (both aircraft and missile) for radar, electronic countermeasures, communication and navigation. The pressure to come up with suitable flush antennas has grown with increases in aircraft and missile speeds, yet performance must not be compromised.

Radar antennas, which must be capable of generating a narrow scan-able beam, are the most difficult to flush into the airframe, Hiatt says.

A "pill-box" type of semi-flush radar antenna, developed by AFCRC, which uses a rotating feed and dielectric lens, is going into production for an undisclosed missile or aircraft. However, newly discovered "surface wave" types show considerably more promise, according to Walter Rotman, one of the scientists in the Airborne Section.

One surface wave type antenna consists of a series of metal or dielectric plates, whose individual heights vary in wave fashion. When microwave energy is fed in at one end of this corrugated surface it can produce a beam which radiated at an arbitrary angle to the surface.

Another new technique which holds promise for flush-type radar antennas is based on the "trough waveguide", developed by Airborne Instruments Laboratory using principles devised at AFCRC. The technique has application to scanning antennas, broadband arrays, and delay lines.

The basic device consists of an almost conventional looking rectangular waveguide, except that one side has been left off and a small center fin added. The trough waveguide can be left open or capped to keep out dust and moisture. Radiation from the open top is prevented by the proper selection of the height of the sidewalls relative to the center vane. As a waveguide, it may be operated over a frequency range three times its cutoff frequency, compared to only a 2:1 range for conventional waveguide.

If the height of the center fin is varied by electro-mechanical means, it can scan the radar beam. If vertical posts are mounted atop the center fin, the device produces an effect somewhat similar to that obtained in a corrugated (surface wave) waveguide. A variety of other trough waveguide possibilities and combinations currently are under study, Rotman said.

Although the Antenna Laboratory does considerable development and research itself, has approximately 50 outside contractors.

Asked about Soviet capability in this

field. Hiatt says that translations of Russian technical journal articles on antennas, electro-magnetic theory and diffraction "show them to be extremely competent."

Computer Laboratory

The AFCRC electronic supporting system programs (TACS, BADGE, etc.) rely heavily on ERD's Computer Laboratory, headed by T. A. Kalin. The Laboratory's activities can be divided into three broad, overlapping areas:

- **System support** for AFCRC's major super-systems programs.
- **Technical development** of new state-of-the-art and computer techniques.
- **Mathematical computing** services for AFCRC.

The application of digital computers to mobile, on-the-firing-line systems such as TACS has forced development of a rugged breed. The Laboratory recently took delivery on the prototype of such a computer, developed by the Eckert-Mauchley Division of Sperry-Rand. It uses magnetic elements (ferractors) in place of almost all vacuum tubes.

Elimination of tubes (except for the "clock" and magnetic drum read-in, read-out amplifiers) results not only in a much smaller, more rugged computer, but greatly reduces power consumption, heat dissipation and air conditioning requirements. The new computer consumes only 6kw.

It is a special purpose, binary-coded decimal machine employing techniques applicable to TACS and BADGE and using 10-digit words (plus sign). It operates in serial fashion, employs two-address commands, and has a magnetic drum storage of 2,000 words. The computer, including console and power supplies, weighs 4,000 lb. AFCRC expects to call for bids to build its TACS computer, probably late this summer following tests on the Eckert-Mauchley machine.

AFCRC people feel quite strongly that they cannot maintain technical competence and keep abreast of new techniques without a considerable amount of in-house research. An excellent example of this philosophy in application is the Automatic Binary Computer (ABC) developed, designed and built here.

Learning Computer ABC's

The ABC has given lab personnel a first-hand knowledge of computer design problems and allowed them to try out new ideas inexpensively.

The ABC is a binary, parallel machine with floating Radix point. Word length is the equivalent of 12 decimal digits. The machine employs four-address commands, has magnetic drum storage for 4,096 words, and a punched-tape input and output. Operators can "talk" to the machine directly in decimal language.

The Laboratory also has a Monroe "Monrobot," a small digital computer which has done yeoman service for general purpose computation, according to Donald Sullivan, chief of the computer applications unit of the applied mathematics section.

Project 'Small Change'

The design of a new digital computer generally is a long, time-consuming process, particularly if it must be contracted outside. (The new Eckert-Mauchley machine required about two years.) To cut both time and expense, the Laboratory's techniques section launched its Project "Small Change"—a program to design about a dozen standard computer circuits (pulse amplifiers, flip-flops, pulse generators, gates, etc.) on convenient plug-in printed circuit boards. With these basic building blocks, the Laboratory figures it can put together a computer quickly to prove or disprove a new idea.

These building blocks have undergone prototype evaluation and now are being produced by a contractor. AFCRC expects the units to help speed design of industry's experimental computers.

Another section activity is sponsorship of state of the art developments in computer components. It has a program at Philco Corp. aimed at applying new silicon surface alloy transistors to computer circuits.

The Laboratory's airborne data processing section devotes its effort primarily to miniaturized packaging techniques for airborne and ground avionic circuitry.

Components & Techniques

In contrast to other ERD labs, which work in rather specialized areas, the Components and Techniques Laboratory has a variety of important programs which encompass many arts, including chemistry, physics, optics, electronics, and combinations of these. Its chief is Dr. E. W. Samson.

The semiconductor electronics section, under Charles Ryan, is doing research on semiconductor materials, processing techniques, and new semiconductor devices. For example:

- **Silicon carbide,** the most promising new material for extremely high temperature transistors—perhaps capable of operating at temperatures of 500-1,000C—is under intensive investigation. (Present silicon transistors have a top temperature limit of less than 300C.) Difficult problems must be solved before silicon carbide becomes a practical semiconductor material. It is difficult to grow in the required monocrystaline structure, equally tough to process because of the high tempera-

• CAMBRIDGE

tures (2,600C) required, and so hard it can be cut only with diamonds. Based on previous work with silicon, the section has some interesting ideas on how to grow silicon carbide crystals.

• **Negative resistance diode,** a new junction-type germanium diode developed here, may greatly reduce the number of components required in a computer flip-flop circuit employing tubes or transistors. The device operates at extremely high frequencies in the range of 50-75 mc.

It resembles a point-contact diode, has the advantage of providing power gain. ERD also has made experimental negative resistance diodes out of silicon and germanium–silicon alloys.

• **Semiconductor surface effects,** now recognized as playing a critically important role in transistor-diode performance and life. Ryan calls surface effects "the least understood aspect of semiconductors, both theoretically and experimentally, particularly at high temperatures."

Under AFCRC sponsorship, a Brown University's professor has developed a new technique for cleaning semiconductor surfaces. The material is placed in a vacuum at a high negative potential and bombarded with positive ions. Another technique, studied by AFCRC's Lt. William Spencer, places the semiconductor material at a positive potential in a vacuum and bombards its surface with electrons.

Radiochemistry

The work of radiochemistry section under Dr. Clarence Turner, will be partly responsible for improved silicon materials. Much of its work is devoted to the semiconductor electronics section's problems. Turner's group has developed a novel refining technique which boosts the purity of silicon tetraiodide, removing contaminating impurities, such as boron which previously could not be separated out.

Before the radiochemistry section could solve the silicon purity problem, it had to develop new techniques for measuring purity. The degree sought exceeded the capability of spectographic techniques, which can detect only one part impurity in 10 million parts of silicon. AFCRC has developed a neutron activation analysis technique which enables it to measure with several orders of magnitude greater sensitivity.

Although Turner was reluctant to give firm figures on purity improvement, he said it should be possible to obtain a 50 per cent increase in resistivity, or 300 ohm centimeters compared to the present 200 ohm cm.

The section expects to take on a new project to measure the effect of radiation and high temperature on electronic components.

AFCRC's electro-optical section has achieved temperatures well over 400,000 degrees Fahrenheit, producing a brightness 700 times greater than that at the surface of the sun. The methods for achieving such temperatures, and techniques for measuring them, were developed by Dr. Heinz Fischer, chief of the section, in connection with a classified program. Dr. Fischer is one of several ex-German scientists now employed at AFCRC.

The temperature exists for less than a millionth of a second. It is achieved by the release of electrical energy into a very small volume of inert gas under high pressure.

Dr. Fischer's group also recently completed a study of scintillations of star light caused by tropopause turbulence which has yielded valuable information on the noise spectrum of the stars. This in turn has resulted in a new technique which AFCRC's Geophysics Directorate intends to use to measure the velocity and direction of upper air winds.

Two contractual efforts by this section have recently resulted in important technological advances. "EVA", produced by Baird Associates, is a device which forms a heat image of areas having as little as one degree Centigrade temperature differential. The second development is an image converter tube capable of pre-intensifying dimly lit images, enabling them to be seen in darkness.

Magnetics

The Laboratory's magnetic section, headed by William Fields, is developing both improved materials and magnetic devices. The materials program is pointed toward techniques for growing ferrite crystals and their use in magnetic devices. Work aimed at improved high-power pulse transformers has resulted in a 10 to 1 size reduction for certain applications.

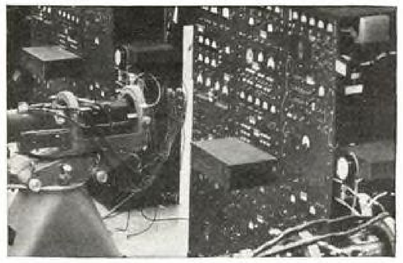
The electron tube section has a large contractural and small in-house effort devoted to improving tube performance and developing special purpose tubes. One example is a new cathode ray tube which accepts information (inputs) in Cartesian coordinates, then converts and displays them in polar coordinates.

ERD's director, Dr. L. M. Hollingsworth, asked what his most pressing needs were, said: "We'd like a radar with limitless range, that weighs nothing and occupies no space. We'd like to be able to communicate with any one, anywhere on the earth, without enemy interception or jamming. But we'd like to be able to both intercept and jam the enemy's communications."

Scientists are not ready to concede that anything is impossible–given sufficient time, manpower and money for research.

for fast engineering, development and production

a separate Sperry division devoted to microwave electronics



Production test consoles

Out of its many years of pioneering and managing major electronics systems, Sperry is keenly aware of the critical role that sub-systems and support equipment play in the *testing, evaluation* and *performance monitoring* of modern weapons systems.

Now—with emphasis upon faster and more extensive service to the customer – Sperry has organized its broad activity in this area into a streamlined team of specialists. It is the Microwave Electronics Division.

This team is a large and experienced one, resourceful engineers with inventive, systems knowledge supported by skilled technicians and craftsmen to convert ideas quickly into pilot models or quantities of hardware. Development, environmental and materials laboratories plus standards specialists combine their tools and talents to assure that items ranging from components to consoles will perform with certainty in operational use.

In addition to its widely-known Microline* test equipment, the new division is expanding its contributions to the military and industry with advanced weapon support systems, antennas and a broad line of precision components.

Emphasis is being placed too upon new instrumentation and standards for advanced research laboratories, special radar systems, target simulators, computers and evaluators for radar, electronic, missile and inertial guidance systems.

A proven key to the division's ability to solve new developmental problems rapidly is the efficient combination of engineering and development laboratories and shops. Each engineering group is supported by a development laboratory staffed with experienced technicians. Engineers work closely with machinists and assemblers to deliver pilot models on minimum schedules.

For quantity production, a complete manufacturing unit has specialized facilities to supply microwave products ranging from

Weapon system support equipment

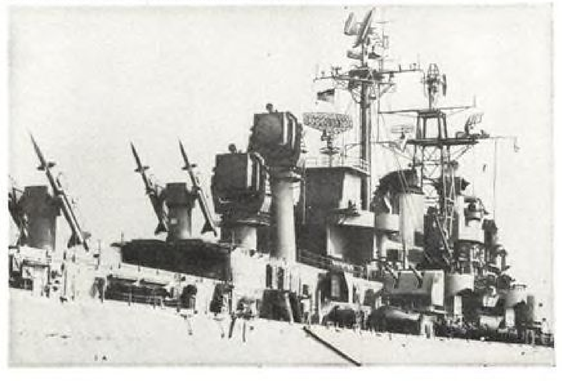
complex waveguide assemblies to complete racks of electronic equipment.

Military agencies or industrial companies concerned with any phase of electronic systems and sub-systems or the testing of such equipment can profit from employing these Sperry capabilities especially organized to speed up important projects and assure their success.

Write us for information about equipment now available or for proposals on new developments.

*T.M. Reg. U. S. Pat. Off.

Special antennas and system components



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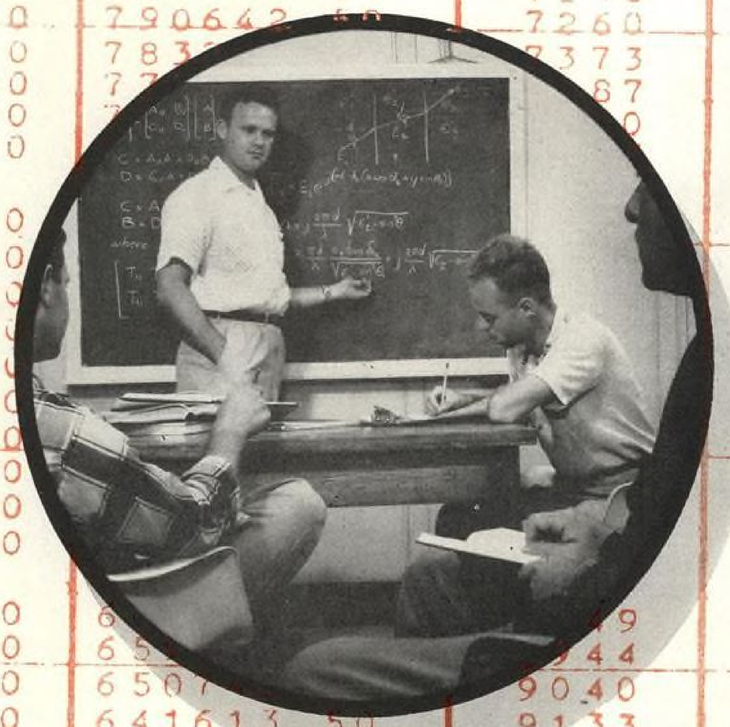
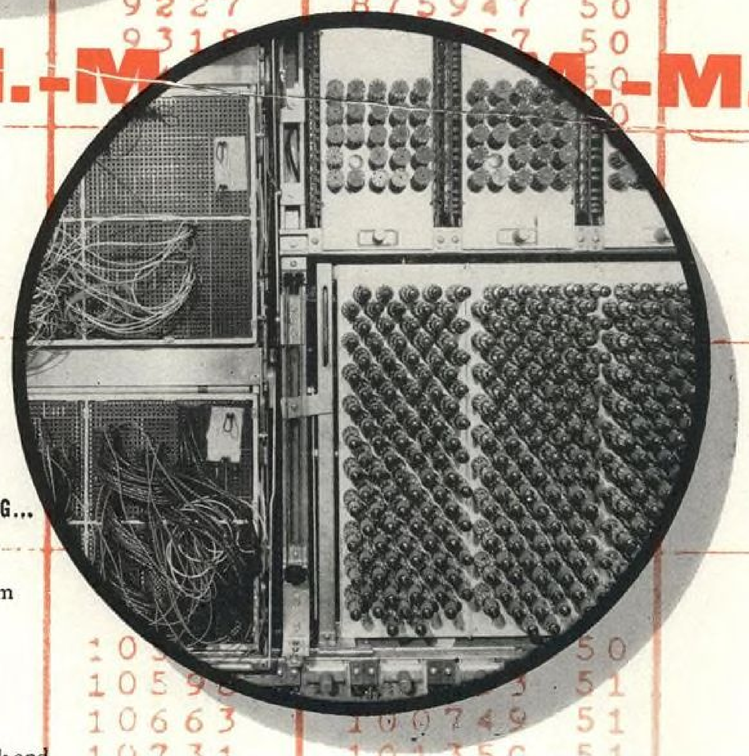


EXPERIENCE
EQUIPMENT
MECHANISMS
AND MEN



E.-E.-M.-M. **E.-E.-M.-M.** **E.-E.-M.-M.**

ZENITH HAS PRODUCED RADOMES FOR THE FOLLOWING...

B 29	F-3D	F-105	S2F
B 36	F-4V	C-119	Sea Venom
B 47	F-8V	C-124	T 33
B 50	F-80	C-130	T 36
B 52	F-84	P2V	TF102
B 58	F-89	P2V2	WV-1
B 60	F-90	P2V3	WV-2
B 66	F-94	P2V4	The Snark and
F-2H	F-96	P2V5	other guided
F-2H1	F-101	P2V6	missiles
F-2H2	F-102	P2V7	
F-2H3	F-103	P5YM	
F2Y-1	F-104	R3Y	

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This is the code for the combination that almost automatically refers radome problems today to the Aircraft Division of Zenith Plastics Company.

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EQUIPMENT that is as complete as can be devised by human ingenuity, for producing and testing the ultimate in radomes for the last word in planes.

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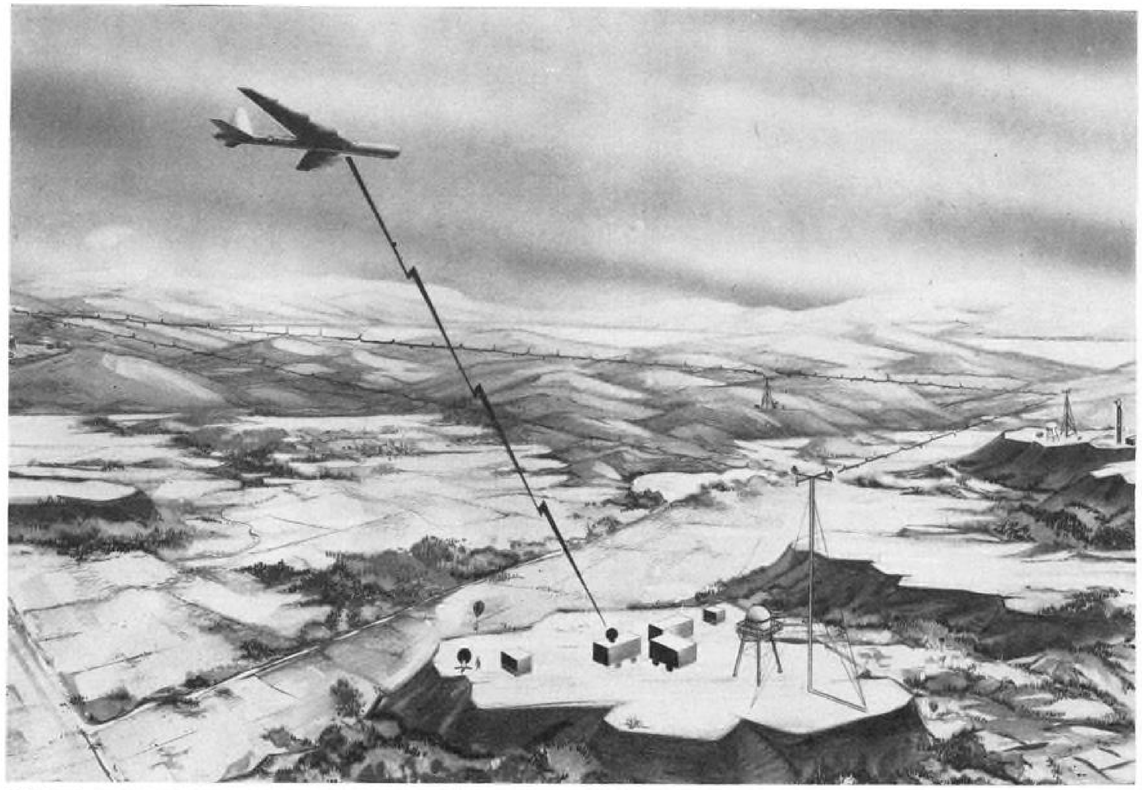


NEW RADC RANGE WILL CHECK OUT MISSILE GUIDANCE EQUIPMENT IN PILOTED AIRCRAFT

Rome Modernizes USAF Communications

Griffiss AFB, N. Y.—Rome Air Development Center will soon launch the development of a large, complex electronic supporting system, signaling an all-out attack on one of the USAF's most pressing problems—communications. Air Force operations currently are handicapped by a communications system which has not kept pace with its increased global responsibilities and the pace of supersonic-nuclear warfare.

The new program aims to integrate and expand USAF's communications lifelines into a speedy, more efficient world-wide network capable of meeting present and anticipated future needs.

RADC is regrouping its laboratories and personnel for the new systems approach to the communications problem and to handle another important assignment—developing the electronic ground environment for defense against the intercontinental ballistic missile (anti-ICBM).

Two New Groups

RADC has formed two new groups from its former Directorate of Electronics:

- **Directorate of Communications,** consisting of three laboratories: Systems, Equipment, and Advanced Development.
- **Directorate of Control & Guidance,** also consisting of three laboratories: Control, Radar, and Missile Support.

Two other vital USAF missions are assigned to RADC's Directorate of Intelligence and Electronic Warfare. It is responsible for developing:

- **Electronic data processing** techniques for storing and utilizing all types of intelligence data.
- **Ground-based countermeasures** equipment for detecting, intercepting, jamming and/or deceiving enemy radar-communications.

This directorate, and the three others which provide important supporting services for RADC's mission, are not affected by the newer organization. The supporting directorates are:

- **Technical Services,** consisting of the Human Factors, General Engineering, and Test Facilities Laboratories and the Engineering Services Branch.
- **Flight Test and Instrumentation.**
- **Procurement** (research and development procurement only are handled).

Communications, the oldest of the electronic arts, has not received the scientific effort devoted to its more glamorous off-spring, such as radar, digital computers and servo mechanisms. As a result, basic communications techniques and approaches used today differ relatively little from those of 15 years ago.

"We need an imaginative approach to the basic problem of communications," Harry Davis, RADC's Technical Director, said. He suggests that multiplexing (time-sharing) of messages on a wide-band channel might permit more efficient use of congested radio spectrum than the long-used technique of private-line, narrow band-width channels.

Global Network

The growth of overseas bases, urgent needs of the Strategic, Tactical, and Air Defense Commands, coupled with the rapid build-up of far-flung radar networks has sharply increased the demands placed upon USAF communications facilities. While these have been expanded, such expansion usually has been on a piecemeal basis to meet the pressing demands of the moment.

As a result no single command has what it considers to be sufficient communications capability. (Nearly 75-80% of all available channels in USAF's global communications system frequently are tied up just in filling the minimum needs of SAC's routine training missions, a USAF spokesman told a recent meeting of the Institute of Radio Engineers.)

What USAF wants and needs is a global network of telephone, teletype, radio, and facsimile facilities capable of meeting both the day-to-day and emergency needs of its many different commands and one which makes efficient use of its facilities.

All USAF bases here and abroad must be linked and there must be automatic routing to find the quickest available communications path to any destination. There should be an automatic priority system which will store temporarily a routine teletype message to free a circuit for a more urgent one.

Equally important, the system should be constructed from standardized equipment building blocks, in the pattern of the Bell System.

On the need for standardized equipment, A. J. Beauchamp said: "We want a common 'glue pot' into which Weapons System Project Offices and Electronic Supporting System Project Offices can dip and come up with the elements to tie their systems together." Beauchamp is in the Communications Branch, RADC Technical Operations.

Bell Conducting Study

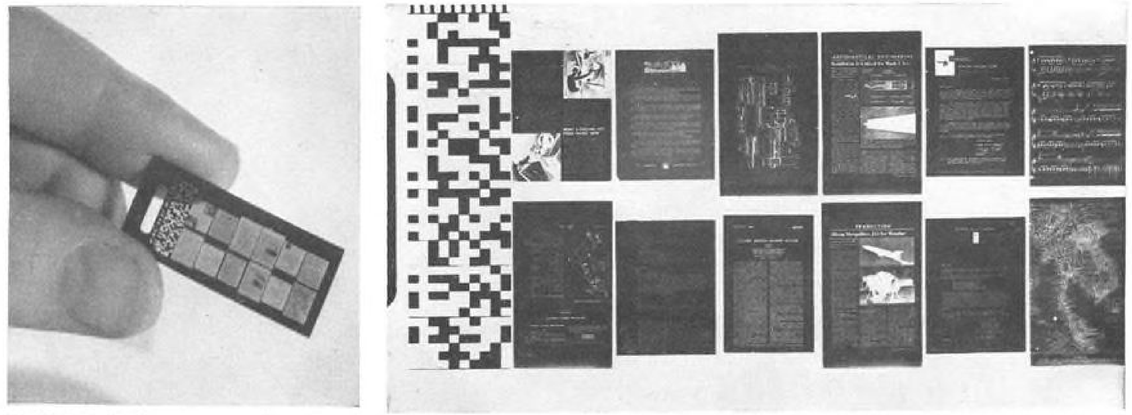
The Air Force is asking for a system that will blanket an area roughly six times that of the Bell System. It wants a 10,000-mi. trunk line whose reliability at least equals that of the present A.T.&T. transcontinental line, Beauchamp said.

The trunkline system must operate in a "hostile" environment (subject to countermeasures), a problem the Bell System does not have.

To handle a program of this magnitude and complexity, the weapon system management pattern of contractor selection will be used. RADC has contracted with Bell Telephone Laboratories for studies on certain aspects of its communications problems. Other current investigations include the systems and equipment of other military services and the problems involving spectrum allocations.

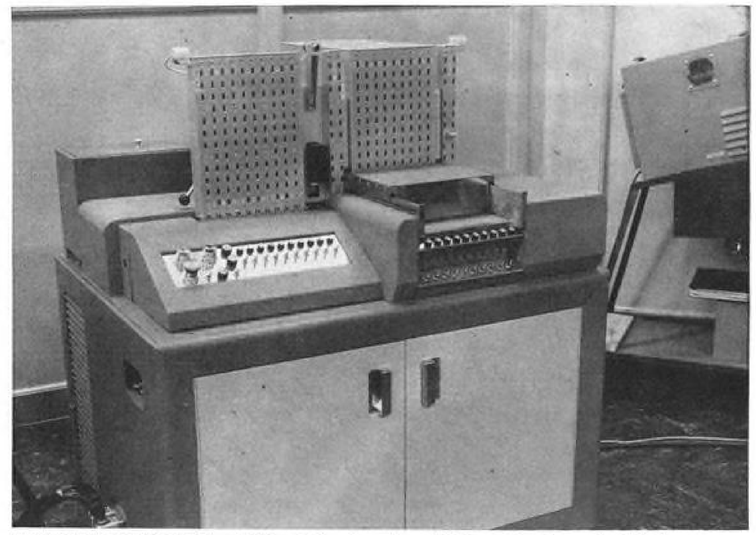
Within a short time RADC hopes to have its preliminary system plans drawn and approved, at which time detailed information will be made available by the center to interested and qualified contractors.

Recognizing that fulfillment of such requirements is a long-term project, industry may be asked for inter-



MINICARD (left) stores up to 12 pages of printed matter (right). Binary code (along left border) automatically locates desired data.

STORAGE SPACE is slashed by 1,000:1.



MACHINE SCANS Minicard film strips to automatically sort out required data.

in solution proposals for improving the effectiveness of existing equipments.

Communications Directorate

The new Communications Directorate will consist of the old Communications Laboratory plus several sections from other laboratories. For example, the Data Transmission (data link) Section of the old Auxiliary Equipment Laboratory now becomes part of the Communications Directorate's Advanced Development Laboratory.

The Advanced Development Lab, headed by O. D. Goldberg, will sponsor research and development in communications techniques. This will include Auroral Zone communications, meteoric scatter, synchronous detection (a new technique which may compete with single sideband), multiplex system studies, anti-jamming techniques, and automatic priority assignment systems.

The lab's activities also will include techniques for special facsimilie, cryptographic and security systems, automatic correction systems for teletype transmission, and high-speed printing and scanning.

Equipment & Systems

Application of these new techniques to specific equipment—microwave, single sideband, scatter communications (both fixed and mobile)—will be the responsibility of the new Equipment Laboratory, headed by Donald L. Dakin. Other equipment projects will include remote radio control, teletype and telephone switching equipment.

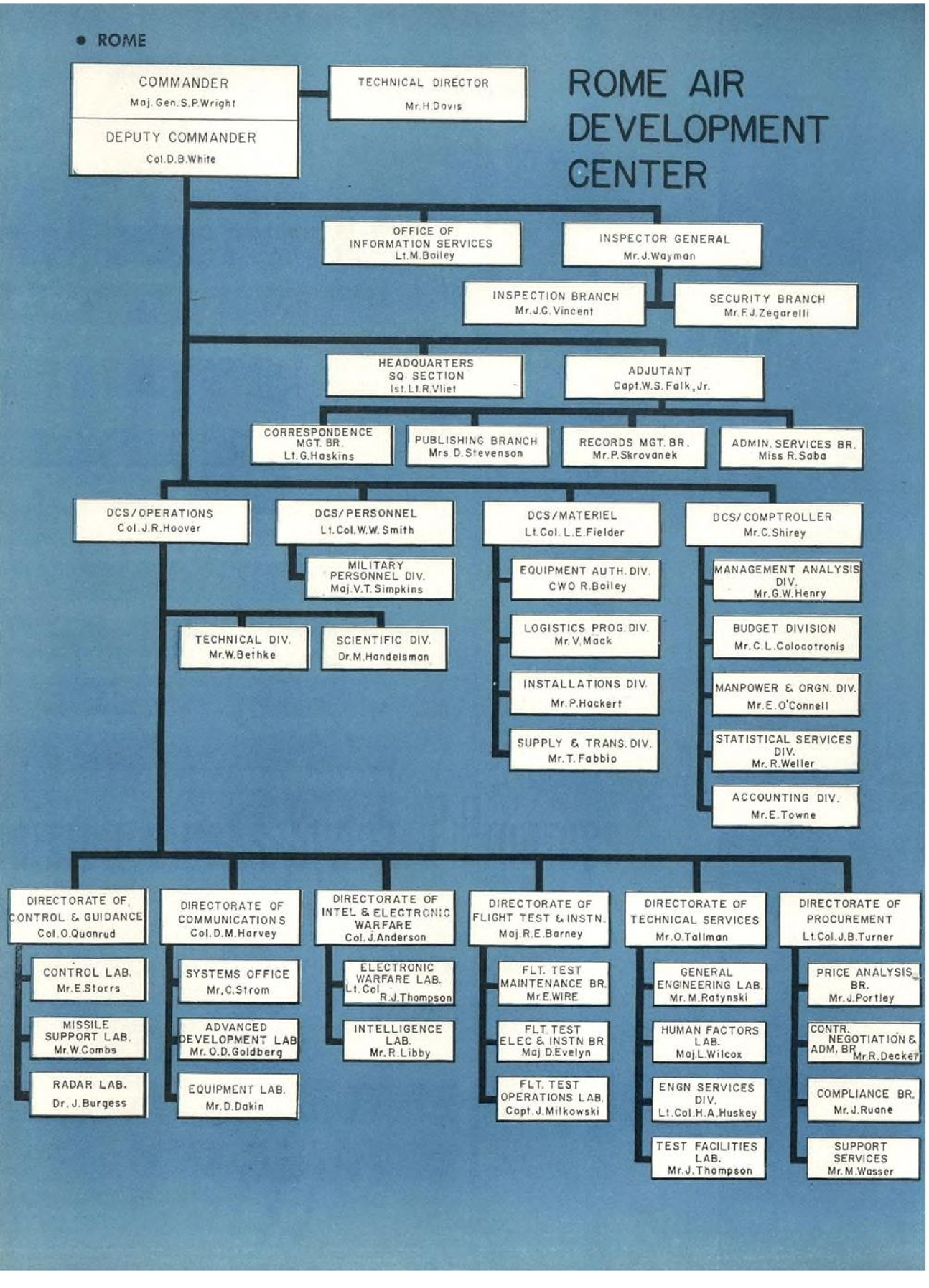
The new Systems Laboratory's major task will be monitoring development of the new global communications program. Charles Strom Jr., will head this lab. Most of its work will be on paper, analyzing system requirements and design, making sure that equipment and techniques developed by its sister labs are put to good use. It also will analyze requirements and design specialized communications systems for intelligence, missiles, tactical countermeasures, and material data handling systems for logistic purposes.

The overall Communications Directorate will be headed by Col. Daniel M. Harvey. Joseph Vogelman, formerly chief of the Electronic Warfare Lab, has been named deputy director.

Electronic Warfare

USAF's major effort in ground-based electronic warfare, for deceiving and/or jamming an enemy's radar and, if possible, intercepting his communications, is concentrated in RADC's Electronic Warfare Laboratory in the Directorate of Intelligence and Electronic Warfare. Lt. Col. Robert J. Thompson is chief of the new electronic warfare laboratory.

Electronic warfare is a never-ending



race against time and the enemy's ingenuity. "Any radar or radio communications can be jammed, given sufficient effort and time," Vogelman said. When successful countermeasures are developed, the enemy redesigns his radio/radar to make it less vulnerable. This in turn requires a redesign of the countermeasures equipment. "Thus the enemy decides what we must develop in electronic countermeasures (ECM)", Vogelman said.

To provide the Air Force with a "Quick Reaction Capability" (QRC) in countermeasures, the Electronic Warfare Lab has built up its capability to develop, design and fabricate new ECM on short notice.

This work is done by the Product Development Branch, headed by Samuel Beane. It recently designed and built in five months a portable device for the Air Defense Command which quickly enables it to locate the source of interference to its radars. RADC may build up three QRC models; if more are required they are contracted outside.

To further increase its QRC in this field, RADC has three "call-type" contracts with outside firms. This enables RADC to order ECM hardware or research on these existing contracts without the delay of negotiating a new contract for every requirement.

ECM War Games

Elements of strategy and theory of games play a prominent part in devising new electronic warfare techniques, Vogelman said. For this reason the EW Lab has an Applied Research and Analysis Branch which plays ECM war games in an effort to figure out how to counter enemy efforts to counter our own ECM—a question of counter-counter-measures.

This section also seeks basically new ECM techniques, such as a recently developed "continuous look-through" technique which permits simultaneous reception and transmission on the same frequency. Although Vogelman would not elaborate on possible applications, the novel technique might be used to simultaneously intercept and jam an enemy's communications.

The radio spectrum seems far too narrow when engineers seek new channels, but it appears tremendously broad to the ECM designer. To blanket the spectrum a number of ECM equipments are needed, and this places a premium on miniaturization—particularly for mobile installations.

The Applied Research & Analysis Branch devotes some of its effort to devising new miniaturization techniques. One novel example is a new filter package smaller than a human fist which permits instant frequency analysis of an unknown enemy signal. Haywood Webb is the Branch chief.

Prototype ECM hardware development is the responsibility of the Countermeasures & Deception, or Detection & Evaluation Branches, depending on the type of equipment involved. The two groups are headed by Irving Eitches and Robert Stevens. This prototype equipment may incorporate ideas conceived under the Applied Research & Analysis Branch, or generated within the prototype equipment sections.

The Detection & Evaluation Branch, for instance, has developed a signal analysis device which makes it possible to "decipher" automatically and break down an enemy signal into its composite frequencies. Another device automatically determines the pulse width of an enemy radar.

ECM Testing Grounds

Facilities for testing all experimental and prototype Air Force ECM, both ground-based and airborne, are located at two sites near RADC and operated by the EW Lab's Engineering-Operational Evaluation Branch, headed by Samuel Zaccari. Here RADC checks the effectiveness of its ground-based and airborne ECM. It also tests the vulnerability of USAF ground radars to ground and airborne jamming equipment.

The two sites are outfited with almost every type of radar and communications equipment in the past and present USAF inventory.

The last of the EW Lab's six branches, called Systems and Equipment Engineering, is responsible for the design of integrated electronic warfare systems from the equipment developed under the two "hardware" sections. Mr. Abraham Tanenhaus is branch chief. These systems include equipment for acquisition and analysis of enemy electromagnetic radiation and for necessary counter-action.

The systems usually are not made fully automatic because human judgement must enter the picture. For example, USAF has ground-based ECM systems which can select automatically the proper frequency and pulse rate required to jam an enemy bomber's airborne radar. But whether to turn on such equipment requires human judgement. Turning it on automatically alerts the enemy bomber, possibly prompting it to take evasive action. Judgement might dictate letting him continue his present path into a nest of nearby interceptors or anti-aircraft missiles.

Intelligence Laboratory

The need for collecting intelligence data about an enemy is practically as old as warfare itself. But the pace of nuclear warfare fought at supersonic speeds has badly outmoded previous techniques for reducing, analyzing,

storing, and recalling the vast amounts of intelligence data needed.

Recognizing this and the fact that recently developed electronic data processing techniques might offer solutions led to the formation of the Intelligence Laboratory about a year ago. It is headed by Richard Libby.

Broadly stated, the Laboratory's objective is to apply existing electronic data processing techniques, or develop new ones. Last July 1, two sections were transferred from Wright Air Development Center to round-out RADC's Laboratory. One will handle interpretation of aerial photos, the other chart and map making.

Because of the highly classified nature of intelligence, many of this laboratory's projects are under wraps. But because business and industry have similar problems of information handling, some techniques pioneered here undoubtedly will find their way into unclassified use.

Minicard

A good example is the Minicard system, a "squeezed down" automatic library developed by Eastman Kodak Co. under sponsorship of the Laboratory's Intelligence Production Branch, headed by Robert Sampson. Minicard permits a 1,000 to 1 reduction in the space required to store information. Even more important, it automatically searches its library and extracts data sought by its human operator.

Minicard is a novel combination of microfilm and punched-card sorting techniques. It uses a film strip measuring 1¾ x § in. (35 x 16 mm.). Along one edge is printed a binary code which serves as an index. Up to 12 pages of printed material and/or photos can be stored on one film, depending on the amount of indexing required.

A thin slit along the coded edge permits it to be mounted, with hundreds of other strips, on a metal "skewer". When one skewer of film strips is placed on an automatic machine developed by Eastman, the individual film strips are automatically removed and scanned by photoelectric techniques to sort out desired information, which then is viewed like microfilm or reproduced.

Indexing Problems

Despite its speed and dexterity, Minicard is no better than the indexing system used, according to Maj. H. F. Wienberg, chief of the Laboratory's Operational Planning Branch. This is a basic problem in storing the vast amount of information collected.

Only humans can read the information and decide how it should be classified and indexed. This usually causes the classification to reflect the classifier's own background. A chemist indexing an article on semiconductor mate-

rials, for example, might list classifications of interest to another chemist but not list classifications under which a metallurgist or physicist might think to look.

This very basic problem has pushed the laboratory into the field of library science and techniques. At present it has a "guinea pig" project which is seeking new classification techniques for the chemical-metallurgical sciences, using abstracts put out by technical societies.

Aerial Reconnaissance

The lab's Data Processing Branch, under Daniel Loreto, is exploring and may soon launch a program to mechanize the utilization of vast amounts of intelligence data obtained on aerial reconnaissance missions. Photos taken on reconnaissance missions now are analyzed by slow manual methods. Unless known landmarks appear in the photo, it is difficult to pinpoint the exact location of the photographed area.

The laboratory is considering the possibility of automatically recording on photo reconnaissance film (or a synchronized magnetic tape) information such as the plane's position (from navigation computers), heading, altitude, and airspeed. The recording would be in a form that would allow automatic data reduction techniques to be applied to locate any desired portion of the film.

Automatic Translation

One of the most fascinating of the laboratory programs is aimed at automatic translation of foreign languages. As a preliminary step, the Intelligence Production Branch is sponsoring development of a Russian-to-English word converter. English-Russian word equivalents will be placed in a high-speed, large capacity storage device which has electric typewriter input and output. When an operator types out a Russian word on one typewriter, the storage device will automatically seek out the English equivalent and cause another typewriter to write them out.

However, a word-by-word translation is far from a finished, usable product, because of syntax problems and multiple word meanings. The lab is studying the possibility of a mechanized translator with built-in "logic" for the syntax of the particular language being translated. For instance, if two words appear together, they might have one meaning; if separated by a third word, they might have another meaning.

The laboratory's Collection Branch, headed by Howard Davis, is developing hardware to assist in the ground-based collection of intelligence. Security prohibits any further statement about its work.

The Applied Science Branch, under Carl Nordstrom, is exploring new state-of-the-art in all fields of science for its possible application to intelligence. It is, for instance, investigating the possibility of using different radioactive isotopes as a means of coding and sorting out data on storage, instead of the photo-electric techniques now employed in Minicard.

Maj. Gen. Stuart Phillips Wright, Commander, Rome Air Development Center . . . born Dallas, Tex., 1903 . . . attended Dartmouth College and Texas University . . . served with pursuit and bomb groups . . . commanded 497th Bomb Group, and served with 73d Bomb Wing and 20th Air Force in South Pacific in World War II . . . communications and electronics posts with USAF Hq. and Strategic Air Command . . . deputy commander Air Proving Ground . . . deputy commander Fifth Air Force (rear) in Korea . . . commander RADC since May, 1954 . . . rated command pilot, command observer and aircraft observer . . . organized and commanded first radar bombing squadron and took it to South Pacific, where it provided radar bombing in combat.

The Operational Planning Branch is investigating the problem of handling the vast amounts of data which would result if the USSR were to accept President Eisenhower's "Open Skies" plan.

In some quarters RADC is known as "that place where they think you can do anything and everything with ground based radar." There is good reason for this reputation.

Control & Guidance

RADC has applied ground radar to air defense (surveillance), ground-controlled interception (GCI), tactical air control systems for interdiction (TACS), instrument approach (GCA) and automatic approach and landing systems and airport surface detection ("taxi radar"). It also believes radar could provide a nationwide semi-automatic traffic control system.

RADC is risking its batting average in an attempt to develop a defense against intercontinental ballistic missiles. RADC is USAF's chief ARDC supporting center for the development of an anti-ICBM (AICBM) ground environment.

Heart of any possible ICBM defense is a technique for early detection at great distances and altitudes. It comes as no surprise that RADC believe it can do this job with ground-based radar.

Although RADC officials will say only that they are working on the problem, the center has officially acknowledged that it has a huge (175 ft. high) radar antenna, built by General Electric Co. at Laredo, Texas. This has led to well-based speculation that it will be used to track missiles fired from the White Sands (N.M.) proving grounds, some 500 miles away.

The newly formed Control and Guidance Directorate, headed by Col. Otto Quanrud, includes a new Missile Support Laboratory.

Missile Support Lab

The new Missile Support Lab, headed by Wilbur Combs (former chief of the Auxiliary Equipment Lab), consists of four branches:

- **Ballistic Missile Branch,** headed by Stanley Rush.
- **Non-Ballistic Missile Branch,** headed by Capt. Dale Ashcroft.
- **Operational Planning Branch,** under Stewart Norris.
- **Instrumentation Branch,** under Edward Kullmann.

Work in ground support systems for such Air Force missiles as Bomarc, Talos and Atlas, previously divided between the Auxiliary Equipment and the Control and Guidance Laboratories, is now located in the Missile Support Lab. The Atlas and AICBM projects are under the Ballistic Missile Branch, the Talos and Bomarc under the Non-Ballistic Missile Branch.

The Missile Instrumentation Branch (formerly part of the Auxiliary Equipment Lab) has just completed a new high-accuracy range for checking accuracy of missile guidance equipment, flown in piloted aircraft. The diamond-shaped range has four Askania cine-theodolite stations at each of four corners, averaging about 12½ miles apart.

To achieve the highest possible accuracy, RADC called in the U.S. Coastal Geodetic Survey to site the stations. During operations, RADC will send up airborne refractometers to measure index of refraction along the flight path and introduce these minute corrections into theodolite readings.

Further evidence that RADC never overlooks an opportunity to apply

• ROME

ground based radar is a recent patent application filed by Edward Kullmann for an automatic tracking theodolite. To speed up the reduction of range data, Kullmann proposes to "slave" each theodolite to an accurate tracking radar which will always keep the theodolite pointed toward the target.

Theodolite operators then will have to crank in only "vernier" corrections to center the crosshairs on the target. Digital pick-offs on the radar would provide instantaneous data on approximate target position. Their accuracy would suffice for much of the subsequent analysis. Manual analysis of the theodolite films to provide data for correcting radar-established target position would be needed only for those portions of the mission that require such extreme accuracy.

Control Laboratory

Ground-based equipment for navigation and control of piloted aircraft is the responsibility of the Control Laboratory, headed by Ernest Storrs. The Lab is divided into four Branches:

• **Guidance,** under Percy Rickets, responsible for long and short-range navigation items like Navarho, Tacan.
• **Control,** under Salvatore Di Gennaro responsible for ground controlled intercept, approach and landing equipment.
• **Special Devices,** headed by Joseph Bennett, responsible for secondary radar, IFF (identification, friend or foe), navigation beacons.
• **Operational Planning,** under Joseph Ryerson, responsible for integrating navigation and guidance systems involving equipments from several of the other branches.

Poor Man's SAGE

RADC has lifted the security wraps from a new semi-automatic ground-controlled intercept computer, the AN/GPA-37, which greatly relieves the GCI operator of the intercept triangulation computations previously required. While not as fully automatic as SAGE, the device is in use today and will serve as an emergency back-stop after SAGE becomes operational.

The device was developed initially by Columbia University and re-engineered and built by General Electric's Heavy Military Electronic Equipment Department.

The GPA-37 not only increases the number of aircraft an individual GCI operator can handle, but permits the use of less highly trained operators, Donald Dakan, chief of the former Weapon System Support Section under which the device was developed, said. The computer itself is of the analog type. The computer can automatically transmit GCI instructions to aircraft via data link.

Another responsibility of the new

Control Branch is automatic GCA. AGCA consists of a precision approach radar (PAR), such as the military FPN-16, CPN-4, or MPN-11, plus a series of automatic trackers for keeping tabs on as many as six aircraft in final approach; computers for calculating what flight path corrections are required, and a data link for automatically transmitting this information to the cockpit of each aircraft under control.

In the cockpit the pilot gets an ILS-type of cross pointer indication, plus distance-to-touchdown information. The data link signals also can be fed into an autopilot to provide automatic approach control.

A new AGCA equipment developed by Gilfillan Bros. now is installed at RADC and is being readied for evaluation. It is designed to provide approach control for aircraft to land at 30-sec. intervals.

An escorted tour of the mobile van in which the AGCA is housed, provided by Stan Tepper, RADC project engineer, and B. Cutler, Gilfillan project engineer, illustrated the important attention to detail required in such equipment. The van includes special semi-automatic test equipment which enables an operator to check out quickly any one of the hundreds of plug-in assemblies used. Another tester enables the operator or maintenance man to examine the wave shape of any critical signal and compare it with the desired shape.

A simulated AGCA run performed by Cutler provided convincing evidence that the automatic feature should be a great boon to GCA operators, relieving them of routine chores of interpretation and instruction so they can monitor the complete situation.

Automatic Departure

While much effort has been devoted to automatic approach and landing, RADC now is investigating the other side of the picture: automatically controlled departure. This is one of the tasks assigned to the Operational Planning Branch under Ryerson. In addition to the obvious advantage of increasing airport capacity, auto-departure control should increase take-off safety, Ryerson believes.

Airport surface detection equipment (ASDE), often called "taxi radar" and developed under RADC sponsorship, has proved extremely useful to show tower operators whether runways and taxi strips are clear.

For military operations, however, where jets may be landing at 30-sec. intervals or less in bad weather, ASDE may not be adequate as an airport navigation device. The reason, Ryerson said, is the high taxi speeds of military jets, the difficulty of finding and following runway turn-offs and taxi strips, and the inherent delays if the pilot must get his ground maneuvering directions from a tower operator viewing ASDE.

RADC is investigating the possible use of flashing lights along the taxi-strips. Another possibility is to use "leader cable" implanted in the taxi strip concrete. Magnetic radiation from the cable is sensed by a device in the aircraft which gives the pilot a turn right or left indication. The British have developed such a system, but Ryerson believes that it may not give sufficient "anticipatory" action when a sharp turn is coming up.

EGECON System

A traffic control and navigation system which makes use of secondary ground radar and requires a minimum amount of airborne equipment is another project within this branch. It is called Electronic Geographic Coordinate Navigation System, or EGECON for short.

EGECON would obtain information on each aircraft's identity from its IFF or ATC transponder beacon, then assign an automatic tracker to keep a check on its position. Position of each aircraft would be transmitted via data link periodically to the aircraft, where it would automatically up-date and correct the dead reckoning computer. The computer then would provide the pilot with position information until the next data link transmission.

RADC currently has an EGECON study contract with Gilfillan and Ford Instrument Co., which makes the AN/ASN-7 dead reckoning computer.

Another project, related to EGECON, is called INCA (Integrated Navigation Communications And so forth). It is a study program with Electronic Control Systems (a Stromberg-Carlson subsidiary) to determine the number of communication-navigation equipments now carried on all types of aircraft and what percentage of the time each is in use.

The newly formed Special Devices Branch is responsible for secondary radar (used to interrogate IFF and similar airborne transponders), ground navigation radar beacons and digital data processing techniques.

MAGTRAC, a new transistor-magnetic amplifier automatic target tracker which keeps continuous check on the position of individual aircraft picked up on surveillance radars, is one of the branch's current projects. The required techniques and the device itself are RADC developments.

The device is extremely small (300 cu. in. per channel), rugged and reliable.

It consists of:

• **Video integrator** and beam splitter which applies statistical techniques to establish exact target position within

the width of the beam, to give more accurate data on target azimuth position and range. The device also converts target position from rho-theta coordinates into rectangular coordinate system.

• **Tracking amplifier,** which derives target velocity information, generates azimuth and range tracking gates, interpolates aircraft position for time intervals between successive radar scans.

New Transponder Role

Work now under way in this branch may hold important implications for the civil ATC transponder-beacon program, according to Gurdon Abell, chief of the former processor section of the auxiliary Equipment Laboratory.

It is the "Data Transmission Feature," which would permit civil ATC transponders to provide information automatically on aircraft altitude, heading, airspeed, destination or estimated arrival time when suitably interrogated from the ground, without pilot action or use of congested voice communication channels.

This information would be supplied automatically and continuously to the airborne transponder by analog-to-digital pick-offs attached to the plane's altimeter, gyro-compass, and airspeed indicator or pre-set by the pilot for such functions as destination and ETA. When a ground controller wanted to know a specific airplane's altitude, for instance, he would set a curser gate over the aircraft's blip on his radar scope. This would automatically indicate which code should be used to interrogate that aircraft. The controller then would push a button marked "altitude", which would initiate a "radar request" addressed to the airplane, asking its transponder specifically for the plane's altitude. This would trigger the plane's transponder to reply instantly with altitude or any other information requested.

Navigation Beacons

Development of small radar ground-based beacons for navigation which are rugged enough to withstand air-drop, is another responsibility of the Special Devices Branch.

A new AN/FPN-13 X-band nav beacon, employing direct crystal control for greater frequency stability and capable of serving a greater number of aircraft, now is replacing long-used World War II beacons. The FPN-13 was built by Webster-Chicago under RADC sponsorship.

RADC wages a never-ending battle to reduce beacon size and weight and increase reliability. One new beacon is only one-third the size and weight of its predecessor, yet it has the same capability. Because ground beacons frequently are expendable, cost reduction is another objective. By redesigning a beacon antenna for easier producibility, Airborne Instruments Laboratory was able to cut price from $2,300 to $400.

Many beacons require their own sources of electrical power—usually in the form of a small gasoline engine driven generator. These must be able to start by themselves and run continuously, unattended for up to a year—with extremely low fuel consumption.

Five years ago RADC was lucky to get more than 50 hours operation before failure. As evidence of progress, a new engine developed by Special Purpose Engine Co. recently ran for nearly 1,800 hours before failure, according to Richard H. Boutillette. Based on the kind of duty cycle to which the engine of a power lawn mower is subjected, this is the equivalent of about 150 years of power mower use.

Radar Laboratory

With so many of RADC's programs built around the use of ground radar it is not surprising that a major effort is being made to improve radar. It is concentrated in the newly formed Radar Laboratory headed by Dr. John Burgess. From an organizational standpoint, the Laboratory has not changed much from the previous Radar and Applied Techniques Laboratory. Its AICBM activities have moved over to the new Missile Support Laboratory while its semiconductor circuitry efforts are shifted to the General Engineering Laboratory in the Directorate of Technical Services.

The new Radar Laboratory has four branches:

• **Search & Height Finder,** headed by John Cruickshank, responsible for development of complete radars.

• **Transmitter,** headed by William Pope, which devotes much of its efforts to improved tubes and modulators.

• **Antennas and Microwave Components,** headed by Ken Eakin, responsible for developing all components found between antenna and transmitter output and receiver I. F. amplifier input.

• **Techniques,** headed by Nicholas Frederick, responsible for developing new receiver circuits and MTI (moving target indicator).

Anti-Jam Effort

One of the major efforts of the Radar Laboratory is to "make radar as invulnerable as possible," RADC Technical Director Harry Davis said.

Asked about progress in making radar less vulnerable to jamming, Dr. Morris Handelsman, former chief of the Radar and Applied Techniques Laboratory, said only that very significant strides have been made.

Developments in high-power klystrons in the early postwar years appeared to spell the doom of magne-

• **ROME**

trons, long used to power radars. Recently, however, "there has been a terrific surge in magnetron capability, thanks to new design twists," Handelsman said. Magnetrons now are giving klystrons a real race, he indicated.

Klystron designers are not sitting tight. Handelsman reported significant new developments in high-power klystrons and grid-control klystrons, and said that they have made steady advances in all-important reliability.

Improvements in microwave components since World War II have permitted significant gains in radar sensitivity, Handelsman said. "Today we can guarantee noise figures of 8-9 db. or better in actual field performance, compared to the 15 db. figure achieved in World War II," he said.

Gains in MTI performance and reliability have reached the point where RADC now plans to standardize on one or two designs and provide them as Government Furnished Equipment to radar manufacturers. This will not only reduce the cost of USAF radars, but also should provide attractive economies in maintenance and training of maintenance personnel, Handelsman believes.

The new MTI is far more reliable, has better performance under varying operating conditions, and is better able to counter certain types of jamming, Handelsman said.

A new type of MTI, developed by Radio Corporation of America, may get around the undesirable characteristic of present MTI which often eliminates moving aircraft radar blips if the airplane is orbiting at a constant radius about the radar.

RCA's new MTI employs a cathode-ray storage tube called the "Radechon." Tests on an experimental model indicate that it may be more reliable, less critical of adjustment and easier to maintain than conventional ones.

Technical Services

The activities of the Directorate of Technical Services run the gamut from exploring the possibility of putting the human sense of smell to practical military use, to developing automatic fault locating techniques; from developing modular shelters to house RADC equipment to providing the services of a small National Bureau of Standards. The Directorate, headed by O. G. Tallman, consists of four groups:

• **Human Factors Laboratory**, under Maj. L. R. Wilcox, which investigates ways to make optimum use of the immutable characteristics of the human being, in combination with electronic equipment.

• **General Engineering Laboratory**, under M. V. Ratynski, whose activities range from interference analysis and control to instrumentation develop-

ment, materials and miniaturization techniques, measurement techniques, and mechanical design engineering.

• **Test Facilities Laboratory,** under J. M. Thompson, responsible for operating RADC's complex of environmental test facilities and conducting suitability tests on components and materials. Recently this lab has taken over the operation of most of RADC's off-base test sites.

• **Engineering Services Division,** under Lt. Col. Homer Huskey, responsible for preparing engineering and production procurement data and RADC's vast radio communications needs.

Human Factors

RADC recognizes that electronic warfare is far more than a battle between electronic systems. It is a battle between their operators. For this reason the human, his capabilities and his inherent shortcomings, must be taken into account in the design of any ECM. This is one of the projects within the Human Factors Laboratory.

Take, for example, the problem of trying to jam the airborne radar of an enemy bomber. The object is to produce maximum interference with the radar navigator/bombardier's task. It is impractical to try to completely obliterate all radar returns. But what is the most feasible type of jamming to confuse and annoy the navigator/bombardier? One of RADC's projects is to conduct simulated bombing runs and determine how much bombing error is introduced by different types of ECM.

Vital Link

The cathode ray tube is the vital link between man and machine in many military systems, but too little is known quantitatively about the affect of tube size, brightness, contrast, resolution and persistence of the radar return on the operator's ability to detect targets quickly.

Human Factors Laboratory psychologists have built what they call a "visual sensitometer" to measure the affect of some of these factors. The laboratory hopes to build up a library of authoritative information which will enable radar display designers to select CRT tube parameters on a scientific rather than an intuitive basis.

Reliability, and the associated problem of easing the skill-level required for maintenance, are under attack by the General Engineering Laboratory on many fronts, including:

• **Automatic performance monitor,** a recent development which continuously checks key radar performance factors such as power output, VSWR, receiver noise figure and local oscillator tuning. If any one deviates from acceptable limits, the monitor automatically sounds an alarm, or switches over to a standby equipment. Although the first monitor was designed for a specific radar, RADC hopes to develop a standard monitor design for all types, Tallman said.

• **Automatic fault locator,** another recent development which automatically samples several dozen critical internal radar voltages, compares them with a build-in standard and automatically indicates when one or more are outside limits. Tallman considers this the first step toward automatic fault prediction—spotting deterioration of radar performance before it results in a breakdown.

• **Circuit redundancy,** possibly with automatic switchover to spare circuits in the event of malfunction. RADC soon will launch a study program of fault prediction techniques which, if feasible, would make it possible to switchover prior to actual failure.

• **Reliability handbook,** prepared by McGraw-Hill, gives designers the latest techniques for designing reliable equipment. RADC plans to bring out new additions to the handbook from time to time. RADC is participating with the Navy in similar project at Cornell Aeronautical Laboratory to produce a handbook on cooling techniques for electronic equipment designers.

Flight Test

To Air Force pilots in operating commands, an assignment to an RADC center flight test facility might sound like a soft job. A few minutes spent with Maj. Robert E. Barney, chief of RADC's Directorate of Flight Test & Instrumentation, provides convincing evidence to the contrary.

RADC's small group of pilots fly 14 types of aircraft, from helicopters to F-100s. With the current shortage of flight personnel, the pilots must be qualified to handle a variety of types.

Flights are difficult to schedule for a number of reasons. One is the experimental nature of equipment being tested, which frequently requires unpredictable maintenance or modification.

Procurement

In Fiscal 1956, RADC's Directorate of Procurement spent some $65 million on research and development contracts. This went to 110 commercial contractors and 23 non-profit groups such as universities.

These contracts were almost all of the Cost Plus Fixed Fee (CPFF) type. But Lt. Col. John B. Turner, Directorate chief, who is moving to RADC headquarters, hopes to explore the use of Cost Plus Incentive Fee (CPIF) type contracts. He believes that CPIF contracts might provide added incentive for contractors to hold down costs.

Left to right: Dr. Howard Baller (radar systems and counter-measures, computers); Dr. Cledo Brunetti, Director of Engineering and R & D (electronic design, automation); Donald F. Melton (nuclear handling, automation equipment); Dr. John E. Barkley, Associate Director for R & D (solid state, infrared)

Zeke Soucek (seated), General Manager of Mechanical Division; Dr. Carl F. Kober, Associate Director for Systems Engineering (radar, infrared and inertial systems); Harold E. Froehlich (balloons and meteorological systems); Dr. Otmar M. Stuetzer (microwave optics, semiconductor physics); Dr. Gottfried K. Wehner (behavior of metals in space flight)

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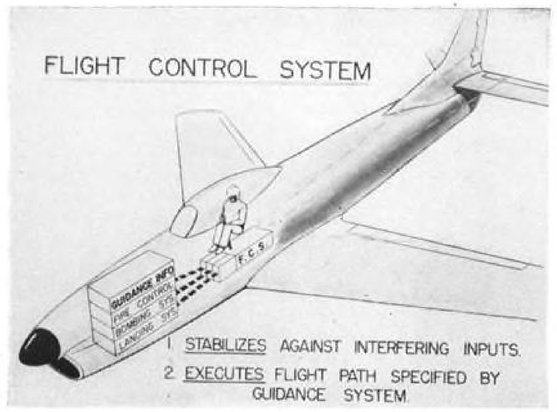
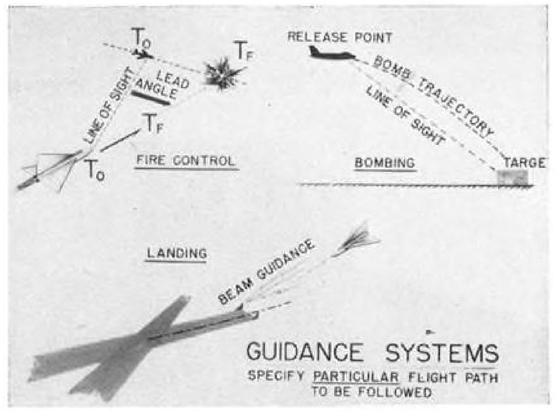




AUTOMATIC FLIGHT CONTROL system has dual role: stabilization of aircraft and execution of flight path required by guidance system.

Automatic Flight Control System Sought

Wright-Patterson AFB, Ohio—A radically new type of flight control system which continuously monitors its own performance and automatically adjusts to give optimum performance is a major goal of Wright Air Development Center's Flight Control Laboratory.

Such an automatic "environment-adjusting system" could speed introduction of new aircraft into the USAF inventory by greatly accelerating tests on experimental aircraft, said Col. J. L. Martin, Jr., chief of the laboratory.

In pushing new aircraft through the sound barrier, designers have run into serious new problems of controllability. As a result, new jet aircraft can not accomplish their military mission without an avionic assist from stability augmentation systems, sometimes called "damper systems."

Ideally, stability augmentation equipment should be debugged and ready when the experimental airplane makes its first flight. But it is difficult to engineer a stable damper system without extensive data on the plane's dynamics. This data is not available until tests are run on the experimental airplane.

To obtain this data requires a long, tedious bootstrap operation. The pilot must first fly the experimental airplane at its more stable altitude and speeds, obtaining stability data for the design and adjustment of the augmentation equipment. In some instances the pilot reports his observations by radio to flight control engineers on the ground who radio back instructions for changing the setting of knobs controlling system parameters.

The tests are repeated, the observations reported and system parameters changed again, until stability is achieved. Then the pilot explores other altitudes, speeds and flight configurations.

Eventually flight control engineers have enough data to determine how augmentation system performance must be varied with speed, altitude and configuration. From this they can design and build an automatic "gain changer." This device automatically changes system parameters as the plane changes speed, altitude or configuration.

But if the flight tests should lead to significant changes in airframe dynamics between the experimental and production models, new flight tests must be run on production aircraft so the gain changer can be re-designed. Another disadvantage of the gain changer, which results from its being tailored to a specific plane's characteristics, is that it cannot cope with unexpected changes in dynamics, such as battle damage or new external stores.

Several Studies

With the rapidly expanding speed and altitude performance of military aircraft, such testing becomes prohibitively expensive both in time and effort.

The proposed environment-adjusting system, however, could automatically perform the system-parameter optimizing function over the entire speed-altitude envelope in a split second, compared to the weeks of point-by-point flight testing now required.

Equally important, its use in production aircraft would always automatically compensate for any change in dynamics.

Martin believes the laboratory's concept offers hope for "significant improvement in the whole flight control field for both piloted aircraft and missiles." The laboratory is sponsoring several design studies on environment-adjusting flight control systems and hopes to buy experimental hardware in the coming year.

All this points up two drastic changes that have taken place during the past 10 years in what is now called automatic flight control:

• **Vital new roles,** in stability augmentation and guidance, which far overshadow the pilot relief function of the old autopilot, the forerunner of present flight control systems.

• **Greater complexity** and sophistication brought on by these new tasks, coupled with increased airplane speeds and operating ranges.

FCL Background

In recognition of these changes, WADC some two years ago broke sharply with tradition and set up the Flight Control Laboratory, to deal with flight control on a systems basis. Problems of aerodynamic stability long had been the responsibility of WADC's Aircraft Laboratory, as had manual control and power boost systems. Autopilots, once assigned to WADC's Equipment Laboratory, several years ago was assigned to the Armament Laboratory, because of bombing and fire control system tie-in. Cockpit instruments had been primarily the responsibility of the Equipment Laboratory, with some navigation and fire control instruments being developed by the Communication and Navigation and Armament Laboratories.

This division of effort was logical in the early days. Inherent airplane stability then was a problem which the aerodynamicist solved with ingenuity, sheet metal, and perhaps a bob weight. The power boost designer worked with hydraulics, while the autopilot engineer worked with electronics.

But this led to needless duplication of flight control equipment and frequent incompatibility between equipment and controls. One airplane ended up with "the equivalent of 2½ auto-

pilots," C. R. Bryan, the Laboratory's Technical Director, said. Even worse, the stability augmenter might work at cross purposes to the autopilot, and airplane instability often resulted when designers tried to work through the airplane's boost system.

The trend toward convergence of these once-separate arts was accelerated by the introduction of interceptor fire control systems. Theory and experience indicated that a much improved weapon would result if radar-computer signals were fed directly to the plane's autopilot to maneuver it into firing position automatically.

However, autopilots that long had been designed to hold a plane on a steady course generally proved ill-suited to the fancy maneuvering required for an interceptor mission. The maneuvering autopilot needed rate-type gyros instead of free, or displacement, type.

Experience has shown that an interceptor flight control system spends about 80 per cent of its time in maneuvering and only 20 per cent in the traditional relief pilot role, Bryan said.

Under One Roof

As the different phases of the flight control art converged, questions of jurisdiction and responsibility arose. Was the stability augmenter the responsibility of the aircraft or autopilot designer? It performed a role which has been the responsibility of the aerodynamicist, but it closely resembled the autopilot in design and hardware. Was the control surface hydraulic actuator and its associated control valve the responsibility of the power boost system designer or of the autopilot designer, who frequently used the same combination? Was an aerodynamic solution to a stability problem to be preferred over a hydraulic or electronic solution?

The new Flight Control Laboratory has been organized to look at the problem from a functional viewpoint rather than the narrow view of the techniques employed to solve it. It has pulled together the work of aerodynamicists, mechanical and hydraulic engineers and electronics people.

The Laboratory believes flight control has two basic functions:

- **Stabilize and isolate** the aircraft from everything except desired guidance commands.
- **Make the aircraft as responsive** as possible to those guidance commands.

Obviously there must be a close working relationship between flight control and guidance systems, but there is a well defined line of demarcation, Martin said. One reason is that a flight control system's characteristics usually must be tailored to those of the airframe on which it will be used, whereas a guidance system (bombing,

fire control, ILS,) usually can serve a number of types.

When flight control is viewed from a functional standpoint, there are at least two logical reasons why cockpit instruments should be included:

• **Guidance signals** frequently are displayed visually as well as introduced into flight control equipment, to let the pilot monitor performance of his automatic equipment and to provide a standby method of operation.

• **Needless duplication** of gyros, sensors and computers results unless there is close integration of instrument and flight control requirements.

The laboratory includes an instrument group responsible for most of the devices that go into the cockpit. (The Weapons Guidance Laboratory retains responsibility for development of gyro heading references and display and the Communication and Navigation laboratory holds responsibility for certain navigation displays.)

A major project in the Flight Control Laboratory is the development of a radically new integrated cockpit display system. (AW July 23, p. 62, July 30, p. 48.)

A special section has been set up to direct and coordinate this bold new program with other interested WADC labs.

Laboratory's Organization

The Flight Control Laboratory is divided into four major branches:

• **Aero-Mechanics,** headed by C. S. Westbrook.

• **Control Synthesis,** under Maj. Constantine Svimonoff.

• **Control Equipment,** headed by Herbert W. Basham.

• **Instruments,** in charge of David Stockman.

The Aero-Mechanics Branch is the former Stability and Control group of the Aircraft Laboratory.

One responsibility of this branch is to determine quantitatively what constitutes acceptable manual flight handling qualities. Human capabilities obviously must be taken into account. The branch is sponsoring programs to evaluate human response characteristics in terms of servo transfer functions, at Princeton University, Franklin Institute and Control Specialists, Inc.

Another major responsibility is analysis of stability and control characteristics of new weapon systems. Other programs include:

• **Flight test techniques** for obtaining dynamic stability coefficients, at Cornell Aeronautical Laboratory.

• **Aero-elastic effects,** how to analyze and simulate them, and the affect of high speed heating on airframe elasticity.

• **Reaction and boundary layer control** as a means of controlling aircraft attitude and flight path.

Development of advanced techniques and components to implement them for the flight control systems 10 years away is the responsibility of the Control Synthesis Branch. "We've intentionally divorced this state of the art group from the problems and daily headaches of providing hardware for current aircraft to enable them to look for brand new ways of doing the job," Technical Director Bryan said.

The new environment adjusting flight control system, which may employ digital computer techniques, is typical of advanced techniques within this branch. Other programs include investigation of:

• **Non-linear servo systems.** Objective is to get much better aircraft damping than is achieved now with linear feedback systems. The laboratory hopes to harness the airplane's inertia to make it "work for us as well as trying to keep it from working against us," Maj. Svimonoff said. A linear system designed to make an airplane resistant to a gust simultaneously makes the plane resist recovery from a gust. With a non-linear system it might be possible to provide extreme "stiffness" when the plane was on desired course but vary this stiffness if it changes course due to a gust. Vertical accelerometers might be employed to sense air turbulence and adjust system parameters.

• **Allowable stick motion.** Stability augmentation systems can be designed so their displacement of the control surface will not cause any movement of the control stick. But if this is done the pilot cannot sense a semi-hardover movement caused by system malfunction until the aircraft goes into the resulting maneuver. A project is being run on a modified simulator to determine how much stability augmentation stick motion is tolerable to a pilot.

• **Automatic refueling control.** Station keeping of two or more aircraft in a refueling operation presents a tough task for a fatigued pilot. The laboratory investigated the possibility of using automatic flight control techniques to make contact, couple up, fly while coupled.

Although the laboratory contracts many of its investigations, it can make its own preliminary crash-program investigations in less time than it would take to write specifications and award a contract, Bryan said.

Advanced Components

Synthesizing the systems of the future is only part of the job. The branch must also anticipate what components will be required to implement such systems and launch their development, Bernard Levine, assistant branch chief, said.

Some of the advanced component developments now under way are:

● FLIGHT CONTROL

• **Hot gas driven pneumatic actuators** as possible substitutes for the hydraulic and electric actuators now employed.
• **Hybrid servo valves** capable of accepting and mixing both mechanical and low level electrical inputs and using them to control the flow of high-power hydraulics.
• **Acceleration limiting systems,** capable of enabling a flight control system to pull maximum safe G's on the airplane but preventing it from exceeding this value.
• **Manual arm-rest control stick** which may replace the traditional "joy stick." It would be mounted in a side console.

Flight Directors

To provide greater impetus for its flight director developments, and to assure their integration with automatic flight control systems, the Control Synthesis Branch has been assigned responsibility for their development and production. One program is development of an experimental flight director for the fighter-bomber.

Another project, with Lear, Inc., is development of a special autopilot using rate integrating (HIG) gyros.

Instruments

The Instrument Branch is responsible for developing most of the instruments which will make up the USAF's new look in cockpit instrumentation, under the direction of the Laboratory's Special Working Group. The branch's activities fall into three areas:

• **Sensors** for measuring the dozens of parameters needed to fly and fight a modern aircraft.
• **Computers** for converting these measurements into quantities of specific value to the pilot and/or crew.
• **Displays** for visual presentation of the information.

Branch Chief David Stockman listed these as the most pressing needs in the field of new or improved sensors:

• **Total temperature (free air)** sensors that require no adiabatic correction. Both vortex and stagnation point sensors are being developed.
• **Accurate static pressure** sensor with errors of no more than 0.3% up to 80,000 ft. or higher. Present USAF goal is to be able to provide 500-ft. separation between its aircraft from 500 to 80,000 ft., and this requires far greater altimeter sensitivity and accuracy than is available now. Stockman said this requirement is "going to be awfully hard to meet."
• **Angular acceleration** sensor, for use in flight control systems.
• **True angle of attack sensor.**
• **Tachometer generator** and other engine instruments capable of operating continuously in an ambient temperature of at least 450F. (General Electric is working on a tach generator design

which it hopes can operate at 600F.)

• **Radiation and control** instrumentation for nuclear powered aircraft. Stockman said old-line aircraft instrument people have shown little interest in the field of radiation instrumentation.

Computers

The trend toward use of central air data computers as a single source of airspeed, altitude, Mach and temperature signals appears certain to be speeded by the USAF's new integrated cockpit display. With that in mind, this branch is sponsoring development of a family of air data computers covering different ranges of altitudes and airspeeds, standardized for use in a variety of aircraft.

This is intended to eliminate past practices where weapon system contractors have sought air data computers tailored to their specific aircraft requirements. Stockman cited one interceptor manufacturer whose specifications would have required the computer maker to spend an estimated 42,000 hrs. re-engineering its design.

After a three-day conference at WADC with representatives of the plane manufacturer, computer maker, flight control system manufacturer and interested WADC laboratories, differences were resolved to permit the use of a standard air data computer, Stockman said. The team now meets once a month to coordinate air data requirements for all user equipment. A similar air data coordination team has been formed for other new aircraft.

USAF now has its MG-1 air data computer, covering the range up to 80,000 ft. and Mach 3 in production at three sources: Eclipse-Pioneer Division of Bendix Aviation Corp., Kollsman Instrument Corp., and Servomechanisms, Inc. It plans soon to bring out a new model, the MG-2, covering the range up to 100,000 ft. and Mach 5.

In the field of engine computers to determine optimum engine operating conditions for take-off, climb, cruise, and landing, WADC has developments under way at Sperry-Rand Corp. and General Electric Co. A slightly different approach, the design of instruments to enable the pilot to optimize engine performance, is under contract to John Oster Manufacturing Co. These programs are an outgrowth of theoretical studies conducted by Massachusetts Institute of Technology.

Stabilized Platforms

Development of stabilized platforms to serve as a reference for flight control systems is another responsibility of this branch. These are less sophisticated and less complex than platforms designed for inertial guidance systems (the responsibility of the Weapons Guidance Laboratory.) Where a plane is equipped with an inertial guidance system, its platform could serve as a standby for flight control, Stockman indicated.

WADC currently is flight testing an Eclipse-Pioneer platform which weighs only 32 pounds, including power supply, in an F-100. It has exhibited drift rates of only one degree per hour in azimuth and two degrees per hour in roll and pitch in laboratory tests. Litton Industries, Inc., recently was given a contract to develop an even lighter stable platform.

By adding accelerometers to such platforms, Stockman believes, they can be used as an "inertial" altimeter, rate of climb indicator and Mach indicator to eliminate time-lags. By combining present-day and inertial techniques WADC hopes to greatly improve the measuring of these critical functions.

Another important development is a G-limiting, or load limit, computer. It will determine continuously how many G's the aircraft can safely pull under its instantaneous flight configuration, fuel load, etc., and how many G's are being pulled. The computer will operate an indicator that shows the pilot his margin of safety, but not burden him with actual G-load numbers. It is being developed by Sperry Gyroscope Co.

The challenge of the integrated cockpit display program has unleashed industry ingenuity, long constrained by the previous requirement that a new instrument had to bear a close resemblance to its predecessor. The result is "great industry enthusiasm" for the program, Stockman said.

Control Equipment

Responsibility for the flight control hardware that goes into new weapons belongs to the Control Equipment Branch, under Herbert W. Basham. This applies to piloted aircraft, guided missiles and target-drones.

Because much of this equipment is contractor purchased and supplied, the branch functions both as a consultant and as a monitor. It helps formulate flight control specifications for USAF operational requirements for a new weapon system, then serves as the engineering representative of the Weapon System Project Office in evaluating the flight control aspects of each contractor's proposal.

During the life of the contract, this branch monitors the contractor to be sure operational requirements are being translated correctly into hardware. Because of the many programs under FCL cognizance, they may spot equipment in one program which could be used profitably by another contractor.

The time may not be far away when

the complex mechanical linkage between the pilot's control stick and the airplane's control surface (or boost system valve) is replaced with an electrical servo system. It has long been recognized that this "fly-by-wire" approach offered attractive possibilities for reducing weight and complexity. However, airplane designers and pilots have been reluctant to entrust such a vital function to electronics whose reliability record leaves something to be desired.

Softening Prejudice

Several things have begun to soften this prejudice. With the advent of aircraft that required boost on all axes, the pilot lost his direct mechanical link to the control surface, although a mechanical tie still existed to the boost servo valve. Meanwhile, airplane designers were forced to turn to avionics for equally vital roles, such as stability augmentation. With the advent of magnetic amplifiers, transistors, and more reliable tubes, one of the last obstacles has been hurdled.

Basham reports "a great deal of activity" in the field of fly-by-wire techniques for manual control. WADC is testing such a system on an F-94, with the mechanical system as a standby. The National Advisory Committee for Aeronautics is running similar tests on a Navy aircraft, Basham said. He said WADC is considering use of fly-by-wire on an up-coming production airplane. If adopted, it will further increase pressures on equipment designers to provide a reliable power source.

Although the RF techniques involved in radio control and telemetry are somewhat foreign to the laboratory, the two are closely related to the laboratory's flight control efforts, from the functional standpoint. This explains why radio control and telemetering was transferred here from the Aerial Reconnaissance Laboratory.

For example, radio control completes the circuit between the flight control system in a target plane or drone and the pilot who is flying it from a mother plane or the ground.

Telemetry is extremely valuable in flight tests of an experimental airplane to enable engineers on the ground to "observe" airplane performance or to determine why an airplane went out of control.

This section of the Control Equipment Branch sponsors developments in telemetry and data handling. It is drawing up a new USAF specification to standardize telemetry techniques, frequencies, etc., for both pulse coded modulation and FM/FM types. This is a sort of up-dating of the original FM/FM standards drawn up some years ago by the Defense Department's Research and Development Board.

The present telemetry band (215-235 mc.) has become so congested that Basham said USAF is considering the additional use of a much higher frequency band.

Difficult Problems Ahead

Martin calls for "more emphasis on the functional problems of control and not on the techniques that are used to get it. The techniques are only of secondary interest."

A good example is the laboratory's attack on the inertia coupling problem, which Bryan called "one of the most serious we have." One solution is the use of stability augmentation on all airplane axes, and this is being tried.

Another possible solution is to reduce the airplane's maximum roll rate. Through the years each new airplane specification has called for higher and higher roll rates, despite the fact that such rates may be far more than the pilot can effectively use or withstand.

Now the laboratory is taking a good hard look at whether such roll rates are required. If not, this might be the best solution to the inertia coupling problem because it would reduce the amount of equipment which must be carried and simultaneously decrease airplane structural requirements, permitting weight and cost reduction. ■

Revolution Due in Avionic Components

By Philip J. Klass

Wright-Patterson AFB, Ohio—Electronic components, their materials and manufacturing techniques will undergo a revolutionary change in the next 10 years. They must in order to meet new USAF requirements for components capable of operating for 1,000 hours at temperatures up to 500 degrees Centigrade in the presence of nuclear radiation.

The agency responsible for sparking this coming revolution is the Electronic Components Laboratory at Wright Air Development Center. ECL already has awarded research and development contracts for a few 500C radiation-resistant components. More will follow in the coming year.

ECL is headed by Lt. Col. Fred C. Schmidt, Jr. The USAF may never employ nuclear propulsion for all of its aircraft and missiles, or operate all of them at speeds that require components withstanding 500C.

Despite this, the new components might become standard for all USAF avionic equipment, airborne and ground-based, to simplify logistics, providing they don't carry serious size, weight or price penalties, according to H. V. Noble, ECL Technical Director. Ground-based equipment, such as computers, operating in a controlled environment would be an exception.

Difficult Task

Some feeling for the difficult task which lies ahead for the components industry can be gained from the fact that metals begin to glow red at 500C. Copper wire oxidizes rapidly at 500C, unless equipped with a protective coating.

Transformer design becomes a real problem because its copper conductors undergo a 5 to 1 change in resistance over the required temperature range of −65 to 500C, according to Noble. This has a significant effect on transformer output voltage (regulation). If transformers are used to supply vacuum tube plate and heater voltages this will result in wide variations in tube performance and reduced tube life.

For optimum tube life, cathode surfaces generally operate at temperatures of about 800C. This suggests that in a hot ambient, no tube heater would be required. But how will a heaterless tube operate in sub-zero Artic temperatures?

Possibly the tubes of the future may use their heaters as a supplemental heat source, being turned on or off as required to maintain cathode temperature. However, this in turn raises problems of accurate measurement and control of cathode temperature.

The prospect that other electronic component characteristics will change markedly over the wide temperature range suggests that equipment designers will have to make wide use of compensating temperature-sensitive circuit elements which will further complicate their already difficult design chores.

The components industry has taken 10 years to raise the top operating temperature of its products from 55C to the present 125-150C limits. Now ECL needs to jump to 500C and wants at least a minimum family of such components in less than 10 years, Noble says.

Radiation Resistance

As if the 500C requirement were not enough, ECL also wants the components to withstand both neutron and gamma flux radiation for 1,000 hours. The two requirements, heat and radiation, spell the doom of organic materials for use in components, Noble believes.

Little is known about the effects of nuclear radiation on different types of components—why some are adversely affected, others not.

For example, theory suggested that radiation would damage the crystal structure of any semiconductor (diode, transistor), and this was indicated by preliminary tests. However, more recent tests run by Admiral Corp. under ECL sponsorship, indicate that diodes made by some manufacturers fail quickly under radiation while diodes made by others stand up quite well.

This in turn has led to the current feeling that the surface condition of a semi-conductor may be a determining factor in its susceptibility to radiation damage. ECL is sponsoring research on the subject. (Cambridge Research Center also is investigating this.)

New ruggedized tubes are not necessarily more radiation resistant than their predecessors. Tests on 5R4 rectifiers showed they are unaffected by radiation which destroyed their ruggedized successors, the 5R4WGY, according to Amos Dicke, chief of ECL's Electron Tube Branch. Residual gases in the tube which ionize under radiation may be responsible for these failures, Dicke believe.

Limited tests also indicate that certain filament-heater materials undergo adverse structural change under radiation.

Stacked Ceramic Tubes

In the field of receiving tubes, ECL is pinning considerable hope on the new stacked ceramic tubes developed by Eitel-McCullough, under ECL sponsorship. These have exhibited good life at temperatures of 350-400C and should eventually reach or exceed 500C, Dicke believes.

Because the Eimac tubes use no mica,

ELECTRONIC COMPONENTS LAB'S RANGE WILL TEST NEW RADOME MATERIALS.

they can be baked at extremely high temperatures to get rid of residual gases, which should make them less vulnerable to radiation. Very limited tests to date appear to confirm their radiation resistance.

Even if transistors prove vulnerable to radiation, their small size, low power consumption and heat dissipation make them too attractive to give up without a struggle. Dicke believes that it should be possible to provide radiation shielding for semiconductors without too great a weight or size penalty.

New semiconductor materials, such as silicone carbide, offer hope of raising top operating limits from the present 200-300C value obtained with silicon, to 500-1,000C.

Contracts Let

Several years ago ECL awarded a few contracts for the development of components capable of operating at 200C. In 1955 ECL added the nuclear radiation requirement. Work to date indicates the inorganic materials required to withstand nuclear radiation should also permit operation up to 500C.

Within the past year, ECL has awarded research and development contracts for the first members of the family of 500C, radiation-resistant components it intends to develop.

Some of these contracts have gone to old-line component manufacturers, like P. R. Mallory & Co., International Resistance Corp., and General Electric. Others have been awarded to comparative newcomers, such as Servomechanisms, Inc., and American Machine & Foundry Co.

Contract awards to date include:

• **Transformers:** General Electric.

• **Fixed capacitors:** American Machine & Foundry, which is exploring use of sintered ceramic oxides, and Servomechanisms, which is investigating evaporated film techniques.

• **Fixed resistors:** Mallory, which is exploring the use of sintered slugs, and International Resistance Corp., investigating use of metallic film techniques.

Charles Doyle, chief of ECL's Resistors, Inductors and Capacitors Branch, said the branch expects to let contracts in the coming year on the following 500C components and/or materials:

• **Potentiometers and high temperature** resistance wire with low temperature coefficient. This effort will be directed to non-precision pots at first, but pointed toward eventual application to precision pots.

• **Jet ignition capacitor,** rated 3 mmfd. at 3,000 volts.

• **New transformer insulating materials** and conductors with lower temperature coefficient of resistivity.

If enough Fiscal '57 funds are available, Doyle hopes also to launch re-

search and development effort for new magnetic materials and servo system components.

When the ECL first started thinking about the new 500C component program several years ago, it found relatively little industry interest. Today, however, the industry is responding to the challenge and up to a dozen contractors have submitted proposals on each contract awarded so far.

The lab's new program also holds important implications for its Electro-Mechanical Branch, headed by Yale Jacobs. This group is responsible for the development of the wide variety of important hardware that goes into avionic equipment, ranging from connectors to relays and from vibration isolators to power supplies.

High-Temperature Radomes

ECL's Radome Branch, headed by F. Behrens, has a head start over its sister branches because it was the first encounter the so-called thermal barrier. It already has some good ideas for making radomes capable of operating at 500C, Eino J. Luoma, assistant branch chief said.

Aluminum oxide looks good and as do a number of ceramics with good dielectric constants and low losses. The ceramics lack the tensile strength of lower-temperature organic materials, although they excel in compressive strength. The tensile strength of aluminum oxide approaches that of organic laminate materials.

The major problem with these materials is fabricating them into large size radomes. ECL is sponsoring a program at Ohio State University to develop sandwich techniques for constructing ceramic radomes out of two thin, concentric ceramic shells. The intervening airspace will be filled with ceramic foam.

Radome designing involves three inter-related factors—aerodynamic shape, structural strength, and microwave optical properties. Luoma said radome designers have made major strides in streamlining radomes without sacrificing good microwave optical properties. In fact, better radomes can be designed than can be built.

The design of a sharp-nosed radome still involves considerable "cut and try," Luoma said. However, this has been speeded greatly by new automatic boresight equipment which cuts radome test time from several days down to an hour. Another useful tester, developed by Microwave Radiation Co. under ECL sponsorship, is a "Surface Wave Dielectrometer." This device, which permits quick, accurate measurement of dielectric constant, and loss factors, may become a primary standard, Luoma said.

The Radome Branch is instrumenting a new test range, the most complete

facility of its type in the nation. (See photo, p. 287.) It will be used to check out transmission-reflection characteristics, beam pattern distortion, and boresight errors.

Advanced Development

ECL operates a small in-house research facility, the Advanced Development Branch, to explore new ideas or techniques which industry may neglect because they have no immediate commercial potential. These activities are in the areas of electron tube, semiconductor, and component techniques. Representative research projects include:

• **Pyroletic and chemical** deposition techniques for creating metal compound films which might be suitable for use in high temperature resistors.

• **"Fire-ball discharge"**, a recently developed principle which has interesting possibilities for use in voltage regulator tubes.

• **High density plasma**, which employs the basic interaction between electromagnetic waves and ionized gases. This principle can be used for some of the same functions now performed by ferrites, such as rotating microwave plane polarization. Advantage of the new technique is that it can operate at much lower frequencies and higher powers than ferrites.

• **New semiconductor materials**, such as aluminum-antimony and indium-antimony, which appear to hold promise for transistor use.

• **Semiconductor surfaces** and their effects on reliability. This is an investigation of the possibility of attaching semiconductor leads in inert gas atmosphere, to prevent surface contamination and on treatment of semiconductor surfaces to prevent changes in characteristics with aging and use.

This branch also monitors outside contracts in support of component developments by other ECL branches.

"We hope to learn more about the cause-and-effect relationships in the manufacture of transistors and take out some of the existing 'black magic,'" Lt. J. L. Hirshfield said.

Aid to Industry

ECL's Application and Design Branch, headed by William Deis, is providing an important, but little known service to the avionics industry. Contractors who build avionic equipment for USAF are required to use "approved components" that have passed military qualification tests, wherever such parts are available.

When a manufacturer proposes to used unapproved components, he may submit reasons why approved parts cannot be used, and the results of his own tests on the new component.

The branch has built up a file of contractor test results on a large number

• COMPONENTS

of unapproved components. It makes this data available to other contractors to save them the time and expense of making their own test.

Contractors can request information on an unapproved component by mailing a special post card form to ECL's Component Engineering Application Section, headed by Stillman Badger. If the data requested is on file it is sent to the contractor. If not, the contractor is notified and his request is filed.

If similar requests are received, they will be referred to the first contractor, who may have run his own tests by then.

Two-Way Street

Badger emphasizes that the ECL service is a two-way proposition and that it can not supply data unless industry reciprocates. Within recent weeks five major manufacturers have come in and offered to supply ECL with all their available test data.

Because this service saves industry and therefore USAF both time and money, ECL would like to expand it.

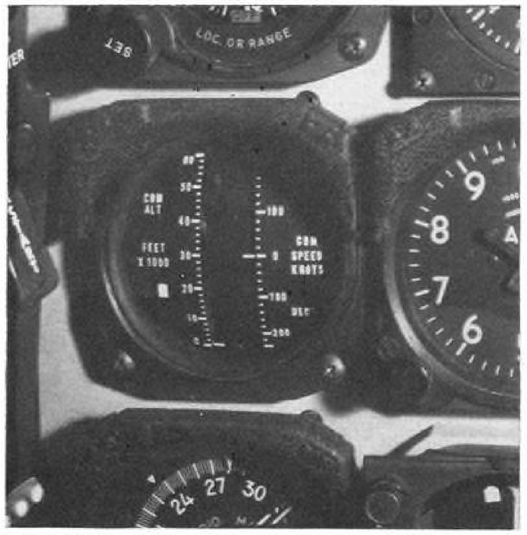
Data that ECL provides does not in itself constitute official USAF approval of the use of unapproved components, even though the data indicates that its use is feasible, but the contractor can cite the data as reference when he applies for approval.

Although the Application and Design Branch deals more in paper than in hardware, it has not escaped the tough radiation resistant development program. The general engineering section, responsible for sealing, printed circuit and cooling techniques and devices has its headaches. For example, the synthetics or rubber sometimes used for the sealing of avionic instruments and components is extremely susceptible to radiation damage.

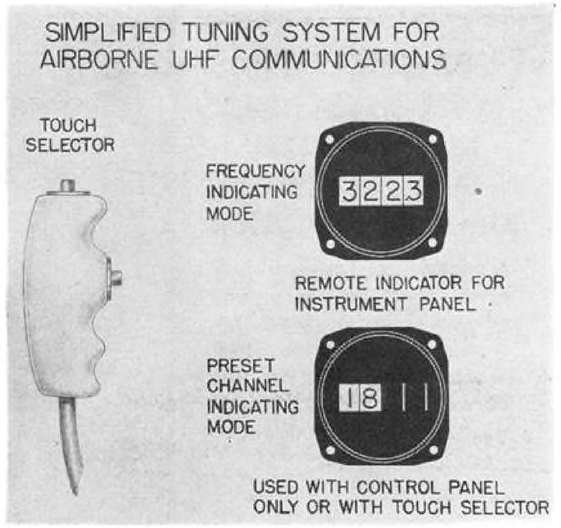
Special Areas

Although industry now is doing most of the work on mechanized assembly and printed circuits, the general engineering section is exploring specialized areas in these fields. It is sponsoring a program at Mallory to apply printed circuit techniques to the design of relays as a step toward possible mechanized assembly.

Printed circuits, miniaturized components, transistors and mechanized assembly are typical of developments begun or pushed along by the services, which now find growing uses in all segments of the electronics industry—including the home entertainment field. It seems safe to predict that the Electronic Components Laboratory's program to develop 500C radiation-resistant components will have an equal if not greater impact on the industry. ■



DATA LINK cockpit indicator shows command altitude, speed.



NEW COCKPIT radio channel remote tuning indicator.

Visual Presentation of Messages Planned

Wright-Patterson AFB, Ohio—This year Air Force pilots will start getting more of their ground to air communications through their eyes and less through their ears.

This is perhaps the most significant trend in Air Force ground to air communications, according to N. Braverman, technical consultant at Wright Air Development Center's Communication and Navigation Laboratory.

Fifteen years ago, pilots received both communications and primary navigation information (low frequency range) through their ears. Omnirange (VOR) and Tacan shifted the navigation data from ears to eyes. With the advent of USAF's new "Data Link," most of the routine ground to air messages will be displayed on cockpit instruments, and in some cases, simultaneously introduced into the airplane's automatic flight control system.

Data Link offers USAF several important advantages over voice communications:

• **Automaticity.** Data Link instructions can be generated and transmitted automatically by ground controlled intercept computers (such as SAGE) or automatic traffic control computers such as Volscan and directly introduced into the airplane's flight control system.

• **Spectrum Conservation.** Data Link makes much more efficient use of the overcrowded radio spectrum because commands can be transmitted far more rapidly than with voice.

• **Private Address.** Data Link instructions are received only by aircraft to which they are addressed, unlike the party line system of voice communications now in use.

• **Less Chance for Error.** Because Data Link instructions are visually displayed in the cockpit, there is less chance for misunderstanding. Because instructions remain on display until changed by ground, there is less chance that a tired pilot will forget them.

• **Less Operator Skill.** Data Ling instructions can be sent by human operators merely by pushing the appropriate buttons. This means operators can transmit messages with little training.

USAF Data Link

WADC's C & N Laboratory is responsible for development of the airborne Data Link decoder which operates in conjunction with the airborne UHF receiver. Rome Air Development Center has overall responsibility for the Data Link system and the ground-based equipment. The present system was designed by General Electric Co.'s Electronics Division.

Because of security, little can be said about how the system operates except that it transmits messages as a burst of pulses. Each message is addressed to the specific airplane(s) for which it is intended. The message may contain desired heading, altitude, airspeed, etc., as well as specific commands, such as "return to base," "lower flaps."

The present Data Link also combines a novel Selcal (selective calling) system for voice communications. If the pilot sets his manual controller to "private line" he will hear only voice communication the ground controller wants to direct to his attention. If he sets the control for "party line" operation, he will hear all ground to air communications on his channel, as with present voice communications operations.

C & N Laboratory

WADC's Communication and Navigation Laboratory consists of five Branches:

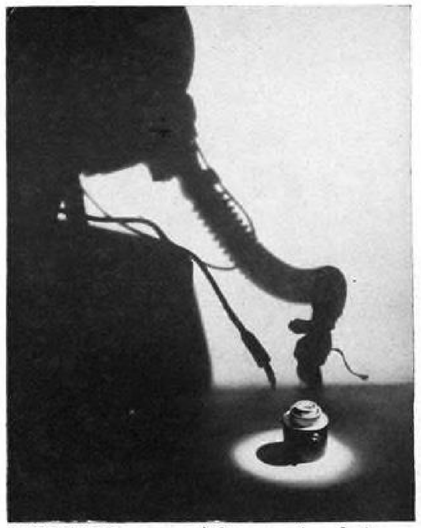
• **Communications,** under George Scheer Jr., responsible for the development of all types of airborne communications equipment, including voice, Data Link, teletype, and specialized items such as public address and intercommunication systems.

• **Ground-Reference Navigation,** under C. S. Franklin, responsible for airborne navigation receivers such as VOR, Tacan, Navarho (long-distance), automatic direction finders, radio/radar altimeters, and air-rescue devices and airborne beacons. This group also has responsibility for ground-based ILS equipment.

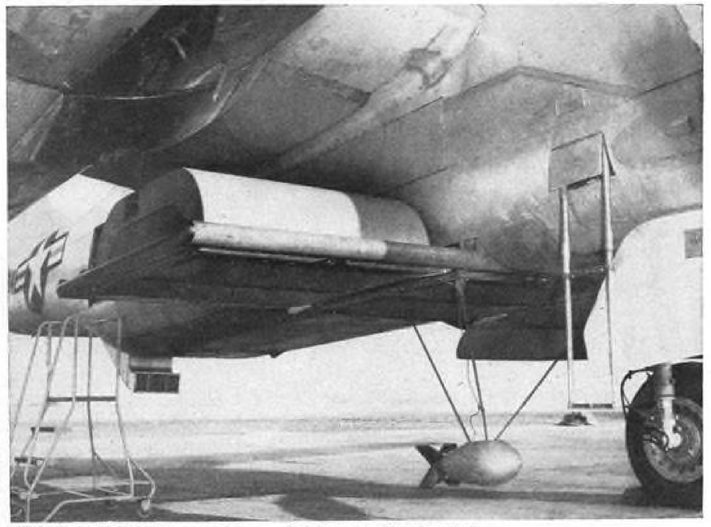
• **Techniques,** under R. E. Kester, responsible for developing new techniques for application to airborne antennas, anti-jamming circuits, and interference prevention.

• **Systems Engineering,** under Lt. Col. V. E. Redding, responsible for insuring that the installation of C & N Laboratory equipment in new aircraft and missiles will provide optimum performance and ease of maintenance.

• **Measurements Development,** under D. L. Lane, responsible for test and evaluation of C & N-developed equipment and development of maintenance



AUTOMATIC oxygen failure warning device.



"LOUD-MOUTH." new airborne high-power loudspeaker.

testers. This branch also provides supporting engineering services to other branches.

The crowded cockpits of modern jets have pushed the pilot's radio receiver channel selector console into spots where it is difficult for the pilot to see the channel markings. To get around this, Communications Branch is sponsoring development of a remote channel indicator which would be mounted on the cockpit instrument panel. Small digital counters will clearly indicate the channel frequency selected.

The next step is to provide "touch tuning"—push buttons on the pilot's control stick, or on a separate grip-shaped touch selector, which will permit remote selection of any desired frequency.

Other recent developments within the branch:

• **AN/ARC-22,** a complete communications-navigation package weighing less than 100 lb., for use in helicopters and liaison planes. It includes a two-way FM communications receiver operating in the 24 to 62 mc. band, a homing device, two-way UHF communications set, VOR receiver, LF/MF direction finder, marker beacon receiver, and interphone. It was developed by Bendix Radio.

• **"Talk Down,"** a parachute-borne public address system and tape recorder which can be dropped from an airplane over enemy troop concentrations. At 10,000-ft. altitude, the AN/ANH-4's parachute automatically opens and it delivers a 3-5 min. canned message as it drifts down.

• **"Big Mouth,"** a huge, powerful airborne loudspeaker, capable of handling nine kilowatts of audio power, which also can be used to broadcast to enemy troop concentrations. It was built by the Baldwin Piano Co.

• **Airborne teletype,** a small, lightweight unit which can be used with USAF's ARC-21 or ARC-58 HF sets. Developed by Kleinschmidt Labs, Inc., it is the first specifically designed for airborne use.

• **Oxygen warning signal generator,** a small transistorized device which generates a pulsed-tone signal in the pilot's headset when the pressure of his oxygen supply falls too low.

Scheer said his group intends to take a fresh look at basic communications techniques. It will examine whether techniques other than present electromagnetic radiation can be used.

The branch is seeking means of avoiding auroral black-outs of HF communications in the polar regions, and Scheer said recently developed techniques look promising.

Navarho Tests

Flight of new airborne Navarho long-distance navigation receivers now are in progress, according to Saul Weissman, assistant chief of the Ground-Reference Navigation Branch. Tests results to date are encouraging. Weissman also believes that an airborne frequency standard, (required for the distance-measuring portion of Navarho), which must maintain its frequency to within one part in one billion, for a period of six hours, can be achieved with an extension of present crystal techniques.

The laboratory is sponsoring feasibility studies on an "atomic clock"—making use of the natural molecular resonant frequency of cesium. Although the atomic-clock type of frequency standard now appears too complex for airborne use, it could be used as a super-accurate frequency reference for checking the airborne crystal frequency standard, Weissman said.

Air Rescue

The C & N Laboratory devotes a major effort to air rescue. A current development nearing completion is the AN/ART-27 rescue beacon, which will be catapulted from an airplane at the instant of a crash. The beacon will automatically align itself into operating position, erect its antenna, and send out a coded alarm (on the HF and VHF bands) which identifies the downed plane and which can be used by ground-based direction finders to pinpoint its location.

The laboratory is developing a transistorized version of its AN/URC-11, a small two-way UHF radio for downed pilots, which went into production last year. The URC-11, only slightly larger than a pack of king-size cigarettes, provides two-way communications at distances up to 60 mi. The battery provides up to 24 hrs. of transmission and reception on a 50/50 duty cycle. With the transistorized version, WADC hopes to double battery life.

Getting small, lightweight, long-lived power supplies for small personal radios is a real problem, Weissman said. The laboratory is investigating solar cells, both as a primary power source and as a secondary source to recharge batteries, and nuclear-powered thermopiles.

The Ground-Reference Navigation Branch also is seeking a fool-proof type of automatic flare-out device which will enable aircraft to make automatic or semi-automatic touchdown in adverse weather. Hazeltine Electronics

Corp.'s APN-71 is one such development. A more recent one will use the AN/APN-94 radio altimeter developed by Raytheon Manufacturing Co. and a flare-path computer developed by North American's Aviation, Inc.'s Autonetics Division. The new system will take roll, yaw and pitch attitude into account and use accelerometers to measure instantaneous vertical acceleration.

Mid-air collision is a pressing military problem as well as a civil one. The branch is studying the proximity warning device problem and several recent unsolicited industry proposals, Weissman said. Techniques now used for flight formation station-keeping are being studied, he said, but WADC has no specific program under way now.

Improved Antennas

A new antenna coupler, developed by Andrew Alford Consulting Engineer, Inc. may solve a pressing communications problem by eliminating blind spots now encountered in UHF coverage. If an aircraft is equipped with only one UHF antenna, phase nulls may cause momentary blackout of reception. If an antenna is used on the belly and another on top of plane, one normally will have unobstructed communications capability. Previously, however, this required some sort of automatic switchover because both antennas could not be coupled simultaneously to receiver.

The new Alford coupler allows both antennas to be connected simultaneously by continuously varying the phase of their incoming signals at an extremely high rate, averaging out the nulls in the two antenna signals.

N. C. Draganjac, head of the antenna section of the Techniques Branch, reports that the new coupler has been successfully tried for air to ground, ground to air, and air to air communications.

The design of high frequency (HF) antennas for jet aircraft is "one of our biggest problems," Draganjac said. The fuselage of a jet interceptor is too short to serve as an antenna at the low end of the band.

The probe type antenna, currently being evaluated under C & N Laboratory sponsorship by Boeing Airplane Co. on its 707, appears promising but not as good as the isolated tail cap type. Where the isolated tail cap cannot be used for structural reasons, the probe probably will come into use.

The new higher power HF sets, such as the Collins ARC-58 (rated 1kw.), raises new corona problems for the antenna designer because of much higher voltages.

Dragnajac said more basic research is needed before USAF can come up with a good high frequency airborne direction finder. A simple HF homing system appears closer at hand. ■

Weapon Guidance

Wright-Patterson AFB, Ohio—Making airplanes into warplanes by means of complex avionic equipment that enables them to deliver bombs, bullets, rockets and missiles is the responsibility of Wright Air Development Center's Weapons Guidance Laboratory.

The new name for WADC's old Armament Laboratory reflects new responsibilities assigned during last year's regrouping of laboratories here, the shedding of some old ones.

New areas include:

• **Inertial guidance** and automatic dead reckoning computers.

• **Airborne countermeasures.** Old Armament Laboratory responsibilities now assigned elsewhere include:

• **Weapon development** (in the strict sense of the word—that is, guns, rockets, etc.), now carried out by Air Force Armament Center, Eglin AFB, Fla.

• **Flight control** now under the new Flight Control Laboratory.

Functional Grouping

These changes reflect a basic WADC philosophy of grouping activities according to their functional use and relationship.

For instance, early bomber defense consisted of flexible guns or inhabited turrets out of which present automatic radar-directed gun turrets have come. However, the growing threat of radar-directed missiles and interceptors equipped with automatic radar fire control systems has focused attention on countermeasure techniques.

Electronic Countermeasures (ECM), may employ different techniques than those used in radar gun turrets, but there is an obvious functional relationship and need for coordination between the two.

Inertial guidance and other dead reckoning navigation computers provide another example. Inertial guidance developments formerly were split between the C & N Laboratory and WGL. However, the new technique showed significant advantages for application to bombing systems. For instance, an inertial type bombing system would emit no tell-tale radiation over enemy territory and could not be jammed.

Since inertial guidance is but one form of dead reckoning computers that might be used for such purposes, it was logical to transfer all types of dead reckoning to Weapons Guidance.

The future military usefulness of inertial guidance "has been enhanced by several recent developments," James V. Burke, Technical Director, says.

The Laboratory's eight branches and their responsibilities:

• **Strategic Bombing,** under Lt. Col. D. K. Dean, bombing systems for Strategic Air Command aircraft.

• **Tactical,** under Lt. Col. D. F. Shea, fighter fire control and bombing systems.

• **Interceptor Systems,** under Lt. Col. W. D. Jones, automatic radar-directed fire control systems for interceptors.

• **Weapons Defense,** under Col. John M. Johannes, development of active and passive bomber defense systems.

• **Guidance Development,** under R. E. Houser, airborne missile guidance systems plus terrain clearance equipment for piloted aircraft.

• **Navigation,** under R. W. Ittelson, inertial guidance, bombing, and dead reckoning systems, and heading references for bombing-navigation systems.

• **Analysis and Design,** under R. W. Hommel, mathematical and design services for the other branches.

• **Services,** under R. M. Ferguson, operates flight test and range facilities.

Navigation Branch

Several interesting unclassified developments of the Navigation Branch are:

• **AN/ASN-9 dead reckoning computer,** an extremely small, transistorized system for use in fighters and helicopters. The ASN-9 weighs only nine pounds and employs plane rather than spherical trigonometry in its calculations to hold down complexity. It is expected to have an inherent error of no more than two per cent. Initially developed by the C&N Laboratory, a prototype is being built by Librascope, Inc., for delivery in October.

• **Type B-1 bomber heading reference,** consisting of an extremely low-drift directional gyro mounted on a gyro stabilized platform. The requirement for a platform-mounted gyro reference stems from the greater maneuverability of high-speed bombers coupled with the demand for greater accuracy. The B-1 is being developed by Kearfott Co., Inc., which also has developed a lightweight Type J-4 platform stabilized gyro reference for fighter planes. The J-4 has a drift rate of about three degrees per hour and weighs less than 32 lb. including associated amplifiers and controls.

• **Sub-miniature compass transmitter,** now under development, will measure only 2x2x1¼ in., yet will provide ± 75 degrees freedom of motion in pitch, ± 15 degrees in roll.

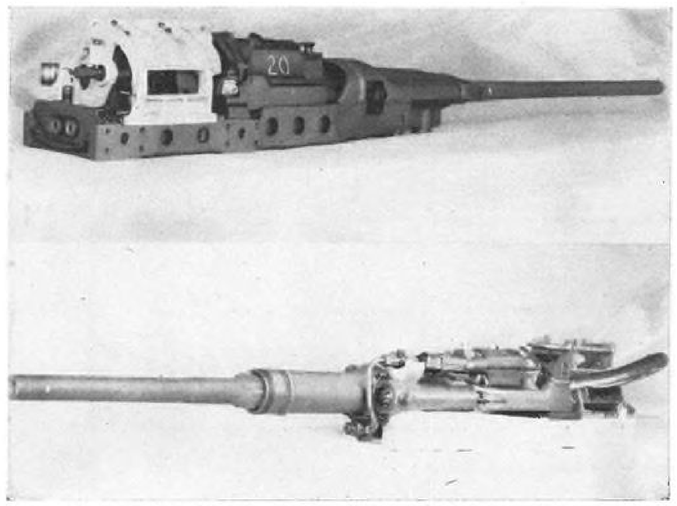
• **Electric ground swinging technique** for compensating gyro-compasses. This new technique, developed by Sperry Gyroscope Co., under WADC sponsorship, will make it possible for two people to calibrate a gyro compass in 2-3 hrs. without moving the aircraft. Present methods require five people, a special facility, and up to eight hours.

Missions Revised

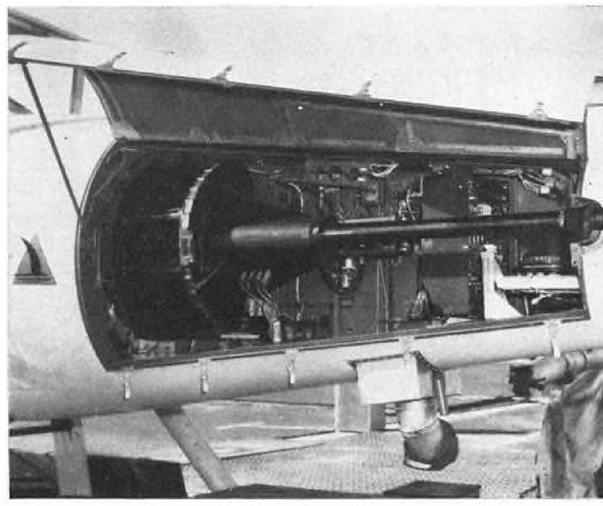
ARMAMENT

B-57B CARRIES 5-IN. HVAR ROCKETS

Armament Center Puts 'Cutting Edge' on Airpower



REVOLVER CANNONS: M-39 20-MM. (TOP), T-182 30-MM.



T-110 SPIN-STABILIZED ROCKET LAUNCHER

Armament Center:

Providing Airpower's 'Cutting Edge'

By Evert Clark

Eglin AFB, Fla.—Until a year ago the Air Force Armament Center had one primary mission—testing new weapons. Since then it has been given the added task of swordsmith—developing the armament that Gen. Jimmy Doolittle called "the cutting edge of airpower."

This new assignment is typical of AFAC's growth in the four and one half years since it became a part of the Air Research and Development Command.

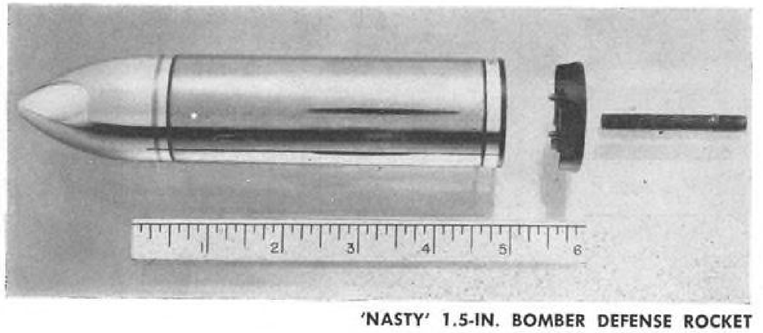
It still is only a tenant at the Air Proving Ground Command's 840 square mile reservation here on Florida's northwest shore. But its ranges now stretch from the Gulf of Mexico into Massachusetts and from Idaho to Puerto Rico. Its work on such things as rocket guns and bomber defense missiles have broadened the scope of its effort in the same way that technology has increased its need for new ranges.

When Maj. Gen. Edward Pont Mechling, then a colonel, took command in February of 1952, AFAC's development tasks numbered 50. Its budget for operating funds and research and development totalled less than $5 million.

Budget at $23 Million

The center now has development assignments running almost to 300, a civilian and military staff that has grown from 600 to 2,000, and an operating

T-171 20-MM. GATLING GUN



'NASTY' 1.5-IN. BOMBER DEFENSE ROCKET

TOW TARGETS: FLUIDYNE RADART (LEFT) AND DEL MAR'S FRANGIBLE RADOP.

and research and development budget of almost $23 million.

It is AFAC's job to initiate development of, supervise and test all non-nuclear munitions for the Air Force. As with most ARDC centers, more than two-thirds of the work which AFAC oversees is done by contractors.

The critical need for integrating armament into supersonic airframes makes AFAC's job no easier. Equipment takes longer in research and development than the airframe itself—so it must be started earlier. If the test job is to be done properly, development of intricate new test equipment sometimes has to begin almost as soon as a new gun or rocket is conceived.

Gen. Mechling does not feel that hydrogen bombs and nuclear warheads have put conventional weapons out of business.

Local War Concepts

"The increased probability of the delay of all-out war means local or peripheral wars remain a very important problem," Gen. Mechling said. "A large number of people consider we should be able to do a good job without nuclear weapons.

"If you start with a small-scale nuclear bang, both sides can build up progressively to get a big bang. If you have the capability of stopping the thing quickly you may avoid this.

"The concepts of limited war are being studied from the War Plans Division down through major command, requirement and development channels," Gen. Mechling said, "and no overall answer has been given yet."

Meanwhile, AFAC's work continues along two main lines—"exploring what we really need for the future as well as developing what is already underway."

Technological progress has done more to affect the center's day-to-day efforts than the development of nuclear firepower.

Aircraft travel at more than twice the speeds of a few years ago. Rocket propellants and gun gases sometimes behave unexpectedly in the thin, cold air of high altitudes.

A pilot may never see his target because electronic devices see it for him, and the path that a bomb or projectile takes may be influenced not only by speed and altitude but by its shape and the way in which it is fired or released from the aircraft.

Guns will still be used on many aircraft for the next 10 years, Gen. Mechling said.

"But there is considerable feeling that in the future, for many combat purposes, guns will not have sufficient range.

"The concensus is that armament is going in the direction of items of longer ranges and more sophisticated types—sophisticated controlled rockets—maybe programmed, maybe seeker. Most will require both types of warheads."

Organization Modified

In addition to its new development assignment, AFAC has been handed new responsibilities in the ballistics field. These new tasks plus further application of management techniques have resulted in organizational changes.

Directly below Gen. Mechling and his Vice Commander, Col. Eugene A. Romig, a Deputy Commander for Development (Col. Frank M. Fazio) and a Deputy Commander for Testing (Col. Arthur W. Cruikshank, Jr.) have been established.

Under Col. Fazio, an Air Munitions Development Laboratory has been formed. The nucleus of its 130 personnel were transferred from the old Armament Laboratory at Wright Air Development Center earlier this year. Lt. Col. Jan M. Laitos was shifted from

Maj. Gen. Edward Pont Mechling, Commander, Air Force Armament Center . . . ordnance expert and author of articles on ordnance and logistics . . . born Knoxville, Tenn., 1904 . . . graduate U. S. Military Academy, 1927 . . . graduate Army Ordnance School . . . holds mechanical engineering degree, Massachusetts Institute of Technology . . . served in ordnance and staff posts with 8th and 15th Air Forces in Europe and Mediterranean theaters, on Army General Staff and as Chief Ordnance Officer . . . transferred to USAF November, 1947 . . . served on Air Staff, in War Plans Division and as Deputy Director of Armament at ARDC Headquarters . . . took command of AFAC on Feb. 8, 1952.

AIR FORCE ARMAMENT CENTER

- COMMANDER — Maj. Gen. Edward P. Mechling
  - TAG — Mr. Henry Maulshagen
  - VICE COMMANDER — Col. Eugene Romig
    - DEP/COMDR FOR TESTING — Col. Arthur Cruikshank
    - DEP/COMDR FOR DEVELOPMENT — Col. Frank Fazio
      - ADJUTANT — Maj. W. Bruce Harlow
      - INSPECTOR GENERAL — Maj William Yeamen
      - PROCUREMENT — Col. Horace Lanford
      - INFORMATION SERVICES — Capt Carl Crites
      - HQ SQ SEC — Capt George Beale
      - DCS COMPTROLLER — Lt. Col. Benjamin Young
      - DCS OPERATIONS — Lt. Col. Elton Young
      - DCS MATERIEL — Col. Richard Henderson
      - DCS PERSONNEL — Lt. Col. Harry Beamer
      - 6570 TH TEST GROUP — Col. Neil Harding
      - 6571 TH MAINT GROUP (ACFT) — Lt. Col. Carl Willey
      - AIR MUNITIONS DEVELOPMENT LABORATORY — Lt. Col. Jan Laitos
        - GUN AND AMMUNITION BRANCH — Maj. Herbert Holdsambeck
        - ROCKET BRANCH — Mr. Charles Barker (acting)
        - BOMB BRANCH — Maj Louis Sert
        - BM/CW BRANCH — Maj. Joe Heatherly
        - ANALYSIS DIVISION — Mr Paul Thomas
        - OPERATIONS DIVISION — Lt. Col. Jack Whitsett
          - DIRECTORATE OF AIRBORNE SYSTEMS TESTING — Lt. Col. Marvin Kay
            - FIRE CONTROL BRANCH — Maj. William Sloan
            - BOMBING BRANCH — Maj. Ralph Hunt
            - TOW TARGET BRANCH — Maj. Emerson Blair
          - DIRECTORATE OF MUNITIONS TESTING — Lt. Col. Walter Glover
            - WEAPONS AND MISSILES BRANCH — Maj. Relf Fenley
            - FUZE TEST BRANCH — Maj. Harold Correll
            - BW/CW BRANCH — Maj. John Lakin
          - DIRECTORATE OF TECH. SUPPORT — Col. Henry Kuchemann Jr.
            - ENGINEERING SERVICES BRANCH — Maj. Walter Rickert
            - MATHEMATICAL SERVICES BRANCH — Mr. Kenneth Woolsey
            - OPERATIONAL SERVICES BRANCH — Maj. George Brenner Jr.
      - ARMAMENT TEST EQUIPMENT LABORATORY — Lt. Col. Jack Sun
        - ELECTRONICS BRANCH — Mr. Ralph Coe
        - BIO-CHEMICAL BRANCH — Maj. Jerry Moore
        - ADVANCED TEST EQUIP. PLANNING BRANCH — Mr. Martin Brown
        - ELECTRO-MECHANICAL BRANCH — Mr. Nathaniel Raley (acting)
        - PHOTO-OPTICS BRANCH — Mr. Herman Scheppler
        - STANDARDS BRANCH — Mr. John Duffy
      - DIRECTORATE OF BALLISTICS — Maj. William Land
        - BOMB BALLISTIC BRANCH — Mr. Elvin Martin
        - GUN MISSILE BALLISTIC BRANCH — Mr. Foster Burgess
        - ROCKET BALLISTIC BRANCH — Mr. Foster Burgess
        - TERMINAL EFFECTS BRANCH — Mr. Robert Cross
        - COMPUTATIONS BRANCH — Dr Austin Brown

executive officer to head the new lab. It is divided into a Gun and Ammunition Branch, a Rocket Branch, a Bomb Branch and a Biological and Chemical Warfare Branch, which is responsible for developing "retaliatory capability, both defensive and offensive" in the BW-CW field.

To prove out the products of development there is an Armament Test Equipment Laboratory headed by Lt. Col. Jack K. Sun. He must have test instrumentation on the ranges and in working order by the time the Armament Laboratory or a contractor is ready to test.

The old office of the Deputy Chief of Staff for Test Operations has been abolished. Col. Cruikshank, the Deputy for Testing, has an assistant and Technical Director, William C. Lazarus, who holds the center's first Civil Service "super-grade" GS-16 rating.

Col. Cruikshank supervises four Directorates—Airborne Systems Testing, Munitions Testing, Ballistics and Technical Support.

Ballistics Mission Added

The Ballistics Directorate, new this year, is responsible for developing all the Air Force's firing and bombing tables, including those for nuclear weapons. It studies not only ballistics and terminal effects but the fundamentals of blast phenomena, fragmentation, hypervelocity, etc., as they relate to the way bombs, rockets and gun projectiles behave.

AFAC also continues to draw support from its Technical Advisory Group, a long-time dream of Gen. Mechling's.

Gen. Mechling set up the TAG almost five years ago. It was a group of 20 civilian advisors from universities and industrial firms, picked to help with the problems arising from development and use of armament test instrumentation. Now there are 25 members and six non-member consultants, divided into four panels on armament testing and instrumentation, ordnance development and testing, bacteriological and chemical warfare development and testing, and data analysis and processing. TAG's Executive Director, Henry Maulshagen works at the center as a full-time liaison man and coordinator, and the panels meet there twice a year.

New Test Ranges

Development of fire-control and bombing-navigation systems was left at the Wright Air Development Center when other armament work was transferred to AFAC, but AFAC has the responsibility for providing test ranges and testing equipment for these systems.

AFAC has completed or is asking for several new ranges:

• **Inertial Systems Range,** probably the world's largest range complex, acquired at the lowest cost. It consists of three segments—airways along which 50-mile-wide sectors of land, spaced 35 miles apart, have been carefully surveyed and photographed to give radar and optical checkpoints. Since a north-south heading is desirable in testing inertial systems, one segment extends from Eglin to the Cambridge Research Center at Hanscom Field, Mass. Another runs from Eglin west to Holloman AFB, N. M., and the third—almost 4,000 miles long—stretches from Mountain Home, Idaho, through the missile test range at Patrick AFB, Fla., to Ramey AFB in Puerto Rico.

Each segment ends in proving grounds or radar bomb scoring areas, so bombing capability can be tested also.

All instrumentation is carried in the test aircraft. Using vertical photos, radar and time and wind information, a navigator can test his system accurately.

The range was laid out by AFAC with the help of Air Force's Aeronautical Chart and Information Center in St. Louis. Lt. Col. Marvin E. Kay, Director of Airborne Systems Testing, said a technical note written about the range one year ago brought "an unprecedented response, mostly from contractors." AFAC has tested at least one contractor-developed inertial system.

• **Joint Range.** USAF, Navy and AEC want to establish this near existing ranges in the Albuquerque, N. M., area. Lazarus said the range is needed because of "increased versatility of nuclear weapons." The requirement for this range "is from the ballistics point of view," Lazarus said.

An AEC spokesman, testifying about the range before a House committee recently, said the Air Force has told AEC it needs a range 100 miles long on which to deliver a bomb to point of impact. He said the range could not be ready before January 1959. In the meantime, he said, AEC will use part of the land recently released by the Air Force near its Tonopah, Nev., range.

• **Combined Functions Range.** Col. Sun, of the Armament Test Equipment Laboratory, said more area is one of AFAC's most urgent requirements. For gravity-dropped bombs, land ranges at Eglin no longer are large enough.

Equally important space problems exist in testing interceptor and bomber-defense missiles. "The philosophy is to stop being land-tied and become waterborne on 'Mare Nostrum'—the Gulf of Mexico," Lazarus said. Eglin is some 840 square miles in size. In the Gulf AFAC can gain a test area 100 miles by 100 miles by acquiring only one square mile around the Gulf's perimeter—small sites on which to locate

instrumentation. Both the Joint Range and the Combined Functions range still are in the planning and policy stages. Most of the test equipment needed is "well within the state of the art, though maybe not developed this far yet," Col. Sun said.

• **Synthetic Radar Target Range.** This range is approved and programmed. It will be patterned on a smaller one, built last year to test the basic ideas. Located at the East end of Choctawhatchee Bay—the body of water between Eglin's shoreline and the Gulf—the range will have a layout of 1,600 radar reflectors which can be arranged to simulate industrial complexes or other targets.

It will give varying target characteristics for evaluation of azimuth, intensity resolution, geometric resolution and range resolution of radars in bombing-navigation systems. One system can be compared to another at various speeds and altitudes. Wright Air Development Center and Strategic Air Command also will use this range.

• **Damage Potential Range.** Completion was expected this summer. Basically it is a 2,000-ft. level track which can be used dual or monorail to duplicate speeds of weapons plus the speed of the aircraft. The goal is to run sleds at speeds of Mach 3.

Some testing will be done with moving targets, some with projectiles firing against stationary targets to determine interior and exterior ballistics and terminal effects. Fuze testing also will be done here.

In addition to these ranges, AFAC's Ballistics Directorate has in recent weeks taken over operation of the Aberdeen Bombing Mission at the Air Force Flight Test Center, Edwards AFB, Calif.

Until last July 1, Army and Navy did ballistics studies at Aberdeen Proving Grounds, Edwards and the Naval Ordnance Test Station at Inyokern, Calif., for USAF. Now AFAC owns and operates the Ballistics Test Facility at Edwards and a computing facility at Los Angeles, and "other facilities will be used"—presumably the new Joint Range, when and if it is established. Data will be reduced to some degree at the L. A. facility before it is sent to AFAC for further reduction and tabulation.

Fuze Testing Mission

Another new installation at AFAC is its Fuze Test Facility, now under construction. AFAC will do its own tests and provide contractor support for complete testing of fuzes, and Air Force expects to get far greater reliability in fuzes as a result. Before this, contractors have had no single place where all types of fuze tests could be run.

Overall fuze testing was assigned to AFAC in August of 1954. AFAC al-

W. C. Lazarus
Technical Director

Lt. Col. J. Laitos
AMDL Director

ready had been doing the aerial testing. A test laboratory, an 80-ft. drop tower, storage and fuze test safety buildings, and facilities at several ranges are under construction now. Facilities and equipment were recommended in a study made by Diamond Ordnance Fuze Laboratories, on contract.

Laboratory Equipment

Laboratory equipment includes:

• **A gamma ray machine** to determine the condition of fuzes after tests. It is portable, costs less than $4,000, can radiograph through as much as eight inches of steel, and an X-ray machine can be used with it.

• **Closed loop television** to help in remotely examining, inerting and sectioning fuzes.

• **Device to simulate** wide altitude, temperature and humidity ranges and provide conditions for sand and dust tests, fog and salt spray tests and rain tests.

• **A shock machine** with a range from 6 to 24 G's; a jolt machine capable of producing a deceleration of 200 to 275 G's; a "jumble machine" to test safety and ruggedness of design during development; two vibration machines; a six-inch air gun for examining fuzes under different acceleration loads.

• **Later other equipment** will be added, including a rig to simulate spin rates in spin-stabilized rockets and projectiles; a centrifuge simulating 10,000 to 60,000 G's "setback" force; another centrifuge (or "programmed accelerator") to provide setback forces equal to those found in rockets and missiles; a static detonating facility; and a retarding tank filled with soap bubbles, where test items can be slowed from about 3,000 feet per second to about 400. This will be backed up with a catch box filled with a low-density material such as Celotex.

Dynamic fuze testing will be done on the damage potential range, a land impact range and a water impact range. Instrumentation will include contraves theodolites, geo-phones, CZR-1 and Fastex cameras and Micro-flash X-ray equipment.

Some of the most interesting work done at AFAC comes under the supervision of the Air Munitions Development Laboratory. It includes a Munitions Planning Group—a small staff of high-rated civilians, all experts in their field, responsible both for current planning and for the future. Each branch in the lab also has an Advanced Development Section.

Representatives of the lab are assigned to major aircraft manufacturers and the lab's work is coordinated closely with the Air Proving Ground next door, with universities and research groups, and with the other services.

Armament Laboratory projects include:

• **The "Nasty" spin-stabilized** 1.5 inch air-to-air rocket for bomber defense, developed by North American Aviation, Inc. Spin-stabilization, accomplished by canting the rocket nozzles, and high velocity keep this type of rocket from "weathervaning" into the wind when it is fired to the side or rearward. This type of rocket would be fired from rocket guns, achieving its highest velocity beyond the end of the barrel.

• **The T-110 rocket gun** for 2.75 inch rockets. This fires a T-131 spin stabilized aircraft rocket round at a moderately high firing rate.

• **The T-132 rocket gun**, firing short, stubby 38 millimeter (1.5 in.) rockets. Canted nozzles or possibly canted fins will be used. The method of stabilization depends on the intended altitude and controversy still exists over where fin and spin are the most useful.

Gatling gun techniques and lighter rockets may produce rates of fire many times faster than that of the T-110, AFAC's experts say.

• **Revolver cannons.** The 20-millimeter M-39 is through its development stage. Research and development and product improvement were done by Ford Motor Co. after Armour Research Foundation did initial development work. Pontiac division of General Motors is producing it. Ford also did research and development on the T-182-E4H 30-mm. revolver cannon, and Oldsmobile is producing it. Both of these weapons are electrically fired.

• **Gatling cannons.** Production of the T-171 20-mm. by General Electric Co. began at Schenectady, N. Y., and is shifting to Burlington, Vt. The T-212 30-mm. now is being tested.

Emphasis on Ammunition

Dr. David C. Sayles, assistant chief of the Gun and Ammunition Branch, said emphasis on conventional gun mechanisms has been reduced recently and attention has turned to ammunition performance.

Projectile shapes have not been modified yet, but "that does not mean it is not under consideration," Dr. Sayles said.

Launch velocity is an important aspect of the branch's work, and location

of fuzes has been a chief factor in considering modification of ammunition. Dr. Sayles said "extensive programs" are underway on location of fuzes—with safety and 100% reliability as the goals.

The lab is studying the effects of high temperatures and high-speed aerodynamics on trajectories and is investigating the use of consumable cartridges, which would simplify gun mechanisms, eliminate storage problems and solve the ejection problem, where damage to the aircraft is a possibility.

"A variety of unconventional gun mechanisms, radically different" is under study, Dr. Sayles said. The shift to higher cyclic rates and larger ammunition is aimed not only at increased kills but at quick kills—so a fighter has no time to fire back, and a bomber has no chance to unload its bombs on a secondary target after it is hit.

Rocket Gun Advantages

Because more firepower and longer range are desired, interest in rocket guns is strong. In such a launcher, the rocket is held until the proper buildup of pressure from the "gun boost" propellant kicks it away—igniting the rocket's own propellants at the same time.

With this two-stage effect, the rocket reaches its maximum speed at the burnout of its own propellant—which is closer to the target than with a conventional rocket, since the gun-fired rocket has not used up part of its own power to escape from the aircraft.

Gun launching gives higher sustained velocity and higher terminal velocity and allows more of the rocket to be used for warhead. In effect the rocket leaves a part of its "hardware" behind—the gun.

'Programmed' Rockets

The Rocket Branch is looking into "programmed" rockets which would go through a pre-set program at the proper time after launching. Programs can be set in through jet vanes or control surfaces. The rocket might carry its own stabilized platform or accelerometer, plus a timer to tell it when to act.

The Rocket Branch also is working on an "advanced warhead system" for "a very long-range missile." Security restricts the lab from saying anything except that it employs "brand new concepts heretofore not used in weapons."

Since all branches of the lab are organized on the systems concept, the bomb and rocket branches are interested in expendable launchers and expendable pylons for aircraft wings. This "clean-wing concept" is aimed at increasing speed and range.

The same high speeds which have affected other types of armament have radically affected bombs. The aerodynamic flow around a bomb-bay at high speeds can "hold" a streamlined

bomb inside the bay, flip it upward against the aircraft, or cause it to fall without the proper stability.

Increased speeds and the rarified air of high altitudes also cause a streamlined bomb to "fly" long distances before it reaches the ground.

Therefore bombs are being redesigned into "bluff" shapes, more like that of a spool than like that of a projectile. These have the advantages of stability, compactness and a slow fall—which is desirable with nuclear weapons.

A great deal of work has been done but the Bomb Branch says that neither the aerodynamic problems nor the problem of containment of explosive within unusual shapes is solved completely.

Armament Laboratory is working on four or five types of electrical fuzes which will replace the 150-odd mechanical fuzes now in use. The electrical fuze concept began after World War II, taking off from the German Rheinmetall-Borsig fuze. But Maj. Louis R. Sert, chief of the Bomb Branch says the difference in the Rheinmetall-Borsig and the Air Force's electrical fuzes today is like "the difference in a crystal set radio and a superheterodyne."

AFAC's Ballistics Directorate, under Maj. William M. Land Jr., takes advantage of development testing done by the Bomb Branch, using "the piggyback method" of collecting basic ballistic data during early development.

Aircraft 'Mission Tables'

Among the tasks assigned to the Ballistics Directorate is that of compiling the Air Force's new "mission tables" for aircraft. These are designed around the aircraft itself, and replace the old bombing tables, which were based on the bomb, regardless of the types of planes that were to use it.

Mission tables covers all of a plane's weapons, giving descriptions, procedures for inspection, monitoring, inflight procedure, emergency procedures, etc. Some of the data is presented in graphic form but most is in tabular form. The directorate's first mission table is being completed now. It will go out to all interested agencies for comments.

The directorate hopes to learn enough about the fundamentals of ballistics in modern aircraft to provide valuable inputs for the design of future weapons.

New weapons developments do the Air Force little good unless they can be tested and evaluated properly. The center subscribes to the philosophy that testing is a continuous spectrum—not something which follows development. It also believes the Air Force should participate in but not run contractor support tests. One of its stated missions is "to provide test resources and services for contractors and other governmental agencies."

The Vitro Corp. helps in this job by

operating range facilities under the Directorate of Technical Support, with a staff of nearly 300 engineering and technical personnel. The directorate does what its name implies—providing drafting services, doing sheet metal work, installing instrumentation in planes, reducing and computing test data, and operating the ranges in conjunction with Vitro.

Installations work now is limited mostly to modification of stock model aircraft. Major installations are done by the contractor or at Wright Air Development Center.

In the future the directorate, under Col. Henry B. Kucheman, Jr., expects to take over most of the major installation work.

AFAC has its first precision electronic tracking system—a Nike radar—on the base now, undergoing the necessary modifications. It will track at greater ranges and higher track rates and with higher accuracy in restricted visibility conditions.

In the field of test equipment, the center is developing or overseeing the development of:

• **An automatic exposure-control device** for photo-theodolites which changes exposure to compensate for rapidly changing light conditions as the instrument sweeps the sky. This should produce a considerable increase in good films.

• **A device to change the focus** of photo-optic instruments automatically.

• **A telescopic-photographic recorder** to give very long-range photos with greater detail. This is near completion.

• **An infra-red bore sight device** to provide more accurate information on the space position of an aircraft, in digital form, which speeds up data reduction greatly. Use of the infra-red technique increases both range and accuracy.

• **An electronic dive angle control** device which uses APS-42A radar and replaces a system of sighting wires, called a "harp" and the harp's human observer.

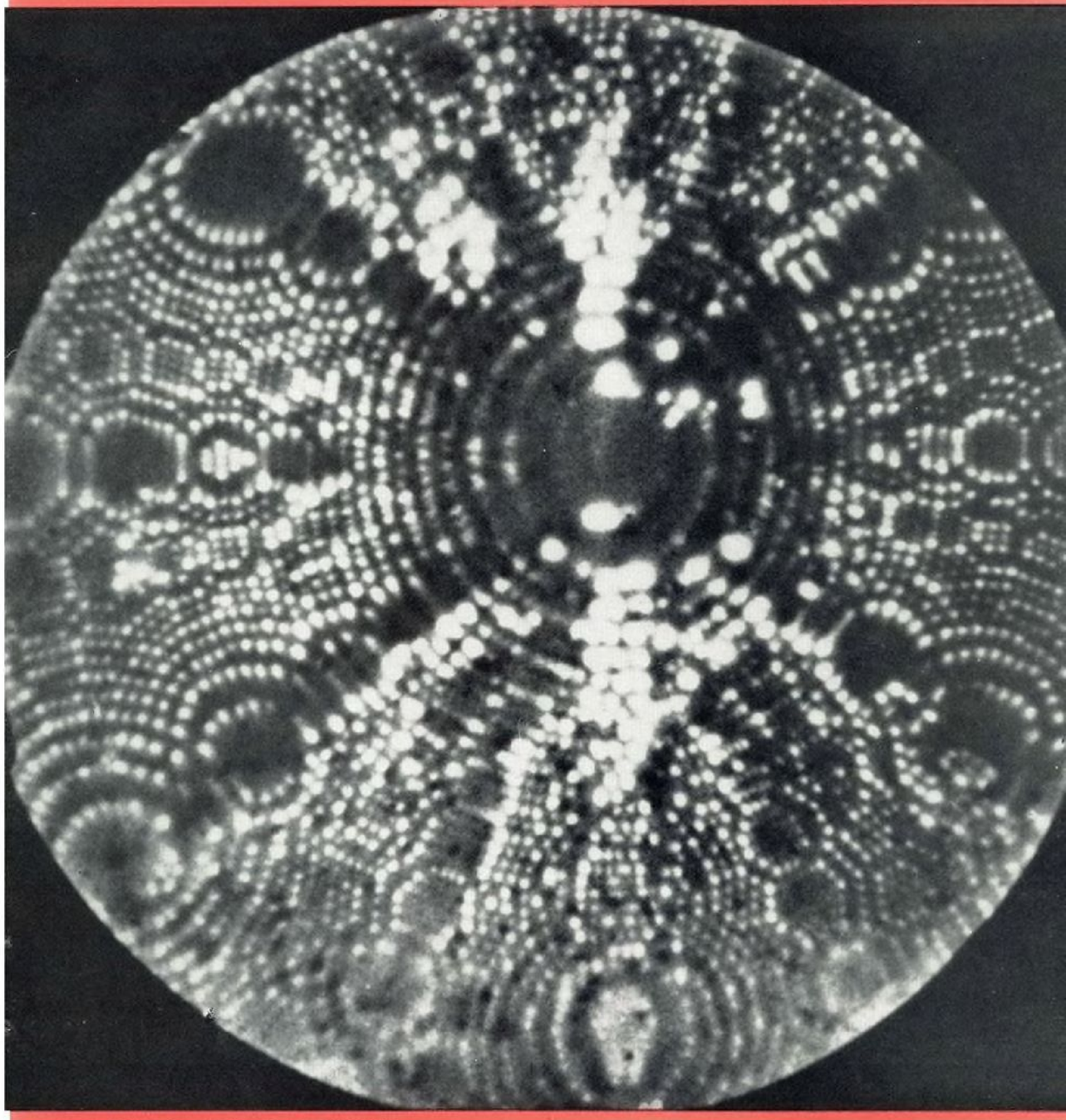
• **A platform for ground testing** of turrets fired under conditions of pitch, roll and yaw.

• **A dynamic fire control assessor** which checks the radar tracking of a moving target against ballistic results.

• **A sharp-winged tow target** for use at speeds above Mach 1. This target, a modification of the East Coast Aeronautics, Inc., "Redbird," has been flown successfully at Mach .9 several times.

AFAC's 6570th Chemical and Ordnance Test Group, with headquarters at the Aberdeen Proving Ground and detachments at Edgewood Army Chemical Center and at Dugway, Utah, supports testing done by the Army Ordnance and Chemical Corps. The 6571st Maintenance Group (Aircraft) operates and maintains 70 different planes of some 27 different types at Eglin. ■

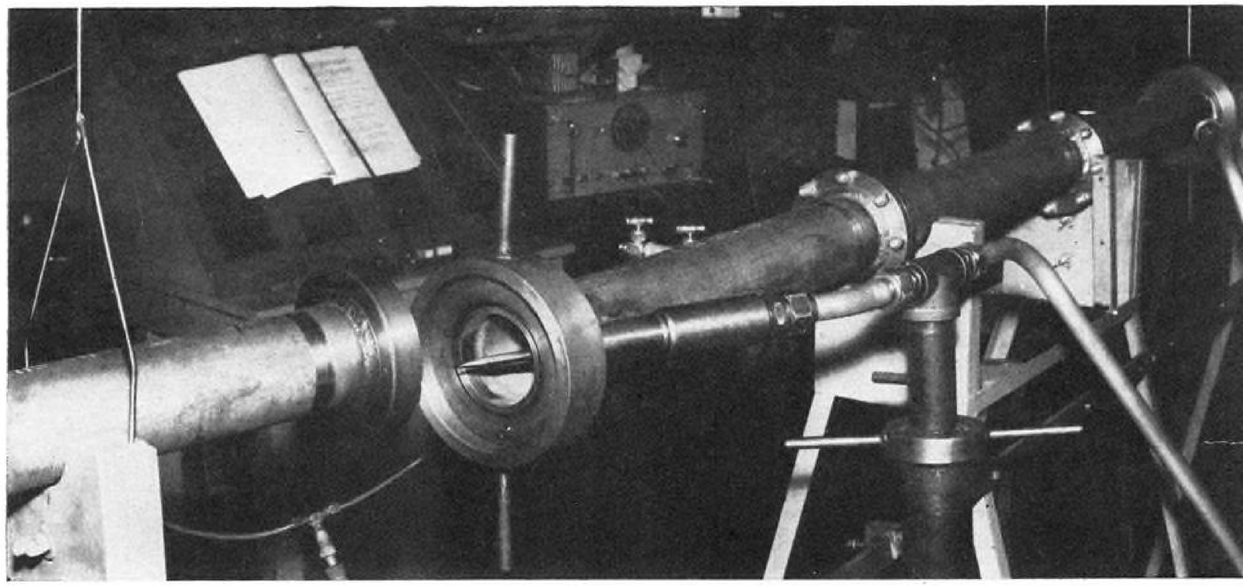
EXPLORATORY RESEARCH



FIRST PHOTO OF SINGLE ATOMS (TUNGSTEN)

AFOSR Sponsors Exploration of New Scientific Areas

Brussels Office Links ARDC to European Scientists



SINGLE PULSE chemical shock tube at Cornell Aeronautical Laboratory should produce clues to combustion processes.

Air Force Boosts Status of Research

Washington—One of the most important developments in the Air Force today is the increased awareness of the need for early research if USAF is to maintain its qualitative lead in weapon systems.

One of the most important results of this awareness is what has happened to the Air Force Office of Scientific Research, manager of a major portion of USAF's exploratory research program.

OSR is housed in Wing 4 of the barracks-like Temporary Building T at 14th street and Constitution Avenue here, and staffed by 115 people. In the 35,000-man Air Research and Development Command, with 10 great centers spread from Massachusetts to California, neither OSR's size nor its manpower total is impressive.

But two developments in OSR's recent history—its elevation to a status equal to the other ARDC centers on Aug. 8, 1955 and its move to the Nation's Capital last July 1—give a truer picture of its importance.

Scientific Crossroads

OSR has been given authority for direct access to the Air Staff as well as all other USAF and government echelons on technical matters. It is located in what is becoming a scientific crossroads of the world from a communications and sponsorship points of view.

OSR officials point out that 33 scientific organizations have their headquarters here. The government is of course the country's largest backer of research and development work, and the head offices of all its sponsoring agencies are here, too.

These changes in OSR's position emphasize three things:

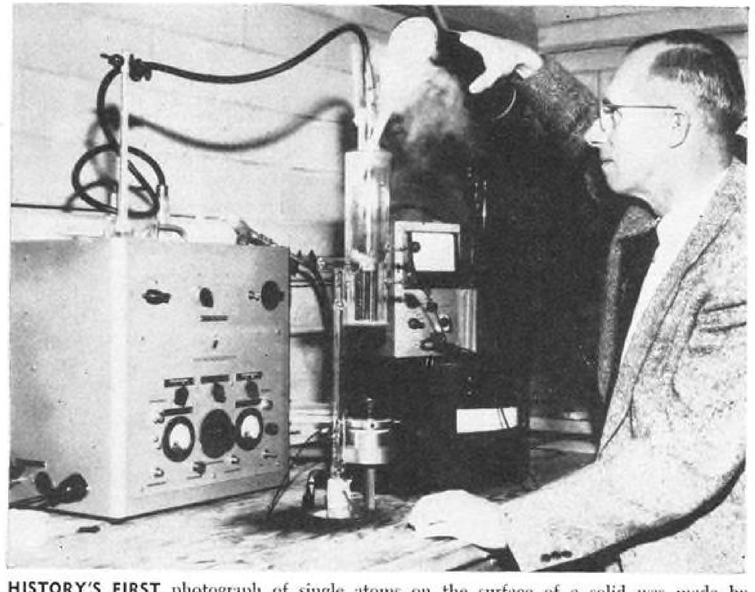
• **ARDC's major effort** to strengthen the position of research within the command.

• **OSR's importance** not only to the command and USAF but to private industry and the country as well.

• **OSR's feeling,** shared by many in the command, that while most of USAF and ARDC are working to stay ahead of Soviet Russia, OSR is working to catch up with the Russians in its field.

Development work is a thing that demands doing today, while the more intangible and less pressing research is easily put off until tomorrow.

"The laboratories have two things—



HISTORY'S FIRST photograph of single atoms on the surface of a solid was made by Dr. E. W. Muller with ion emission microscope at Pennsylvania State University.

problems and new ideas," Brig. Gen. Marvin C. Demler, ARDC's Deputy Commander for Research and Development, said. "They have to work on the problems, and the new ideas get dropped."

Power's Big 'R'

Lt. Gen. Thomas S. Power, ARDC's commander, is acutely aware that the press of time and the command's awesome responsibility—from the first glimmer of an idea until the resulting piece of hardware is in its grave—sometimes has forced ARDC to do development work at the expense of research. He has taken many steps to remedy this.

"I would never be criticized for what I didn't do in exploratory research," Gen. Power said, "and this is just where I should catch hell."

OSR's commander, Brig. Gen. Hollingsworth F. Gregory, said that in the past "there has been a big 'D' and a little 'r' in R&D, and Gen. Power wanted to give the 'r' a bigger status."

Three years ago OSR had some 200 projects under way. More than half the contracts were for less than $20,000. It now has from 550 to 600 projects going, at an average cost per contract of $30,000.

Fewer than 10 per cent of its contracts are with industrial research organizations. Most of the rest are with universities, although industry's interest in exploratory research is growing rapidly, partly as a result of stimulation by OSR.

OSR's staff of 115, which will grow to about 135 in Fiscal '57, includes only two dozen Air Force officers.

In Fiscal 1956, OSR had a budget of about $14 million. (Almost every dollar goes on contracts. OSR's operating budget is very small).

For Fiscal '57 ARDC has set OSR's budget requirement at $25 million and is still pressing for that. OSR's total program costs not much more than a long-range bomber, and a single research finding might save billions of dollars.

OSR's Threefold Mission

OSR's mission is threefold:

- **Plan, initiate and manage** an exploratory research program "to provide new scientific knowledge" which may result in "significant new concepts of air warfare and steady improvement of aerial weapon systems and their use in air warfare."
- **Recognize the implications** and possible applications of significant scientific advances.
- **Recommend to Gen. Power** policies and procedures which will encourage and stimulate research and "enhance relations with the scientific community."

Col. W. O. Davis, Deputy Commander for Operations, sees OSR's job as one of communications. He said OSR is a service organization, dealing only in ideas.

"The only in-shop work we do is thinking," Col. Davis said. "We are managers, and managers are translators. The proper communications pattern is management."

Speaking Several Languages

OSR's translators must speak the languages of practical military men, scientists, industry's planners and engineers—and the not always easy language of the Defense Department, Bureau of the Budget and Congress—that is, the public.

Even within those areas OSR must speak many dialects. The "fragmentation of science" means that even scientists of different disciplines do not always understand each other readily. OSR attempts to serve as their line of communication.

The military services were slow to learn the complex job of managing research, but Col. Davis feels that OSR has had considerable success along this line.

OSR currently is doing a study for the National Research Council to see how its techniques can be applied on a national level.

OSR feels that its stimulation of research produces a number of important by-products:

- **Cross-education of scientists.** Aerodynamicists, for example, have found that dissociation, ionization and recombination of particles of air and metals around the nose-cone of a hypersonic missile produce problems with which they aren't equipped to deal. Therefore, the physicist and the chemist have been brought into aerodynamics and hypersonics in a new way. (These new associations have brought not only new ideas but new names: USAF now refers to these areas as "aerothermodynamics" and "aerothermochemistry.")
- **Cross-fertilization at the weapon systems level.** "Solving a problem in one area contributes to another area and enables the weapon system planner to work in somewhat less than his usual vacuum," Col. Davis said. "It gives him a realistic reading both on what we can do and what the Russians can do.

"Fundamentally, we are optimistic and by being so we also are being most conservative," he said. "To be scientifically pessimistic would be to say that the Russians couldn't do the job either."

- **Building the nation's scientific** potential. Aside from the cross-education of scientists, almost every OSR contract with a university attracts graduate students into areas of USAF interest. OSR estimates, for instance, that some 1,200 graduate chemistry students have been drawn into work on OSR contracts and have gone on into industry.

"Prior to World War II nearly all of the basic research was being done abroad," Col. Davis said. "Even today a great many of the people doing basic research in this country are foreign-born.

"There is a great need to replenish the reservoir of basic scientific knowledge and create a new potential."

Although exploratory work "should be research that won't pay off in development for five to ten years or more," Col. Davis said, OSR is continually coming up with results that may be immediately useful.

Exploratory research as USAF defines it is research done not in direct support of any existing requirement, but "aimed" research—related to USAF's general objectives.

Areas of USAF Interest

Since OSR must work in this almost unbounded area over a period of many years, it has divided USAF's scientific interests into seven broad areas which will remain the same possibly as long as there is an Air Force:

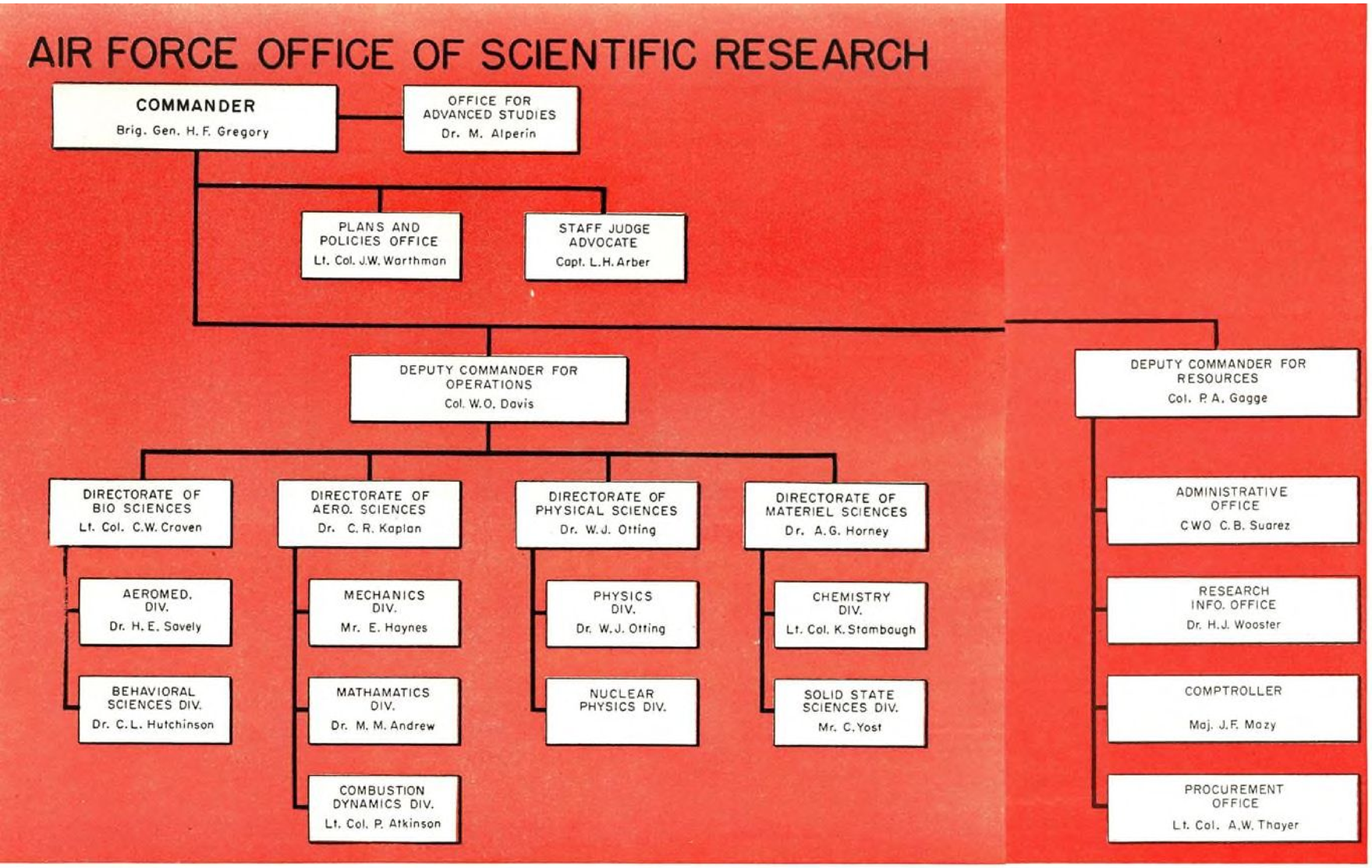
- **Atmospheric flight.**
- **Extra-atmospheric flight.**
- **Detection & identification.**
- **Communication & control.**
- **Information handling & analysis.**
- **Target reduction.**
- **Human effectiveness.**

Its four operating directorates and nine divisions are broken down similarly to the classical science divisions at a university, which eases organizational and communications problems in dealing with the universities.

Directorates & Divisions

They are:

- **Directorate of Bio-Sciences,** with an Aeromedical Division and a Behavioral Sciences Division (social and psychological sciences).
- **Directorate of Aeronautical Sciences,** with Mechanics, Mathematics and



Brig. Gen. Hollingsworth Franklin Gregory, Commander, Air Force Office of Scientific Research . . . born Rockwell, Tex., 1906 . . . graduate Mississippi College, 1926; Air Corps Technical School, 1932; Armed Forces Staff College, 1947; Armed Forces Industrial College, 1949; Strategic Intelligence School, 1951 . . . learned to fly at Brooks and Kelly Fields . . . research and development duties, Materiel Command, Wright Field, 1938-1942 . . . Seventh Air Force in South Pacific in World War II . . . USAF Hq. in requirements and research and development posts . . . senior military member, Office of Chief Scientific Advisor, AEDC . . . Air Attache in Paris, July, 1952 to February, 1956 when he took command of AFOSR.

Combustion Dynamics Divisions.
• **Directorate of Physical Sciences,** with Physics and Nuclear Physics Divisions.
• **Directorate of Material Sciences,** with Chemistry and Solid State Sciences Divisions.

Communication Channels

OSR is constantly advertising for new sources of ideas. It accomplishes its basic objectives—contact and communications—through publications, by having its personnel attend scientific meetings, visit universities and industry.

Aside from scientific meetings, Col. A. P. Gagge, Deputy Commander for Resources, said symposia are about the best means for contact. "The symposium is one of the best tools we've got," he said. "It will never be replaced by paper work."

Possibly the three most important contributions Gen. Power has made to ARDC are his increased emphasis on research, his attempts to let industry know more about USAF's thinking on future weapon systems, and the reorganizing he has done within the command to accomplish these goals.

OSR plays an important part in the symposia, and in the long-range planning done by the command. Its symposia are attended by equal numbers from science, military and industry.

OSR's new Research Information Office will brief industry, arrange symposia and seminars, maintain coded files on all contracts (partly to serve as a distribution list for making USAF's needs known), write trend reports and generally improve communications work.

The Long-Range Future

Just as a development laboratory needs to give some thought to research while it is busy developing, OSR must try to envision USAF's needs of 40 to 50 years from now while it works more directly on problems for an Air Force 15 or 20 years away.

It probably was one of the first groups in the Air Force to give thought to extra-atmospheric flight, and to wonder what aspects of it were comparable to flying in the atmosphere.

"It is possible that space is a new military environment altogether," Col. Davis said. "What are the strategic and tactical considerations out there?

"What we need is a few young Clausewitz types, people greatly interested in strategy and tactics, to do this sort of thinking."

OSR looks to Rand, Inc., the operating commands, the Air Staff and other agencies for studies like this. But, as in other areas, "We have not put up our noses at young scientists," Col. Davis said. "We do not believe all good scientists are already at work."

In spite of the shortage of engineers

and scientists, Col. Davis believes that as far as percentages go, "your younger generation is possibly better than in the past, qualitywise."

But OSR—with its great need for "generalists" who can deal across the board of scientific disciplines—has learned that too many universities give "technical training rather than education," Col. Davis said.

"Too often the scientist or engineer has not had enough general physics and mathematics so he can at least see how what he does affects other fields."

Need Understanding

For this reason, among many others, OSR's primary aim is to gain and help other scientists to gain an understanding broader than their own specific fields. OSR's new crest will bear the motto: "First acquire understanding."

"If we got understanding prior to development," Col. Davis said, "we could do the development in half the time, instead of having to operate in the dark as we do in so many fields now."

OSR's Office for Advanced Studies, Post Office Box 2035, Pasadena 3, Calif., has the responsibility "to think in these scientific areas" listed above and seek this understanding.

It has a staff of nine, which will be increased to 15 in the next year or so. They are hired not as inventors or engineers but as thinkers. The office engages in summer studies, picking up consultants in various fields as they are needed. It also monitors some of OSR's contracts in the West Coast area.

Advantages of Contracting

OSR's system of buying the research time of others has many advantages:

- The man who does the work wants to do it. Usually he has proposed the project himself. Some 40 per cent of OSR's proposals come in without previous contact with the scientist.
- **OSR buys talent which USAF** could not reach otherwise. Even if the Air Force could induce the world's best research brains to leave university and laboratory life and work for it, it could not afford them. With the contracting system, however, it can reach not only the best in this country but also in Europe. ARDC's European Office at Brussels investigates sources and sends proposals back to OSR for evaluation (see following article). If OSR likes a proposal it transfers funds to Brussels and the office lets the contract.
- **OSR can be selective** among these highly-qualified sources. Even though it always is anxious to find new sources, it receives proposals in a ratio of six to every contract granted.
- **By sending men to Europe** periodically to monitor its contracts there, OSR

OUT OF THIS WORLD

in the SATELLITE

Hundreds of miles out in space a rocket burns out . . . and back on earth, optic and electronic instruments begin tracking the first unmanned Satellite as it is launched into its orbit.

Speeding into outer space is perhaps the most rigorous test of components that man has ever devised.

Martin, Baltimore, prime contractor on Project Vanguard, has specified A-MP Terminals and Connectors for the Project because of their proven dependability and enduring quality. Aircraft-Marine products have always been designed to be ahead of the present and abreast of the future.

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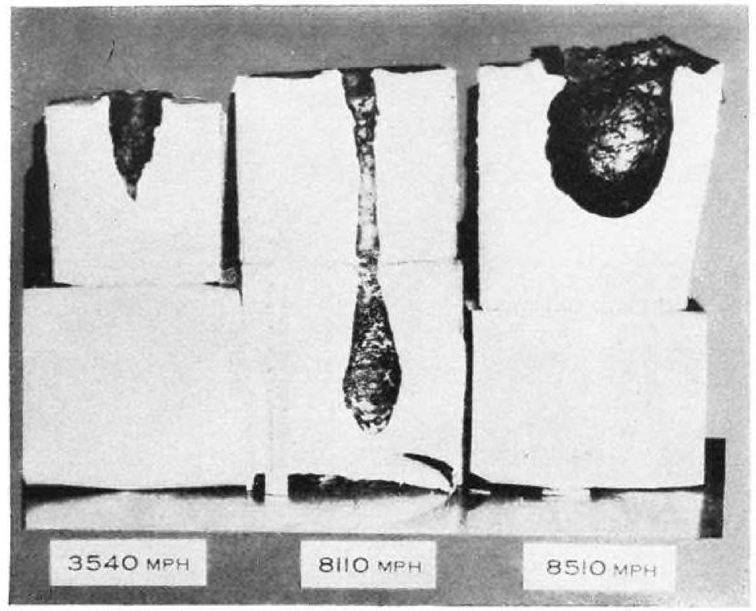


HIGH-SPEED IMPACT PRODUCES CRATER EFFECT

also serves as a liaison between the European and American scientific communities.

• **OSR gets ideas** and weapons it would not have otherwise, and at an extremely low cost. One major breakthrough at the exploratory research level can save millions of research and development dollars.

• **In addition to the resources** of universities and private organizations, it has the rapidly growing research facilities of industry available to it.

For the simple reason that USAF will never be able to pay for all the research needed in support of new aerial weapons, OSR has been asking industry to share research costs on a reasonable basis. Gen. Gregory said industry has given "excellent cooperation" so far.

"Most of the research at this level is not classified nor proprietary and it will be of use to industry as much as to the Air Force," Gen. Gregory said. "Industry is realizing this, and we are working with them to a greater and greater extent."

Most of OSR's divisions work relatively little with industry because of the nature of their research. But the Mechanics Division—which deals with fundamental fluid mechanics, aeroelasticity and solid mechanics—said its contracting breaks down roughly this way:

• **American universities**—$2 million.
• **Institutions**—$140,000.
• **Industry**—$130,000.
• **European sources**—$75,000.

One Mechanics Division project illustrates how tough a job OSR has in trying to recognize implications of scientific work and then sell it to others.

About four years ago Dr. Edwin L. Resler, an associate research professor at Maryland University's Institute for Fluid Dynamics and Applied Mathematics, wanted to study dissociation of air molecules subjected to extremely high temperatures and pressures.

He proposed a shock tube that would simulate temperatures and pressures up to those which would be found at Mach 40, and possibly even Mach 100.

Although many who heard of the proposal scoffed at it, several industrial companies now are using the tube, and it is the only one that can give data in the Mach 40 range.

High-Speed Impact

Another example of exploratory research that may pay big dividends is the high-speed impact phenomenon discovered by Dr. von Valkenberg at the University of Utah.

Using a gas gun, he fired plastic pellets into targets of wax. This gave low shock velocities. It did not require high velocity to get penetration. As the velocity of the pellets increased, penetrations were deeper, just as expected.

But at a speed around 8,500 mph., the pellet suddenly exploded or sublimated, making a shallow pentration but a wide crater, apparently because the pellet's energy was released so fast it turned from a solid to a gas.

This crater-producing phenomenon now is being investigated with metals. One ARDC officer suggested it might eventually find application in an anti-missile missile's warhead. Small particles hitting an incoming ICBM's skin might cause tiny explosions, making the skin "pock" to such a degree that friction would burn it up.

• EUROPEAN OFFICE

Brussels Office Links ARDC To Europe's Scientific Research

Brussels, Belgium—The European Office of the Air Research and Development Command is USAF's window on the European scientific world.

It serves not only to scout Europe's foremost scientific talent but also as a liaison point between the American and European scientific communities —a focal point for the exchange of scientific information.

The European office was established late in 1952. It has no budget of its own, letting contracts only for ARDC centers at home, with funds which they provide.

Exploratory Research

To date the office has let some 200 contracts, a great many of them in the field of exploratory research and most of them unclassified.

The office is headed by Brig. Gen. Don Flickinger, whose background fits him well for the job. His last two assignments before Brussels were as Director of Research at ARDC Headquarters and as first chief of the Air Force Office of Scientific Research after it achieved center status.

Since a great deal of the European effort is in the exploratory research field, OSR is one of Gen. Flickinger's best customers.

Gen. Flickinger's staff totals only 33. But through scientific meetings, visits from Air Force Technical Liaison Officers, press releases, AGARD announcements, personal contacts, and the frequent visitors from ARDC installations in the United States, the office tries to keep Europe's scientists and research institutions abreast of USAF's areas of interest.

Recognizing that the basic research work underlying much of today's technology came from Europe, ARDC believes it is investing in ideas that will pay off not only for tomorrow's Air Force but across the board in whole fields of science.

The Brussels office does not solicit research proposals, although it might contact a scientist whose work is known, to be certain he knew USAF had a need in his field.

When a scientist submits a proposal through the Brussels office, it gets a preliminary investigation before it is sent to the proper ARDC center.

At the center concerned, the proposal is given a technical evaluation. If it is approved, funds are transferred to Brussels, the contract is negotiated by the office here, and the project is under way.

The scientist submits his final Technical Report to this office, it is forwarded to the center involved and the project is completed.

How Research Pays Off

"In most cases the final Technical Reports do not result in a production item that can be manufactured in the U. S.." Gen. Flickinger said. "In other words we are not trying to sponsor development of hardware or gadgets.

"But just as frequently the research done in Europe helps solve applied research and development problems being undertaken by USAF laboratories and contractors in the U. S."

Close liaison work with contractors or prospective contractors in the initial phases of a project pays off. The Brus-

Brig. Gen. Don Flickinger, Commander, European Office . . . first Director of Human Factors, ARDC, 1951 . . . served as Director of Research and Assistant Director for Technical Operations at ARDC Hq. . . . first commander of AF Office of Scientific Research . . . born Erie, Pa., 1907 . . . graduate of Stanford University, 1929, and Stanford Medical School . . . postgraduate training Vanderbilt School of Medicine, Harvard School of Medicine, School of Aviation Medicine . . . rated aerial observer . . . medical officer of the day at Pearl Harbor on Dec. 7, 1941 . . . served with 7th Fighter Command and in China-Burma-India theater . . . commanded Aeromedical School . . . Director of Research, Aeromedical School . . . Air Surgeon, Hq. 8th Air Force.

• EUROPEAN OFFICE

sels staff often advises a scientist to steer clear of work already being performed in the United States.

As a result, less than 10 per cent of all the proposals submitted through the Brussels office are rejected because of duplication.

Who Does the Work

Most of Brussels' contracting is done through universities, although the research talent being bought on a university contract may belong only to one man.

The distribution of European ARDC contracts breaks down this way:

- **Universities: 64 per cent.**
- **Industry: 17 per cent.**
- **National research institutes: 16 per cent.**
- **Individuals: 3 per cent.**

USAF's research efforts were extended to Europe both because ARDC must explore every possible avenue and because Europe's educational environment and approach to science produce a greater percentage of basic research—the perfect complement to the development and production talents of American science and industry.

Belgium was picked for its "very international flavor, and to avoid getting involved in the political arena," Gen. Flickinger said.

Dozen Countries Involved

A recent breakdown of 124 outstanding contracts by countries shows the broad scope of ARDC's activities:

Austria	1	Israel	3
Belgium	12	Italy	12
France	12	Holland	4
Germany	45	Norway	3
Spain	4	Sweden	5
Switzerland	4	U. K.	19

One of the greatest benefits to USAF is that a dollar spent on research in Europe goes roughly two and a half times as far as in the United States, because of the lower salary scales and the fact that European scientists frequently are less concerned with monetary rewards than their American counterparts.

How Scientists Benefit

There are advantages for the European scientist, too:

- **Since most of the work** is unclassified, he is free to publish results in native scientific journals. Both he and his country benefit.
- **ARDC financial support** often means he can undertake work he could not do otherwise.

Occasionally an ARDC contract will result in a temporary exchange of scientists between countries, and in some cases European scientists accept permanent jobs in the United States.

HUMAN FACTORS

PARACHUTIST'S ARTIFICIAL ENVIRONMENT

Human Factors Experts Integrate Men and Machines
AFPTRC Helps USAF Economize on Time and Talent

Mating Man To New Weapon Systems

By George Christian

Baltimore—The Human Factors Division of the Air Research and Development Command's Directorate of Development, is fast becoming the "go, no-go" gage of the most vital areas within the Air Force. Chief is Col. John M. Talbot.

The division's own research and development program—in the fields of human engineering, personnel training and aeromedicine—is pacing USAF's integration of men and machines into weapon systems.

The program's prime objective is to match the human sub-system to the flying machine with high efficiency so as to produce a maximum-performance weapon system which will possess the greatest possible potential.

Major human factors agency is the Air Force Personnel and Training Research Center at Lackland AFB, San Antonio, Tex. (See following article.)

Human factors scientists have the crucially important job of determining the basic criteria for selecting and training Air Force personnel for the many complex tasks to be performed. If the men chosen are not capable of launching, flying or maintaining the extraordinarily complicated and expensive weapon systems entrusted to them, the lethal machines are worthless.

Tackling the Unknown

The principle hurdle confronting the flight surgeons, psychologists, physicists, biologists and others who make up the complex of ARDC is how to tackle the unknown.

How will men and machines react to speeds, altitudes and temperatures never before experienced?

How do you man USAF so it will be capable of handling weapon systems of the future?

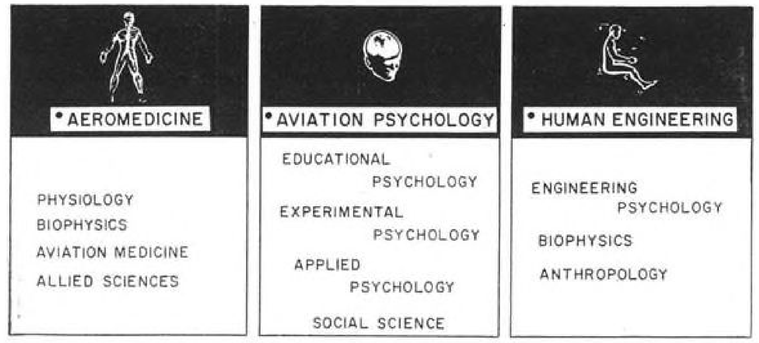
How do you train men to do jobs heretofore unknown?

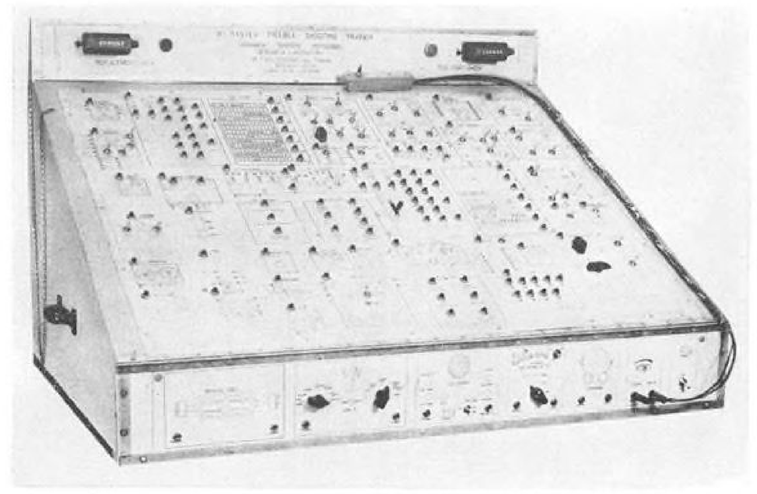
Or, what sort of training syllabus do you prepare for a man to perform a job he cannot perform in test—such as launching an intercontinental ballistic missile or taking off for the moon?

Human Factors Goals

Some major goals of the human factors effort are:

• **Human engineering.** A new concept just getting under way is to have human engineers sit at the elbow of weapon system engineers from the initial design stages straight through





MAC-1 K-BOMBING SYSTEM TRAINER

E-4 FIRE CONTROL SIMULATOR

to the hardware stage. (In the past, they were not associated with a weapon system until the mockup stage). Purpose is to assure the weapon system's compatability with Air Force manpower available, to see that a man will not need three hands to operate it, and to see that it will be readily maintainable.

Newest comer to the growing procession of weapon systems to which human factors scientists are giving their close-attention is WS-125A, the nuclear-powered bomber system being planned for the Air Force.

The big problem is crew radiation. It is not now possible to provide sufficient shielding to restrict crew radiation dosage to the 300 milliroentgens (mr.) per week allowed by the Atomic Energy Commission. Human factors researchers, in conjunction with many other organizations, are searching for a way around this apparent impasse. Navy experience with the nuclear-powered submarine Nautilus is useless to the Air Force—the most radiated man in the ship's entire crew was exposed to about 600 mr. (a two-week dosage by AEC standards) in a whole year.

• **Personnel Training.** Because in the Air Force more than in any other service, men will operate singly rather than in groups—lone interceptors, single atomic bombers, compared to mass infantry attacks and the bee-hive activity aboard heavily populated Navy ships—prediction and evaluation of human behavior takes on an all-important stature.

This is one of the most mysterious areas of human factors that psychologists and psychiatrists have to plumb. They are faced with such posers as:

What motivation drives a man to pilot an inordinately complicated plane at searing speeds through foul weather and withering enemy counter-fire to knock down an attacking atomic bomber, knowing that if he succeeds he may destroy himself in the process?

How do you dissect such a well-worn but significant phrase as "pilot error?" Was the error trained into the pilot, or was it intrinsic to the aircraft, inviting a mistake? Or did the man really malfunction, and if so, why? What prompts a man to malinger?

• **Aeromedicine.** This rapidly expanding field is a fraught with new problems. Here flight surgeons, physiologists, biophysicists and many others delve into such riddles as how to combat zero G, when a pilot finds himself weightless and becomes disoriented; vertigo, an unpredictable dizziness that seems to be related to the increasing speed and noise of supersonic aircraft; and Q loads, determined by indicated air speed and measured in pounds per square inch pressure on the body, which can smash a pilot.

Another aeromedical problem facing scientists squarely is bailout survival. This requires that the pilot be protected from excessive Q loads and deceleration, and that the body body/seat, or body/capsule, be stabilized sufficiently to prevent fatal spinning immediately after ejection.

The human factors division at headquarters works hand in hand with many other military and civilian agencies to help solve as rapidly as possible the seemingly unending problem surrounding the design of WS-125A as an operating weapon system.

Among them are the Aeromedical Panel of the Air Force's Scientific Advisory Board and the Atomic Energy Commission's and USAF's Medical Advisory Group for ANPP (Aircraft Nuclear Propulsion Program).

Currently, human factors scientists are busy feeding results of their radiobiological research program to the Nuclear Systems Project Office in terms that are useful to engineers who must design and build the WS-125A—namely reactor radiation effects on a human body's biological end points.

Predicting Behavior

Predicting and evaluating human behavior is a major roadblock facing human factors researchers. As one told AVIATION WEEK, "If we could, with certainty, predict how an airman is going to act at any particular moment, we would make a real breakthrough in the area of human behavior, and major performance improvements (of human beings) could be anticipated."

What are the components of human behavior? A human factors scientist suggested these several intangibles:

• **Motivation,** that impulse which makes a man perform a specific act at a specific time. There is no known way of accurately predicting that a given person will be inspired to perform the same act each time he is subjected to a given stimulus.

• **Intelligence,** a quality for which there is no actual qualitative measurement. Batteries of tests allow researchers to select intelligent persons from among masses, but the tests are not completely satisfactory for selecting on an individual basis. Much work is being done to refine the tests.

• **Emotional stability,** an intangible component of human behavior which has considerable bearing on how a man behaves under stress. Often, men who stand up best under fierce combat conditions are emotionally unstable maladjusted, anti-social, aggressive types.

• **Adaptability,** a little-known process which allows some people to adjust easily to a new order of things, accept discipline, and generally switch from civilian to military routine without problems.

• **Morale,** an indefinable quality which scientists have not yet been able to put

• HUMAN FACTORS

into a test tube and scrutinize.

Some of the questions the researchers must deal with are:

While these behavior components are all properties of the human nervous system, do they have a common denominator—are they all facets of a common process that goes on in the human brain? Superficially, they all seem to be very different, but what causes, integrates and controls these intangibles?

Urgent Problem Areas

Dr. A. W. Hetherington Jr., outlined these urgent problem areas now being explored by human factors division scientists:

• **Determining the ability** of a pilot to do the many jobs required of him within the time profile of a particular mission, or a phase of operation within a mission.

For instance, here are typical duties that the pilot of a modern interceptor might have to carry out in less time than it takes to read them: radar search, scope interpretation, analysis of the tactical situation, attack conversion, tracking to maintain correct scope pattern, target identification, lock-on, judging the rate of closure, changing over to optical tracking, converting to lead pursuit, firing, breaking off to a position of tactical advantage.

• **Squeezing every ounce** of data possible from test flights. Because of the considerable danger and great expense involved in test flying—a thousand ground man-hours may be expended on one plane to obtain a single hour of test flying—loss of a single channel of data or a minute's flight test time may require expensive re-scheduling. Because the pilot usually is alone, it is difficult for human factors to assure the most efficient use of his every moment in the air.

• **Helping engineers design** into very high performance aircraft the means for crew members to escape safely. This factor breaks down into three conditions where escape systems must function:

Low altitude, low speed—the parachute must open quickly enough to retard a crew member's fall.

Low altitude, high speed—the severe deceleration forces over a short period of time must be within human tolerance limits. Tumbling or spinning must be eliminated or reduced to a minimum because such motions reduce a man's tolerance to deceleration.

High altitude, high speed—the deceleration forces will be lower than those experienced at low altitude because thin atmosphere reduces Q forces. But the duration of deceleration will be considerably longer, which may have even worse effects on a human body than high deceleration over short periods.

The crux of the escape problem is this: Human tolerance limits are fairly well defined. The unknown quantity is: At what levels of aircraft performance are these limits reached?

Research scientists believe the limits of human tolerance to escape in an ejection seat, where injury is the tolerance criteria, are speeds not exceeding 600 knots and altitudes under 50,000 ft.

But what is the yardstick of injury? A researcher suggested that "injury" in this case be defined as a reversible injury or one that will heal itself without undue attention, such as a cut, bruise or slight sprain, as opposed to a fracture or deep cut which would require medical attention to remedy.

Another way of defining an "acceptable" injury is to say that it would not interfere with a man's ability to perform his primary duty when he hits the ground, be that self-preservation, such as seeking a hiding place or paddling a raft, or attacking the enemy.

Destructive Cacophony

The cacophony of modern military aircraft and missile engines—turboprop, turbojet, ram jet, rocket and afterburner—can translate noise into acoustic energy which may be destructive to crew, to airframe and to creatures on the ground.

• **Effects on crew.** Acoustic energy can

cause many adverse effects on pilot and crew. Very high intensity noise in the 160-120 decibel range can create situations ranging from intolerable—such as ruptured ear drums—to nuisance value, such as temporary deafness, with its duration depending on the intensity and duration of the noise.

Noise also may have more subtle, sinister effects on the human body. Since acoustic energy can be transmitted directly through flesh and bone it may be potentially injurious to the nervous system.

Some unusual effects attributable to acoustic energy are nausea, because of possible effects on nerve endings in the abdomen, and loss of equilibrium, or vertigo—conceivably caused by jarring the nerve endings in the ear's semicircular canals.

Scientists also are investigating the possible effects of acoustic energy on muscular coordination. These studies treat sound as a force rather than as a noise.

• **Effect on airframes.** Careful investigation has shown that some acoustic energy outputs are high enough to cause early fatigue failures in basic airframe structure. The same energy is also suspected of promoting premature failure of such relatively delicate aircraft component as avionic gear and instruments.

• **Effects on ground creatures.** The Air Force receives an increasing number of complaints from persons trying to raise animals near air bases, concerning the biological effects of low-flying planes on livestock. Some of the complaints—usually accompanied by a demand for reimbursement—are: mink eat their young, chickens lay fewer eggs, cows produce less milk, and turkeys stampede.

The sound created by gas turbine and rocket powerplants spreads over a broad frequency spectrum. Generally, the lower frequencies—below 1,000 cycles per second—cause the greater damage, while the higher frequencies are easier to attenuate.

A potentially interesting concept, still only a laboratory curiosity, is that of "sound cancellation" (AW Nov. 28, p. 33). This theory suggests that sound pressure fluctuations may be completely suppressed by creating opposing fluctuations exactly out of phase with those to be eliminated.

Perfection Without Practice

The general task of training people to do specific jobs with precision and speed, either as individuals or as a team, is a difficult one. The job takes on added complexity when it comes to training a man to do a job correctly the first time when he cannot practice because it is politically too dangerous and financially expensive to try. Such is the

case in training operators to launch an intercontinental ballistic missile such as Atlas.

Yet if the day comes when the missile has to be launched for blood, it is imperative that the operators perform the job unerringly. Answers lie in simulators and part-task trainers.

This brings up other crucial factors. How much transfer does a man get from a simulator to actual hardware? Is the transfer substantially the same for different men with identical training on the simulator? How much simulation do you need and how realistic does it have to be?

The latter question is particularly significant because realistic simulation costs a lot of money, and it is often difficult and costly to change a realistic simulator to keep up with modifications to the actual flying machine.

Nevertheless, insufficient simulation leads to poor transfer. The problem is: Where is the dividing line between too much and not enough?

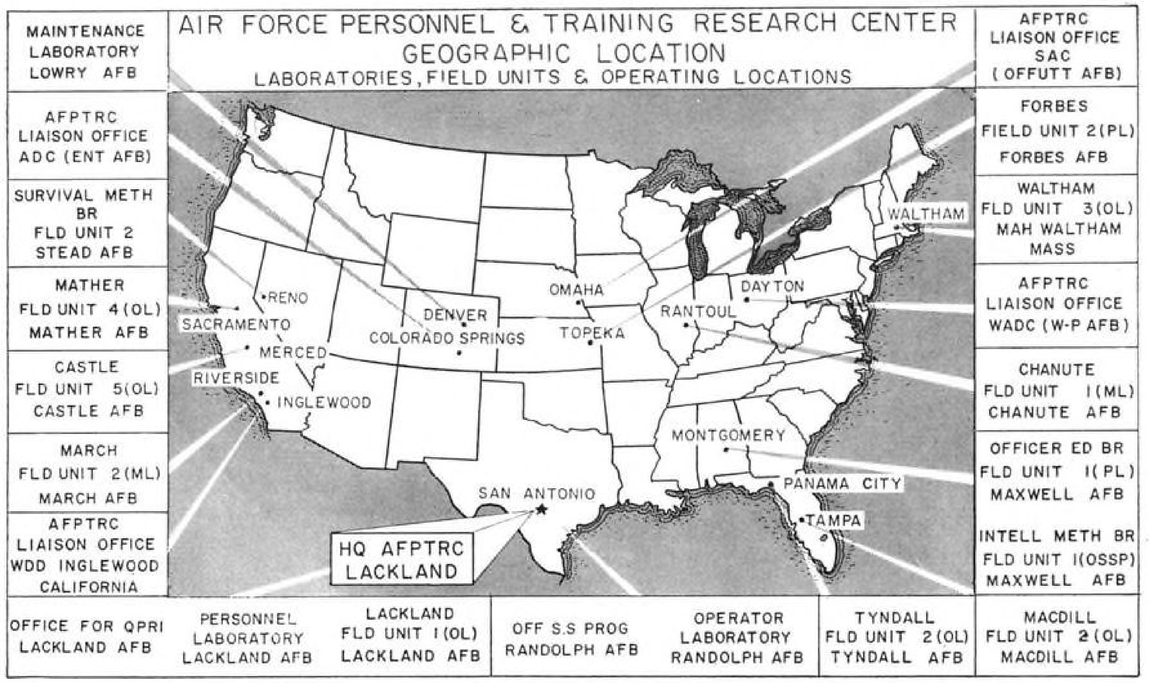
Training Advances Needed

An intense engineering effort is necessary to accomplish the advances USAF requires in the development of special training devices in these major areas:

- **Complete mission simulation**, including 270 deg. visual simulation. This the Air Force wants in 10 years.
- **Full training in a device** capable of simulating all environmental conditions such as G-forces, motion, vibration, noises and lighting.
- **Universal computers** for flight simulators so that machines may be kept up to date without expensive and lengthy down-time, and to make the simulators match successive changes in the weapon system.
- **Synthesized trainer components** which are less expensive to buy, require less lead time to obtain and are more reliable and more maintainable than the operational units now used on trainers. Examples are use of operational radar, and other actual avionic, hydraulic or pneumatic components on trainers.
- **Aircraft observer flight simulator** to give observers (bombardier-navigators) the same mission-type training as is given to pilots.
- **Bomb scoring system** to allow Strategic Air Command and Tactical Air Command to score crews on simulated bomb releases.

In addition, the Air Force wants trainer and simulator manufacturers to continue to emphasize reducing the size of their products and increasing their reliability and maintainability.

Although the human factors scientists deal largely with the abstract and often in the future, ARDC and USAF continually receive from them valuable data that makes the task of molding a weapon system easier.



Lackland Improves Use of Manpower

Lackland AFB, Tex.—The principal resource with which the Air Force Personnel and Training Research Center deals is human beings, rather than laboratory animals or machines.

"There are no monkeys and rats in this outfit. We do all our research with officers and airmen," Col. Herbert N. Cowles, commander, said.

"We do not study mazes and gadgets. Rather, we try to learn more about basic human traits and individual and group behavior characteristics."

AFPTRC does study some electronic and mechanical equipment—in the form of simulators and trainers—but only to determine how it can best fit men and machines together.

Wide Network of Offices

The Center, formed in 1954, has three major laboratories—the Personnel and Operator Laboratories at Randolph AFB and the Maintenance Laboratory at Lowry AFB. Other major units are the Office for Social Science Programs at Randolph and the Office for Qualitative Personnel Requirements Information at Lackland.

Several other units also come under the Center—Intelligence Research Field Unit, Maxwell; Survival Research Field Unit, Stead AFB; Strategic Air Command liaison office, Offutt AFB; Air Defense Command Office at Ent AFB; Strategic Systems Branch at Mather AFB; Defense and Tactical Systems Branch at Tyndall AFB.

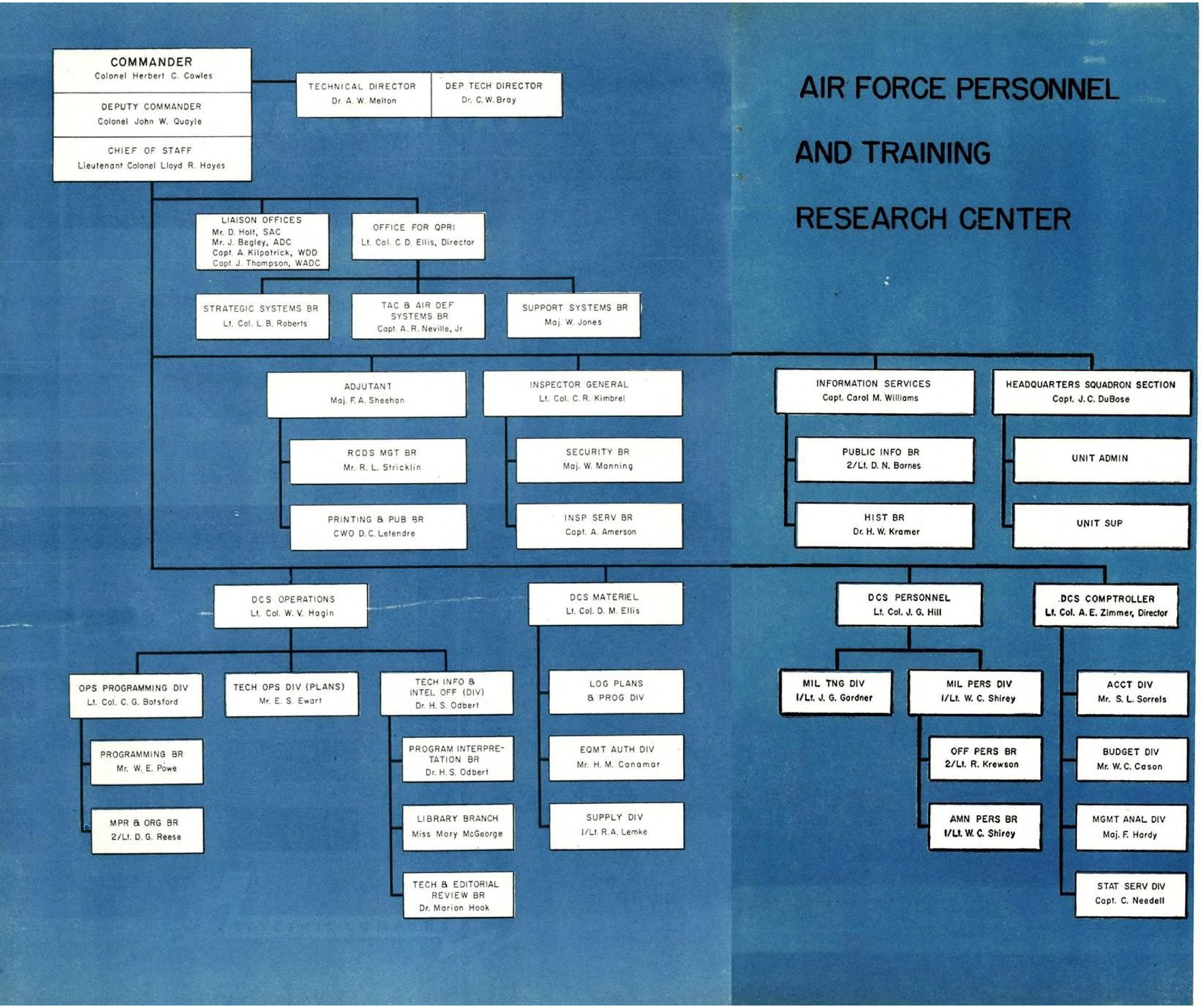
A quick statement of AFPTRC's mission might be, "To help the USAF economize on two essential commodities—time and talent."

A Center spokesman gave this more formal statement of its goal:

The mission of AFPTRC is to maximize the effectiveness with which the limited manpower resources of the United States are utilized through:

- **Determining personnel requirements** of new weapon systems.
- **Improving selection,** classification, assignment and other aspects of the personnel system.
- **Improving training methods** and devices.
- **Improving of team work** and organization effectiveness from the level of individual weapon system crews up through the overall Air Force management structure.
- **Improving methods** for collecting and

Col. Herbert N. Cowles, Commander, Air Force Personnel and Training Research Center . . . born Chicago, Ill., 1908 . . . graduate Northwestern University . . . geology and geography instructor, Southern Oregon College . . . attended Michigan University and Air War College . . . reserve since 1929, active duty since early 1941 . . . special missions in Europe and North Africa . . . Air Training Command Staff 1944 . . . Pacific Air Command, 1947-1949 . . . War Plans Division, Office of Deputy Chief of Staff for Operations, USAF Hq. and chief, Budget and Legislative Division, Directorate of Personnel Planning, 1951 . . . commander AFPTRC (formerly Human Resources Research Center) since August, 1952.



analyzing human factor elements of intelligence data.

By helping other ARDC centers to anticipate personnel and training problems generated by new weapon systems, AFPTRC will help minimize training costs and personnel deficiencies when new systems are adopted, avoid time-consuming and expensive equipment retrofits, and improve future personnel training systems.

By helping to solve personnel and training problems associated with existing weapon systems, the center can improve present USAF personnel and training (P & T) systems.

By accomplishing the necessary research in psychology and social sciences, it can make radical reductions in the lead time required to develop personnel and training know-how. The goal is to have a pool of information broad enough to permit rapid answering of new questions as they arise.

Dual Approach Used

To accomplish its many-sided mission, AFPTRC uses men of many different skills and professions—psychologists, sociologists, mathematicians, electronic engineers and test pilots.

To achieve the Air Force's basic aim of producing the most efficient weapon system controllable by man requires the services of three types of specialists—human engineer, the personnel psychiatrist and the training psychiatrist.

The human engineer tries to fit the machine to the man. Working with design engineers throughout a weapon system's development cycle, he recommends design characteristics that will make the machine most readily used and easily maintained by the greatest number of people.

The P&T psychiatrist works to fit the man to the machine. He develops ways of selecting the best man for the job at hand and devises new training methods to make it easier and faster to fit men to machines.

Since the jobs overlap, each man must keep close track of what the other is doing.

Personnel Laboratory

Mission: "To support the Air Force's personnel system."

To accomplish this, the lab:

• **Does research in support** of an officer and airman career progression program and proposes an advanced education curriculum for officers going to command and staff positions.

• **Develops techniques** for selecting and classifying pilots and other key personnel. As a result many able young men with high school education or one to two years of college have been sent to aviation cadet training.

Validity of USAF pilot selection tests is underlined by these figures,

Dr. L. G. Humphries
Technical Director

Lt. Col. R. L. Beers
Maintenance Lab

using as yardsticks 100 Air Force ROTC graduates going into primary pilot training of those cadets scoring in the upper three brackets (7, 8 and 9), five can be expected to wash out with a loss in training costs of $30,000. Of those scoring in the middle three brackets (4, 5, 6), 21% are expected to wash out at a loss of $180,000. In the bottom brackets, 83% probably will wash out at a whopping cost of $498,000. (Cost per eliminee was figured at $6,000).

Careful checks have shown that aviation cadets compete successfully with ROTC graduates. Also, a greater percentage remain in service after their training.

Mission: "To continually improve the effectiveness with which men function as components of weapon systems by determining skills and knowledge required and improving training procedures and devices."

Emphasis is given to establishing linkage between a new weapon system and its crew so that trained personnel will be available as soon as the system becomes operational.

Part of the lab's current technical program, in the perceptual area, involves working with Strategic Air Command on the problem of target identification. Obviously, the best planned bombing mission is a total failure if the target cannot be identified.

The problem is complicated because radar target presentation is more difficult to identify than visual and if war started tomorrow, 90% of all bombing would be done with radar target identification.

Four devices are used to help observers identify targets:

• **Multiple pictures** so the observer can analyze the target area from several angles.

• **Motion pictures** of the radar scope's presentation. This is not too satisfactory. Because of the degradation factor of today's movie film, it has difficulty picking up the faint traces on the scope which might mean the difference between identifying and failing to identify the target.

• **Video recorder** which reproduces

Lt. Col. C. D. Ellis
Qualitative Personnel

Lt. Col. W. V. Hazen
Personnel & Training

scope presentation electronically, overcoming the degradation factor.

• **Comparator,** a new type of bombing system which will give either a side-by-side or superimposed presentation of the target and the area over which the bomber is flying. No decision has been reached as to which is the better presentation.

Other projects under way include:

• **Target study** to analyze how and why identification errors were made.

• **Determination** of emergency procedures to be taken by the observer in case mechanical malfunction, unpredicted weather conditions, or other impediments create last-minute obstacles.

• **Trainer utilization study** to get maximum use from the machines and speed up training.

Mission: "Identify training requirements for new weapon systems early in the development stage and improve procedures and devices for training maintenance personnel for new and existing systems."

This laboratory has a technical research program covering five areas:

• **Efficient learning conditions.** This revolves around attempts to shorten as much as possible the time required to train a man to do a specific job. Studies have determined that considerable improvement in performance level results when training conditions are arranged so that learning takes place with the least effort.

• **Maintenance training equipment** characteristics. The problem of providing rugged, easily adjusted maintenance equipment which will teach students all the problems of tracing out circuitry, trouble-shooting and the many other headaches of maintaining today's complex aircraft is greatly simplified by using simulator-type training devices instead of actual aircraft equipment. Malfunctions may be set into simulators without damaging them and they can be quickly readjusted for each new problem.

• **Measurement of individual** proficiency. The lab has developed simulator-type devices which measure a man's individual job proficiency at var-

ious points in his training, and later in his career. The aim is to provide a means of determining how well improvable skills have been learned.

• **Effective on-the-job performance aids.** In an effort to avoid forcing a man to memorize masses of material, only part of which is of any significant value during most of his career, the maintenance lab came up with a mechanic's handbook.

With this in his pocket, a mechanic can pinpoint malfunctions without an intimate knowledge of the whole system he is working on.

• **Forecasting maintenance job requirements.** Here the lab is faced with the same problem confronting the other laboratories — what training requirements and skills will be needed to train men to maintain newer, more expensive and more complicated weapon systems as they are produced?

Social Science Programs

The mission of the Office for Social Science Programs is: "The application of social science knowledge to such problems as team-work and morale, leadership and motivation, and intelligence data collection, target communication, survival, escape and evasion, and resistance to interrogation."

This office has developed improved methods for recruiting volunteers for the Ground Observer Corps, helped Wright Air Development Center solve a big ground noise problem, and invented a device to measure the level of mechanics' morale after the introduction of new job methods.

The office also has engaged in studies (sometimes with the help of universities) including: a four-year analysis of the Soviet social system and trends (Harvard); effectiveness of leaflet dropping, including the aspects of physical distribution, speed of news dissemination, and news effectiveness (University of Washington); and how to influence unattainable people.

QPRI Budget

AFPTRC's commander, Col. Cowles, said the Office of Qualitative Personnel Requirements Information is one of the Center's most important non-research programs. It is an engineering service.

Mission: "To provide information and recommendations on personnel and training problems generated by new Air Force weapon systems."

QPRI is a relatively new set of initials in the Air Force's lexicon. One of the first air weapon systems on which the organization did a study was the Lockheed F-104 Starfire.

In Fiscal 1956, the Center used $1,712,000, of which $1,612,000 was under the Technical Program and $100,000 was under the Operational Program. ■

DRESSED TO LEAP from a balloon 18 miles above the earth, Capt. Henry Neilsen bows under the weight of five shells of protective clothing comprising an artificial environment, oxygen and other survival gear.

Aeromedicine Reinforces

By Russell Hawkes

Weak, slow and vulnerable to injury, man still is a vital part of any weapon system.

The Aero Medical Laboratory at Wright Air Development Center, commanded by Col. Jack Bollerud, and the Aero Medical Field Laboratory at Holloman Air Development Center, commanded by Lt. Col. John P. Stapp, have the essential job of learning how to protect man and reinforce his weaknesses.

Aside from its own large inventory of talent, the Aero Medical Laboratory at WADC calls on the resources of private organizations which hold 185-200 contracts and do 60% of the lab's research and development work.

Its total effort cost $4 million in Fiscal 1956 and will cost $3.4 million in Fiscal 1957. The new figure reverses an upward trend in expenditures which amounted to an increase of $500,000 anually in 1955 and 1956.

The lab is divided into seven operating branches, employing 397 people. They include 275 professional engineers and scientists. The branches are:

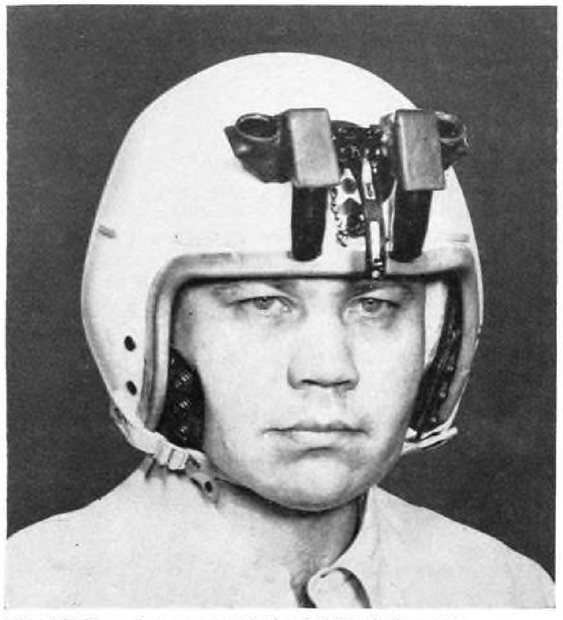
- **Administration and Service** which provides design, drafting and technical services and administrative support.
- **Three branches** that emphasize research—Physiology, Psychology and Biophysics.
- **Two branches** which emphasize development—Engineering and Development and Clothing.
- **Aircrew Effectiveness Branch**, which integrates the results of Aero Medical Lab work into weapons systems.

One of the lab's responsibilities is for research and design of oxygen systems, pressure breathing devices and pressure suits.

Most medical men consider pressure breathing undesirable but it is difficult to find an alternative.

Pressure breathing has been found to be an effective means of raising man's altitude ceiling above 40,000 ft., the safe upper limit when 100% oxygen is breathed at the pressure of the surrounding atmosphere. With increasing altitude, carbon dioxide and water vapor occupy an increasingly larger portion of the available lung volume. At 50,000 ft., where atmospheric pressure is only 87 mm. of mercury, the lungs would theoretically be entirely filled with these two gases at their respective partial pressures of 40 mm. and 47 mm. of mercury. Under these conditions oxygen must be introduced at a pressure higher than atmospheric.

Pressure breathing has shortcomings of its own. It is tiring and it requires a certain amount of practice because it reverses normal lung action.



HELMET binoculars compensate for fast jet closing rates.

UNDER-ARM preserver floats survivor in upright position.

Frail Man

Ordinarily, inhalation is caused by the muscular expansion of the chest cavity and exhalation is caused by relaxing and muscles. With pressure breathing, relaxing the muscles allows the pressurized oxygen to flow into the lungs, and a muscular effort is required to exhale.

Because pressure breathing requires deliberate effort, it is possible for the pilot to expel too much carbon dioxide through his lungs. This upsets the control of respiration, which works by sensing the blood's carbon dioxide.

Although some extra altitude is attainable with pressure breathing alone, the use of this system is limited to positive pressures of 10 to 12 mm. mercury. Pressures above this level not only make it difficult to seal a face mask but also inhibits normal circulation of the blood by compressing blood vessels in the chest cavity and obstructing the return of venous blood to the heart. This in turn reduces the volume of blood pumped by the heart and could lead to fainting in a short time, depending on the level of pressure and the vasomotor response of the individual.

At 63,000 ft. pressure altitude the blood vaporizes at body temperature if pressure is not maintained at a level higher than that of the ambient air.

Pressure Suits

When a pressurized cabin cannot be used, the solution to the problem of flight above the useful altitude of pressure breathing is the pressure suit. It is designed to balance the back pressure exerted upon the hydrostatic column of blood by pressing on the entire skin, compressing the veins and capillaries and increasing venous pressure. This is done on most current suits by a capstan tube which expands, tightening the fabric in a suit already skin-tight.

Aero Medical Laboratory scientists are not convinced that this is the best way to design a pressure suit—but it is the most practical principle for flight. It is the principle of the proven T-1 suit, designed for use in the X-1 generation of research aircraft.

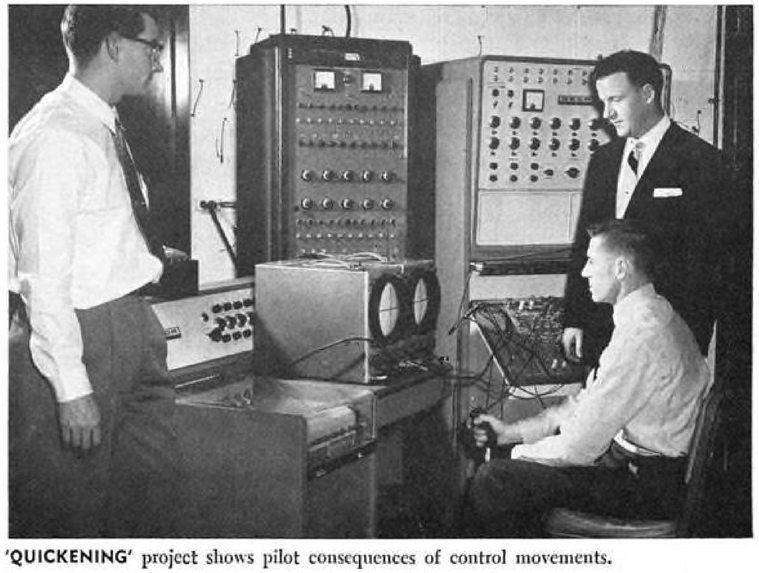
A better method would be to fill a suit with water. This requires no apparatus and would apply a relatively constant pressure all over the body, but few pilots could accustom themselves to being soaked for the duration of a long flight.

Task of a Tailor

To imitate nature, Aero Medical Lab scientists studied the effects of altitude, effort, fatigue, and emotional stress on respiration. They found that in a stressful situation the volume of

ALTITUDE, fire, arctic, rocket fuel, summer flying and summer uniforms.

LT. COL. JOHN P. STAPP, chief of Aero Medical Field Laboratory.



'QUICKENING' project shows pilot consequences of control movements.

respiration may be greatly increased and the quantity of oxygen burned increases proportionately.

Designing a pressure suit is a difficult job of tailoring. Suits must be skin tight and perfectly fitted to a great variety of human shapes which have a tendency to change continuously, according to the habits of the owner. The lab once had to fit a suit to a bandy-legged amateur opera singer with a chest measurement of 56 inches.

To learn the extent of the problem in the future, the lab is practicing anthropometry, the study of human dimensions. Periodic measurements of the generation of World War II crew members have been carried on down to the present to show the effect of age upon the changing human shape. A continuous study of successive generations is measuring the development of the race.

The Aero Medical Lab is seeking a single protective suit made up of five shells which would provide a completely integrated safe environment. It must be pressurized and air conditioned and must protect against high G-loads and immersion in cold water.

The design of seals is proving difficult. Rubber, the most obvious material, develops limitations at the extreme altitudes expected in the next few years. Research indicates that strong ultraviolet radiation and ozone, both present in quantity in the upper atmosphere, cause rubber to deteriorate rapidly.

Living in a pressurized state causes some peculiar effects which the lab is now studying. One is a distortion of sound that occurs when the medium at the source and the medium at the ear have different densities. This is expected to cause some difficulty in interpreting speech, audio signals, etc.

If man's next step to a higher altitude carries him into an orbit outside the earth's atmosphere, rockets must provide the power. The lab is studying the effect of accelerations on the order of those anticipated from manned rocket firings.

It has long been known that heavy transverse G-loads can be withstood for some time without undue discomfort or damage. The question in the minds of Aero Medical Lab researchers is whether a human pilot can perform a useful control function during the burning time of the rocket.

Similar studies are being carried out to determine the effect on pilot performance of having to work under relatively low G-loads positive over a considerable period, as might be the case in a combat situation.

The beating that a human body absorbs during escape from a plane at high speed and high altitude provides a fruitful source of aero medical problems which become increasingly pressing as progress brings faster, higher flying airplanes.

Between speeds of Mach .6 and Mach 1.5 a 15% increase in speed raises the drag-induced deceleration of a man in an ejection seat by 50%. At Mach 1 the decelerations are outside the generally accepted human tolerance of 30 Gs.

Sleds at Holloman

The 5,000 ft. rocket sled track and the 120 ft. catapult sled track at Holloman are being used by the Aero Medical Field Lab to study the effects of wind blast, drag-induced deceleration and tumbling in the moments immediately after ejection. The 5,000 ft. track has a speed capability of 2,000 feet per second, acceleration of 40 Gs and deceleration of 150 Gs. The 120 ft. track is capable of 200 fps., 25 Gs acceleration and 200 Gs deceleration.

Lt. Col. Stapp has made runs on the rocket sled which subjected him to deceleration forces similar to what he would experience if he ejected at Mach 1.7 at 35,000 ft.

Experience with ejection seats has sold the lab on the value of the ejectable capsule. It is now the policy of the lab, WADC and USAF to require an escape capsule in all designs capable of attaining 600 knots indicated air speed or 50,000 ft altitude.

Spinning, Tumbling, Jostling

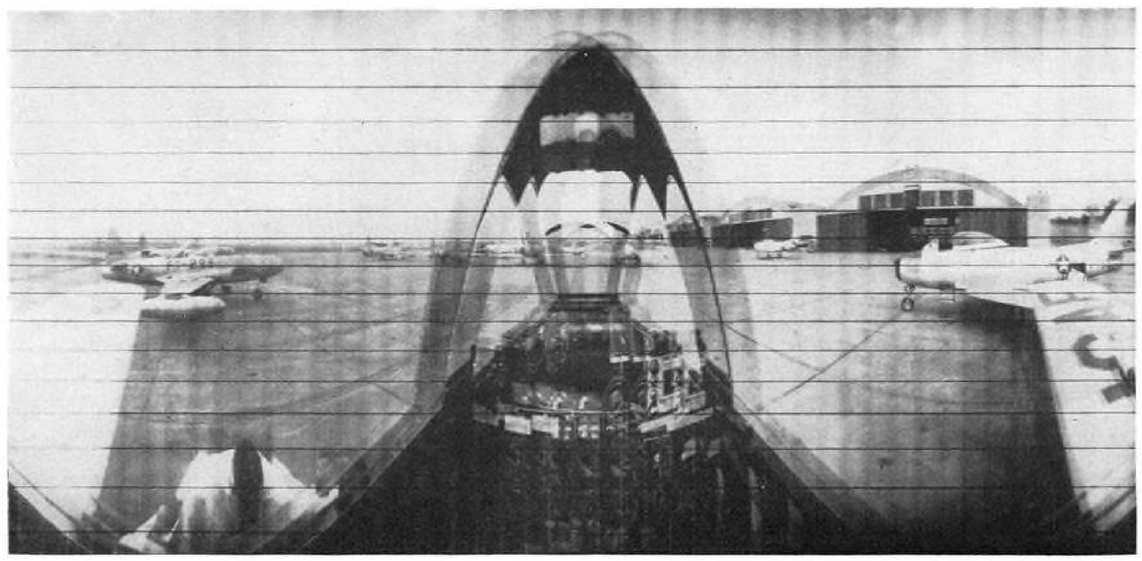
After an escape at high altitude, a long free fall with the parachute unopened is necessary to return the pilot as quickly as possible to an environment in which he can survive. Human parachutists from Aero Medical Lab have jumped from altitudes greater than 40,000 ft. and instrumented dummies have been dropped from as high as 80,000 ft.

Capt. Henry P. Neilsen, the lab's altitude record holder, is scheduled to make three jumps from new high altitudes sometime this fall.

The first jump will be from about 60,000 ft., the second from about 75,000 ft., and the third from 90,000 ft. or higher. Each jump will be made from a free balloon. The last will be from as high as the balloon will go—which could be more than 100,000 ft.

Several agencies and contractors are building gondolas which may be used on the big balloons. WADC is building one which abandons the high strength-weight ratio spherical shape in

'CIRCUIT CAMERA' ROTATES AT PILOT'S EYE LEVEL TO LOCATE SINGLE-EYE BLIND SPOTS.



favor of one shaped like a squat bomb case. It is expected to provide greater stability during its descent after the jump.

Past experience has taught the lab that aerodynamic pressure differentials on the body in a long free fall cause it to spin—usually stretched out horizontally and spinning around a vertical axis at speeds that may be as high as 200 rpm. at high altitude, slowing down at lower altitudes.

A 5-ft. diameter stabilizing drogue chute has been found to keep the body vertical and inhibit the spin, but the jumper sometimes must keep himself from pirouetting rapidly on his longitudinal axis.

The spin can be simulated at WADC on a turntable capable of whirling subjects at speeds as high as 200 rpm. Human volunteers have never spun faster than 125 rpm. A spin table mounted in one car of the human centrifuge at WADC is capable of applying the spin at an animal subject simultaneously with a high linear G-load applied by the centrifuge.

This test simulates the combined spinning and rapid deceleration that takes place for a few seconds after ejection.

The linear G is applied first toward the head, then toward the feet as the body tumbles rapidly. The combined forces produce a "jostling" of the internal organs which can produce damage.

At Holloman the weightless condition is being produced for periods up to 30 seconds by flying an F-94 along a ballistic trajectory. The Air Force is planning for flight in space and is greatly interested in the physiological and psychological results of the zero-G condition.

The Human Equation

In the field of psychology, the Aero Medical Lab is trying to find a transfer function to represent man's part in the servo equation. The task of protraying human performance by a single mathematical expression has so far baffled the lab's scientists because of the infinite variety of responses possible.

Lab psychologists also are studying the advantages of quickening the combination of several inputs in a single instrument presentation to show the pilot the trend and the consequences of his control movements. Such instruments would greatly reduce the skill level required for precision flying.

Work in bio-acoustics is being done with the hope of reducing the discomfort and physiological damage caused by the intense noise generated by jet engines and aircraft, rocket motors, etc.

Hearing loss, vertigo, nausea, and bleeding at the ears have resulted from prolonged exposure to these sounds. The lab is making mathematical and physical analyses of their vibratory characteristics and testing protective devices at the source and at the receptor.

Human vision is increasingly inadequate for the demands placed upon it in flight. At supersonic speeds, flight by visual reference to objects outside the aircraft requires better perception than the average person has. Night flying and the extreme altitudes of space raise the problem of finding an external reference on which the eye can focus.

The Aero Medical Lab is trying to produce practical helmet-mounted binoculars. The demand for these arose when USAF discovered that over 60% of the pilots in the Korean war carried hand-held binoculars. The lab is also interested in the development of image-stabilized binoculars to eliminate eyestrain caused by jiggling of the glasses. A test model has the reflectors mounted on gimbals and stabilized by small magnets.

A periscope development project is under way which USAF hopes will eliminate the need for the big drag-producing, difficult-to-cool cockpit bubble necessary for visibility on present aircraft.

A periscope also could provide forward visibility for planes taking off and landing in a nose-high attitude, which reduces direct runway visibility.

'Empty Field Myopia'

In studying the performance of the eye under operational conditions, Aero Medical Lab has encountered the problem of "empty field myopia," a form of near sightedness that attacks even the normal eye when it has no reference point on which to focus. This occurs in night operations and is expected to occur in space.

The lab is using an infra-red "retinascope" to measure the refraction of infra-red reflected through the lens of the eye of a subject in a darkened room. The results are expected to show what happens to the structure of the eye with empty field myopia.

Cockpit visibility of aircraft is being measured, using the circuit camera developed by the Civil Aeronautics Administration. The camera has two lenses to simulate the pilot's eyes. It is placed at head level in the cockpit and rotated 360 degrees. The film automatically moves under a slot aperture, making a panoramic view showing five degree grid lines and single-eye blind spots in a metric rather than a graphic form.

One Aero Medical Lab study is checking the effect of high G-loads upon vision. Aside from the black-out caused by the increased apparent weight of the blood and the hypoxia of the brain and retina which result from inability of arterial pressure to compensate, results indicate there is a decrease in visual acuity due to mechanical effects upon the eye itself.

The G-load on the crystalline lens of the eye causes the supporting tissues to sag and the lens to move out of focus. Placing the pilot prone or supine does not eliminate the effect.

New Clothes and Food

The Aero Medical Lab is responsible for the development of much of USAF's uniform and protective clothing—from a proposed uniform for the Air Force Academy to ABC (Atomic, Bacteriological, and Chemical warfare) protective garments.

As part of ARDC's Aircraft Nuclear Propelled Program (ANPP), the lab is studying the possibility of designing a suit to protect crew members from the radiation of the pile.

Aero Medical Laboratory is responsible for the development of foods and feeding systems to meet the special needs of the Air Force.

In Korea bad pre-flight feeding resulted in a loss of air crew efficiency due to abdominal cramps caused by the expansion of gases in the intestines. It has long been known that the volume of internal gas doubles at a pressure altitude of 16,500 ft. and increases sevenfold at 39,000 ft. The lab is developing foods and feeding schedules which will avoid this.

While long-range undernourishment is not a problem among Air Force flight crews, lab studies indicate that feeding neglect which is tolerable for eight hours may become critical in 24 hours and destroy the weapon system in 48 hours.

With the advent of nuclear powerplants, the effect of radiation upon food becomes important.

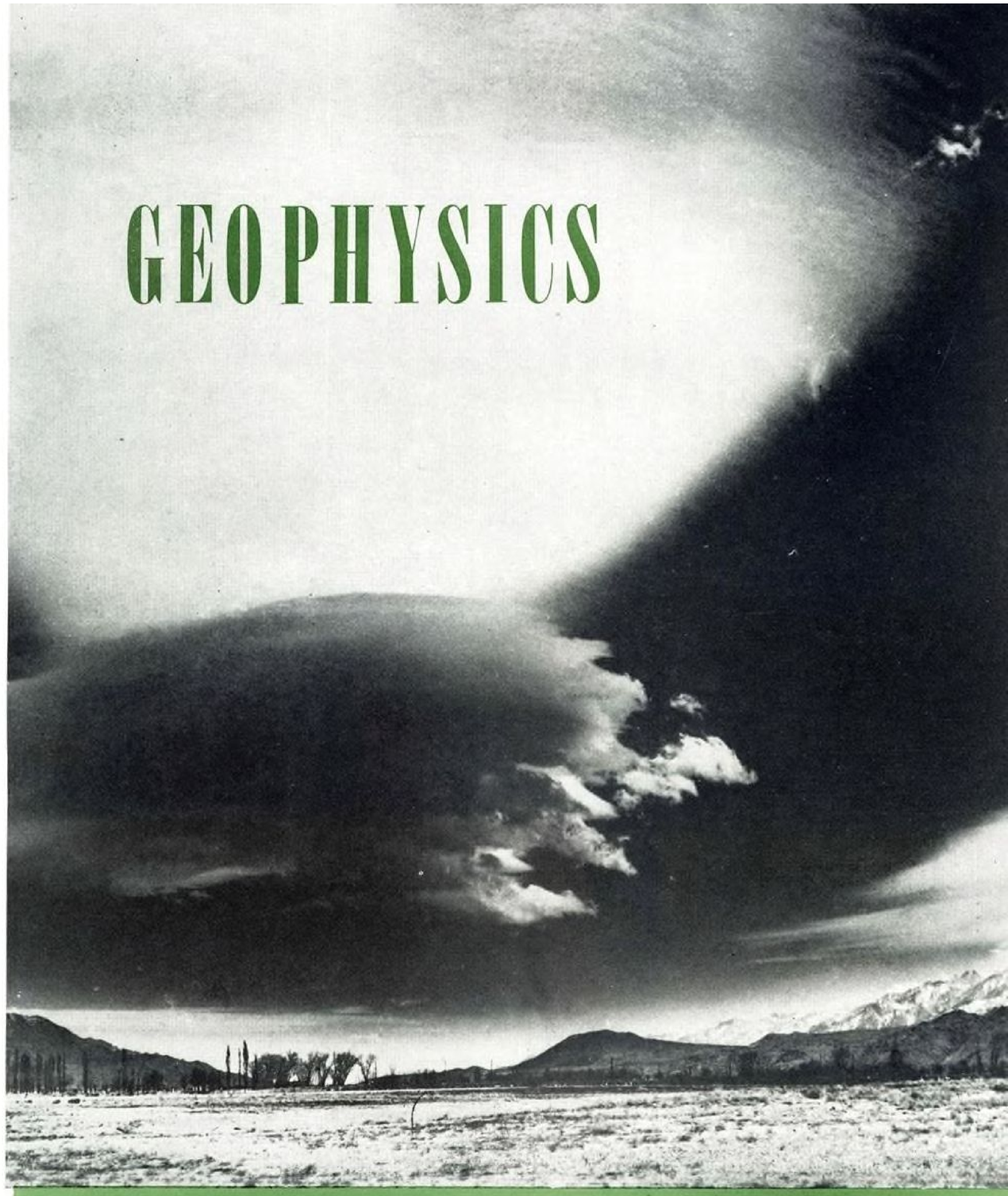
Air Force also hopes to take advantage of the beneficial effects of food upon the boredom that will be experienced in flights of the long duration possible for nuclear aircraft.

Research has shown that prolonged flight changes the respective palatability of foods. Noise, vibration, and decreased oxygen hinder the digestive process. At the end of a long flight appetites decrease and food is apt to be regarded more critically.

Comparative studies show that potatoes, vegetables and salads become about 20% less desirable in the air. Soups and meats hold up fairly well and desserts and baked goods remain popular.

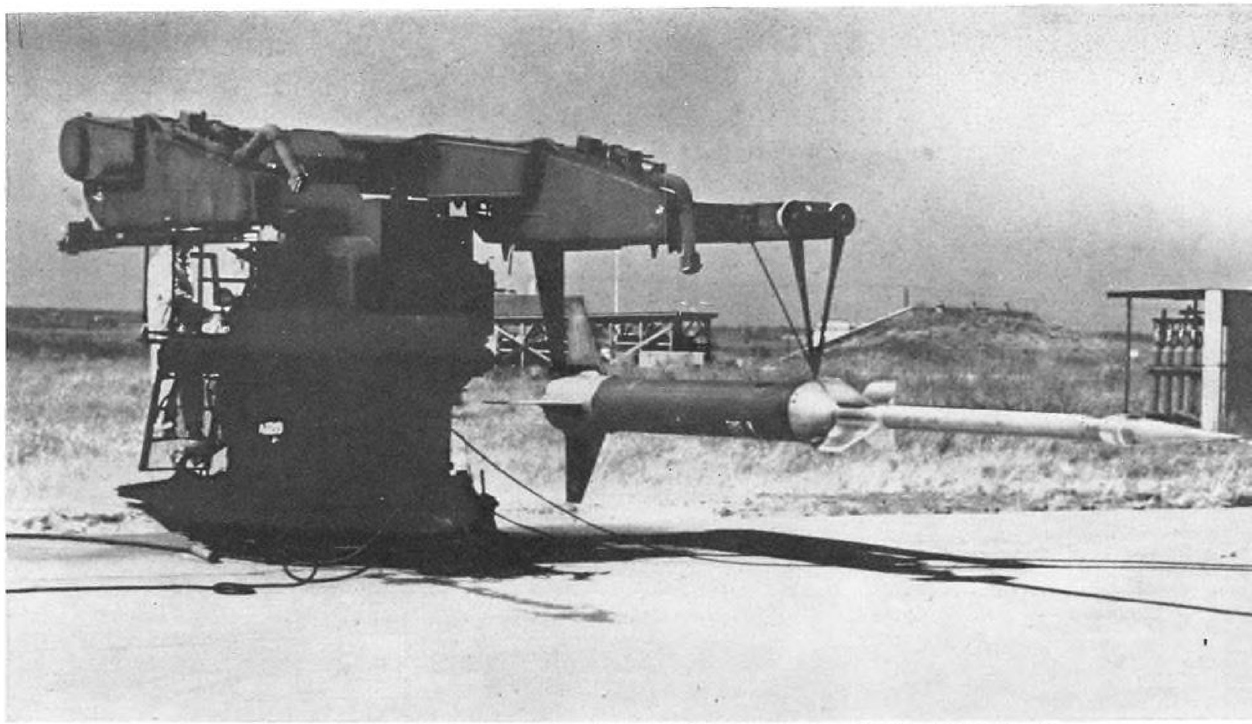
Aero Medical Lab is searching for a single, non-perishable survival ration that will be adequate for all climates and survival situations. The range of modern aircraft being what it is, a single flight may traverse many types of climate and terrain. ■

GEOPHYSICS



LENTICULAR CLOUD FORMED IN 'SIERRA WAVE'

Geophysics Develops USAF's 'Map' for Space Flight



DAN ROCKET (DEACON AND NIKE) USED IN GRD-UNIVERSITY OF MICHIGAN STUDIES AT WALLOP'S ISLAND, VA.

Geophysicists Survey Realm of Flight

Hanscom Field, Mass.—Victory in war often has gone to the side with the best maps. It is the purpose of the Geophysics Research Directorate of Cambridge Research Center to provide the Air Force with a "map" of its potential theater of operations—a vast four-dimensional region extending outward from the surface of the earth through the changing fluid atmosphere to unknown limits in the space beyond.

USAF's "map" must be a body of knowledge about the many physical processes and dimensional relationships which influence the operation of aircraft and missiles.

Because of its mission, the Directorate's definition of geophysics is broad. GRD studies delve into solar physics, space physics, ionospheric physics, atmospheric physics, meteorology, micrometeorology, geodesy, geomagnetism, and other terrestrial sciences. Some of these sciences also are being extended to include actual control of geophysical processes.

The Directorate's mission is closer to pure research than the missions of most ARDC units. There is little development of end-items of equipment except for balloons and ground-based meteorogical instruments designed for USAF by the Atmospheric Devices Laboratory. End-items of technique are more common but the product is primarily knowledge.

Serving Three Air Forces

The members of GRD are conscious that they serve three Air Forces—the Air Force in-being, the Air Force of the near future, and the Air Force of the distant future.

The requirements of the three Air Forces differ in the degree of precision and the operational readiness required of Geophysics Research Directorate's problem solutions.

For the Air Force in-being, present knowledge must be applied to present problems. The problem input usually is supplied by USAF's operational commands such as Strategic, Tactical and Air Defense Command. The solution output often is of the "quick-and-dirty fix" type and is deplored by research people as evidence of poor planning in the past. Relatively often the solution will appear in the form of an end-item of hardware or technique for use by the Air Force.

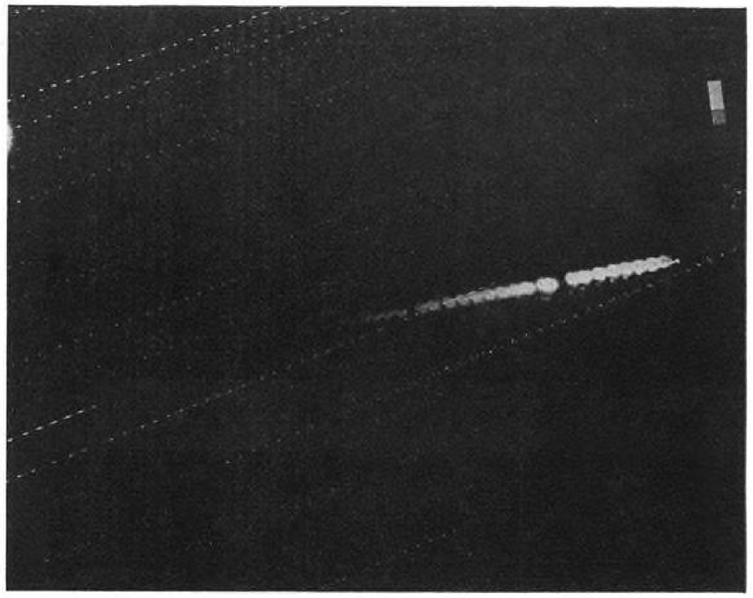
GRD hopes to reduce the need for this type of solution by solving the problems of the Air Force of the near future before they arise. The fast development pace in aviation imposes strict time limitations on this work and solutions must be nearly as specific and complete as those for the Air Force in-being. Problem input usually is supplied by the aircraft and missile builders. Solution output is in the form of design criteria for aircraft on the drawing boards and operational techniques for their use.

No specific end-items are sought for the Air Force of the distant future. It is served by advanced research studies to determine the physical laws which will provide design criteria for weapon systems that will be in service in 20 or 50 years.

Talent & Organization

Rich in talent, the 450 people who form the Directorate include what may be the most potent concentration of scientific talent in the broad field of geophysics. The principles of organization stress the importance of having expert scientists not only in the laboratory but in key administrative posts.

The aim is to eliminate a communication barrier and avoid the corporate split personality that often results when separate administrative and scientific classes have to live together. The value of the arrangement is believed to more



AEROBEE-HI EMITTED NITRIC OXIDE CLOUD WHICH GLOWED ON RELEASE OF STORED SOLAR ENERGY

than offset the loss of scientific talent from the laboratory.

GRD and the Contractor

About 20% of the dollar value of GRD's work is done at Cambridge. The remaining 80% is done by contractors, including non-profit research foundations, universities, and private industry. There usually are 15 or more foreign contractors doing unclassified research. This avoids an additional drain on overworked scientific manpower in this country, gets the work done at less cost, and in some cases draws on experience not available in this country.

Working scientists in the Directorate have the collateral duty of monitoring the work of contractors in their own specialized fields.

The field of geophysics is so broad and the number of organizations engaged in geophysical research is so small that there is relatively little competition for contracts. Because of this most contracts are let on a "sole source" basis rather than by competitive bidding.

Faced with the same shortage of scientific, engineering, and technical manpower that plagues the rest of aviation, GRD is using a pool of partially trained graduate students to help fill the gap, thus taking advantage of the proximity of good schools in the Boston area. Some students doing unclassified work have been able to use their project reports as theses for graduate degrees.

The basic need of all science is measurement. One of GRD's concerns is to provide an inventory of research equipment for making these measurements.

The Directorate has developed balloons capable of probing the atmosphere up to altitudes of about 100,000 ft. It is a paradox of modern science that balloons, the earliest means of successful flight and long considered obsolete, should now prove superior to many vehicles of later concept as research devices.

Although rockets can reach higher altitudes than balloons, they can take measurements only for a few seconds before plunging back to the earth. They are, of course, also immensely more expensive.

One type of balloon is the non-extensible polyethylene constant level balloon such as the "Moby Dick." This type of balloon rises or sinks with the altitude of a given value of barometric pressure, making it possible to chart the contour of pressure levels.

Simultaneous Launchings

The trajectory of a balloon may be traced to show movement of the parcel of air in which the balloon is imbedded.

Drift rate differentials of several balloons released simultaneously indicate horizontal wind shear and changing distances between balloon tracks indicate converging or diverging air flow. These measurements, too, may be correlated with pressure level contour and weather.

Some of the balloons have been tracked around the world by radio direction finder. The information gained is useful in perfecting theories of the general circulation of the atmosphere, which are important in the development of long-range forecasting techniques. One ballon launched last February at Vernalis, Calif., traveled three-quarters of the way around the earth in 14 days, driven by the temperate zone westerlies.

Currently under development is an air-launched balloon to be released in the center of circular storms such as hurricanes to serve as radar reflecting beacons for tracing storm movement.

The balloons are expected to travel with the eye of the storm. Development of this balloon poses a considerable engineering problem because of the stresses involved in launching from a fast-moving airplane.

Another balloon is being developed as a missile target.

Rockets for Research

The Directorate is responsible for the rockets used in geophysical research. Though it is not called on to design rockets, it must instrument them, operate them and occasionally modify them.

The Directorate now has a considerable inventory of rockets:

• **Aerobee-Hi,** a joint Air Force-Navy development of the retiring Aerobee, currently is the best rocket the Air Force has for extreme altitude studies. It can carry a 150-lb. payload to an altitude of 140 miles or more. This is more than twice the altitude attainable with the old Aerobee carrying the same payload.

• **For somewhat lower altitudes,** two-stage versions of smaller rockets such as the 300-lb. Deacon have been used.

• **One of these is** DAN (Deacon-And-Nike), a Deacon rocket lifted 80,000 or 100,000 ft. by a Nike booster before firing. The Cajun is a new two-stage rocket system capable of lifting its payload to altitudes of 50-60 miles.

• **A new air-launched rocket** known as Rockaire soon will be in use. It is designed to be fired from a fighter in a vertical pull-up at an altitude above the densest part of the atmosphere. Burnout is at about 50,000 ft. and maximum altitude is about 250,000 ft. It is fin-stabilized and uses solid propellant with a burning time of 3 seconds. Information will be telemetered from the 40-lb. instrument payload to a second aircraft bearing telemetering receivers nearby. Parachute recovery of the instrument section may be provided for the first few firings. Rockaire is designed and fabricated by Douglas Aircraft Co. and will be assembled by GRD crews at the launching sites. GRD also may modify the rocket for specific tasks.

Nearly all of GRD's rocket launchings are from bases in New Mexico. As a result the upper atmosphere over New Mexico is well studied but the degree to which the results can be extrapolated to other regions is uncertain. This will be rectified to some extent during the International Geophysical Year (June 1957-December 1958) by the joint operation of a launching station at Ft. Churchill on Hudson Bay by Canada and the United States.

It is reasonable to assume that someone will continue to operate the site after the Geophysical Year ends. The Ft. Churchill location will permit discrimination of effects with latitude. Rockaire firings at various other locations are expected to supplement firings from the fixed sites. Data thus gained will have broad applicability.

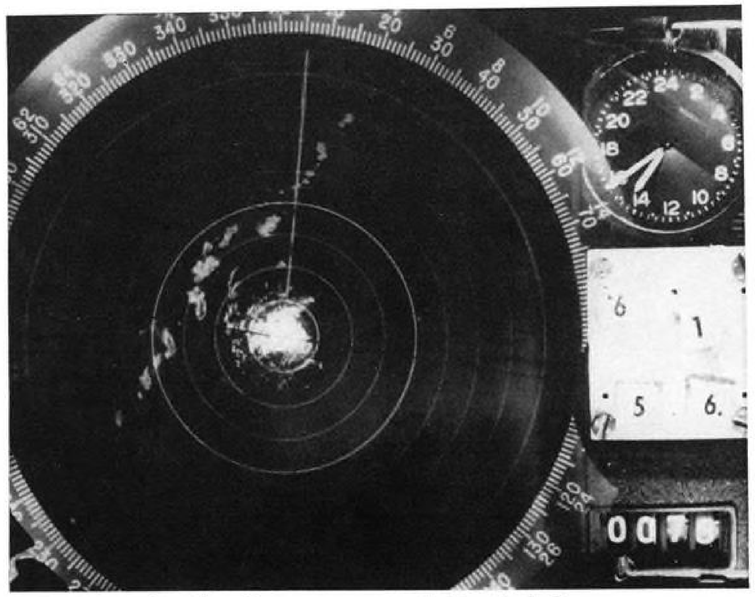
Automatic Meteorology

GRD recently has completed work on the "ARDC Model Atmosphere, 1956," which extends from 300 to 500 kilometers. This and a recently revised standard atmosphere extending to 300 kilometers probably will become design requirements for aircraft and missile designers with Air Force contracts.

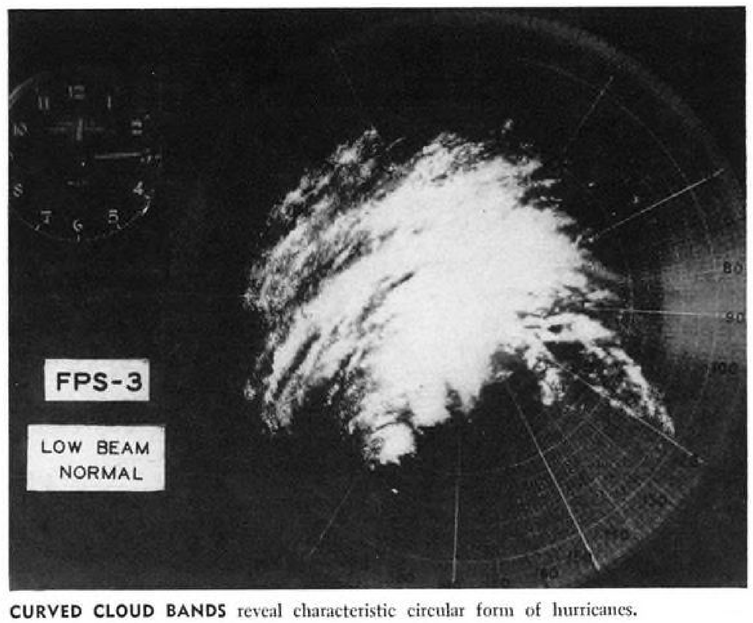
The new standard and model atmospheres extend the ICAO standard to altitudes accessible only to rockets. The ICAO standard was based upon balloon soundings. The new model atmosphere probably will be revised periodically on the basis of additional data.

Efforts are being made to increase the efficiency of weather observing and data transmission and to remove the subjective element from analysis and forecasting. Three approaches are automation of data collection and transmission, objective map analysis,

AEROBEE-HI rocket used by geophysicists for upper atmosphere research.



RADAR SCOPE shows line of severe storms over the New England area.



CURVED CLOUD BANDS reveal characteristic circular form of hurricanes.

and numerical weather prediction. The three approaches may someday be unified into a single automatic system.

Observations from runway-located instruments are already being telemetered automatically to the meteorological offices at some air bases. The next step is to transmit the data to central collecting points automatically and automatically disseminate it to forecasting stations.

Automatic map analysis is the electronic plotting of isolines for use in the preparation of forecasts. It is already being done in a crude way by a joint Air Force-Navy-Weather Bureau team using IBM 701 and 704 computers. The approach is based on the results of a GRD-Princeton study.

Numerical weather prediction is the automatic preparation of prognostic charts by electronic computers. To date experiments have been limited to relatively simple isoline forecasts for the upper atmosphere. Though numerical weather prediction would be the last step in a completely automatic procedure, its technique is nearest to operational use. At first precipitation and local effects will have to be entered by a human forecaster. In five or ten years the experts believe it will be possible to forecast automatically the precipitation associated with any storm 500 miles or more in diameter.

Aircraft Landing Aids

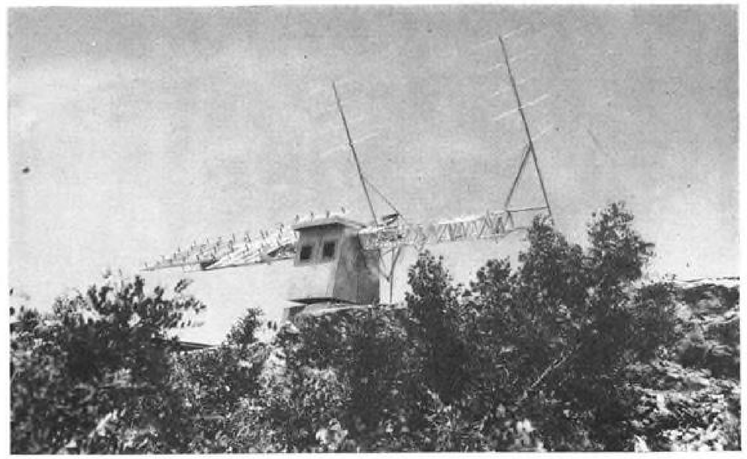
Instrument weather lowers the number of planes that can land at an airport in a given time because of the reduced distance at which the pilot can see and recognize the ground. For safety's sake the traffic controller must expand the interval between landings, causing traffic to stack up.

Currently, the distance at which the pilot can see and recognize the runway threshold is presented by the indirect criteria of ceiling at the station and horizontal visibility on the ground.

A project now under way aims at making these minima more accurate and more definite so the interval can be closed up or aircraft diverted to alternate airports without wasting fuel in missed approaches. The only realistic measure of visibility is the slant range at which the pilot can see the runway. The slant range can be given in terms of the altitude at which the pilot can look forward along the glide path and see the runway threshold or the threshold lights. This altitude is called the Threshold Contact Height.

Sperry's Measuring System

Sperry Gyroscope Co. developed a system for determining this height under a GRD contract in 1954. It is being tested at Newark Airport by a U.S. Weather Bureau team assisted by Sperry



ANTENNA for measuring sun's radiation at Sacramento Peak Observatory, Sunspot, N. M.

and supervised by GRD. Three sets of measurements are combined in equations which compute the Threshold Contact Height. This can be given to the pilot as a minimum.

In the Newark tests, incoming pilots are requested to report "runway" or "lights" the moment they see one or the other. When the report is heard an operator trips the shutter of a camera which photographs a radar scope showing the actual Threshold Contact Height for comparison with the predicted one. The three basic measurements in the equation are:

- **The photometric properties of the runway threshold—light emission or reflectance, background brightness, etc.**
- **Horizontal visibility.**
- **Cloud height, at which altitude visibility should increase suddenly.**

Project Great Plains

In Project Prairie Grass the Directorate is carrying out a study of small scale turbulence and the diffusion of gases and aerosol particles at low altitudes. The project is an extension of an earlier one called Great Plains.

In one phase of Great Plains, sounding balloons with an equal rate of ascent were released from evenly spaced positions arranged in a line parallel to the direction of the surface wind. Each balloon was released as the balloon from the next station upwind passed overhead.

In a uniform air mass with the wind moving at the same speed and in the same direction at all levels, all balloons would pass over the last station evenly spaced in a vertical line. The extent and direction of departure of the balloons from this relationship was photographed to show diffusion and wind shear.

This study uncovered a phenomenon which USAF feels may explain certain crashes that took place when aircraft were making apparently normal night landing approaches to airports in the central plains.

"Nocturnal wind maxima" were found which were first believed to be a type of low level jet stream. Further study proved that the winds extend over a broad area horizontally in the Plains states.

May Explain Crashes

The wind maxima were found to occur between 2 a.m. and 4 a.m. Top speeds were about 60-65 mph. and occurred between 1,000 and 1,300 ft. altitude with surface winds between 10 and 20 mph. The vertical gradient averaged about 40 mph. per 1,000 ft. The winds seemed to have no fixed directional characteristic and at dawn they disappear.

The steep vertical gradient could cause the ground speed and angle of descent of the aircraft to change rapidly yet imperceptibly because of the dark, making pilots overshoot or undershoot their approaches.

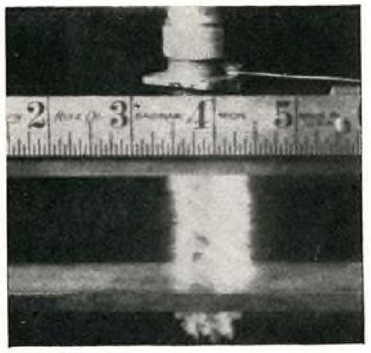
In Prairie Grass diffusion of gases and aerosol particles is being studied by releasing sulphur dioxide from a point source and measuring the amount collected from the air by a number of "bubblers" containing slightly acidified hydrogen peroxide to trap sulphur dioxide traces.

The bubblers will be arranged in four concentric semi-rings at 100, 200, 400 and 800 meters from the source. Results of the study are expected to find application in atomic biological and chemical warfare, radioactive waste problems near nuclear powerplants, and air pollution control in smog areas.

Modifying the Weather

In several fields GRD is endeavoring not only to understand the Air Force's environment but to control it.

Weather modification studies by GRD have produced techniques which



HEAVY current vaporizes copper wire.

are not quite operational in a series of eight experiments. The Directorate has been successful seven times in opening holes in super-cooled stratus clouds. The holes were 100-200 sq. mi. in area and persisted for as long as one-half hour.

Series of Studies

The modification work has been based on a long series of studies of water drop and ice crystal formation. It has been fairly well established that drops form on nuclei of ice or hygroscopic particles of sea salt, ammonium sulfate, silver iodide and other chemicals. Ice crystals are the most important nuclei for initiating precipitation above 40 degrees latitude.

Until two or three years ago there was little definite information available on ice crystal nuclei but it has been

WIRE becomes incandescent gas.

GASES expand after wire burns.

suggested that meteoric dust may serve as nuclei. Despite the lack of knowledge, the formation of ice crystals has been prevented in some cases. The formation of cloud droplets has proved a more difficult problem. The Directorate has found it possible to enhance or inhibit nucleus activity by "poisoning" the nuclei with minute traces of methyl amine or ethyl amine gases.

Suppressing Contrails

Contrails are being studied to learn a way of suppressing them, making visual detection by the enemy more difficult.

Contrails are water formed by the combination of hydrogen from hydrocarbon fuels with oxygen in the combustion process.

It has been found that burning one pound of fuel adds one-and-a-quarter pounds of water to the atmosphere. The first remedy probably will be fuel additives but some study is being made of the possibility of using exotic (non-hydrocarbon) fuel such as carbon disulfide. None have been successful yet because they produce less energy than a hydrocarbon fuel.

Weather-Sun Tie

GRD has made a first step toward controlling the release of energy received from the sun and stored photochemically in the upper atmosphere. After laboratory studies of the effect of radiation on gases at low pressure, clouds of nitric oxide were emitted.

from rockets at extreme altitude.

The nitric oxide augmented the natural release of energy and appeared as a glowing, ionized cloud. It is conceivable that the effect may be used to produce reflectors for scatter communication or to provide local illumination at night.

The Directorate is searching for the tie between the earth's weather and changes and irregularities in the energy output of the sun. Atmospheric observations will be checked against solar observations made from the Sacramento Peak Observatory near Holloman AFB, N. M. GRD scientists believe their's will be the best solar observatory in the free world after it has been completely instrumented later this year.

Ozone Concentration

One key to the solution appears to be the ozone concentrations in the upper atmosphere which seem to correlate both with solar variability and with atmospheric pressure density, temperature, and synoptic weather. GRD currently is trying to improve methods of measuring ozone concentrations.

A new technique coming into use is called VODARO (Vertical Ozone Distributions from the Absorption and Radiation of Ozone). GRD will establish two widely separated measuring stations to permit descrimination of VODARO data according to geographic location.

One station will be at Flagstaff, Ariz., and the other probably will be in Europe.

Another key might be in the short term variability of the electro-magnetic field of the earth and its relationship to solar variability and the changes in cosmic ray incidence which apparently are associated with solar flares. Some short term variations are in the audio range from 1.50 cycles per second.

Measuring Earth's Field

USAF also is interested in the long-term or secular variations in the field. GRD is about to start a project measuring the dipole field of the earth by finding the lowest concentration of cosmic rays. This occurs at the geomagnetic equator, which is the line of least geomagnetic force and is caused by deflection of the cosmic rays toward the geomagnetic poles.

The results will enable scientists to predict the strength and character of the geomagnetic field in time and space.

It will require the analysis of a mass of information large enough to cancel statistical errors.

Data must be included on daily and tidal variations and those in magnetic storms caused by the influence of solar changes and cosmic rays.

Direct measurement of cosmic ray

intensity will be made by a B-36 which will carry a neutron pile around the world, bracketing 15 degrees to either side of the geographic equator.

Ionosphere Studies

The shape and structure of D and lower E layers including "Sporadic E" (clouds of ionized gas 10-100 mi. dia.) of the ionosphere are being analyzed by bouncing radio frequencies as low as 18 kilocycles against them and measuring the return. A horizontal dipole antenna about two miles long is used for the transmitter. The reflected signals indicate the contours, absorptivity, structure of turbulence, and horizontal drift of the ionospheric layers. Normal drift has been found to be approximately 50 meters per second. Velocities within turbulence are considerably higher.

The ionosphere in the Arctic is being measured by an airborne ionospheric recorder with a transmitter which sweeps frequencies from one to 25 megacycles.

The mobility of the airborne unit permits it to study areas not available to ground bases.

The coupling between atmospheric electricity and the mechanics of weather also is being studied by the Directorate. The results will be important to future work in long-range forecasting and weather modification.

Electric Force Fields

One of the first essentials is an understanding of the electrical fields involved.

This is growing out of GRD studies of the ionosphere, the current (about 100,000 amps) which flows there, and the electrical fields between the ionosphere and the ground.

The density, volume, and mobility (speed in the presence of an electrical field) of ion concentrations in the lower atmosphere have been measured experimentally and will be correlated with meteorological factors. The magnitude and direction of current flow between the ionosphere and the ground also are being measured.

Some experts theorize that thunderstorms generate the current flow between the ionosphere and the ground. GRD is tracking thunderstorms with ground-based and airborne instruments measuring current, electrical potential, and ion concentrations. It is also studying other types of storms, minor shower clouds, and non-thunderstorm electricity.

It has been found that the top of the horizontal mixing zone, called the "exchange layer," can be identified by relatively heavy ion concentrations as well as by meteorological characteristics.

The Directorate has a "Sferics" observation net which is capable of detecting electro-magnetic radiation in the radio frequency and audio frequency ranges from thunderstorms as much as 2,000 miles away.

Fix on Lightning Strike

A Sferics detector draws a signal from three directional antenna arrays widely separated to provide a good fix on a lightning strike.

A new technique is to present the information graphically on a PPI scope showing the three lines of bearing crossing at the point of discharge. The gain can be turned down to eliminate the lines and show only the point of intersection. Radar presentation can be made simultaneously on the same scope for reference to terrain and aircraft.

Other Projects

Other GRD studies include:

• **Exploding wire experiments.** Wire is instantly vaporized by the intense heat generated by putting up to 150,000 amps through it. Power is supplied by a 100 microfarad capacitor charged to 10,000 volts. The results will have value in other areas than geophysics. The temperatures attained in the exploding wire experiment have not been announced but GRD experts believe that any substantial increase in the

temperatures will require that protection against thermo-nuclear reactions be provided.

• **Geodesy.** The force and direction of gravity at various points on the earth's surface is being measured to get more accurate figures on the earth's shape. GRD is backing solar eclipse expeditions.

Simultaneous coronograph sightings of the stage of the eclipses will allow scientists to compute accurately the relative position of different points on the earth. The results are important in missile guidance system development and map making.

• **Optimal flight planning.** GRD in association with the Cook Research Laboratories of Skokie, Ill., is perfecting a technique called "4D flight planning to improve coordination of air crew, meteorological and operation personnel and extend pressure pattern navigation techniques for use above the altitude of jet stream cores.

• **Severe storm program.** The Directorate is studying violent or hail-bearing local storms larger in area than tornados and smaller than hurricanes. The characteristic shape has been identified by radar and storms are being observed to determine how they move and change and where hail falls relative to reference points in the storm area.

• **Surface trafficability measures.** The Directorate has developed an "airborne drop penetrometer" which lights a flare on impact with the surface if its bearing strength is above a critical value. Seismographs have proven valuable in determining the thickness and strength of Arctic ice. An airborne seismometer is now under development which will accurately measure the propagation of the various shock waves from a charge dropped on the ice as an indication of trafficability.

• **Statistical forecasting.** Local forecasting on the basis of a long standing historical record of the meteorological parameters of past weather is a promising approach being explored. It is based on the theory that if the conditions leading up to and surrounding a certain type of weather should recur the weather also will recur. Because of the rarity of exact repetition of conditions, forecasts may be stated in terms of probability.

• **High altitude wind measurement.** GRD contractors are using star "twinkle" as a measure of upper winds. The twinkle has been found to be caused by the movement of turbulent cells having different optical refraction. Movement is caused by the high altitude winds. GRD scientists believe the frequency of the twinkle can be translated into accurate terms of speed and direction. ■

TECHNICAL FIELDS OF INTEREST

AIR RESEARCH AND DEVELOPMENT COMMAND

Through the cooperation of AVIATION WEEK, the Air Research and Development Command is at present conducting a survey to determine this country's untapped research and development potential.

The information obtained will be entered in the proper ARDC Center Source Files and all firms so entered will be considered for future Air Force Research and Development programs.

All organizations or institutions interested in contracting for ARDC are requested to complete the inclosed "tear-out" source forms and return them to the proper ARDC center, Attn.: Contractor Relations Branch, as soon as possible with accompanying technical resumes and brochures.

If your company does no research or development work, or has no facilities for research work, please do not complete this form. If your company has sent in similar information within the past year, do not complete the form.

Your reply, of course, will not obligate your company, ARDC or AVIATION WEEK in any way.

AIRCRAFT AND FLIGHT EQUIPMENT
- Aircraft Instruments
- Aircraft Design
- Aircraft Structures
- Flight Operating Problems
- Flight Safety
- Gliders
- Lighter-Than-Air
- Propellers
- Rotating-Wing Aircraft
- Water-Borne Aircraft

ASTRONOMY, GEOPHYSICS AND GEOGRAPHY
- Astronomy
- Cartography
- Climatology
- Geodetic Engineering
- Geography
- Geomagnetism
- Meteorology
- Mineralogy
- Oceanography
- Seismology

CHEMICAL WARFARE EQUIPMENT AND MATERIALS
- Biological Agents
- Flame Throwers
- Incendiaries
- Protection and Decontamination
- Pyrotechnics
- Screening Agents and Smokes
- War Gases

CHEMISTRY
- Chemical Engineering
- Inorganic Chemistry
- Organic Chemistry
- Physical Chemistry

COMMUNICATIONS
- Combat Information Centers
  - Data Transmission Systems—Digital
  - Data Transmission Systems—Analog
  - Plotting Boards and Computers
  - Video Transmission Systems Engineering
    - Transmitters
    - Receivers
    - Displays
- Telephone, Repeater, Multiplex and Teletype Systems Engineering
  - Telephone and Telephone Circuits
  - Teletype, Repeaters, Perforators, Reperforators
  - Switchboards
  - Multiplex
  - Central Office
  - Switching Devices
  - Cables
  - Facsimile-High Speed Printing and Scanning

RADIO COMMUNICATIONS
- Microwave Systems
- Long-Range Fixed Plant Communication Engineering Short and Medium-Range Fixed Plant Communication Engineering
- Mobile Communication Systems Engineering
- Propagation Engineering
- Transmitters
  - LF, Low and High Power; Amplitude and FM
  - MF, Low and High Power; Amplitude and FM
  - HF, Low and High Power; Amplitude and FM
  - VHF, Low and High Power; Amplitude and FM
  - UHF, Low and High Power; Amplitude and FM
  - SHF, Low and High Power; Amplitude and FM
  - Single Sideband
  - Synchronous Detection
  - Pulse
  - RF Amplifiers
- Receivers
  - LF, MF, HF, VHF, UHF, SHF
  - Single Sideband
  - Synchronous Detection
  - Pulse
- Anti-Jam Techniques and Equipment
- Interference Elimination and Suppression, Blankers and Delay Lines

SOUND RECORDING AND AMPLIFICATIONS
- Audio Equipment
  - Records and Reproducers
  - Audio Amplifiers
  - Speakers
  - Microphones
  - Headsets
  - Speech Compression
  - Keyers

TELEVISION

WIRE COMMUNICATIONS

DETECTION

ACOUSTIC
- Microwave Panoramic Type Receivers VHF-UHF Panoramic Receivers
- Microwave Instantaneous Signal and Frequency Analysis Equipment
- Droppable Intelligence Sensors-Acoustic

DIRECTION FINDERS
- Communications Equipment—LF, MF, HF, VHF, UHF, SHF

INFRARED
- Detection Equipment—Passive

Magnetic

Passive Detection
- Broadband Microwave Antennas
- Broadband VHF-UHF Antennas
- Microwave Panoramic Type Receivers
- VHF-UHF Instantaneous Signal and Frequency Analysis Equipment

OPTICAL
- Countermeasure Devices

RADAR AND RADIO
- Long-Range Systems, Fixed
- Long-Range Systems, Mobile
- Medium-Range Control and Guidance
- Short-Range Precision
- Transmitters
  - Magnetron
  - Klystron
  - Vacuum Tube
  - Driver Chains
- Modulators
  - Magnetic
  - Thyratron
  - Spark Gap
  - Hard Tube
- Receivers
  - Duplexer
  - TRS
  - Mixers
  - Amplifiers
  - Special, FM Stacked Beams
  - New Techniques
- Moving Target Equipment
  - Delay Lines
  - Integrators
  - Cancellation Units
  - MTI Test Equipment
  - New Techniques
- Processing Equipment Indicators
  - Cathode Ray
  - Monitor
  - Projection
- Display
  - Plotting
  - Situation
  - Projection
  - Combining
- Tracking Equipment
  - Magnetic
  - Electronic
  - Transistor
- Anti-Jam Techniques and Equipment

ELECTRICAL EQUIPMENT
- Batteries
- Control and Protective Equipment
  - Electrical Control Equipment
  - Frequency Synthesizers and Oscillators
  - Security Devices (Cryptographic)
- Distribution Equipment
- Heating and Lighting Equipment
  - Heating Devices
- Power Equipment
  - Motor Generators
  - Gas
  - Diesel

ELECTRONICS AND ELECTRONIC EQUIPMENT
- Antennas
  - Broadband Microwave Antennas
  - Broadband VHF-UHF Antennas
  - LF, MF, HF, VHF, UHF, SHF Directional and Omnidirectional
  - High Speed
  - High-Definition
  - Microwave
  - Special
  - Antenna Couplers
  - Masts and Towers
  - Pedestals
  - Reflector-Structures
  - Feed Systems
  - Towers
  - Radomes
  - Diplexers
  - Transmission Lines (RF)
  - Antenna Drive Systems
- Accessories
  - Power Supplies—AC and DC Regulated and Unregulated, Dynamotors Generators
- Electronic Theory
- Electronic Tube Devices
  - Klystrons
  - Magnetrons—Carcinotrons, Stabilitrons
- Modulation Studies
- Wave Propagation
- Countermeasures
  - Electronic Warfare System Studies
  - Jammers
    - Broadband Microwave Transmitting Tubes
    - Carcinotrons
    - Broadband UHF-VHF Transmitting Tubes
    - Noise Generators
- Decoys (Microwave)
  - Corner Reflectors
  - Camouflage-Absorbing Materials, Reflecting Materials, Chaff
  - Interrogator-Responder Beacons
- Components
  - Power, Audio and RF Transformers and Inductors
  - Circuit Breakers
  - Relays
  - Metallic Rectifiers
  - Motors
  - Power and Control Cables and Connectors
  - Magnet and Hook-Up Wire
  - Meters
  - Switches
  - Sockets
  - Capacitors
  - Resistors

FLUID MECHANICS
- Dynamics
- Compressibility
- Statics
- Hydrodynamics
- Thermoaerodynamics
- Theoretical Aerodynamics
- Experimental Aerodynamics

FUELS AND COMBUSTION
- Gaseous Fuels
- Liquid Fuels
- Solid Fuels
- Gaseous Propellants
- Liquid Propellants
- Solid Propellants
- Combustion

GROUND TRANSPORTATION EQUIPMENT
Amphibious Vehicles
Automotive Parts and Accessories
Railroad Equipment
Special Purpose Vehicles
Automatic Trailers
Trucks

GUIDED MISSILES
Aerodynamics and Ballistics
Guidance and Control
Handling and Launching
Propulsion
Warheads and Fuzes

INSTALLATION AND CONSTRUCTION
Air Conditioning and Refrigeration Equipment
  Air Cooling Devices
  Heating Devices
Construction Equipment
Sanitation Engineering
Structural Engineering
  Shelters
  Racks
    Mobile
    Permanent Station Equipment
  Transit Cases
Fortifications
Military Installations
Public Utilities
Repair and Maintenance Facilities
Yards and Docks
Vulnerability Studies

MATERIALS (NON-METALLIC)
Adhesives and Sealants
Ceramics
Hydraulic Fluids
Leather and Textiles
Lubricants
Miscellaneous Materials
Paints and Finishes
Plastics
Rubber and Elastromers
Wood

MATHEMATICS
Pure Mathematics
Statistics

MEDICAL SCIENCES
Anatomy and Physiology
Biochemistry
Biology
Dentistry
Hygiene and Sanitation
Medical Specialties
Medical Supplies and Equipment
Nutrition
Pathology
Pharmacology and Toxicology
Psychiatry and Neurology
Surgery
Veterinary Medicine
Visual and Auditory Studies

METALLURGY
Mining and Refining
Structural Metallurgy
Bronze, Brass and Bearing Alloys
Heat-Resistant Alloys
Iron and Alloys
Light Metals and Alloys
Miscellaneous Non-Ferrous Metals and Alloys

MILITARY SCIENCES AND OPERATIONS
Defense
Intelligence
  Intelligence Sensors
    Seismic
    Acoustic
    Chemical

Data Handling and Display
  Storage and Retrieval-Magnetic, Photographic, Electro-Mechanical
  Presentation-Electronic, Photographic, Optic
  Dissemination and reproduction—Magnetic, Photographic, Lithography
  Conversion (Raw Data to Processable Form)—Photographic, Electronic, Electro-Optics

Logistics

Operations
  Intelligence Parameters Studies
  Target Analysis
  Enemy Capabilities
  Intelligence Systems Studies
Organization and Administration
Psychological Warfare
Strategy and Tactics

NAVIGATION
Celestial Navigation
Dead Reckoning and Pilotage
Electronic Navigation
  Short-Range Hyperbolic Systems
  Short-Range Phase Matching Systems
  Long-Range Navigation Systems
  Medium-Range Control and Guidance
Remoting
  Terminal Equipment
  Microwave Links
  Multicouplers
  Traveling Wave Tube
  Cable
Display Equipment
  Direct Readout
  Horizontal
  AZ-EL, Indicator
Character Display
  Colored Display
  Photographic
IFF Equipment
  Interrogators
  Responders
  Coders
  Decoders
  Crypto Boxers
  Indicators
Beacons
  Lightweight Droppable
  Tactical X-Band
  Long Life
  Signal Enhancement
Corner Reflectors
  Transponders
  Crystal Enhancer
  Signal Integrators
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  Crystal
  Atomic
  Molecular
  Frequency Dividers
Inertial Systems
Navigational Instruments
  Very Short-Range High Definition Landing Sets
  Very Short-Range High Definition Airport Surveillance Sets
  Medium-Range Traffic Control Surveillance Sets
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  Equipment and Areas of Interest
    Mobile Target Indicator-Coherent and Non-Coherent
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NUCLEAR PHYSICS AND NUCLEAR CHEMISTRY
Atomic Structure
Nuclear Reactions
Radioactivity
Isotope Separation
Reactors and Particle Accelerators
Health Physics
Military Applications

NUCLEAR PROPULSION
Accessories
Components
Control
Cooling
Design
Installation
Operations
Performance
Shielding
Testing

ORDNANCE
Ammunition and Explosives
Armor
Armored Cars
Ballistics
Bombs
  Bomb Scoring and Control
  Fire Control and Bombing Systems
Explosions and Blast Effects
Fire Control and Bombing Systems
Guns
Mounts and Turrets
Proximity Fuzes
Rockets and Launchers
Tanks
Underwater Ordnance

PERSONNEL AND TRAINING
Personnel Procurement and Administration
Industrial Relations
Wages, Salaries and Benefits
Education and Vocational Training
Military Training and Indoctrination

PHOTOGRAPHY AND OTHER REPRODUCTION PROCESSES
Cameras
Photographic Processes, Techniques and Equipment
Miscellaneous Reproduction Processes, Techniques and Equipment

PHYSICS
Acoustics
Crystallography
Electricity and Magnetism
Optics
Quantum Mechanics
Solid State Physics
Spectra and Molecular Theory
Thermodynamics

PRODUCTION AND MANAGEMENT
Fabrication
Management, Accounting and Publications
Plant Design and Production Planning
Quality Control
Tooling

PROPULSION SYSTEMS
Reciprocating (Internal Combustion)
Gas Turbine and Jet
Rocket
Steam

PSYCHOLOGY AND HUMAN ENGINEERING
Experimental Psychology
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QUARTERMASTER EQUIPMENT
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Food and Containers
Furnishings
Kitchen Equipment
Personal Equipment
Protective Equipment

RESEARCH AND RESEARCH EQUIPMENT
Administration and Programs
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  Parts List
  Specifications
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  Engineering Standards
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  Analog
  Digital
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  MTI Test Equipment
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Religion

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Air Transportation
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RESEARCH AND DEVELOPMENT SOURCE INFORMATION

NAME OF CONTRACTOR	STREET ADDRESS	CITY AND STATE

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TYPE OF ORGANIZATION ☐ CORPORATION ☐ PROPRIETOR ☐ PROFIT ☐ NON-PROFIT ☐ PARTNERSHIP	STATE IN WHICH INCORPORATED

PARENT ORGANIZATION OR SUBSIDIARIES	NUMBER OF EMPLOYEES	
	TOTAL	RESEARCH SCIENTISTS
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Under each section listing, cite description or examples of your work with a few key words or phrases. ***Please Be Specific.*** If you do not find a section directly applicable to your work, choose the section or sections that are closely related and list your type of work under these. If additional space is required, continue on a separate sheet.

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   B. Work history.
   C. Books or papers published.
   D. Patents.
   E. Current fields of activity.

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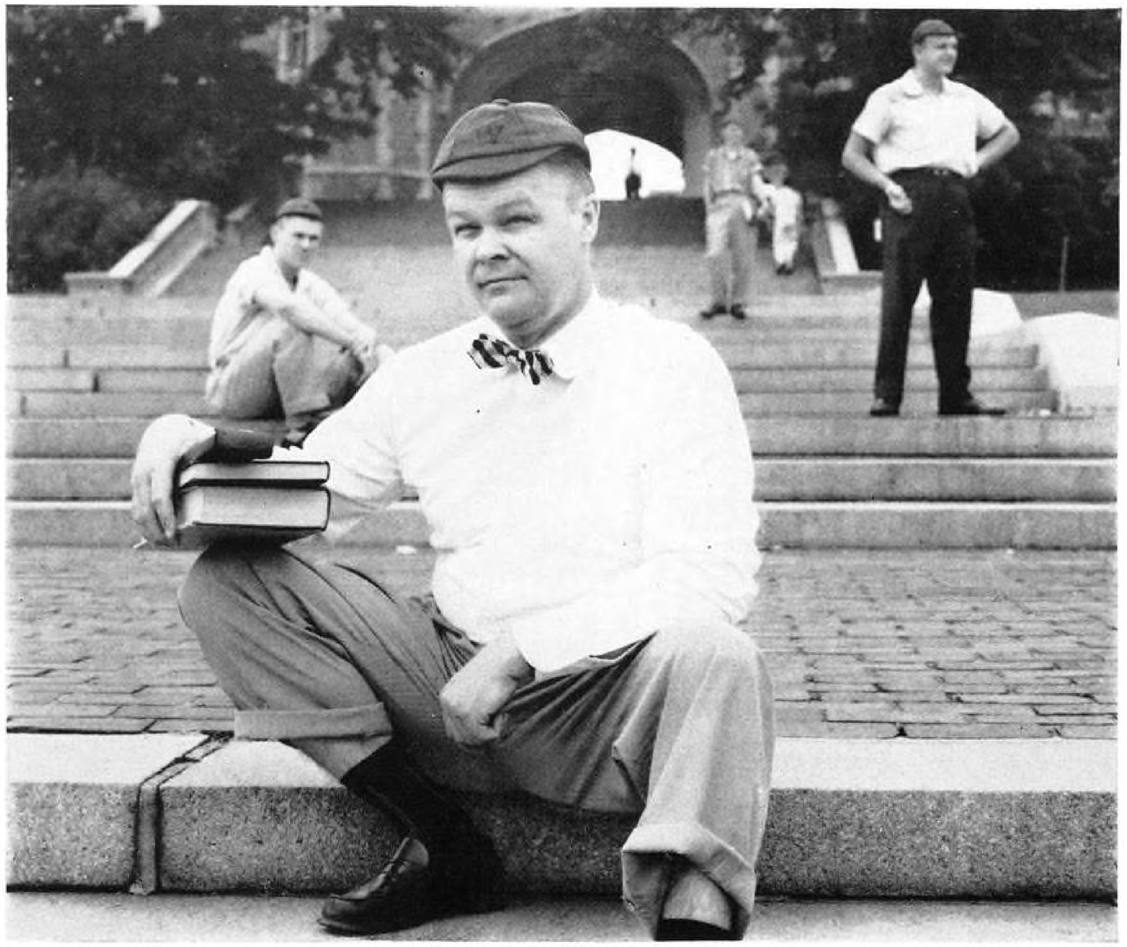

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Arnold Engr Co., Morengo, Ill.
Arnold Lee Associates, 225 W. 57 St., New York, N. Y.
R. Arnold Co., Boston, Mass.
Aro Equipment Corp., Bryan, Ohio.
Arrowhead Rubber Co., 2300 Curry St., Long Beach, Calif.
Arctic Institute of North America, 2 E. 63 St., New York, N. Y.
Asch Equipment Co., 642 Keowee St., Dayton, Ohio.
Ashe Radio Co., 1125 Pine St., St. Louis, Mo.

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Associated International Research, 102 Mt. Auburn St., Cambridge, Mass.
Astra Pharmaceutical Co., 7½ Neponset St., Worcester, Mass.
Ateliers de Construction Electriques, Chareroi, Belgium.
Atlantic Pacific Wire Co., 112-1 Northern Blvd., Elmhurst, N. Y.
Atlantic Para Corp., 750 Soffol St., Lowell, Mass.
Atlantic Research Corp., Alexandria, Va.

Atlantic States Industries, 20 Mechanic St., New Rochelle, N. Y.
Atlantic X-Ray Co., 909 Boylston St., Boston, Mass.
Atlas Industrial Co., 849-39 St., Brooklyn, N. Y.
Atlas Screw Specialties Co., 450 Broom St., New York, N. Y.
Auburn Research Foundation, Auburn, Ala.
Audio Video Products, 730 Fifth Ave., New York, N. Y.
Aurex Corp., 1117 N. Franklin St., Chicago, Ill.
Arthur O. Austin, PO Box 19, Barberton, Ohio
Austin Charles Inc., 121 Opera Place, Cincinnati, Ohio
Automat Engineering, Cambridge, Mass.

Automatic Electric Sales Co., 1033 W. Van Buren St., Chicago, Ill.
Automatic Temperature Control Co., 5212 Pulaski Ave., Philadelphia, Pa.
Avco Mfg. Corp., 2630 Glendale Rd., Cincinnati, Ohio
Aviation Engineering, 58-15 Northern Blvd., Woodside, N. Y.
Avion Instrument Corp., 299 State Highway 17, Paramus, N. J.
Avro Acft. Ltd., Toronto, Canada
Avtron Mfg. Co., 877 Addison Rd., Cleveland, Ohio
Axelson Mfg. Co., PO Box 98, Vernon Sta., Los Angeles, Calif.

B

B and G Corp., 136 W. 52 St., New York, N. Y.
B J Electronic Corp., 2010 Lincoln Ave., Pasadena, Calif.
B O Corp., 242 W. 36 St., New York, N. Y.
B T U Eng. Co., 243 Broadway, Cambridge, Mass.
B W Construction Co., Box 1151, Bryan, Tex.
Babcock Radio, 7942 Woodley Ave., Van Nuys, Calif.
Babcock Wilcox Co., 161 E. 42 St., New York, N. Y.
Bacon Vulcanizer, 1295 67th St., Oakland, Calif.
Baird Associates, 33 University Rd., Cambridge, Mass.
Bakelite Corp., 30 E. 42 St., New York, N. Y.
Baker Brush Co., 83 Grand St., New York, N. Y.
Baker Co., Inc., 113 Astor St., Newark, N. J.

James G. Baker, 7 Grove St., Winchester, Mass.
Baker Raulang Co., 1250 W. 80th St., Cleveland, Ohio.
Balco Research Laboratories, 49-53 Edison Place, Newark, N. J.
Edward J. Baldes, 102 2nd Ave. SW, Rochester, Minn.
Baldwin Co., 1801 Gilbert Ave., Cincinnati, Ohio
Baldwin-Lima-Hamilton Corp., Chester Pk. & Simpson, Philadelphia, Pa.
Ballantine Labs Inc., Fanny Rd., Boonton, N. J.
J. R. Ballentine Co., PO Box 238, Ysleta, Tex.
Bally Ribbon Mills, Bally, Pa.

Bane Co., 700 W. Paisand St., El Paso, Tex.
Alfredo Banos, Jr., 3211 S. Barrington Ave., Los Angeles, Calif.
Baltimore Inst. Co., 716 W. Redwood St., Baltimore, Md.
Barber-Colman Co., 229 Loomis St., Rockford, Ill.
Barden Corp., 30 Franklin St., Danbury, Conn.
Barker Williamson, 235 Fairfield Ave., Upper Darby, Pa.
Barkley Dexter Labs., 50 Frankford St., Fitchburg, Mass.
Barksdale Valves, 5125 Alcoa, Los Angeles, Calif.
Barnebey Cheney Co., E. 8th Ave. & Casady Rd., Columbus, Ohio
Barnes Engineer Co., 30 Commerce Rd., Stamford, Conn.

• CONTRACTORS

Barnes Reinecke, 230 E. Ohio, Chicago, Ill.
Barrie Michel Inc., New York, N. Y.
L. N. Barry Co., 700 Pleasant St., Watertown, Mass.
Bassons Industries, 1432 W. Farms Rd., Bronx, N. Y.
Bastian Blessing Co., 4201 Peterson Ave., Chicago, Ill.
Battelle Memorial Institute, 505 King Ave., Columbus, Ohio
Bausch & Lomb Optical Co., 635 St. Paul St., Rochester, N. Y.
Bay State York Co., 100 Brookline St., Boston, Mass.
Baylor University, Waco, Tex.
Bayshore Industries, PO Box 151, Elkton, Md.

Beach Associates, Dayton, Ohio
Beacon Electric Inc., 411 Columbia St., Utica, N. Y.
Beasley Construction Co., Muskogee, Okla.
Crandall Beaumont, 2609 Walnut St., Kansas City, Mo.
Becker & Becker Associates, 509 Madison Ave., New York, N. Y.
Beckman Instrument Inc., 2200 Wright Ave., Richmond, Calif.
Beckman & Whitley Inc., 985 San Carlos Ave., San Carlos, Calif.
Bee Industries, 1124 Westminster Ave., Alhambra, Calif.
H. R. Beebe Inc., 110 Genesee St., Utica, N. Y.
Beech Aircraft Corp., 6600 E. Central Ave., Wichita, Kans.

Russ Beech Co., 50 Church St., New York, N. Y.
Heroy Beers, 3712 Haggar Dr., Dallas, Tex.
Nicholas Q. Begovich, 1539 Bundy St., Culver City, Calif.
George Behm Sons, 24 McDonough St., Dayton, Ohio
Bell Aircraft Corp., Blue Mound Rd., Fort Worth, Tex.
Bell and Howell Co., 7100 McCormick Rd., Chicago, Ill.
Bell Sound Systems, 555 Marion Rd., Columbus, Ohio
Belmont Radio Corp., 75 E. Walker Dr., Chicago, Ill.
Belock Instr. Co., College Pt., N. Y.
Bendix Aviation Corp., Fisher Bldg., Detroit, Mich.

Benson Lehner Corp., 1193 W. Olympic Blvd., Los Angeles, Calif.
Benson Mfg. Co., 18th & Agnes Aves., Kansas City, Mo.
B. Berg Agency, Hollywood, Calif.
Berger Brothers Co., 135 Derby Ave., New Haven, Conn.
Berkeley Scientific, 2200 Wright Ave., Richmond, Calif.
E. A. Berman Co., 268 Northampton St., Boston, Mass.
Bernate Powder Co., 1112 Cumpston St., N. Hollywood, Calif.
W. E. Berndt, 655 S. Warren St., Syracuse, N. Y.
Beryllium Corp., Tuckerton Rd., Reading, Pa.
Beta Electric Corp., 333 East 103rd St., New York, N. Y.

Better Fabrics Test Co., 101 W. 31st St., New York, N. Y.
Bettinger Corp., Gore St., Waltham, Mass.
J. G. Biddle Co., 1316 Arch St., Philadelphia, Pa.
Bigelow Sanford Co., 140 Madison Ave., New York, N. Y.
Binks Mfg. Co., 3114 W. Carroll Ave., Chicago, Ill.
Biot and Arnold, 110 W. 42nd St., New York, N. Y.
Bird Electronic, 1798 E. 38th St., Cleveland, Ohio
Bishop J. and Co., Malvern, Pa.
Bjorksten Research Laboratory, 1525 E. 53rd., Chicago, Ill.
Blaw Knox Co., PO Box 1198, Pittsburgh, Pa.

Bailey Electric Co., 200 Union St., Erie, Pa.
Blinks Mfg. Co., 4915 Pacific Blvd., Los Angeles, Calif.
Bloomingdale Rubber, Delaware Ave. and Flower St., Chester, Pa.
Bodde Screen Co., 8829 Venice St., Los Angeles, Calif.
Bode Finn Co., 1518 E. First St., Dayton, Ohio
Boder Scientific Co., 719 Liberty Ave., Pittsburgh, Pa.
Boeing Aircraft Co., 7755 Marginal Way, Seattle, Wash.
Boesch Mfg. Co., 45 River St., Danbury, Conn.
Bogart Mfg. Co., 315 Siegel St., Brooklyn, N. Y.

• CONTRACTORS

Seymour M. Bogdonoff, Princeton University, Princeton, N. J.

Bogue Electric Mfg. Co., 52 Iowa Ave., Paterson, N. J.
Bol Ltd., 118 E. 25th St., New York, N. Y.
Bolsey Research, 118 E. 25th St., New York, N. Y.
Beranek Newman Bolt Co., 16 Eliot St., Cambridge, Mass.
Bomac Laboratories, Inc., Salem Rd., Beverly, Mass.
Bond Research Laboratories, 84 Winslow Ave., Somerville, Mass.
Bone Engr. Corp., 701 W. Broadway, Glendale, Calif.
Boonton Molding Co., 326 Myrtle Ave., Boonton, N. J.
Allen Hamilton Booz, 135 S. LaSalle St., Chicago, Ill.
George W. Borg Corp., 120 S. Main St., Janesville, Wis.

Borg Warner Corp., 2020 Harrison Ave., Rockford, Ill.
Borman Engineering, 5356 Reverton Ave., N. Hollywood, Calif.
Boston College, Chestnut Hill, Boston, Mass.
Boston Edison Co., 39 Boylston St., Boston, Mass.
Boston Insulation Wire, Boston, Mass.
Boston Museum, The Fenway, Boston, Mass.
Boston Ordnance, 666 Summer St., Boston, Mass.
Boston University, 755 Commonwealth Ave., Boston, Mass.
Thomas Bourne Associates, DuPont Circle Bldg., Washington, D. C.
Bowen and Co., 4712 Beth Ave., Bethesda, Md.

Bowlus Sailplanes, Los Angeles, Calif.
Bowmar Instrument Co., 2415 Penn St., Fort Wayne, Ind.
Bowser, Inc., 1302 E. Creighton Ave., Fort Wayne, Ind.
Bradford Novelty Co., 760 Main St., Cambridge, Mass.
Allen Bradley Co., 136 W. Greenfield Ave., Milwaukee, Wis.
W. H. Brady Co., Chippewa Falls, Wis.
Brailsford Co., Rye, N. Y.
Braun Corp., Los Angeles, Calif.
Breeze Corp., Inc., 700 Liberty Ave., Union, N. J.
Breta Institute of Science Research, Milan, Italy

Given A. Brewer, Marion, Mass.
Brigham Young University, Provo, Utah
Bristol Co., Platts Mills, Waterbury, Conn.
Bristal Engineering Co., Beaver Dam Rd., Bristol, Pa.
Broadview Research, 1127 Chula Vista Ave., Burlingame, Calif.
Watson Brody, Cambridge, Mass.
Brook Truck Body Co., Pinebrook, N. J.
B. D. Brooks Co., 310 Atlantic Ave., Boston, Mass.
Brooks and Perkins, 2457 Woodward Ave., Detroit, Mich.
Brooks Uniform Co., 75 W. 45th St., New York, N. Y.

Brown Instrument Co., 529 Hunter St., Dayton, Ohio
Brown Line Co., Beverly Hills, Calif.
Brown and Mole Inc., 1305 Strong Rd., Copiaque, N. Y.
Brown Sharpe Mfg., 235 Promenade St., Providence, R. I.
Brown Steel Tank Co., 2901 S.E. Fourth St., Minneapolis, Minn.
Brown Trailers, Toledo, Ohio
Brown University, Prospect St., Providence, R. I.
Browning Laboratories, Inc., 742 Main St., Winchester, Mass.
Brujac Corp., 103 Lafayette St., New York, N. Y.
Charles Bruning Co., 965 Commonwealth Ave., Boston, Mass.

Brunswick Balke Collender Co., 623-633 S. Wabash Ave., Chicago, Ill.
Brush Beryllium Co., 4301 Perkins St., Cleveland, Ohio
Brush Electronic Co., 3405 Perkins Ave., Cleveland, Ohio
Henry Brutcher, 3185 N. Marengo St., Altadena, Calif.
Buckbee Mears Co., Lindeke Blvd., St. Paul, Minn.
H H Buggie Co., 726 Stanton St., Toledo, Ohio
Bulova Research Development Laboratories, 62-1 Woodside Ave., Woodside, N. Y.

Burger Iron Co., 1615 Springfield St., Dayton, Ohio
Burgess Battery Co., Old Rand Rd., Freeport, Ill.
William E. Burk, 510 Yale Blvd., Albuquerque, N. M.
James Burke Inc., 321 S. Wabash Ave., Chicago, Ill.
Burndy Engineering Co., 107 Bruckner Blvd., New York, N. Y.
H. L. Burns, 1536 S.E. 11th Ave., Portland, Ore.
Burns and Roe, Inc., 233 Broadway, New York, N. Y.
Burr Oil and Supply, PO Box 618, Albuquerque, N. M.
Burroughs Adding Machine, 6071 Second Blvd., Detroit, Mich.
Burton Mfg. Co., 11201 W. Pico Blvd., Los Angeles, Calif.
Burton Rodgers Inc., Blade & Helen Sts., Cincinnati, Ohio
Butler Mfg. Co., 7400 E. 13th St., Kansas City, Mo.
Butler University, Indianapolis, Ind.
Byron, Inc., 1226 Wisconsin Ave., Washington, D. C.

C

C. E. C. Instruments, 1025 E. Green St., Pasadena, Calif.
C. G. S. Laboratories Inc., 391 Ludlow St., Stamford, Conn.
C. & S. Construction Co., P. O. Box 881, El Paso, Tex.
Cadillac Electric Co., New York, N. Y.
Calgon Inc., 323 Fourth Ave., Pittsburgh, Pa.
Calidyne Co., 128 Cross St., Winchester, Mass.
California Institute of Technology, 1201 E. California St., Pasadena, Calif.
California Oxygen Co., 1215 18th St., Sacramento, Calif.
California Reinforced Plastic Co., 951 61st St., Oakland, Calif.
California Research Corp., 299 Bush St., San Francisco, Calif.
J. A. Callaman, 247 E. Illinois, Chicago, Ill.
Cambridge Corp., 2 Industrial Pkwy., Lowell, Mass.
Cambridge Instr. Co., Grand Central Term., New York, N. Y.
Camburn Inc., 32-47 57th St., Woodside, N. Y.
Camera Equipment Co., 1600 Broadway, New York, N. Y.
Cameraflex Corp., 1947 Broadway, New York, N. Y.
Camfield Mfg. Co., 718 N. Seventh St., Grand Haven, Mich.
Canadian Commercial Co., 1746 Massachusetts Ave., Washington, D. C.
J. S. Canner Co., Inc., 46 Millmount St., Boston, Mass.
Cannon Electric Co., 3209 Humboldt St., Los Angeles, Calif.
Russell B. Cannon, Cincinnati, Ohio
Canoga Corp., 5955 Sepulveda Blvd., Van Nuys, Calif.
Canton Drop Forging Co., 2100 Willett Ave., Canton, Ohio
Capehart Farnsworth Co., 3700 Pontiac St., Ft. Wayne, Ind.
Capewell Mfg. Co., 60 Governor St., Hartford, Conn.
Carbide & Carbon Chemical Co., 30 E. 42 St., New York, N. Y.
Carbon Product. Co., Columbus, Ohio
Carborundum Co., Latrobe, Pa.
Cardox Corp., 307 N. Michigan Ave., Chicago, Ill.
A. D. Cardwell, 97 Whiting St., Plainville, Conn.
Carlisle Finch Co., 4562 W. Mitchell, Cincinnati, Ohio
G. O. Carlson Co., Marshalton Rd., Thorndale, Pa.
Carnegie Institute of Technology, Schenley Park, Pittsburgh, Pa.
Carnegie Institution of Washington, 16th & P NW, Washington, D. C.
Carpenter Ligho. Co., 1809 W. Columbia St., Springfield, Ohio
Carrier Corp., 400 S. Geddes St., Syracuse, N. Y.
J. C. Carter Co., Costo Mesa, Calif.
Carter Laboratories, 3229 Foothill Blvd., Pasadena, Calif.
Cascade Research Corp., Los Gatos, Calif.
Case Institute of Technology, 1090 Euclid St., Cleveland, Ohio
Cashman Brothers, Newbury Port, Mass.
Catholic Univ., 620 Michigan Ave. NE, Washington, D. C.
Caywood Schiller Associates, 203 N. Wabash Ave., Chicago, Ill.
Cedar Engineering Co., 5806 W. 36 St., Minneapolis, Minn.
Cedars of Lebanon Hospital, Los Angeles, Calif.
Cemco Industrial Co., Galion, Ohio
Central institute of Deaf, 818 S. Kings Highway, St. Louis, Mo.
Central Sales Mfg. Co., Richwood Place, Denville, N. J.
Central Scientific Co., 79 Amherst St., Cambridge, Mass.
Central Scientific Co., 1700 Irving Park Rd., Chicago, Ill.

Central Square A Print Co., 200 Broadway, Cambridge, Mass.
Central State College, Wilberforce, Ohio
Central Sta. Alarm Co., 610 N. Askard St., Dallas, Tex.
Central Transformer Co., 910 W. Jackson Blvd., Chicago, Ill.

Centro Research Lab., Briarcliff, N. Y.
Century Electronics Co., 34 Oleander St., Cocoa, Fla.
Century Engineers Inc., 2741 N. Naomi St., Burbank, Calif.
Century Geophysical Co., 1333 N. Utica, Tulsa, Okla.
Century Metalcraft Co., 14806 Oxnard St., Van Nuys, Calif.
Century Products Co., 5925 Highway No. 7, Minneapolis, Minn.

Frank Ceravalo & Sons, R. D. 2, Rome, N. Y.
Cessna Aircraft Co., R. F. D. #5, Wichita, Kans.
Champion Spark Plug, 900 Upton Ave., Toledo, Ohio
A. B. Chance Co., 210 N. Allen St., Centralia, Mo.
Chandler Farquhar Co., 900 Commonwealth Ave., Boston, Mass.
Chapel Electric Co., 44 S. Ludlow St., Dayton, Ohio
Chase Aircraft Corp., P. O. Box 1478, Trenton, N. J.
Chatham Electronics Co., 475 Washington St., Newark, N. J.

• CONTRACTORS

Chemco Photo Prod. Co., 175 Fifth Ave., New York, N. Y.
Chemold Co., 2308 Broadway, Santa Monica, Calif.

Cheney Brothers, Manchester, Conn.
Chicago Aero Survey, 332 S. Michigan Ave., Chicago, Ill.
Chicago Development Co., 5810 47th Ave., Riverdale, Md.
Chicago Metal Hose, 1315 S. Third St., Maywood, Ill.
Chicago Minature Lamp Co., 1500 N. Ogden Ave., Chicago, Ill.
Chicago Pneumatic Tool Co., 570 E. Larned St., Detroit, Mich.
Chicago Telephone Supply, 1142 W. Beardsley Ave., Elkhart, Ind.
Chromalloy Co., of America, 109 W. 64th St., New York, N. Y.
Chromatic TV Laboratories, Paramount Bldg., Times Square, New York, N. Y.
Cinch Mfg. Corp., 1026 S. Homan Ave., Chicago, Ill.

Cincinnati Research Co., P. O. Box 95, Cincinnati, Ohio
Cincinnati Testing Co., 316 W. 4th St., Cincinnati, Ohio
Cintronic Corp., Cincinnati, Ohio
Cities Service Oil Co., 70 Pine St., New York, N. Y.
Civil Bldg. Supply, 1405 N. Clinton St., Fort Wayne, Ind.
Clark Crystal Co., Marlboro, Mass.
David N. Clark Co., 360 Park Ave. Worcester, Mass.
Clark Equipment Co., P. O. Box 178, Battle Creek, Mich.
Clary Multiplier Co., 408 Junipero St., San Gabriel, Calif.

Clayton Mfg., 1363 N. Temple Blvd., El Monte, Calif.
Cleaver Brooks Co., 225 N. Grand Ave., Waukesha, Wis.
Clematis Machine Fix Co., 52 Clematis St., Waltham, Mass.
Cleveland Pneumatic Tool Co., 3781 E. 77th St., Cleveland, Ohio
Clevite Corp., Cleveland, Ohio
Climax Molybdenum, 500 Fifth Ave., New York, N. Y.
Clowe & Cowan, 805 N. Virginia, Roswell, N. M.
Coast Mfg. Supply Co., Livermore, Calif.
Coast Paint, 1507 Grande Vista Ave., Los Angeles, Calif.

Coast Pro Seal Mfg., 2627 N. Hollywood Way, Los Angeles, Calif.
Coca Cola Bottling, 1507 Dana St., Cincinnati, Ohio
Coffing Hoist Co., Danville, Ill.
Cole Instrument Co., 1320 S. Grand Ave., Los Angeles, Calif.
Coleman Engineering Co., 6040 Jefferson Blvd., Los Angeles, Calif.
Coleman Instrument Co., 716 S. Troost St., Tulsa, Okla.
Colerick Supply Co., 12 Liberty St., Utica, N. Y.
Colgate University, Broad St., Hamilton, N. Y.
Colin Campbell Co., Danbury, Conn.
Collens Instrument Co., 56 Cooper Square, New York, N. Y.

Collins Radio Co., 835 35th St., NE, Cedar Rapids, Iowa
Colorado A. & M., Fort Collins, Colo.
Colorado School of Mines, Golden, Colo.
Columbia Broadcasting System, 25 Madison Ave., New York, N. Y.
Columbia Research Development, 4608 Indianola St., Columbus, Ohio
Columbia University, Broadway & 116th St., New York, N. Y.
Columbian Rope Co., 307 Genesee St., Auburn, N. Y.
Calvin Laboratories, 364 Glenwood Ave., E. Orange, N. J.
Combustion & Explosion Co., Pittsburgh, Pa.
Commercial Controls, 1 Leighton Ave., Rochester, N. Y.

Commercial Picture Equipment Co., 1802 W. Columbia, Chicago, Ill.

• CONTRACTORS

Commercial Research, 20 Bartlett Ave., Detroit, Mich.
Commonwealth Engineering Co., 1771 Springfield St., Dayton, Ohio
Communication Co., 300 Greco Ave., Coral Gables, Fla.
Communication Equipment Co., 5646 W. Race, Chicago, Ill.
Community Measuring Laboratories, 350 Leland Ave., Plainfield, N. J.
Compagnie General De Telegraph, 79 Blvd. Haussman, Paris, France
Compco Corp., 2251 W. St. Paul Ave., Chicago, Ill.
Computer Control Co., Wellesley, Mass.

Computer Research Corp., 3348 El Segundo, Manhattan Beach, Calif.
Comstock Wescott, 1430 Massachusetts Ave., Cambridge, Mass.
Concord Radio Corp., Chicago, Ill.
Condenser Products Co., 1369 N. Branch St., Chicago, Ill.
Conmar Products Co., 140 Thomas St., Newark, N. J.
Connecticut Hard Rubber Co., 407 East St., New Haven, Conn.
W. B. Connor Engineering Co., Danbury, Conn.
Conrad Industry Coolers, Holland, Mich.
Conray Corp., 29 W. Apple St., Dayton, Ohio
Consolidated Diesel Electric Co., Ludlow & Canal Sts., Stamford, Conn.

Consolidated Electrode Co., 919 N. Michigan Ave., Chicago, Ill.
Consolidated Engineering Co., 620 N. Lake Ave., Pasadena, Calif.
Consolidated Hammer, 2711 Miami St., St. Louis, Mo.
Consolidated Industries, By-Pass Route 52, Lafayette, Ind.
Consolidated Vacuum Co., 735 Ridge West, Rochester, N. Y.
Consolidated Vultee, 3156 Pacific Highway, San Diego, Calif.
Consolidated Vultee, Grants Lane, Fort Worth, Tex.
Consultants Design, 1101 Lee Highway, Rosslyn, Va.
Consulting Psychology Inc., 805 Peachtree Bldg., Atlanta, Ga.
Continental Aviation Engineering Corp., 1500 Algonquin Ave., Detroit, Mich.

Continental Electric Co., 325 Ferry St., Newark, N. J.
Continental Motors, 205-215 Market St., Muskegon, Mich.
Continental Oil Co., Ponca City, Okla.
Continental Silver, 32 33rd St., Brooklyn, N. Y.
Control Devices, 8299 E. Nine Mile Rd., Van Dyke, Mich.
Control Engineering, 875 Washington St., Canton, Mass.
Control Institute, Blindorn, Oslo, Norway
Control Instrument Co., 6735th St. Brooklyn, N. Y.
Control Specialists, 115 E. Arbor Vitae, Inglewood, Calif.
Converto Mfg. Co., Cambridge City, Ind.

J. C. Conway, Sabina, Ohio
Cook Electric Co., 1457 Diversey Pkwy., Chicago, Ill.
H. Cook Sporting Goods, 523 Central, N. W., Albuquerque, N. M.
Cooper Metal Associates, 1360 Deise St., Cleveland, Ohio
Cooper Precision Products, 5625 W. Century Blvd., Los Angeles, Calif.
Coordination Research Council, 30 Rockefeller Plaza, New York, N. Y.
Cornelius Co., 1621 E. Hennepin Ave., Minneapolis, Minn.
Cornell Aeronautical Laboratories, 4455 Genesee St., Buffalo, N. Y.
Cornell Dubilier El, 333 Hamilton Blvd., S. Plainfield, N. J.
Cornell University, Ithaca, N. Y.

Corning Glass Works, Walnut St., Corning, N. Y.
Myron Cornish, 68 Far Hills Rd., Dayton, Ohio
Corvey Engineering Co., 1737 DeSales St., N. W., Washington, D. C.
Cory Corp., 221 N. LaSalle, Chicago, Ill.
Courter Electric, 440 6th St., N. W. Grand Rapids, Mich.
Cox Engineering Co., 40 Worth St., New York, N. Y.

R. C. Coxhead Co., Union Bldg., Syracuse, N. Y.
Craig Machine, Inc., 90 Holton St, Danvers, Mass.
Cram and Ferguson, 248 Boylston St., Boston, Mass.
R. W. Cramer Inc., Miller St., Centerbrook, Conn.

Crandall Co., 619 Oakwood St., Dayton, Ohio
Crane Co, 836 S. Michigan, Chicago, Ill.
Creative Development Mfg. Co., Dayton, Ohio
Credda, Inc., 19 W. 26th St., New York, N. Y.
Crest Laboratories, Inc, Rockaway Beach, N. Y.
Crippen Erlich Laboratories, 1138 E. North Ave., Baltimore, Md.
Bing Crosby Enterprises, 9030 Sunset Blvd., Los Angeles, Calif.
Crosby Laboratories, P. O. Box 233, Robbins, Hicksville, N. Y.
Crouse Hinds Co., 1347 Wolf St., Syracuse, N. Y.
Crown Engineering, 3821 N. Broadway, Albuquerque, N. M.

Crucible Steel Co. of American, Oliver Building, Pittsburgh, Pa.
Crystall Research Lab., 29 Allyn St., Hartford, Conn.
Cube Steak Machine Co., 591 Hillside St., Needham, Mass.
Cubic Corp., 2841 Canon St., San Diego, Calif.
Culligan Soft Water Co., Box 788, Tularosa, N. M.
Cummings Machine Wks., 9 Melcher St., Boston, Mass.
Cummins Engine Co., 1515 Harrisburg Pike, Columbus, Ohio
Cund Engr. Corp., 80 S. Vine St., Meriden, Conn.
W. H. Curtin Co, P. O. Box 118, Houston, Tex.
Curtis Automotive, Vandalia, Ohio

Helene Curtis Industries, 4401 W. North Ave., Chicago, Ill.
Curtis Laboratories, 2718 Grifith Pk. Blvd., Los Angeles, Calif.
Curtiss-Wright Corp., Passaic & S. Main, Wood Ridge, N. J.
Cushing and Nevell, 101 Park Ave., New York, N. Y.
Custom Scientific Co., 1000 S. Main St., Dayton, Ohio
Cutler-Hammer Inc., 804 Plum St., Cincinnati, Ohio

Cutter Wood & Sand, 222 Third St., Cambridge, Mass.

D

D. and D. Equipment Co., 624 Arroyo St., San Fernando, Calif.
D. K. Mfg. Co., 5059 S. Kedzie, Chicago, Ill.
Dale Products, Inc., P.O. Box 8117, Albuquerque, N. M.
H. L. Dalis Inc., 175 Varick St., New York, N. Y.
Victor Dalmo Co., 1414 El Camino Real, San Carlos, Calif.
Dane Electronic Laboratory, 316 Stuart St., Boston, Mass.
C. R. Daniels, Inc., Daniels, Md.
Dartmouth College, Hanover, N. H.
Datamatic Corp., 151 Needham St., Newton Highlands, Mass.
Daven Co., 191 Central Ave., Newark, N. J.

Dover Co., 43 W. Apple St., Dayton, Ohio
Davies Laboratories, Inc., 4705 Queensbury Rd., Riverdale, Md.
Davis Refrigeration Co., 120 Tupper St., Buffalo, N. Y.
Ward D. Davis, Fairlawn, N. J.
Dawe Electronics, Boston, Mass.
Day Construction Co., Ranboud, Ill.
Daystrom, Inc., Archbald, Pa.
Dayton Aircraft Products, 17 Stainton Ave., Dayton, Ohio

Dayton Aviation Radio Equipment, P.O. Box 167, Vandalia, Ohio
Dayton Blakewell, 1939 Santa Fe Ave., Los Angeles, Calif.
Dayton Instruments, Inc., 404 Winston Ave., Dayton, Ohio
Dayton Key Shop, 18 E. 4th St., Dayton, Ohio
Dayton Nut Products, 919 N. Main St., Dayton, Ohio
Dayton Rubber, 2342 W. Riverview Ave., Dayton, Ohio
Dayton Sofwater Co., 1288 McCook St., Dayton, Ohio

Dayton Stencil Works, 113 E, 2nd St., Dayton, Ohio
Debell Richardson, Water St., Springfield, Mass.
Decade Instrument Co., Maple Ave., Caldwell, N. J.

Deep Rock Oil, 616 S. Michigan Ave., Chicago, Ill.
Del Mar Engineering Laboratories, Los Angeles, Calif.
Delphos Machine, 3901 Delphos Ave., Dayton, Ohio
De Mambro Radio Supply, 1095 Commonwealth Ave., Boston, Mass.
De Mornay-Bonardi, 780 S. Arroyo Pkwy., Pasadena, Calif.
De Mornay-Budd, Inc., New York, N. Y.
J. P. Den Hartog, 64 Fairbanks Ave., Cambridge, Mass.
Denison Engineering Co., 1160 Dublin Rd., Columbus, Ohio
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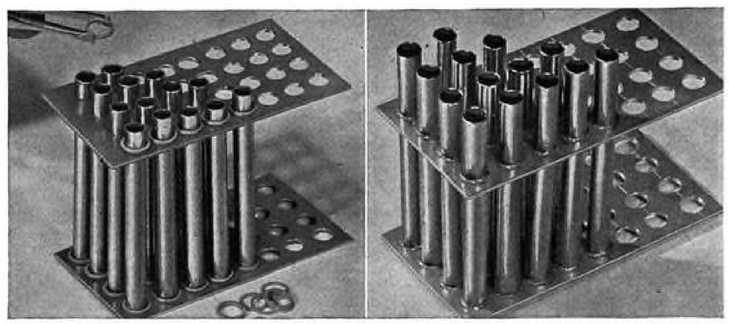

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R. A. Hawks Co., 123 E. Montecito, Sierra Madre, Calif.
James H. Hawn, 3269 Karen Ave., Long Beach, Calif.

Haydon Mfg. Co., Torrington, Conn.
Hayes Aircraft Co., PO Box 2287, Birmingham, Ala.
Hayes Industries, Wildwood Rd., Jackson, Mich.
Hazeltine Electric Corp., 58-25 Little Neck Pkway., Little Neck, N. Y.
Hefco Co., 2012 Sherwood, Detroit, Mich.
Heiland Research Corp., 130 E. Fifth Ave., Denver, Colo.
Heineman Electric Co., Trenton, N. J.
Albert Heins, 10435 Lindberg Ave., Pittsburgh, Pa.
Heitz Lightburn, New York, N. Y.
Helicopters Inc., Stratford, Conn.

Helipot Corp., 916 Meridian St., Pasadena, Calif.
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Hobart Bros. Co., 1221 Hobart Sq., Troy, Ohio
Hobart College, Geneva, N. Y.
Hoffman Laboratories Inc., Box 2471, Terminal Annex, Los Angeles, Calif.
Hoffman Radio Corp., 3761 S. Hill St., Los Angeles, Calif.

Hogan Laboratory Inc., 155 Perry St., New York, N. Y.
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Holmes & Marver Co., Los Angeles, Calif.
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Homelite Corp., 4405 Riverdale Ave., Pt. Chester, N. Y.

Hooker Electric Co., Buffalo & 47th Sts., Niagara Falls, N. Y.
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Herman Hosher, 385 Putnam Ave., Cambridge, Mass.
Frank G. Hough Co., E. Sunnyside Ave., Libertyville, Ill.
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Houston Corp., Los Angeles, Calif.
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Kurtz Labs, Yellow Springs, Ohio
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Leland Electrical Co., 1501 Webster St., Dayton, Ohio
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Stanford University, 1915 University Ave., Stanford, Calif.
Lenkurt Electric Sales, 1105 County Rd., San Carlos, Calif.

Lepel High Frequency Laboratory, 37th Ave., New York, N. Y.
Harold Lerman, 2268 Grand Concourse, Bronx, N. Y.
Lessels & Associates, 916 Commonwealth Ave., Boston, Mass.
R. G. Letourneau Inc., 2301 N. Adams St., Peoria, Ill.
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Levinthal Electronic Prods. Co., 2821 Fair Oaks Ave., Redwood City, Calif.
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Life Electronic Sales Co., 345 Broadway, New York, N. Y.
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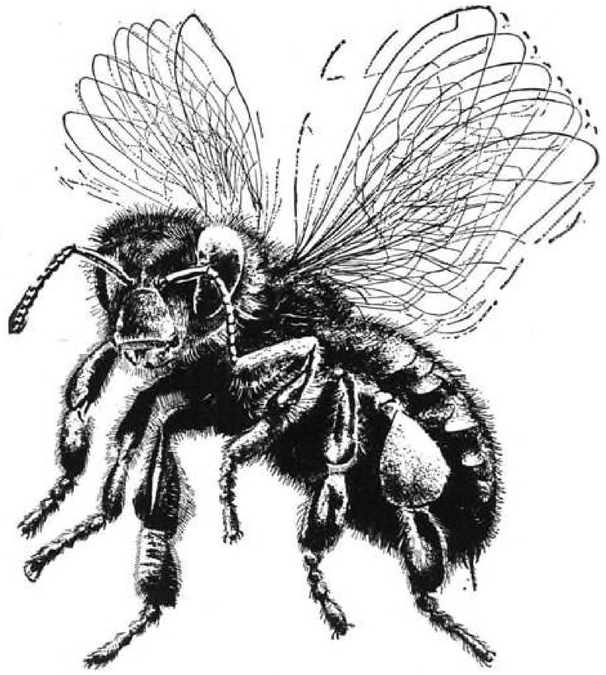

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Litton Bros. Indust., E. Brittan Ave., San Carlos, Calif.

Litton Industries Inc., 336 N. Foothill Rd., Beverly Hills, Calif.
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Logetronics Inc., 1177 New Hampshire Ave., Washington, D. C.
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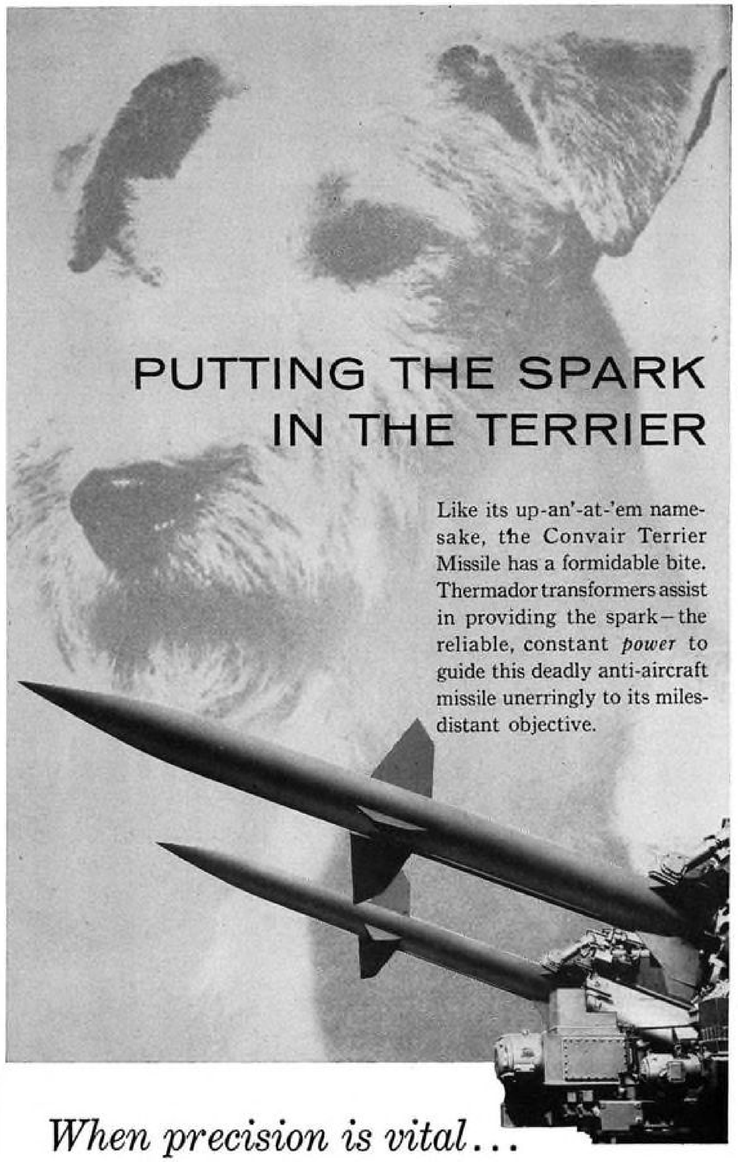

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McIntosh Engineering Laboratories, 320 Water St., Binghamton, N. Y.
McKays Co., 473 N. Cleveland Ave., St. Paul, Minn.
E. S. McKittrick, 7839 S. Stafehtg Prk., Hunt Park, Calif.
J. L. A. McLaughlin, P.O. Box 529, La Jolla, Calif.
McLean Development Laboratories, Strong Ave., Copioque, N. Y.

McMaster University, Westdale, Hamilton, Canada
McMillan Laboratories, Inc., 28-3 Central St., Ipswich, Mass.
P. M. McPherson Co., Acton, Mass.
Mearl Mfg. Co., 220 Westfield Ave., Roselle Pk., N. J.
Measurements Corp., Intervale Rd., Boonton, N. J.
Mechanical Products, 1824 River St., Jackson, Mich.
Mechanisms Co., Uhrichsville, Ohio
Medical College of Alabama, 619 S. 19th St., Birmingham, Ala.
Medical Instrument Research, 2656 N. Pasadena Ave., Los Angeles, Calif.
Dr. A. B. Meinel, Williams Bay, Wis.

Mellon Institute, 4400 Fifth Ave., Pittsburgh, Pa.
Melpar, Inc., 3000 Arlington Blvd., Falls Church, Va.
Mepco, Inc., 37 Abbett Ave., Morristown, N. J.
Mercury Electronics Co., P.O. Box 45, Red Bank, N. J.
Meridan Corp., 2525 Jim Daly Rd., Inkster, Mich.
Merz Engineering, Inc., 200 S. Harding St., Indianapolis, Ind.
Messinger Bearings Co., Erie Ave., Philadelphia, Pa.
Metal Goods Corp., U. S. National Bank Bldg., Denver, Colo.
Metal Hydrides, Inc., 12-24 Congress St., Beverly, Mass.

Metal Trims, Inc., P.O. Box 171, Youngstown, Ohio
Metalab Equipment, 270 Duffy Ave., Hicksville, N. Y.
Metalectro Corp., Laurel, Md.
Metalurgical Research and Development Co., Barr Bldg., Washington, D. C.
Metalwerk Planees, Reu Tyrol, Austria
R. H. Metcalf Co., 3883 Fulton Ave., Dayton, Ohio
Metcut Research Associates, 3980 Rosslyn Dr., Cincinnati, Ohio
Meterology Research, Inc., 1704 E. Walnut St., Pasadena, Calif.
Metropolitan Aircraft, 8075 Woodly St., Van Nuys, Calif.
Metropolitan Electronics, New York, N. Y.

Metron Instrument Co., 432 Lincoln, Denver, Colo.
Meyer Plumbing Co., 2118 Salem Ave., Dayton, Ohio
Miami Dickeson Co., 821 Springfield St., Dayton, Ohio
Miami University, Oxford, Ohio
Miami Valley Hospital, Dayton, Ohio
Mica Insulator Co., 801 Broadway, Schenectady, N. Y.
Micamold Electronic Co., 1087 Flushing Ave., Brooklyn, N. Y.
Michigan State University, E. Lansing, Mich.
Mico Instrument Co., 80 Trowbridge St., Cambridge, Mass.
Micro Metallic Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.

Microlab, 301 S. Ridgewood Rd., S. Orange, N. J.
Micrometrical Mfg., 345 S. Main St., Ann Arbor, Mich.
Microwave Associates, Inc., 22 Cummington St., Boston, Mass.

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Micro Wave Development Laboratories, 220 Grove St., Newton, Mass.
Microwave Radiation Co., 312 Pacific Ave., Venice, Calif.
Midland Finishes, E. Water St., Waukegan, Ill.
Midland Specialty Co., 425 W. San Antonio St., El Paso, Tex.
Midwest Engineering Development Co., Kansas City, Mo.
Midwest Geophysical, 3401 S. Harvard Ave., Tulsa, Okla.
Midwest Mfg., Galesburg, Ill.
Midwest Research Institute, 425 Volker Blvd., Kansas City, Mo.
Midwest Tank Mfg. Co., 2075 S. Belmont St., Indianapolis, Ind.
Midwestern Geophysical Laboratories, 180 E. California St., Pasadena, Calif.
Midwestern Instruments, Fourth & Sheridan, Tulsa, Okla.
Miehle Printing Press, 1335 Maple St., Los Angeles, Calif.
Dr. J. W. Miles, 450 Tuaelitan Rd., Los Angeles, Calif.
Chas. Millar Sons Co., 501 Main St., Utica, N. Y.
August E. Millen, 9226 Hudson Blvd., N. Bergen, N. J.
I. Miller Sons, Jersey City, N. J.
Miller Metal Products, 2215 Russell St., Baltimore, Md.
Miller Research Laboratories, 2833 Maisel St., Baltimore, Md.
William Miller Corp., 325 N. Halstead Ave., Pasadena, Calif.
Millivac Instruments, 416 Crown St., New Haven, Conn.
Lupton Mills Supply Co., 1152 Market St., Chattanooga, Tenn.
Mine Safety Appliance, 230 N. Braddock Ave., Pittsburgh, Pa.
Minneapolis-Honeywell Regulator Co., 2600 Ridgway Rd., Minneapolis, Minn.
Minnesota Electric Co., 47 W. Water St., St. Paul, Minn.
Minnesota Mining Mfg., 900 Fauquier Ave., St. Paul, Minn.
Mira Corp., 2656 N. Pasadena Ave., Los Angeles, Calif.
Mishawaka Rubber Mfg., 407 N. Main St., Mishawaka, Ind.
Missouri Research Laboratories, 2609 Washington Ave., St. Louis, Mo.
C. E. Mitcham Co., Box 432, Albuquerque, N. M.
Mitchell Camera Co., 666 W. Harvard St., Glendale, Calif.
Mitchell Camera Co., Los Angeles, Calif.
Model Engineering Mfg., Inc., Bayne City, Mich.
Modelectric Products Co., 1500 Bangs Ave., Asbury Park, N. J.
Dr. F. Moeller, Johannes Gutenberg, Mounz, Germany
Molded Insulation, 335 E. Price St., Philadelphia, Pa.
Molded Latex Products, 27 Kentucky Ave., Paterson, N. J.
Momsen Dunnegan Rya, El Paso, Tex.
Monadnock Mills, 901 E. 14th St., San Lendro, Calif.
Monitor Products Co., 815 Fremont Ave., Pasadena, Calif.
Monomer Polymer, Inc., Leominster, Mass.
Monowatt, 95 Hathway St., Providence, R. I.
Monroe Calculating Machine Co., 555 Mitchell St., Orange, N. J.
Monsanto Chemical Co., Nicholas Rd., Dayton, Ohio
Cottrell Moore, N. Cohoctan, N. Y.
Moraine Box Co., P.O. Box 118, Dayton, Ohio
Morgan Machine Co., 1230 University St., Rochester, N. Y.
Morrill Construction Co., 515 Crafts St., Cambridge, Mass.
Morris Distributing Co., 1153 W. Fayette St., Syracuse, N. Y.
Morris Steel Supply, 419 W. Central Ave., Albuquerque, N. M.
Morse Instrument Co., 21 Clinton St., Hudson, Ohio
Moseley, F. L., 409 N. Fair Oaks, Pasadena, Calif.
Motch Merryweather, 1213 W. Third St., Cincinnati, Ohio
Motor Generator Co., Troy, Ohio
Motorola, Inc., 4545 W. Augusta Blvd., Chicago, Ill.
Mount Holyoke College, S. Hadley, Mass.
Mt. Washington Observatory, Gorham, N. H.
Mt. Wilson Observatory, 813 Santa Barbara, Pasadena, Calif.
Mt. Zion Hospital, 1600 Divisaders St., San Francisco, Calif.
H. M. Mueller Corp., 6106 Excelsior Blvd., Minneapolis, Minn.
Muir Head Co., Beckham, England
Multiple Brecker Co., 918 Beacon St., Boston, Mass.
Multitek Corp., 150 W. Ivy St., Inglewood, Calif.
Munston Mfg. Service, 43 Vesey St., New York, N. Y.
Murdock Webbing Co., P.O. Box 788, Pawtucket, R. I.
Mutual Contracting, 202 First Ave., Atlantic Heights, N. J.
Mycalex Corp. of America, 60 Clifton Blvd., Clifton, N. J.
Mystic Woodworking Co., 26 Mystic Ave., Medford, Mass.

N

NOPCO Chemical Co., 15 Essex St., Harrison, N. J.
Nankervis Co., 19255 W. Davison Ave., Detroit, Mich.
Narda Corp., 160 Herrichs Rd., Mineola, N. Y.
Narmco, Inc., 1882 Moore St., San Diego, Calif.
Nash Engrg. Co., 242 Wilson Rd., So. Norwalk, Conn.
Nassau R & D Assn., Inc., 66 Main St., Mineola, N. Y.
Nathan Products Co., 2157 Prospect Ave., New York, N. Y.
National Academy of Science, 2101 Constitution Ave., Washington D. C.
National Aero Research Institute, Amsterdam, Holland
National Aerotreen Co., Ft. Worth, Tex.
National Appliance Co., Swan Island, Portland, Ore.

National Capacitor Co., 25 School St., Quincy, Mass.
National Cash Register, 1324 S. Patterson Blvd., Dayton, Ohio
National Cine Equipment Inc., 209 W. 48th St., New York, N. Y.
National Co., 61 Sherman St., Malden, Mass.
National Construction Co., 767 E. Third St., Boston, Mass.
National Design Research Co., 1354 Main St. No., Ann Arbor, Mich.
National Elec. Machine Shop, 919 Jesup Blair Dr., Silver Springs, Md.
National Engineering Co., 426 So. Spring St., Los Angeles, Calif.
National Firework, W. Hanover, Mass.
National Foremans Institute, 3164 Portsmouth Ave., Cincinnati, Ohio

National Instruments Lab., 6108 Rhode Island Ave., Riverdale, Md.
National Luchtvsartlab, Sloterweg 145, Amsterdam, Holland
National Paint & Oil Co., 207 N. Second St., Nashville, Tenn.
National Opinion Research, 5711 S. Woodlawn, Chicago, Ill.
National Research Corp., 70 Memorial Dr., Cambridge, Mass.
National Scientific Lab., 2010 Massachusetts Ave., Washington, D. C.
National Semiconductor Co., Evanston, Ill.
National Spectro Lab., 6300 Euclid St., Cleveland, Ohio
National Union Electric Corp., 350 Scotland Rd., Orange, N. J.

Native Laces Textile, 261 Fifth Ave., New York, N. Y.
NEA Service, W. Third & Lakeside, Cleveland, Ohio
Neeco Contractors, 744 S. Euclid Ave., Tucson, Ariz.
Needham Mfg., 591 Hillside Ave., Needham Hg., Mass.
Neely Enterprises, 7422 Melrose St., Los Angeles, Calif.
Nelson, Dr. Wilbur C., University of Michigan, Ann Arbor, Mich.
Neomatic, Inc., 9010 Bellanca Ave., Los Angeles, Calif.
Network Mfg. Corp., 213 W. Fifth St., Bayonne, N. J.
New Bedford Cordage, Boston, Mass.
New England Laundry, 12 Beacon St., Somerville, Mass.
New England Transformer Co., 47 McGrath Highway, Somerville, Mass.
New Hudson Mfg. Co., 56849 Grand River, New Hudson, Mich.
New Jersey Electric Co., Kennilworth, N. J.
New Jersey Zinc, 160 Front St., New York, N. Y.

New London Instrument Co., P.O. Box 189, New London, Conn.
New Mexico College, State College, N. M.
New Mexico Military Institute, Roswell, N. M.
New Products Mfg. Inc., 631 Wayne St., Dayton, Ohio
New York Academy of Sciences, 1 East 63rd St., New York, N. Y.
New York Air Brake, 230 Park Ave., New York, N. Y.
New York Air Brake, Watertown, N. Y.
New York State College, Alfred, N. Y.
New York Test Labs., 80 Washington St., New York, N. Y.
New York University, Washington Sq., New York, N. Y.

Newark College of Engrg., 367 High St., Newark, N. J.
Newark Special Tool, 97 St. Francis St., Newark, N. J.
Newark Wire Cloth Co., 351 Verona Ave., Newark, N. J.
Newton Co., Manchester, Conn.
Ney, J. M. Co., 71 Elm St., Hartford, Conn.
Nichols Products Co., 325 W. Main St., Morristown, N. J.
Nichols Rauch, Ann Arbor, Mich.
Niles-Bement-Pond, 1 Charter Oak Blvd., W. Hartford, Conn.
Noble Co., 1860-7th St., Oakland, Calif.
Nobles Engrg. Mfg. Co., 645 E. 7th St., St. Paul, Minn.
Non-Linear Systems, Inc., Del Mar Airport, Del Mar, Calif.
Norden Ketay, 99 Park Ave., New York, N. Y.
Norman, J. O., Inc., P.O. Box 943, Roswell, N. M.
Norrman Ernst Labs., Wilams Bay, Wisc.
North American Aviation, Inc., International Airport, Los Angeles, Calif.

North American Brass, Waterbury, Conn.
North American Instruments, Inc., Altadena, Calif.
North American Lace, 8th & Alleghany, Philadelphia, Pa.
North Carolina College, Durham, N. C.
North Carolina State College Agriculture, Raleigh, N. C.
North Electric Mfg., 501 South St., Galion, Ohio
Northeastern Engineering, Bedford St., Manchester, N. H.
Northeastern University, 360 Huntington Ave., Boston, Mass.
Northern Radio Co., 143-5 W. 22nd St., New York, N. Y.
Northrop Aircraft, Inc., Northrop Field, Hawthorne, Calif.
Northwest Airlines, 1885 University Ave., St. Paul, Minn.

Northwestern University, 619 Clark St., Evanston, Ill.
Norton Co., 1 New Bond St., Worcester, Mass.
Norton Mfg. Co., 525 W. 76th, Chicago, Ill.
Noville Associates, 906 S. Robertson Blvd., Los Angeles, Calif.
Nox Rust Chemical Co., 333 N. Michigan St., Chicago, Ill.
Nuarc Co., Inc., 824 S. Western, Chicago, Ill.
Nuclear Development Associates, 80 Grand St., White Plains, N. Y.
Nuclear Instrument & Chemical Corp., 225 W. Erie, Chicago, Ill.

Nuclear Measurements Corp., 2470 N. Arlington Ave., Indianapolis, Ind.
Nuclear Research Corp., 2563 Grays Ferry Rd., Philadelphia, Pa.
Nuclear Research Development Co., 1094 Sutter St., St. Louis, Mo.
Nucleonic Co. of America, 497 Union St., Brooklyn, N. Y.
Nutile Machine Co., 14 Eastern Ave., Winchester, Mass.

O

O and M Machine, 7421 E. Slauson Ave., Los Angeles, Calif.
Oakwald Labs., RFD #4, Box 124, Alexandria, Va.
Oakwood Tool Engrg. Co., Dayton, Ohio
Oberlin College, Oberlin, Ohio
Odin Associates, P.O. Box 4242, Pasadena, Calif.
Oerlikon Tool & Arm, Asheville, N. C.
Offner Electronics, 5320 N. Kedzie, Chicago, Ill.
Ohio Chemical and Mfg., 1177 Marquet St., Cleveland, Ohio
Ohio State University, 310 Administration Bldg., Columbus, Ohio
Ohio University, Athens, Ohio

Ohmart Corp., 2236 Bogen St., Cincinnati, Ohio
Okeefe and Merritt, 3700 E. Olympic Blvd., Los Angeles, Calif.
Oklahoma A & M College, Stillwater, Okla.
Okonite Co., 1940 Canal St., Passaic, N. J.
Olin Mathieson Chemical Corp., P.O. Box 48, Niagara Falls, N. Y.
Oliver Corp., Battle Creek, Mich.
Olson Industrial Products, 40 W. Water St., Wakefield, Mass.
Olympic Development Co., 30 Commerce Rd., Stamford, Conn.
Olympic Glove Co., 95 Madison Ave., New York, N. Y.
Olympic Radio & TV, 34-01 38th Ave., Long Island City, N. Y.

Oneil and Associates, Annapolis, Md.
Oneil, H. T. and Associates, Washington, D. C.
Oneil, L. E. and Associates, 446-C Patterson Rd., Dayton, Ohio
Ontario Research Foundation, Toronto, Canada
Operations Research, Inc., 8485 Fenton St., Silver Springs, Md.
Ophthalmolog Foundation, 111 E. 59th St., New York, N. Y.
Optical Film Engrg. Co., 2731 N. Sixth St., Philadelphia, Pa.
Optical Plastic Co., 69 Southfield Ave., Stamford, Conn.
Optomechanism, Mineola, N. Y.
Optron Labs., 2725 Salem Ave., Dayton, Ohio

Ordnance Associates, 845 El Centro St., S. Pasadena, Calif.
Oregon Electrical Mfg. Co., 2232 E. Burnside St., Portland, Ore.
Oregon State College, Corvallis, Ore.
Orlando Research Inc., P.O. Box 6491, Orlando, Fla.
Oro Mfg., Adrian, Mich.
Oronite Chemical Co., 200 Bush St., San Francisco, Calif.
Ortley Chester, 125 Bridge Ave., Bay Head, N. J.
Otis Elevator Co., 35 Ryerson St., Brooklyn, N. Y.
Overberger, Dr. C. C., 99 Livingston St., Brooklyn, N. Y.
Owens Corning Fiberglas, 1833 Nicholas Bldg., Toledo, Ohio
Owens-Illinois, 1700 N. Westwood, Toledo, Ohio
Ozalid Corp., 419 Central Ave., Albuquerque, N. M.

P

PCA Electronics, Inc., 2180 Colorado Ave., Santa Monica, Calif.
Pachmayr Gun Works, 1220 S. Grand Ave., Los Angeles, Calif.
Pacific Airmative, 2940 N. Hollywood Way, Burbank, Calif.
Pacific Mercury TV, 1450 Aetna St., Van Nuys, Calif.
Pacific Optical Co., 6145 W. Century Blvd., Los Angeles, Calif.
Pacific Parachute, Seattle, Wash.
Pacific Scientific Co., 1430 Grande Vista Ave., Los Angeles, Calif.
Packard Bell, 12333 W. Olympic Blvd., Los Angeles, Calif.
Padblock Co., Inc., P.O. Box 492, Wichita, Kans.
Page Communicat Engineer's, 710 14th St., NW, Washington, D. C.
Pako Corp., 1010 Lyndale Ave., No., Minneapolis, Minn.
Pan American Airways, Chrysler Bldg., New York, N. Y.
Panoramic Radio Prod, 10 S. Second Ave., Mt. Vernon, N. Y.
Par Metal Products, 32-62 49th St., Long Island City, N. Y.
Parke Moth Lab, Inc., Concord, Mass.
Parker Appliance Co., 17325 Euclid Ave., Cleveland, Ohio
Parker Browne Co., P.O. Box 181, Ft. Worth, Tex.
Parker, Frank A., Auburndale, Mass.
Pason College, Fairfield, Iowa

Parsons Industries, Traverse City, Mich.
Parsons Machine Co., 617 S. Olive St., Los Angeles, Calif.
Parsons, Ralph M., Co., 135 W. Dayton St., Pasadena, Calif.
Pasadena Hydraulics, Inc., 273 N. Hill Ave., Pasadena, Calif.
Pastushin Corp., 5651 W. Century Blvd., Los Angeles, Calif.
Patten Co., Inc., 142 Green St., Worcester, Mass.
Patterson Kelley Co., E. Stroudsburg, Pa.
Patterson Moos Co., Jamaica, N. Y.
Patterson Moos Co., 32-36 47th Ave., Long Island City, N. Y.
Peerless Corp., Watertown, Mass.

Peerless Instrument, 90-15 Corona Ave., Elmhurst, N. Y.
Peerless Radio, 92-32 Merrick Rd., Jamaica, N. Y.
Peninsular Chemical Research, 11035 NW, 5th Ave., Gainesville, Fla.
Pennsylvania Refining Corp., 2686 Lisbon Ave., Cleveland, Ohio
Pennsylvania Salt Mfg. Co., Chestnut Hill, Philadelphia, Pa.
Pennsylvania State College, State College, Pa.
Pennsylvania Testing Lab, 30 E. Court St., Doylestown, Pa.
Penola Oil Co., 15 W. 51st St., New York, N. Y.
Pereny Equipment, 893 Chambers Rd., Columbus, Ohio
Perkins Eaton Machine, Boston, Mass.

Elmer Perkin Corp., 230 N. Michigan Ave., Chicago, Ill.
Elmer Perkin Corp., Main Ave., Norwalk, Conn.
Perkins, C. D., Princeton, N. J.
Permanent Filler Co., 1800 W. Washington Blvd., Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Personnel Research Center, 1104 Macabe Bldg., Detroit, Mich.
Petcar Research Co., Newark, N. J.
Peterson Construction Co., 431 W. Chestnut Ave., Monrovia, Calif.
Peterson Neville Co., 365 Dorchester Ave., S. Boston, Mass.
Pfaff and Kendall, 84 Foundry St., Newark, N. J.

Pfaudler Co., 1000 West Ave., Rochester, N. Y.
Phebco, Inc., 3640 Woodland Ave., Baltimore, Md.
Philadelphia Air Transport Co., P.O. Box 27, Morristown, Pa.
G. A. Philbrick Research, 230 Congress St., Boston, Mass.
Philco Corp., 18th & Courtland Sts., Philadelphia, Pa.
Philharmonic Radio TV, 235 Jersey Ave., New Brunswick, N. J.
Philips Lab, Broadway, Irvington, N. Y.
Phillips Petroleum, Bartlesville, Okla.
Phoenix Chemical Lab, 3953 W. Shakespeare, Chicago, Ill.
Phoenix Trimming Co., 2000 N. Racine Ave., Chicago, Ill.

Photocon Research, 1062 N. Allen St., Pasadena, Calif.
Photogrammetry, Inc., 901 Pershing Dr., Silver Springs, Md.
Photographic Products, 1000 N. Olive St., Anaheim, Calif.
Photoplating Co., 215-17 NE. Fifth St., Minneapolis, Minn.
Photostat Corp., 303 State St., Rochester, N. Y.
Photoswitch, Inc., 21 Chestnut St., Cambridge, Mass.
Photron Instrument Co., 6516 Detroit St., Cleveland, Ohio
Physiological Institute, Gottingen, Germany
Piasecki Helicopter, 100 Woodland Ave., Norton, Pa.
Pickard and Burns, 240 Highland Ave., Needham, Mass.
Pickett and Eckel, 9020 Las Tunas Dr., Alhambra, Calif.
Pierce Wire Recorder, Evanston, Ill.
Pioneer Electric Research, 7212 Circle, Forest Park, Ill.
Pioneer Industries, Reno, Nev.
Pioneer Parachute, 168 Forest St., Manchester, Conn.
Piqua Engrg. Co., 112 E. Ash St., Piqua, Ohio
Pitman, George, 2733 Stratford Ave., Cincinnati, Ohio
Pitman Mfg. Co., 300 W. 79th Terrace, Kansas City, Mo.
Pitometer Co., 50 Church St., New York, N. Y.
Pittsburgh-Des Moines Steel Co., 3436 Neville Island, Pittsburgh, Pa.

Pittsburg Erie Saw, 1569 Tower Ave., St. Louis, Mo.
Pittsburg Lectrodry, Ft. 32nd St., Pittsburgh, Pa.
Pittsburgh Plate Glass, 2000 Grant Bldg., Pittsburgh, Pa.
Plainville Metal Co., College Highway, Plainville, Conn.
Plan Research Corp., 10966 Leconte Ave., Los Angeles, Calif.
Plastic Rubber Products, 3110 Oakridge Dr., Dayton, Ohio
Plastimold, Inc., Attleboro, Mass.
Plax Corp., 672 Farm Ave., Hartford, Conn.
Podbielnia, 341 E. Ohio, Chicago, Ill.
Polamold Lab, Springfield, Ohio

Polar Engineering, Danbury, Conn.
Polarad Electronics, 43-2 34th St., Long Island City, N. Y.
Polarizing Instrument Co., Irvington, N. Y.
Polaroid Corp., 730 Main St., Cambridge, Mass.
Pollack, Max, Co., Inc., Poquonnock Rd., Groton, Conn.
Pollock, Dale, 82 Union St., New London, Conn.
Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y.
Polytechnic Research Development Co., 202 Tillary St., Brooklyn, N. Y.
Polytechnical Labs, Detroit, Mich.
Pomona College, Claremont, Calif.

Ponsford Equipment Co., 305 Canal St., El Paso, Tex.
Pool, Robert M., 700 Gainsborough Rd., Dayton, Ohio
Porter and Berkley, Brockton, Mass.
Porter, H. K., Co., Joliet, Ill.
Portland Copper Tank, S. Portland, Me.
Potter Aeronautical Co., 85 Academy Rd., Newark, N. J.
Potter Brumfield, Price & Gibson Sts., Princeton, Ind.
Potter Instrument Co., 115 Cutter Mill Rd., Great Neck, N. Y.
Potter Mfg. Co., Boston, Mass.
Powder Power Tool, 719 S.W. Woods St., Portland, Ore.

Power Generator, Ltd., 25 N. Montgomery St., Trenton, N. J.
Precision Products, 719 7th St., N.W., Washington, D. C.
Precision Rubber Products, 3110 Oakridge Dr., Dayton, Ohio
Press Wireless, Inc., 25 Prospect Ave., W. Newton, Mass.
Pressed Steel Car, 417 S. Hill, Los Angeles, Calif.
Prestoseal Mfg. Corp., 37-27 33rd St., Long Island City, N. Y.
Prewitt Aircraft Co., 410 S. Springfield Rd., Clifton Hgt., Pa.
Princeton Knit Mill, 450 Seventh Ave., New York, N. Y.
Princeton Radiation Chemistry Lab, P.O. Box 12, Princeton, N. J.
Princeton University, Brunswick Pike, Princetan, N. J.

Princeton Worsted, 115 Bloomsbury St., Trenton, N. J.
Process Equipment Corp., 8 Lister Ave., Hillside, N. J.
Producers Service, 2704 W. Olive St., Burbank, Calif.
Product Development Research, 2365 Leforge Rd., Ypsilanti, Mich.
Product Technicians, 130 E. Maine St., Rochester, N. Y.
Productioneer, Inc., 726 W. Nineteenth St., Chicago, Ill.
Products Development Corp., 307 Bergen Ave., Arlington, N. J.

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Products Instrument, Chicago, Ill.
Propulsion Research, 1860 Franklin St., Santa Monica, Calif.
Prossner Sons, Inc., 244 E. Whitesboro St., Rome, N. Y.
Protection, Inc., 6521 W. St., Inglewood, Calif.
Protective Treatment, 420 Dellrose St., Dayton, Ohio
Prototype Development, 79 Ridgewood Ave., Ridgewood, N. J.
Providence College, River Ave., Providence, R. I.
Psycho Service, Inc., 909 W. Jefferson Blvd., Los Angeles, Calif.
Phychological Research, 121 E. 94th St., New York, N. Y.
Public Health Services, 312 W. Ninth St., Cincinnati, Ohio
Puget Sound College, Tacoma, Wash.
Purdue University, Lafayette, Ind.
Pure Carbonic Co., 295 Vassar St., Cambridge, Mass.
Purolator Products, 970 New Brunswick Ave., Rahway, N. J.
Pyramid Electric Co., 1445 Hudson Blvd., N. Bergen, N. J.

Q

Quantum, Inc., Box 45, Mount Carnel, Conn.
Queens College, 65-3 Kisena Blvd., Flushing, N. Y.

R

R. S. Products Corp., 4600 Germantown Ave., Philadelphia, Pa.
Radiation Count Lab, 5122 Grove St., Chicago, Ill.
Radiation Engineering Lab, Main St., Maynard, Mass.
Radiation Inc., P.O. Box 217, Melbourne, Fla.
Radiation Instrument Development, 2337 W. Marquette, Chicago, Ill.
Radio Ceramics Corp., Angola, Ind.
Radio Corporation of America, Front & Cooper Sts., Camden, N. J.
Radio Development & Research, 26 Cornelison Ave., Jersey City, N. J.
Radio Engrg. Lab, 36-4 37th St., Long Island City, N. Y.
Radio Frequency, Powerville Rd. Pkwy., Boanton, N. J.
Radio Inventions, New York, N. Y.
Radio Magazines, Inc., 67 W. 44th St., New York, N. Y.
Radio Receptor Co., 240 Wythe Ave., Brooklyn, N. Y.
Radio Shack Corp., 167 Washington St., Boston, Mass.
Radio Supply Co., Walton & Franklin St., Syracuse, N. Y.
Radio Wire Television, 110 Federal St., Boston, Mass.
Radioplane Co., 8000 Woodley Ave., Van Nuys, Calif.
Ragazzini, J. R., New York, N. Y.

Rahm Instruments, Inc., 12 W. Broadway, New York, N. Y.
Ramo-Wooldridge Co., 8820 Bellanca Ave., Los Angeles, Calif.
Ramsey, Norman F., Cambridge, Mass.
Rand Corp., 1700 Main St., Santa Monica, Calif. ,
Rathbun Co., Presque Isle, Me.
Rattray, G., Co., Inc., 116-8 Myrtle Ave., Jamaica, N. Y.
Rau Fastener Co., Providence, R. I.
Rauland Corp., 4245 N. Knox Ave., Chicago, Ill.
Raydist Navigation, 2514 W. Pembroke Ave., Hampton, Va.
Raymond Deicer Co., 5300 Pacific Hgt. Prk., Hunt Park, Calif.

Raytheon Mfg. Co., 100 River St., Waltham, Mass.
Rea, J. B., Co., 1723 Cloverfield Blvd., Santa Monica, Calif.
Reaction Motors, Denville, N. J.
Read Standard Corp., 370 Lexington Ave., New York, N. Y.
Reading Batteries, Fifth St., Reading, Pa.
Reco Mfg. Co., 80 Boston St., Winchester, Mass.
Recordak Corp., 441 Madison Ave., New York, N. Y.
Recreation Equipment Co., Anderson, Ind.
Red Lion Cabinet, Red Lion, Pa.
Reed Research, Inc., 1048 Potomac St., N.W., Washington, D. C.

Reeves Hoffman Corp., 7 Hyat St., New York, N. Y.
Reeves Instrument Corp., 215 E. 91st St., New York, N. Y.
Reevesound Co., 304 E. 44th St., New York, N. Y.
Reflectione Corp., Post Rd., Stamford, Conn.
Refrigation Equipment Co., 832 S. Ludlow St., Dayton, Ohio
Regent Jack Mfg., Co., 11905 Regentview Ave., Downey, Calif.
Regis College, Weston, Mass.
Reiner Electronics, 152 W. 25th St., New York, N. Y.
Reinforced Plastics, Vineyard Haven, Mass.
Reisen Lumber Millwork, 1070 Morris Ave., Union, N. J.
Reliance Mfg. Co., 212 W. Monroe, Chicago, Ill.

Rem-Cru Titanium, Midland, Pa.
Remington Corp., Auburn, N. Y.
Remington-Rand Co., 315 Fourth Ave., New York, N. Y.
Rensselaer Polytech, RPI Grounds, Troy, N. Y.
Republic Aviation Corp., Conklin St., Farmingdale, N. Y.
Republic Pictures, 659 Steward St., Hollywood, Calif.
Republic Steel Co., Republic Bldg., Cleveland, Ohio
Resdel Engineering, 2351 Riverside Dr., Los Angeles, Calif.
Research Calculation Co., 7 Water St., Boston, Mass.
Research Development Co., 429 E. Collom, Philadelphio, Pa.
Research Equipment Service, Chicago, Ill.

Research, Inc., Sexton Bldg., Minneapolis, Minn.
Research Welding, 13638 Santa Fe Ave., Southgate, Calif.
Revere Copper Brass, 196 Diamond St., Brooklyn, N. Y.
Revere Corp. of America, 322 N. Cherry St., Wallingford, Conn.
Revere Electric Mfg. Co., 6009 N. Broadway, Chicago, Ill.
Rex Plastics, 607 Seneca Creek Rd., Buffalo, N. Y.
Reynolds Metal Co., 2000 S. 9th St., Louisville, Ky.
Rheem Mfg. Co., 9236 E. Hall Rd., Downey, Calif.
Rhode Island State College, Kingston, R. I.
Rhodes Lewis Co., 4008 W. Jefferson Blvd., Los Angeles, Calif.
Rhodes, M. H., Inc., 30 Bartholomew Ave., Hartford, Conn.

• CONTRACTORS

Wm. M. Rice, Institute, 6100 Main St., Houston, Tex.
Bernard Rices, Sons, New York, N. Y.
Rich Electronic, Inc., 212 N.W. 8th Ave., Miami, Fla.
Richardson Bellows, 1 W. 57th St., New York, N. Y.
Ridell Instruments, Wilams Bay, Wisc.
Paul Rider, 6947 Pershing St., St. Louis, Mo.
Ringwood Chemical Co., Ringwood, Ill.
Riverside Metal Co., 1 Pavillon Ave., Riverside, N. J.
Robbins and Meyers, 1345 Lagonda Ave., Springfield, Ohio
Robbins Mills, 1407 Broadway, New York, N. Y.
Robertshaw Fulton, 110 N. Cotterman St., Greensburg, Pa.
Rocket Jet Engineering Co., 614 W. Colorado, Glendale, Calif.

Rockwood Sprinkler Co., 38 Harlow St., Worcester, Mass.
Rohm and Haas Co., 222 W. Washington Sq., Philadelphia, Pa.
Rohr Aircraft Corp., Ft. of H St., Chula Vista, Calif.
Rollins Co., Ltd., 2010 Lincoln Ave., Pasadena, Calif.
Rome Cable Co., 421 Ridge St., Rome, N. Y.
Rome Electrical Supply Co., 102 Erie Blvd., Rome, N. Y.
Geo. D. Roper Corp., Rockford, Ill.
Rose Bros., Arlington, Va.
E. J. Rose Son, 35 Trefton Dr., E. Braintree, Mass.
Karl E. Rose, 1317 W. Riverview, Dayton, Ohio.
Rose Polytechnic Institute, Terre Haute, Ind.
Rosen Raymond Co., 32nd & Walnut Sts., Philadelphia, Pa.
F. W. Ross, 719 N. Melborn Ave., Dearborn, Mich.
Roth Office Equipment Co., 113 E. Third St., Dayton, Ohio
Roth Rubber Co., 1860 54th Ave., Cicero, Ill.
Rounds, L. M. Electric, 807 W. Thomas St., Rome, N. Y.
Royal Electric, Inc., Jamestown, Ohio

Royal Heaters, Inc., 1024 Westminster Ave., Alhambra, Calif.
Royer and Roger, 123 E. 39th St., New York, N. Y.
Roy Lyn, Inc., Glendale, Calif.
Rubicon Co., Ridge Ave. at 35th St., Philadelphia, Pa.
Ruckstell, Hayward, 410 San Fernando Rd., Los Angeles, Calif.
Ruco, Inc., Box 515, Dayton, Ohio
Bard J. Ruddy, Inc., 1147 Mohawk St., Utica, N. Y.
Ruddys Feed Store, 700 Brandt St., Dayton, Ohio
Rudolph, O. C., Sons, P.O. Box 446, Caldwell, N. J.
Ruffe, Inc., 7525 N.W. 37th Ave., Miami, Fla.
Runner Associates, Mt. Vernon Pl., Golden, Colo.
Rutgers University, College Ave., New Brunswick, N. J.
Rutherford Electric Co., Culver City, Calif.
Rutico, Inc., 490 S. Fair Oaks Ave., Pasadena, Calif.
Ryan Aeronautical Corp., 2701 Harbor Dr., San Diego, Calif.
Ryan Industries Co., 19159 John R St., Detroit, Mich.
Ryan Velluto, 145 Main St., Cambridge, Mass.
J. D. Ryerson, Associates, 412 E. Genesee St., Syracuse, N. Y.

S

S. K. F. Industries, Front & Erie Ave., Philadelphia, Pa.
Sacramento Meter Co., Alamagordo, N. M.
Sacramento State Co., Freeport Blvd., Sacramento, Calif.
Safe Flight Instrument Co., 4 Water St., White Plains, N. Y.
Safeway Heat Element Co., Newfield & Heat Sts., Middletown, Conn.
Sager Electric Supply, 201 Congress St., Boston, Mass.
Sanborn Co., 195 Massachusetts Ave., Cambridge, Mass.
Sanborn Co., 107 Washington St., Albuquerque, N. M.
Sanborn Map Co., 10 Cedar St., New York, N. Y.
Serl Sandberg, Pasadena, Calif.

Sanders Associates, Inc., 137 Canal St., Nashua, N. H.
Sandman Electric Co., 660 Parker St., Boston, Mass.
Sangamo Electric Co., 1301 N. 11th St., Springfield, Ill.
Santa Barbara Research, Goleta, Calif.
Santa Clara College, 820 Alvisto, San Clara, Calif.
E. H. Sargent Co., 4647 W. Foster St., Chicago, Ill.
James Saunders Co., 24 N. Patterson Blvd., Dayton, Ohio
Sawyer Bailey Co., 1559 Niagara St., Buffalo, N. Y.
Schoar And Co., 754 W. Lexington St., Chicago, Ill.
Schaevitz Engineering, Crescent Blvd., Camden, N. J.
Schenectady Products, Schenectady, N. Y.
Frank Schenuit Co., Railroad & Union Ave., Baltimore, Md.
G. T. Schjedahl Co., Medical Arts Bldg., Northfield, Minn.
Schoene Electronics, 1410 S. Grand Ave., Evansville, Ind.
Dr. E. Schofper, Hechingen, Germany

Schriber Sheet Metal, 915 S. Perry St., Dayton, Ohio
Schultz Tool Mfg. Co., 425 S. Pine St., San Gabriel, Calif.
Carl W. Schutter, 80 E. Montauk Hwy., Rockville Center, N. Y.
Schwab Textile Corp., 43 Union Square, New York, N. Y.
Schwarzkopf Microanalysis, 56-19 37th Ave., Woodside, N. Y.
Schweizer Aircraft, P.O. Box 147, Elmira, N. Y.
L. N. Schwien Engineering, 5736 Washington Blvd., Los Angeles, Calif.
Science Research Associates, 57 W. Grande Ave., Chicago, Ill.
Scientific Associates, 2062 E. Piedmont Rd., Atlanta, Ga.
Scientific Specialty Co., 55 Union St., Brighton, Mass.
Scott Aviation Corp., 1314 Depew Ave., Lancaster, N. Y.

Scott Engineering Service, Dayton, Ohio
Seaboard Electric Co., 417 Canal St., New York, N. Y.
Seaboard Machine Co., 3212 E. Olympic Blvd., Los Angeles, Calif.
Seaviews Electric Co., 406 Main St., Avon, N. J.
Edw. Seckel, Princeton, N. J.
Dr. Frederick Seitz, University of Illinois, Urbana, Ill.
Selby Shoe Co., 1020 7th St., Portsmouth, Ohio
E. R. Selfert Co., Syracuse, N. Y.
Seline & Son, 705 S. 16th St., Omaha, Neb.
Seminar Films, 347 Madison Ave., New York, N. Y.

Sensitive Research Instruments, 9 Elm Ave., Mt. Vernon, N. Y.
Sentry Co., Foxboro, Mass.
Prof. Hyman Serban, Lafayette, Ind.
Service Blue Print Co., 400 E. First St., Dayton, Ohio
Service Corp. of America, Marion, Ohio
Service Metal Fabricators, 2209 Michigan Ave., Santa Monica, Calif.
Seva Corp. of America, 2020 Jericho Turnpike, New Hyde Park, N. Y.
Servomechanicisms, Post & Stewart Aves., Westbury, N. Y.
Shamrock Specialties, 229 4th Ave., New York, N. Y.
Shaw Estes, 1407 S. Akard, Dallas, Tex.

Sheffield Corp., 721 Springfield St., Dayton, Ohio
Sheldon Machine Co., 4258 N. Knox St., Chicago, Ill.
Shell Oil Co., 50 W. 50th St., New York, N. Y.
C. A. Shelton Electric Co., Hubbond St., San Fernando, Calif.
Shepard Elevator Co., 2413 Colerain Ave., Cincinnati, Ohio
R. H. Sheppard Co., 101 Philadelphia St., Hanover, Pa.
Sheridan Supply Co., Beverly Hills, Calif.
Sherman Bros., Inc., 205 W. 39th St., New York, N. Y.
Sherman Fairchild, 30 Rockefeller Plaza, New York, N. Y.
Sherron Electric, 1201 Flushing Ave., Brooklyn, N. Y.

Sherwin Williams Co., 101 Prospect Ave., NW, Cleveland, Ohio
Shillstone Test Laboratories, 2301 W. Dallas Ave., Houston, Tex.
Chas. H. Shook, Inc., 582 W. Second St., Dayton, Ohio
Shoop Engineering, 1516 S. Wabash Ave., Chicago, Ill.
Siegler Corp., 2001 E. Artesia St., Long Beach, Calif.
Halsk Siemens, West Zone, Germany
Reinger Wer Siemens, Erlanger, Germany
Sierra Electronic Co., 1040 Britten Ave., San Carlos, Calif.
Sierra Engineering Co., 123 E. Montecito, Sierra Madre, Calif.
Sierra Products, Burbank, Calif.
Sierracin Corp., Burbank, Calif.
Sies Electric Supply Co., 734 E. 11th St., Chattanooga, Tenn.
Robert G. Siff, 11 W. Monument Bldg., Dayton, Ohio
Sigma Instruments, 170 Pearl St., Boston, Mass.

Sikorsky Aircraft, South Ave., Bridgeport, Conn.
Simmonds Aerocessory, 105 White Plains Rd., Tarrytown, N. Y.
Simmons Bros., Inc., 30-28 Starr Ave., Long Island City, N. Y.
Sintercast Corp. of America, New York, N. Y.
Siskin Steel Supply Co., 701 W. 23rd St., Chattanooga, Tenn.
Skiatron Electronics TV Corp., 30 E. 13th St., New York, N. Y.
Sherman Skinner, Inc., 246 Stuart St., Boston, Mass.
Wm. Skinner Sons, 45 E. 17th St., New York, N. Y.
Skydyne, Inc., River Road, Pt. Jervis, N. Y.
Skyline Clothing Co., 424 Central Ave., Peekskill, N. Y.
A. O. Smith Corp., 8533 N. 27th St., Milwaukee, Wis.
Carl E. Smith, 4900 Euclid Ave., Cleveland, Ohio

Smith College, Northampton, Mass.
E. H. Smith Co., 901 Pershing Dr., Silver Springs, Md.
H. A. Smith Machine Co., 226 Harrison St., Syracuse, N. Y.
Hinchman Smith Co., 234 W. Congress St., Detroit, Mich.
J. H. Smith Mfg. Co., Little Britain Rd., Newburgh, N. Y.
L. B. Smith Inc., 357 W. Fayette St., Syracuse, N. Y.
Smith Metal Arts Co., 1721 Elmwood Ave., Buffalo, N. Y.
Morris Smith Co., Myrtle and Wolcott, Ferndale, Mich.
Neal A. Smith, 67 Westview Ave., Worthington, Ohio
Smith and Schaeffer, 3717 Eastern Ave., Cincinnati, Ohio
Ted Smith, Upper Darby, Pa.
Smithsonian Institution, Washington, D. C.
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Solano Laboratories, Berkeley, Calif.
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Sonotone Corp., Box 2, Elmsford, N. Y.
Sorensen and Sons, 375 Fairfield Ave., Stamford, Conn.
Soroban Engineering Inc., Box 338, Melbourne, Fla.
Carl N. Soule, 700 Xenia St., Dayton, Ohio
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Sound Scriber Corp., 226 S. Ludlow St., Dayton, Ohio
Soundrive Engineering, 3300 Cahuenga Blvd., Los Angeles, Calif.
Soundscriber, 146 Munson St., New Haven, Conn.
South Florida Test Service, 4201 NW 7th St., Miami, Fla.
South Shore Machine Co., 8 Brooks Ave., Quincy, Mass.
Southern Ohio Fabric, 3533 Cardiff St., Cincinnati, Ohio
Southern Research, 917 S. Twentieth St., Birmingham, Ala.
Southwest Research Institute, 8500 Culebra Rd., San Antonio, Tex.
Southwest Production Co., Alamo Downs, Box 85D, San Antonio, Tex.
Southwestern Independent Electronics, 2831 Post Oak Rd., Houston, Tex.

Sparkler Mfg., Filters Lake, Mundelein, Ill.
Sparton Radio-TV Co., 50 W. North St., Jackson, Mich.
Moss Spaulding Co., 42 Franklin St., Boston, Mass.
Special Purpose Engineering, Box 741, Norwalk, Conn.
Special Purpose Engineering, 25 Vanderbilt Ave., New York, N. Y.
Specialties, Inc., Skunks Misery Rd., Syosset, N. Y.
Specialty Distributors, 425 Peachtree St., NE, Atlanta, Ga.

Spectrochemical Laboratories, 1010 Wood St., Pittsburgh, Pa.
Henry Spen Co., Inc., 1995 Pitkin Ave., Brooklyn, N. Y.
Spencer Laboratories Co., 186 Massachusetts Ave., Cambridge, Mass.
Spencer Turbine Co., 486 New Park Ave., Hartford, Conn.
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Sperry Products, Inc., Danbury, Conn.
Sperry-Rand Corp., 452 Swann Ave., Alexandria, Va.
Spica, Inc., 7 Grove St., Winchester, Mass.
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Spool Cotton Co., 743 5th Ave., New York, N. Y.

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Sprague Electronics Co., 201 Beaver St., N. Adams, Mass.
Sprague Engineering Sales, 1144 W. 135th St., Gardena, Calif.
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Srepco, Inc., 135 E. Second St., Dayton, Ohio
Stackpole Carbon Co., 1942 Tannery St., St. Marys, Pa.
Stainless, Inc., Third St., North Wale, Pa.
Stallman of Ithaca, 123-131 S. Tioga St., Ithaca, N. Y.
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Standard Armament, 3012 N. Hollywood Way, Burbank, Calif.
Standard Bent Glass, P.O. Box 469, Butler, Pa.
Standard Coil Products, 1919 Vineburn Ave., Los Angeles, Calif.
Standard Container, 484 Bloomfield Ave., Montclair, N. J.
Standard Electric Products, 2240 E. Third St., Dayton, Ohio
Standard Electric Time, 89 Logan St., Springfield, Mass.

Standard Mfg. Co., 1332 Canton St., Dallas, Tex.
Standard Molding Co., 1517 E. Third St., Dayton, Ohio
Standard Oil, 2500 New York Ave., Whiting, Ind.
Standard Oil of California, 225 Bush St., San Francisco, Calif.
Standard Oil of Indiana, 910 S. Michigan Ave., Chicago, Ill.
Standard Oil of New Jersey, 30 Rockefeller Plaza, New York, N. Y.
Standard Piezo Co., 267 E. Pomfret St., Carlisle, Pa.
Standard Pressed Steel, 421 E. Washington Blvd., Los Angeles, Calif.
Standard Register, 626 Albany St., Dayton, Ohio
Standard Rolling Mill, 196 Diamond St., Brooklyn, N. Y.
Standard-Tomson Co., 216 S. Main St., Dayton, Ohio
Stanford Research Institute, Standard Village, Menlo Park, Calif.
Stanley Aviation, 2500 Dallas St., Denver, Colo.
Wm. Stanley Co., 401 Broadway, New York, N. Y.
Stanleys, Alamagordo, N. M.
Stanwyck Winding Co., Newburgh, N. Y.
State Laboratory, Inc., 37 E. 28th St., New York, N. Y.
Statham Laboratories, Inc., 12401 W. Olympic Blvd., Los Angeles, Calif.
Stavid Engineering, 312 Park Ave., Plainfield, N. J.
Roger Stearns Mfg. Co., Denver, Colo.

Stechert Hafner, Inc., 31 E. Tenth St., New York, N. Y.
Steel Products Engineering, 1205 W. Columbia St., Springfield, Ohio
Steelcraft Manufacturing Co., 9017 Blue Ash Rd., Rossmoyne, Ohio
Stehli and Co., Inc., 1372 Broadway, New York, N. Y.
Stein Bros. Mfg. Co., 1401 W. Jackson, Chicago, Ill.
Steiner Ives Co., Springfield Rd., Union, N. J.
W. P. Steiner, 9107 Kingsbury Dr., Silver Spring, Md.
M. Steinthal and Co., 222 Fourth Ave., New York, N. Y.

Stephen Douglas Co, Santa Monica, Calif.
Stereatronics, Inc., 66 West End Rd., Weston, Mass.
Sterling Precision Instrument, 34-17 Lawrence St., Flushing, N. Y.
Sterling Radio Products, P.O. Box 1746, Houston, Tex.
S. Sterling Co., 1531 W. McNichols, Detroit, Mich.
Stevens Arnold Co., 22 Elkins St., S. Boston, Mass.

Stevens Institute, 5th & Hudson, Hoboken, N. J.
J. P. Stevens Co., 1410 Broadway, New York, N. Y.
L. E. Stevens Co., 525 W. Sixth St., Cincinnati, Ohio
Stever H. Guyford, Massachusetts Institute of Technology, Cambridge, Mass.
Stewart Bolling Co., 3190 E. 65th St., Cleveland, Ohio
Stewart Warner Corp., 1300 N. Kostner Ave., Chicago, Ill.
Stoddard Aircraft Radio, 6644 Santa Monica Blvd., Hollywood, Calif.
C. H. Stoelting Co., 424 N. Homan, Chicago, Ill.
B. K. Stoneman Sons, 617 1515 Ave., Inglewood, Calif.
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Stotter Inc., 1441 Broadway, New York, N. Y.
Stotts Friedman, 620 S. Main St., Dayton, Ohio
Philip Stout, Baltimore, Md.
Strangman Mfg. Co., 34 Crafts St., Newtonville, Mass.
Stratex Insts., 1861 Hillhurst, Los Angeles, Calif.
Stratos Corp., Conklin St., Farmingdale, N. Y.
Streeter Amet, 4101 N. Ravenswood, Chicago, Ill.
Stroemungs Technical University, Berlin, Germany
Stromberg Carlson, 160 Carlson Rd., Rochester, N. Y.
R. G. Strome, 4302 Natl. Pike West, Springfield, Ohio
Stroock Co., New York, N. Y.
Stroukoff Aircraft Co., W. Trenton, N. J.
Struthers Dunn Co., 150 N. Thirteenth St., Philadelphia, Pa.
John Stulen Co., Gibsonia, Pa.
Stupakoff Ceramic, Hillview Ave., Latrobe, Pa.
Suchy Division Inc., 358 Fifth Ave., New York, N. Y.
Robert D. Sultzback, 24 N. Douglas Ave., Springfield, Ohio
Summers Gyroscope Co., 2328 Broadway, Santa Monica, Calif.
Sun Oil Co., 1608 Walnut St., Philadelphia, Pa.
Sun Rad Electronics, 650 Avenue of the Americas, New York, N. Y.
Sunstrand Machine Tool, 2531 11th St., Rockford, Ill.
Superdraulic Corp., P.O. Box 583, Somerset, Ky.

Superior Air Products, 132 Malvern St., Newark, N. J.
Superior Auto Inc., 24 Sprague St., Dayton, Ohio
Superior Electric Co., 83 Laurel St., Bristol, Conn.
Superior Pipe, Cleveland Heights, Ohio
Superior Tube Co., Germantown Pk., Norristown, Pa.
Surel Electric Constr., 1511 Lexington Ave., New York, N. Y.
Surface Combustion, 400 Dublen Ave., Columbus, Ohio
Surgeon General, Pentagon, Washington, D. C.
Surpenant Mfg. Co., 199 Washington St., Boston, Mass.
Sverdrup and Parcel, 915 Olive St., St. Louis, Mo.
Swarthmore College, Swarthmore, Pa.

Swedlow Plastic Co., 3757 Wilshire Blvd., Los Angeles, Calif.
B. K. Sweeny Mfg. Co., 1601 23rd St., Denver, Colo.
Swift Industries, 10 Love Lane, Hartford, Conn.
Switlik Parachute, 1325 E. State St., Trenton, N. J.
Sylvania Electric Products, 1740 Broadway, New York, N. Y.
Symons Flying Service, Bishop, Calif.
Synthetical Laboratory, 5558 W. Ardmore, Chicago, Ill.
Syracuse University, 205 University Place, Syracuse, N. Y.
Systems Design, Inc., 550 Fifth Ave., New York, N. Y.
Systems Development, 410 Chenango St., Binghamton, N. Y.
Systems Research Laboratory, 300 Woods Dr., Dayton, Ohio
O. E. Szekely Assoc., 5312 Westminster Ave., Philadelphia, Pa.

T

T. K. M. Electric Co., Rochester, N. Y.
Taber Instrmt. Corp., N. Tonawanda, N. Y.
Tafel Electric Supply Co., Nashville, Tenn.

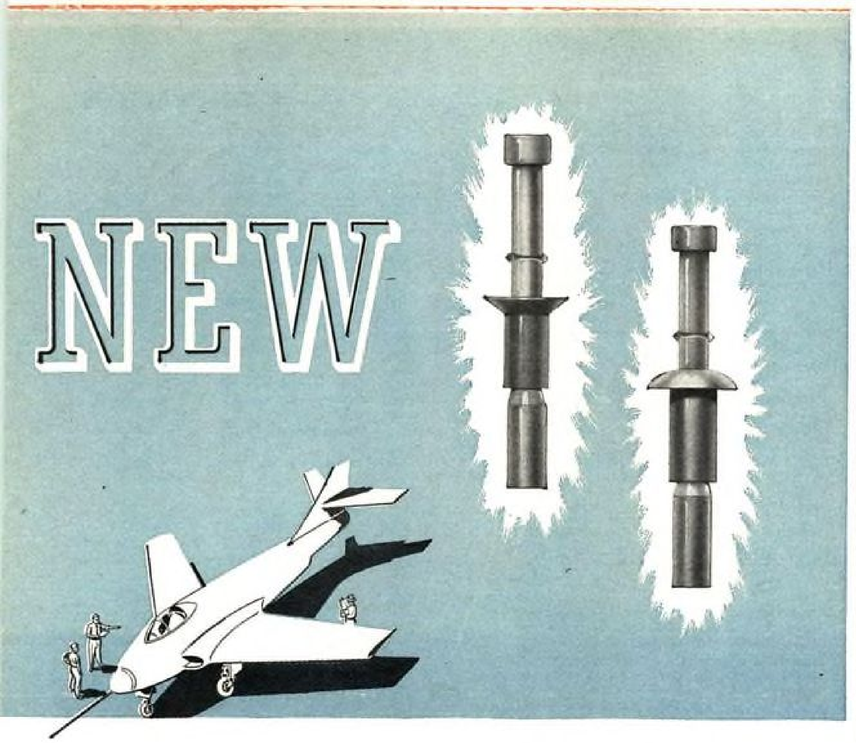
Talco Engr. Co., 2685 State St., Hamden, Conn.
Taller Cooper, Inc., 75 Front St., Brooklyn, N. Y.
Talon, Inc., Meadville, Pa.
Tannewitz Works, Grand Rapids, Mich.
Tappan Stove Co., 250 Wayne Ave., Mansfield, Ohio
Task Corp., 253 N. Fair Oaks Ave., Pasadena, Calif.
Frank Tatsch, 1150 N. Main St., Silver City, N. M.

T. L. Taylor Eng. Sales, 2100 St. Paul St., Baltimore, Md.
Taylor Fibre Co., Norristown, Pa.
Thomas Taylor Sons, 50 Houghton St., Hudson, Mass.
Taylor Wharton Iron, Easton, Pa.
Technical Material, 700 Fenimore Rd., Mamaroneck, N. Y.
Technical Operations, 6 Schouler Court, Arlington, Mass.
Tech Research Development Foundation, Haifa, Israel
Technical Research Group, 51 W. 45th St., New York, N. Y.
Technical Service Inc., Livonia, Mich.
Technicon Co., 215 E. 49th St., New York, N. Y.
Technicraft Corp., 1701 Main St., Kansas City, Mo.
Techno Scientific, 901 Nepperhan Ave., Yonkers, N. Y.
Technology Instr. Co., 531 Main St., Acton, Mass.
Teiner Engineering Corp., 115 Madison St., Malden, Mass.
Tektronix, Inc., 712 Se. Hawthorn Blvd., Portland, Ore.
Telechron Inc., Ashland, Mass.
Telecomputing Corp., 12838 Saticoy St., N. Hollywood, Calif.
Telemark Inc., 79 Prospect Ave., Stamford, Conn.

Teleregister Corp., 445 Fairchild Ave., Stamford, Conn.
Teletronics Labs., 54 Kinkel St., Westbury, N. Y.
Teletype Corp., 1400 Wrightwood Ave., Chicago, Ill.
Televalt Corp., 245 W. 55th St., New York, N. Y.
Television Products, Chicago, Ill.
Temco Aircraft Co., P.O. Box 6191, Dallas, Tex.
Temple University, Broadway & Montgomery, Philadelphia, Pa.
Tennessee A. I. College, Nashville, Tenn.
Tennessee Corp., 21st Ave., Tampa, Fla.
Tenney Engrng Inc., 1090 Springfield Rd., Union, N. J.
Terry Steel, 31 E. 27th St., New York, N. Y.
Test Equip. Sales, 4447 N. Bodine St., Philadelphia, Pa.
Test Research Svs, 12 Normandy Rd., Bronxville, N. Y.
Texas A. and M., College Station, Tex.
Texas Co., Chrysler Towers, New York, N. Y.
Texas Eng. and Mfg., P.O. Box 6191, Dallas, Tex.
Texas Instruments, 6000 Lemmon St., Dallas, Tex.
Texas Metal Mfg. Co., 6114 Forrest Park Rd., Dallas, Tex.
Thermal Research Eng., Mill Rd., Conshohoken, Pa.
Thermo Elect Co., 109 Fifth St., Rochelle Park, N. J.

Thieblot Aircraft, 4924 Hampden Lane, Washington, D. C.
Thiokol Corp., 778 N. Clinton Ave., Trenton, N. J.
A. S. Thomas Co., Inc., 20 Beacon St., Boston, Mass.
Arthur H. Thomas Co., 230 S. Seventh St., Philadelphia, Pa.
Thomas Industries, Ft. Atkinson, Wis.
C. J. Thompson, Davenport, Fla.
Thompson Fence Co., P.O. Box 489, El Paso, Tex.
Thompson Products, 2196 Clarkwood Rd., Cleveland, Ohio
Time Electron Sales, 368 Broadway, New York, N. Y.
Times Facsimile, 540 W. 58th St., New York, N. Y.

Geo. W. Timmons, 780 W. Lane St., Columbus, Ohio
Tinius Olsen Test, Easton Rd., Willow Grove, Pa.
Tison Bros., 2226 S. Sepulveda, Los Angeles, Calif.
Titanium Metals Co., 60 E. 42nd St., New York, N. Y.
Titeflex Inc., 500 Frelinghuysen Ave., Newark, N. J.
Tobe Deutschmann Co., Providence Hwy., Norwood, Mass.
Tokheim Oil Tank Co., 1602 Wabash Ave., Fort Wayne, Ind.
Topp Industries Co., 5255 W. 102nd St., Los Angeles, Calif.
Tornquist Machinery Co., 3830 Santa Fe Ave., Los Angeles, Calif.



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A new, more effective fastener for the aircraft industry has been developed and is now being produced at the Cherry Rivet plant in Santa Ana, California. Designated the Cherry "700," the new rivet provides a wide grip range, positive hole fill, high clinch, uniform stem retention and permits 100% positive inspection.

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This latest fastener advancement is a typical example of how the Cherry Division has paced the industry with new and improved fasteners and the tools and accessories for applying them—all of which are designed, developed and produced in the Santa Ana plant.

This plant is devoted exclusively to the manufacture of products for the aircraft industry.

For information, write for the new Cherry "700" bulletin to Townsend Company, Cherry Rivet Division, P.O. Box 2157-N Santa Ana, California.

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Trailmobile Co., 31st & Robertson, Cincinnati, Ohie
Training Aids, Inc., 4515 Sepulveda Blvd., Sherman Oaks, Calif.
Trane Co., 1978 S. Los Angeles St., Los Angeles, Calif.
Trans Aircraft Corp., New Castle, Del.
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Transistor Products, Inc., 55 Union St., Boston, Mass.
Transitron Electronics Co., 407 Main St., Melrose, Mass.
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Traylor Bos., Mt Vernon Rd., Evansville, Ind.
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Trinity College, Hartford, Conn.
Trinity University, San Antonio, Tex.
Troy Welding Shop, 6203 Second St., NW, Albuquerque, N. M.
Tube Soles, 5400 Alcoa Ave., Los Angeles, Calif.
Tucker Sno Cat Corp., P.O. Box 888, Medford, Ore.
Tufts College, 136 Harrison Ave., Medford, Mass.
Tulane Univ., New Orleans, La.
Tularosa Gas Co., P.O. Box 1751, Tularosa, N. M.
Tull Metal Co., 285 Marietta, NW., Atlanta, Ga.
Turbomeca, Bordes, France
Tuskeegee Inst., Tuskeegee, Ala.
H. W. Tuttle and Co., 261 W. Maumee, Adrian Mich.

U

U. and S. Supply, Inc., 509 S. West St., Syracuse. N. Y.
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Ultrasonic Corp., 640 Memorial Dr., Cambridge, Mass.
Underwood Corp., 1124 E. Yandell Blvd., El Paso, Tex.
J. Unertl Optic Co., 3551 East St., Pittsburgh, Pa.
Union Carbide & Carbon Co., 30 East 42nd St., New York, N. Y.
Union Oil Co., 617 W. 7th St., Los Angeles, Calif.
Union Steel Co., 7301 Telegraph Rd., Los Angeles, Calif.
Union Switch & Signal, 1820 S. Bradock, Swissvale, Pa.
Uniscience, Inc., 112 Crooked Billet, Hatboro, Pa.
United Ad Corp., 41 Haig St., Hamden, Conn.
United Aircraft Co., 400 Main St., Hartford, Conn.
United Aircraft Products, 1116 Bolander Ave., Dayton, Ohio
United Airlines, Inc., 5959 S. Cicero Ave., Chicago, Ill.
United Chromium, Inc., 100 E. 42nd St., New York, N. Y.
United Electronics, Concord, Mass.
United Engineers, 150 Causeway St., Boston, Mass.
United Geophysical, 1200 S. Marengo St., Pasadena, Calif.
United Labs, Inc., Dayton, Ohio
United Manufacturing Co., 180 Whalley Ave., New Haven, Conn.
United Shoe Machinery, Beverly, Mass.
U. S. Dynamics Corp., 1250 Columbus Ave., Boston, Mass.
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SINCE 1941, when General Electric built America's first jet engine, the Company has provided the Armed Forces with more than 31,000 jet engines. Just in the past eight years, General Electric jets have flown over five billion miles, logged ten and one half million hours in such famous aircraft as the Boeing B-47 and the North American F-86 Sabre.

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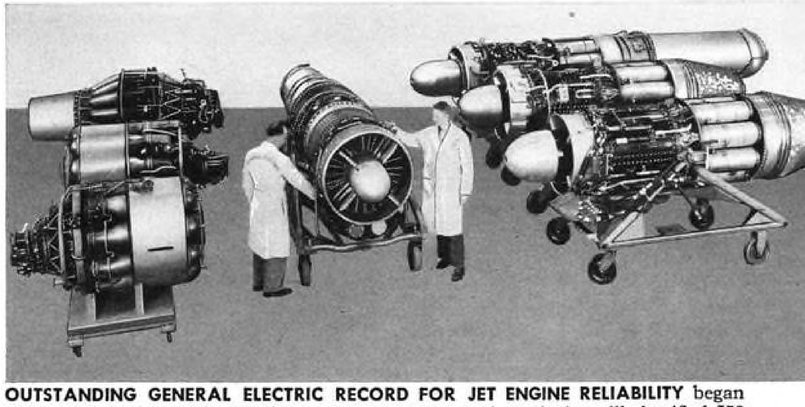

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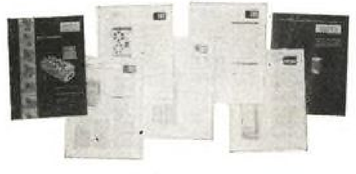

A mark of the Ampex leadership in magnetic tape recorders is the fact that every machine produced equals or exceeds all published performance specifications. A general tape instrumentation brochure and descriptive literature on various models are available on request. Write Dept. UU 2788

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Unique barrel-type package fits perfectly in the nose of the aircraft. Overhead slide-rail mounting provides easy pull-out for service.

STAINLESS STEEL is the material from which Bell X-2 wing and tail are fabricated. Other X-2 pictures are on pages 72-73.

X-2 Hits 1,900 mph. to Set New Record

Washington—The Bell X-2 rocket-powered research plane has set a new unofficial world speed record of 1,900 mph., almost three times the speed of sound.

The X-2 was piloted by Lt. Col. Frank K. (Pete) Everest and surpassed the former unofficial record of 1,650 mph. and Mach 2.5 set by Maj. Charles Yeager flying the Bell X-1A in December 1953. The X-2 flight was 763 mph. faster than the official world speed record set earlier this year by the British Fairey Delta.

At the altitudes where Col. Everest attained his maximum speed, the X-2 reached Mach 2.9. The X-2 is powered by a 15,000 lb. thrust Curtiss-Wright rocket engine.

The X-2 record was set late in July at the USAF Flight Test Center, Edwards AFB, but official announcement of the flight was censored by the Department of Defense despite strong Air Force pressure to release it.

Gen. Nathan F. Twining, USAF Chief of Staff, had intended to announce the X-2 record in a recent speech at the National Press Club here, but all references to Col. Everest's flight were deleted in last-minute censorship by Defense Secretary Charles E. Wilson and his assistant for public and legislative affairs, Robert Tripp Ross. Gen. Twining was finally permitted to make a brief and vague reference to the X-2 record flight in his speech before the Air Force Association convention.

Top level USAF officers, familiar with the high speed flight research program and its technical implications, agreed that no military security was involved in revealing the X-2's maximum speed or altitude achievement. Genuine military secrets lay in the details of the performance parameters of the airframe and its rocket powerplant on its way to and from the peak speed and altitude and their application to the latest supersonic aircraft designs.

Defense Department censorship of the X-2 record flight preceded another bitter battle between USAF and Assistant Secretary Ross' office in which the contents of a proposed guided missile forum presented by the Air Research and Development Command were heavily censored, and the appearance of Maj. Gen. B. A. Schriever, head of the USAF ballastic missiles program, canceled (see page 456).

The Bell X-2 fell considerably short of its maximum design performance of 2,500 mph. on the 1,900 mph. flight. Heat problems with the turbo-fuel pump prevented getting maximum 15,000 lb. thrust from the Curtiss-Wright double-barreled rocket engine.

No unusual flight characteristic such as those experienced by Maj. Yeager in the X-1A were encountered during the X-2 high-speed runs. The X-2 was air launched from a B-50 mother ship and landed on its unusual nose wheel and fuselage skid gear on the Rogers dry lake bed.

Second half of the Bell X-2 high-speed research program will be done by Capt. Iven Kincheloe, Jr., a jet ace of the Korean war, who will attempt to push the research plane to its maximum altitude performance estimated at 120,000 ft., 30,000 ft. higher than the 90,000 ft. unofficial record set by Maj. Arthur Murray in the X-1A.

Capt. Kincheloe has begun several attempts to extend the altitude limits of piloted aircraft but was forced to abort due to mechanical problems.

The record flight in the X-2 marked the climax of a long and distinguished career as an experimental test pilot at Edwards AFB for Col. Everest. It was his final assignment at the USAF Flight Test Center where he has been chief of the flight test operation laboratory. He has been one of the principal high-speed research program pilots since the first supersonic flights of the Bell X-1 in the fall of 1947. He has been assigned to attend the Air University at Maxwell AFB.

The Bell X-2 was built as part of the co-operative USAF, Navy and National Advisory Committee for Aeronautics high-speed flight research program to extend limits of piloted aircraft into supersonic flight areas.

Guided Missiles Bar Disarmament, Complicate U. S. Task, AFA Told

By Claude Witze

New Orleans—Introduction of guided missiles as a tool of war will make disarmament impossible and vastly complicate the task of keeping U. S. military strength up to par, the Air Force Assn. was warned last week at its tenth annual convention.

During a five-day session that saw little attention paid to more-conventional weapon systems, T. F. Walkowicz, AFA national director, warned:

• **The next war** can be started by accident, whim, mechanical malfunction or by a relatively-small power employing trickery.

• **Once missiles are in America's** arsenal, our entire concept of military logistics may be rewritten with industry being given more direct contact with the using commands, eliminating the need for all or part of the Air Materiel Command's present complicated set-up.

ICBM Means New Era

Walkowicz said that the intercontinental ballistic missile will bring a new era of dangerous instability to the world since a target country will have almost no warning of attack.

For this reason, Walkowicz said, it probably will be necessary for a democracy to decentralize control over the means of making war, even to the level of a commander who has responsibility for pushing a button.

Walkowicz also pointed to the possibility of a country such as the Soviet Union providing the intercontinental ballistic missile to a relatively-smaller power, say Egypt. In such a case, he said, an "apprentice dictator" could fire the weapon at Moscow, resulting in possible retaliation against the U. S. by the Russians, who would look upon this country as the logical warmaker.

Such an event, he added, might mean that the U. S. and Russia would destroy each other, "leaving Nasser to run the world as well as the Suez Canal."

Missile Program Costs

It also was pointed out that, since World War II, the U. S. has spent $5 billion on the missile program, or two-and-one-half times the cost of the first atomic bomb. At present, there are some 100,000 people working on the project.

Another possibility cited by Walkowicz is that of defense radar being fooled and causing an outbreak of war. He said:

"Sunspots or a severe electrical disturbance could give the impression through radar that missile attack is under way.

"Or to make it more human, someone could think he saw a missile attack in the warning equipment and start retaliation."

Combat Logistics

At the convention meeting on combat logistics, Gen. Edwin W. Rawlings, chief of the Air Materiel Command, told aircraft industry leaders that he fully expects major changes in logistics methods when the ICBM arrives.

The Air Materiel Command, he said, already is laying plans for this shift.

In the meantime, he said, his program is now keyed to the assumption that when war starts with the more-conventional weapons in present USAF units, it will be decided within 30 to 60 days.

This concept is largely responsible for the Air Force policy, now almost a year old, that places great reliance upon the aircraft industry, with consideration of such factors as industrial compressibility and industrial acceleration.

The doctrine means that the USAF will fight with what is on the shelf and assembly line and must get the greatest possible use from that material.

"Logistically," Gen. Rawlings said, "this concept also dictates that all combat forces must have sufficient material immediately available to them to sustain them during the decisive phase.

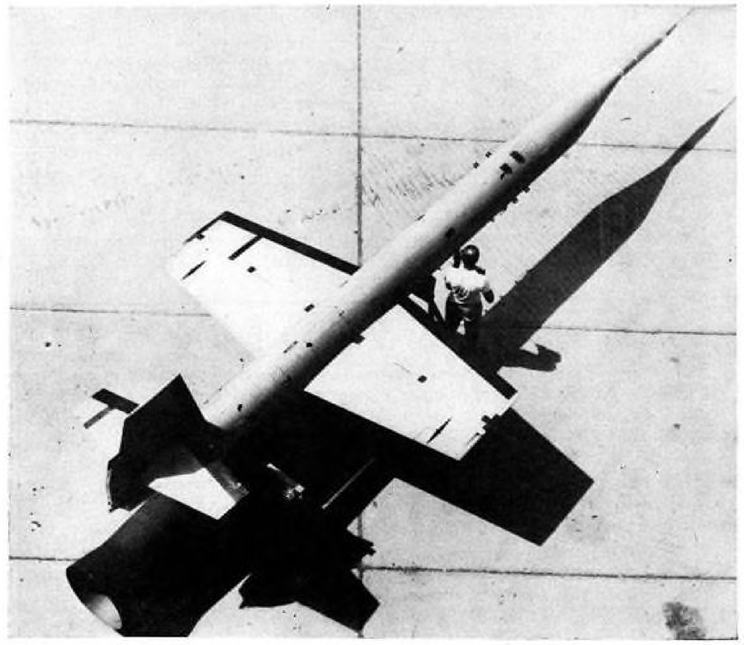
"In this age of supersonic speeds and devastating weapons, we cannot rely upon rear-area build-ups cushioned by comfortable margins of time and distance. There will be no rear area. The front will be where our aerial weapons strike and wherever the enemy may strike us."

Reliance on Management

Gen. Rawlings also emphasized that AMC's job must be geared to full consideration of the shortage in technical and engineering personnel, as well as to the limitations on the amount and types of facilities the USAF can build.

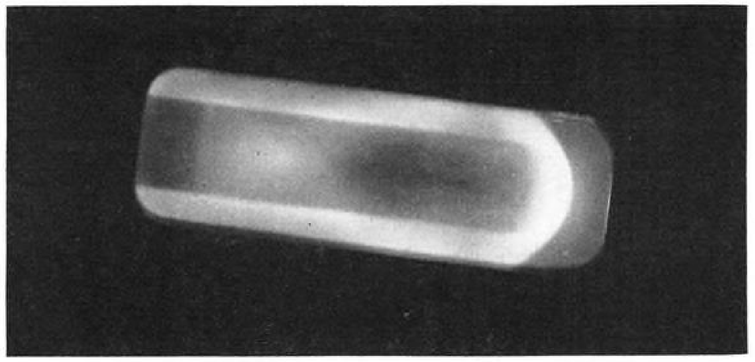
"Management," he said, "must be dynamic, aggressive and responsible. Management must consider the use of our resources in the light of our limitations. We will be certain losers if we stockpile large quantities of antiquated equipment."

Gen. Rawlings was accompanied by Maj. Gen. William O. Senter, comman-



Lockheed X-7 Tests Ramjets

Lockheed X-7 supersonic ramjet test vehicle has been used during the last four years for development testing of Marquardt ramjets for the Boeing Bomarc air defense missile (AW April 11, 1955, p. 9). The X-7 is air launched from a B-29 and driven to supersonic speed by a rocket booster. Ramjet cuts in when rocket booster reaches maximum acceleration. Parachute recovery system is used to retrieve the test vehicle. X-7 is also used to flight test other missile components. Most X-7 flight testing has been done at Holloman AFB.



Shock Wave at 18,000 mph.

Nose cone model for an ICBM forms a shock wave in gasses in a shock tube at a speed of 18,000 mph. The test was photographed by a Schlieren camera at the Everett, Mass., laboratory of the Avco Manufacturing Corp. Temperatures in the tube are 1½ times the heat of the sun. Aviation Week reported April 30 (page 53) that speeds approaching Mach 25 and temperatures as high as 15,000F had been simulated in the shock tube by Avco.

der of the Oklahoma City Air Materiel Area.

Gen. Senter told the convention that 50% of AMC's modification and overhaul work is being done by contractors. He pointed up the complexity of these jobs when he revealed that the Oklahoma City Air Materiel Area had planned its maintenance and repair work on the Boeing B-52 through 1960 before the first Stratofortress was received.

Two convention speakers indicated that the advent of guided missiles may have profound effects upon the USAF reserve system.

Lt. Gen. Charles B. Stone, head of the Continental Air Command, said there is a strong possibility that reservists will man missile systems. He pointed out that, if this should come about, the regular Air Force would be able to give more attention to "those systems not at all practical for the part-time airman."

By this, Gen. Stone apparently was referring to the fact that it will become less-and-less practical for reservists to fly manned aircraft as supersonic speeds and vast electronic complications become more common. Missiles, on the other hand, might be a practical weapon for the part-time airman.

David S. Smith, Assistant Secretary of the Air Force for Manpower and Personnel, said introduction of new weapon systems increases the "kill capability" for a given level of manpower. This, he added, will have great impact upon the "training, equipment and composition of reserve components. He added:

"When the time comes to select reserve personnel for assignment to guided missile sites, their proficiency in engineering and technical fields will be the deciding factor in determining their qualifications for the job.

Schriever Speech Canceled

New Orleans—The scheduled appearance of Maj. Gen. Bernard A. Schriever, top USAF expert on the intercontinental ballistic missile, before the Air Force Association's 10th annual convention was canceled last week on the eve of the first session. The apparent reason—Defense Department pressure.

Gen. Schriever, commander of the Air Research and Development Command's Western Development Division, was scheduled to appear on the program with Lt. Gen. Thomas S. Power, ARDC commander, and three other ARDC generals in an unclassified discussion of missiles. His name was scratched without explanation.

It is known, however, that there was considerable discussion at the Pentagon about the contents of the paper Gen. Schriever had prepared. This led to speculation here that the General may have abandoned the project because of the deletions made under Defense Department's increasingly-strict security attitude.

Reliable sources at the convention, however, declared that the General was ready to attend but had been stopped by higher authority.

Cleared portions of Gen. Schriever's speech were later incorporated into the presentation of Brig. Gen. Don O. Ostrander, Gen. Power's assistant for guided missiles.

The Pentagon also was reported to feel that, if Gen. Schriever appeared at the New Orleans meeting, it would be difficult to deny future requests for his appearance before other meetings.

Radford Skeptical Of B-52 Increase

Washington—Adm. Arthur W. Radford, chairman of the Joint Chiefs of Staff, has urged the Air Force not to "tie down" too much money on B-52 production but to put more effort into finding a successor for the Boeing Stratofortress.

Adm. Radford said he "hopes" such an aircraft might be available in Fiscal 1958, "and I don't care whether it is medium or heavy."

In testimony before the Senate Air Power Investigating Subcommittee released last week, the Admiral said no decision has to be made this year on whether to increase the B-52 program beyond the presently-planned 500 aircraft since the Air Force contract with the Boeing Airplane Co. extends through October, 1958. He added:

"I foresee that the Air Force budget for Fiscal 1958 will have to provide money either to continue the B-52 or to buy another plane to keep the Strategic Air Command forces modernized."

The USAF, he said, now has "three or four lines of attack" towards developing a B-52 successor. "It may be," he added "that there will have to be an even more radical approach to a solution of the problem than there has been."

He also differed with earlier testimony by Lt. Gen. Donald L. Putt, USAF deputy chief of staff for research and development, who said lack of funds is holding back development of the B-52 replacement. "I am not so sure that what they need is more money," Adm. Radford said. "They probably should re-orient some of their basic approaches." Other points included:

• **Estimates as to when guided** missiles will be operational are generally overly optimistic.

• **Unification** of the Army, Navy and USAF into a single service "would not solve anything. We could all go into the same uniform and we would still have compartmentation within this single uniform.

• **U. S. atomic weapon capability** is moving "towards more powerful deterrents with smaller forces."

• **Tendency of U. S. intelligence** agencies is to overestimate Russian air strength. "There is good reason to believe that we normally overestimate Communist capabilities in almost every respect. In general, in the intelligence field they tend to err on the safe side.

"I think we are in a dangerous position vis-a-vis the Communists in that respect today, because there has been an almost hysterical assumption of great capabilities on the part of the Communists, some of which, in my opinion, actually do not exist."

TURNLOCK, contested as USAF fastener.

Pending Test, USAF Drops Fastener Order

Pending completion of some engineering service tests, the controversial technical order which called for the exclusive use of Turnlock type panel fasteners in Air Force maintenance has been rescinded, Aviation Week has learned from the Commander, Air Materiel Command, Wright Patterson AFB, Ohio.

T.O. 44H1-1-9 was a first step in in USAF attempt to reduce the variety of types and sizes of quick operating panel fasteners (AW April 16, p. 55). Members of the airframe industry and all six manufacturers of other types of fasteners who were aware of the order strongly objected to the Air Force's (Supply Division of AMC) choice of the Turnlock "universal" fastener.

Main technical objection of the airframe users was that the Turnlock, due to its design, can be locked without necessarily pulling up the panels completely. Therefore, they said, it was possible for a mechanic to think his job done when actually the panels were still loose.

Letters to Aviation Week from the presidents of Camlock Fastener Corp. and Pachmayr Corp. further amplified the two fastener industry sides of the issue. J. Mills Summers, president of Camlock, one of the firms threatened with sales cuts by the technical order (present annual volume in this type of fastener well over the several million mark), claimed that the action was detrimental to free enterprise (AW May 14, p. 154).

Frank Pachmayr, president of Pachmayr Corp., said that since others are free to produce the government owned patent, his company's investment of $500,000 in perfecting the Turnlock has been in the best national interest (AW July 9, p. 122).

The rescinding order, T.O.-0-1-44C, was issued by the Supply and Logistics Division of the Topeka Air Force Base.

First Half Financial Reports Are Mixed, But Generally Favorable

First half reports beginning to flow from the aircraft industry presented a picture of divergent performances within the industry, but on the whole bore out predictions at the inception of the year that business would be good (AW Mar. 12, p. 194).

Periodic investment analyses, as the summer report of Bache & Co., pointed to the high defense budget and substantial backlogs as indications of a favorable financial outlook. However, continued wide variations in the industry are likely, the report says, with diversified producers outperforming the rest.

The Value Line Survey notes stability in the aggregate for the industry, but considers that current prices of most aircraft stocks fully discount or overdiscount the earnings and dividends in prospect for the coming year.

Mid-year board meetings and reports produced these individual segments of the industry picture:

• **General Dynamics Corp.**

Directors voted a three-for-two stock split, effective Oct. 10 and declared for payment Nov. 10, the day the additional shares are to be distributed, a quarterly dividend equivalent to 75 cents a share on the shares now outstanding or 50 cents a share after the split.

As in the Boeing Aircraft Co. split, voted earlier last month, a factor was the desire of the corporation for broader participation by investors in the corporation growth. Also contributing to the General Dynamics step were the record first-half sales and earnings—$414 million compared with $342 million in the 1955 period and earnings per share of $2.20 compared with $1.85—and forecasts for the immediate future. Backlog, including orders for the Convair 880 jet airliner, was estimated at $1.7 billion, and contracts under negotiation totalled $427 million. First half net income was $11 million, compared with $9.3 million in the first half of 1955.

• **Martin Co.**

Earnings per share increased to $1.05 a share for the second quarter compared with 59 cents for the first, but six months earnings per share of $1.64 were a decrease from the $2.05 for the first six months of 1955.

Martin reported a situation similar to that of Douglas Aircraft Co.—increased sales volume but lower earnings. Martin sales for the first half of 1956 were $138 million compared with $126 million last year. However, operating income this year dropped to $8.7 million compared with $9.7 million and net income to $4.4 million from $5.5 million.

• **Republic Aviation Corp.**

Effects of the four-month strike that ended in June were reflected in a drop in sales for the first half of 1956 to $163 million compared with $300 million in the first half of 1955. Net income for this year dropped to $3.5 million from $9.5 million in the same period last year, and earnings per share fell from $6.47 in the first half of 1955 to $2.38 in the first half of this year.

Strike-depleted inventories will be reflected in the third quarter, Republic said, but consolidated sales for the year are expected to reach $300 million. The company is anticipating substantial orders for the F-105.

Responding to the expanding importance of missiles, which investment men believe will gradually become the prime focus of military business, Republic leased a 34,000 sq. ft. building at Mineola, L. I. for its Guided Missiles Division.

Renegotiation of 1952 fiscal profits resulted in a refund to the Federal Government of $1,077,164. After adjustment of the New York franchise tax, the net cost to Republic was $987,587.

• **McDonnell Aircraft Corp.**

Peak sales, earnings, backlog and payroll are reported for the fiscal year ending June 30. Sales were up 20%, from $154 million to $186 million, and earnings after taxes increased from $4.5 million to $6.7 million, or from $3.07 to $4.55 a common share.

Backlog doubled, from $305 million June 30, 1955, to $679 million. This includes a 126% increase in missile work. Employment was at 16,436 persons and payroll was $79 million.

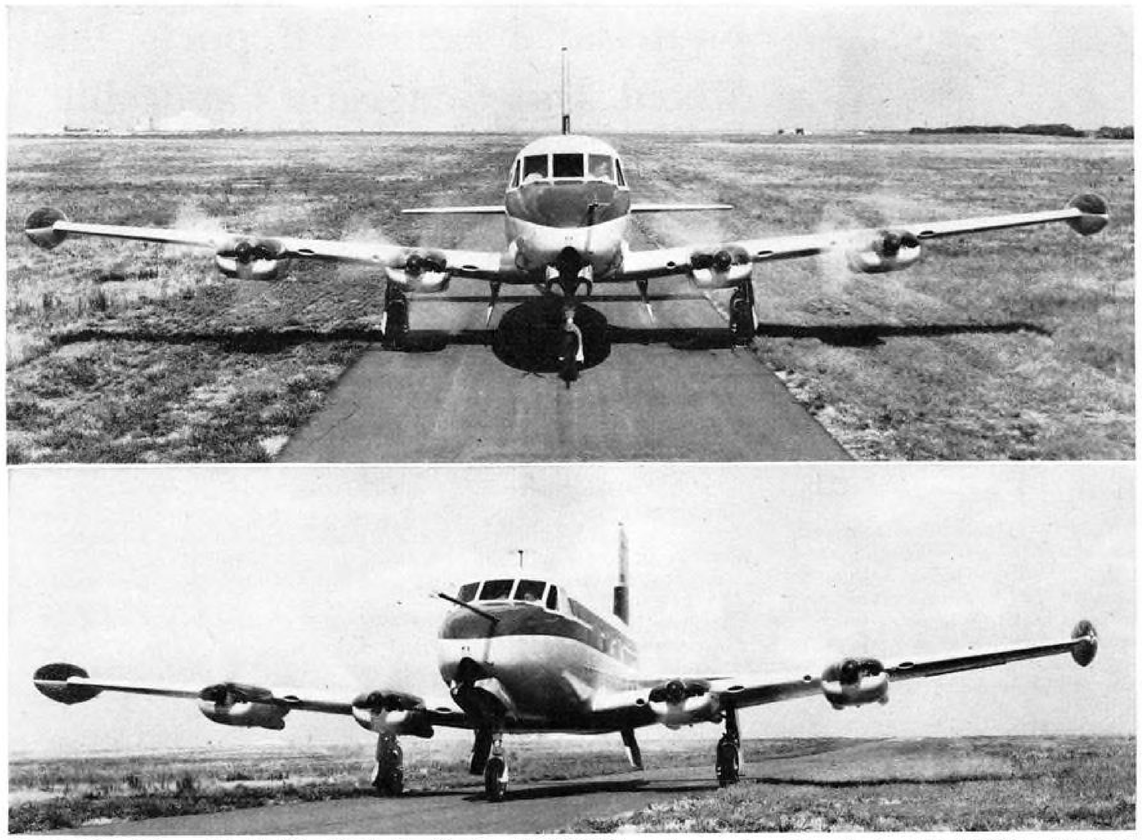
Renegotiation is completed through June 30, 1953, and no refunds were required for Fiscal 1952 or 1953.

• **Solar Aircraft Co.**

Annual report predicts bright future with the transition in output completed. Solar became more active in the last year in missile components, new types of jet engine components and gas turbine engines produced for several new applications.

Reports from abroad were scarcer, but Britain exulting in the Comet order by Capital, could point to a six-month export total of $146 million, which is within $25 million of a record total rung up for all of 1955.

Netherlands Fokker Aircraft, which has licensed the Fairchild Engine and Airplane Corp. to build the F-27 Friendship, reported a 1955 net profit increase of 21% over the previous year.



PROTOTYPE of Cessna Model 620 with the four Continental GSO526-A engines running. Powerplants, rated at 320 hp. takeoff, are mounted in underslung nacelles for maintenance accessibility. The airplane is on a taxi strip at Cessna's Pawnee plant, which is adjacent to McConnell Air Force Base, Wichita, Kans. First flight of the pressurized executive transport will be made at the Air Force base.

Cessna 620 Begins Taxi Tests To Prepare for Initial Flight

Cessna's Model 620 four engine executive transport began taxi tests last week. Following the pattern set in Cessna's conservative, unrushed development of the airplane, no date has been established yet for the first flight, which is to be made at McConnell Air Force Base adjoining Cessna's Pawnee plant at Wichita.

"We will fly the airplane when we are completely satisfied it's ready to fly," Cessna President Dwane L. Wallace said. Wallace likewise sidestepped any formal statement of price, which has been described unofficially as in the $300,000 range (AW April 2, p. 66).

Week before last the Model 620 prototype was rolled out of Cessna's paint shop with a three color exterior paint. Familiarization, functional and cockpit tests were carried on last week to familiarize V. Dale Westfall, chief test pilot on the 620 project, and W. H. Stinson, co-pilot, with the instrumentation.

Pressurization and air-conditioning, provided by an AiResearch gas turbine in the aft fuselage, were tested, and the landing gear, which had completed 4,500 cycles in March in mockup, completed an additional 500 cycles. Flutter tests also were made.

Additional performance figures:

- **Takeoff distance** over a 50-ft. obstacle at sea level is 1,800 ft.
- **Landing distance** over the same obstacle is 2,250 ft.
- **Rate of climb** at sea level is approximately 1,600 fpm.
- **Maximum range** is 1,700 mi. or more than 1,550 mi. with an average of one hour holding time.
- **Endurance at 65%** power will be about 7¼ hr.
- **Takeoff gross weight** is 13,650 lb., and landing gross is 13,000 lb.

Other specifications:

- **Span and length** are 55 ft. and 41½ ft. respectively.
- **Wing loading** is 40.1 lb. sq. ft.
- **Power loading** is 10.6 lb. hp.
- **Fuselage height and width** is 84 in. and 74 in.
- **Overall height** is 16½ ft.
- **Wheel base** is 12.7 ft. and tread is 18.3 ft.
- **Fuel capacity** is 535 gal. stored in outer wing panel and tip tanks.

C-130 Drops Record Loads in Delivery Test

Aerial delivery tests of the Lockheed C-130 Hercules turboprop cargo-transport at the El Centro, Calif., Naval Auxiliary Air Station included dropping a 27,000-lb. dummy load of iron and 18 Type A-22 containers weighing 29,000 lb.

Each established a record, Lockheed said. The one was the largest single load extracted by parachute from an airplane for aerial delivery, and the other was the largest multiple load ever dropped, and probably the heaviest cargo floating out of any aircraft, either by parachute extraction or tilting out an open door.

In other flights, the C-130 dropped a road grading machine, weighing 19,000 lb., and a 40mm. gun mount, weighing 7,500 lb., as combination load.

One of the first multiple drops of three units also was made. It consisted of an M-55 gun mount, a 105mm. howitzer, and an Army jeep, the total weight 14,500 lb.

Twenty-five paratroopers made the first jumps from the C-130 after articulated dummies had been dropped. The jumps were both free fall, where the jumper pulls his own rip cord, and static line, in which the chutes are extracted by an anchor line in the airplane.

Thirty-seven drops were made in the weeks of testing, using two to six cargo parachutes. In the case of the 27,000 lb. dummy load of iron, dropped from 2,000 ft., six 100-ft. cargo parachutes lowered the load and platform to the ground. The 18 A-22 containers each had individual parachutes.

President's Airways Request Cut

Washington—The House of Representatives, in a final action before the close of the 84th Congress, trimmed $23 million from the $68 million requested by President Eisenhower to telescope the Civil Aeronautics Administration's five-year federal airways program into three years (AW July 23, p. 40).

The Senate, after originally voting the full amount, later agreed to accept the House cut to $45 million. President Eisenhower's request for the additional funds was made as a result of the mid-air collision of two airliners over Grand Canyon (see page 463).

Other actions taken by Congress in its rush to close the session included:

- **Talos.** Congress refused to appropriate $16.4 million for construction of Air Force launching facilities for the Talos missile, competitor in the continental air defense role with the Army's Nike. The Army was voted approximately $137 million for new Nike installations.
- **Re-equipment Financing.** After prolonged debate, the House recommitted —or, in effect, killed—legislation that would have permitted subsidized airlines to set aside earnings from the sale of equipment for the purchase of new equipment without having the earnings deducted from their subsidy allocation. The vote to recommit was 196 to 153. The Senate previously had passed the measure by a substantial 53-to-22 vote.
- **Government Salaries.** Substantial increases in executive salaries were voted by Congress. These included: chairman of Civil Aeronautics Board, $20,500 (from the present $15,000); CAB member, $20,000 (from $15,000); Secretary of Defense, $25,000 (from $22,500); Deputy Secretary of Defense, $22,500 (from $20,000); Assistant Secretaries of Defense, $20,000 (from $15,000); Secretaries of Army, Navy, and Air Force, $22,000 (from $18,000); Under Secretaries and Assistant Secretaries of the services, $20,000 (from $15,000); administrator of Civil Aeronautics, $20,000 (from $15,000); director of National Advisory Committee for Aeronautics, $20,000 (from $17,500).
- **Transportation Tax.** Legislation removing the 10% airline transportation tax on travel to the Caribbean, Central America, Alaska and Hawaii was signed by the President.
- **Prototype Testing.** The House failed to act on legislation, passed by the Senate and approved by House Commerce Committee, which would authorize the Civil Aeronautics Administration $12.5 million for testing new types of commercial aircraft.
- **Airmail Postage.** The Senate Post Office Committee killed legislation increasing the airmail postage rate from six to seven cents an ounce.
- **Alaska-Hawaii Airlines.** The President signed a measure requiring the Civil Aeronautics Board to grant permanent certificates to intra-Alaska and intra-Hawaii airlines.

News Digest

BOAC will buy Boeing 707 equipped with British engines, industry sources in London report. Equipment committee recommendation to purchase 16 may be cut to eight, with options for eight more, it is reported.

Folland Gnat prototype crashed on test flight last week. Folland chief test pilot E. A. Tennant ejected safely at 1,000 ft. altitude. Company said aircraft was making high-speed run.

First flights have been made by Bristol Britannia long fuselage 301 and Vickers Viscount 800, also a long fuselage model.

Bell Aircraft Corp. stockholders voted to establish Helicopter Division in Ft. Worth, Tex., as wholly owned subsidiary. Number of directors was increased from 15 to 16, and approval of stock option incentive and deferred incentive compensation plans were approved for key personnel.

RCAF began tests of Beechcraft Model 73 Jet Mentor at Wichita, Kans., to determine whether it meets requirements for Canadian primary trainer.

Nuclear specialist has been hired by Temco Aircraft Corp., to pick a field where company might develop nuclear capability. Engineer is Fred Grisak, former Convair senior nuclear engineer who was in charge of preliminary design of reactor Convair is testing on B-36.

Republic F-105, christened Thunderchief, is described by company as having short, very thin swept back wings and long cylindrical fuselage. Intake ducts for turbojet engine are in wing roots. One-piece flying tail (stabilator) is set low on aft fuselage, on the underside of which is located a ventral fin for lateral stability.

Airborne countermeasures equipment to mask airplane from ground radar by transmission of signal on same frequency will be manufactured by General Electric's Light Military Equipment Department under $43 million USAF contract.

Regulus II missile, a supersonic, longer-range version of Regulus surface to surface missile, will be built for Navy by Chance Vought Aircraft. Regulus II, which has been flight tested successfully, will be used on surface ships and submarines and at shore bases. Contract is for $12 million.

Allis-Chalmers Manufacturing Co. will build compressor rotors for J79 turbojet engines at Terre Haute, Ind., works under multi-million dollar contract with General Electric Co.

Lockheed's X-17

New Orleans—Lockheed's X-17 hypersonic test missile for the intercontinental ballistic missile program was referred to at the Air Force Assn. convention. First identified by Aviation Week (May 21, p. 23), as a three stage missile using solid propellant rocket motors, the X-17 is being used to study the "critical problems of bringing the intercontinental ballistic missile back into the earth's atmosphere from outer space." Launchings are made at Patrick AFB. The test missile is fired into the ionosphere from where it "plunges at tremendous speeds" back into the earth's atmosphere. Lockheed's Missile Division uses it to investigate, among other factors, atmospheric heating effects and the suitability of various metals. Defense Department security policies prevented mention of the X-17 designation in the speech by Brig. Gen. Don R. Ostrander, ARDC's assistant for guided missiles.

Commerce Scored for Airways Tangle

By L. L. Doty

Washington—The Commerce Department and executive branch were charged last week with sharing direct responsibility for today's "woefully inadequate" navigation facilities and the "outmoded" U.S. air traffic control system.

In a final report to Congress, the House Government Operations Committee called for an end to generally-ineffectual "forums" set up to settle aviation conflicts and said proper airways development will come only from good leadership and budgetary action. Specifically, the report urged:

• **Speedup of studies** under way by Presidential Aviation Advisor Edward Curtis and an increase in his "limited" budget.

• **End to membership** of the Civil Aeronautics Board and Federal Communications Commission on the Air Coordinating Committee. The report also asked for a clarification of ACC's role in policy-making matters and criticized the "predominance of military" within the agency's structure.

• **Settlement of the VOR/DME-Tacan** impasse. "Little excuse exists for further procrastination in this matter," it declared.

Executive-Branch Failure

The report charged the executive branch with failing to appreciate the significance of civil aviation and its requests for appropriations.

The Department of Commerce was accused of continued failure since World War II of presenting "an adequate case for funds necessary for air traffic control and airport development."

Congress was also tacitly implicated in charges leveled against several government groups. The committee said, however, that if "there has been congressional reluctance to appropriate, it is due in large measure to the timidity of the executive branch in stating its requirements."

During the hearings, Charles Lowen, Civil Aeronautics Administrator, first suggested that the CAA five-year plan for traffic control could be "telescoped" into three years. This was later confirmed by Commerce Secretary Sinclair Weeks. Later, prompted by the mid-air collision over Grand Canyon on June 30, President Eisenhower requested an additional $68,000,000 to help accelerate the program.

Final action on the Presidential request took some of the sting from the report's criticism of the Commerce Department. Commerce Under Secretary Louis Rothschild firmly supported the $68-million request and drew strong backing from the Senate. However, economy-minded members of the House trimmed the measure to $45 million during the closing hours of the 84th Congress. The Senate went along with the cut in the rush wind-up (see page 459).

The report based its criticism on past history and specifically upon the CAA request for $41.5 million for its Fiscal 1956 airports program. This was chopped to $31 million by the Commerce Department. The Bureau of the Budget, "following," the report said, "its usual pattern," slashed the amount to $11 million. Congress restored the cut to $20 million.

Reorganization Demanded

Presidential Advisor Edward Curtis drew the whole-hearted support of the committee. The report, however, expressed concern over the small amount alloted to the Curtis project for improving airways facilities.

"It is difficult to conceive," the report said, "how with a budget of $150,000 and a permanent professional staff of three, Mr. Curtis can attain his goal with expedition."

The report did not recommend that "speed be substituted for thoroughness" but emphasized that the Curtis study "can and should be quickened" with additional money and a larger staff. It warned that "the nation can ill afford to continue the current aviation organizational muddle."

In this respect, the report called for a drastic reorganization of executive-branch agencies concerned with aviation. To continue with the present federal structure in aviation, it said, "would mark Mr. Curtis' study as a futile effort," the report said.

The report also concluded that CAB, through its membership in the Air Coordinating Committee, is bound to decisions and recommendations by the ACC and thus loses its quasi-judicial, quasi-legislative regulator status. Since ACC has no statutory authority to make decisions, the report said, the CAB membership and that of the FCC "represents a flagrant flouting of the will of Congress."

The committee demanded clarification of the authority of the ACC to make it clear that the agency has no control over matters "in which Congress has vested authority elsewhere." CAA, it was noted, has a Congressional grant to control the use of airspace and no such powers have been delegated to any other agency of the government. The report warned that an executive order, such as that which established ACC,

Eastfoto

Passengers Board East German Airliner

Two Il-14 airliners with the name of Deutsche Lufthansa, the East German airline, are parked at the line's airport, Berlin-Diepensee. Mark on the rudders of the two Il-14s is the same emblem used by Lufthansa, West German airline. Il-14 has thrust augmentation system similar to that of Convair 440. Tubes are visible at rear of nacelle over waving passengers. Plane in background is a Czech Li-2.

"must not be used to nullify congressional enactment."

While no recommendations were made on the organizational structures of ACC and the Air Navigational Board, the report criticized the "predominance of the military services" in both groups.

Surprise was expressed that the Civil Aeronautics Administration is not a member of either body while the Defense Department and the three military services are represented on both. "This conflicts with our tradition of vesting final authority in civil, rather than military officials."

Tacan Dispute

The VOR/DME-Tacan dispute was cited as an example of the lack of planning and direction of aviation problems within the federal government. The report said "valuable time already lost can never be recaptured," and that the controversy should be settled within the 30 to 40 days after August 20 as promised by Rothschild.

The hearings, which began June 25, were conducted by the House Government Operations Subcommittee headed by Rep. Robert Mollohan (D.-W. Va.).

CAB Begins Hearings On Mid-Air Collision

Washington—Public hearings on the Trans World Airlines-United Air Lines Grand Canyon crash began in Washington last week with the introduction of two surprise witnesses who said they saw the TWA Super Constellation and United DC-7 collide on June 30.

The two witnesses, Mr. and Mrs. Eugene J. Siefer, told Civil Aeronautics Board investigators they saw two airliners collide in the Grand Canyon area while they were driving on U. S. Highway 66 near Flagstaff, Ariz., en route to California from their home in Ottawa, Ohio.

The Siefers waited until their return from their California vacation on July 10 before they contacted the CAB through the editor of the Putnam County Standard.

Both witnesses said the two airplanes, which Mr. Siefer identified as Constellation and DC-7 types, appeared in a break between two large cloud formations on converging courses. They said the airplanes collided, then remained joined together as they continued in level flight until obscured from view by a mountain.

Siefer said the airplanes were in view less than ten seconds, and that he saw no smoke, flames or debris after they came together. The witness testified that the two planes continued to fly to the east after they collided "just like they stuck together."

Washington Alternate At Baltimore Studied

Washington—The Civil Aeronautics Board has launched an investigation to determine whether a portion of Washington's air traffic should be diverted to Baltimore's Friendship International Airport to relieve air traffic congestion at Washington National Airport.

The CAB will decide whether Washington now has adequate airline service and whether Friendship should be designated alternate or co-terminal with Washington National Airport.

The CAB investigation was begun after Congress refused to appropriate funds to start construction on an alternate Washington airport at Burke, Va. Secretary of Commerce Sinclair Weeks asked the Board to consider diverting some Washington traffic to the Baltimore airport until new airport facilities are established at Washington.

The administration asked Congress to approve a last minute $34 million appropriation to revive the Burke project which has been dormant since 1950. The Senate Appropriations Committee refused to approve the project and decided to set up a subcommittee to study it for possible action next spring.

Airlines Report Big Profit Gains

Four airlines have issued first half financial reports which described substantial increases in traffic and profit. The reports came on the heels of an investment firm report calling attention to the favorable market developments in the airline field (AW July 30, p. 41).

• **United Airlines.** Record traffic and revenues gave United the highest earnings for any six-month period of its history—$5.2 million after taxes, or $1.64 a share. It was a 23% increase over the first half of 1955 in which earnings of $4.2 million or $1.52 a share were reported.

Total traffic increased 14% and revenue passenger traffic of 3,063,000 was a gain of 16%, both compared to the 1955 period. Operating revenues for the first six months were $126 million, and operating expenses were $115 million, each figure representing a 13% increase. First half federal and state income taxes were $6.1 million. Further traffic volume gains were predicted by W. A. Patterson, United president.

• **Continental Airlines** net income increased 212%, from $157,869 for the first six months of 1955 to $493,218 for the first half this year. The earnings per share increase was from 33 cents to $1.04.

Operating revenues total $9 million, a 25% increase of the $7.2 million for the first half of 1955. Operating expenses were $8.4 million, a 22% increase over the $6.8 million for the first half of 1955.

Continental extended until late September its option to purchase five Viscount 810/840 turbo-prop transports in addition to the 15 it has ordered already. Purchase of the five additional planes depends on Continental's route applications to serve Phoenix, Ariz., Palm Springs and San Diego, Calif., and San Francisco-Oakland and Dallas-Ft. Worth non-stop, and via cities in Nevada, Arizona, New Mexico and Texas.

• **Slick Airways Inc.** reported a net income of $406,000 after taxes, equal to 48 cents a share. The carrier lost $531,000 after recovery of prior year taxes last year.

Gross revenues for the first half of 1956 were $10.1 million. Last year they were $4.6 million. Slick carried 37,569,000 ton-miles of freight and passengers, a 75% increase over the first half of 1955. Military, contract and charter operations increased traffic 440%.

• **American Airlines** net earnings for the first six months of 1956 totaled $9,739,000 exclusive of profit from aircraft sales, the airline has reported. An additional $932,000 profit from the sale of aircraft brought the total net to $10,671,000.

Last year's total net for the comparable period was $8,537,000.

During the 1956 period, American carried 3,814,302 passengers a total of 2,343,933,000 passenger miles, an increase of about 13.5% over last year's passenger-mile total. Air freight for the 1956 period totaled 31,914,000 ton miles, an increase of 1.6%.

Revenues for the first half of 1956 reached $140,139,000, up 12.2% over 1955.

CAB Fare Review Is Limited to Trunk Lines

Washington—The Civil Aeronautics Board last week rejected airline proposals to expand the General Passenger Fare Investigation and will limit its investigation to a review of the general level of trunk airline passenger fares.

A CAB order limited the issues in the case in an effort to hold down the size of the investigation and complete it by next summer. Local airlines will be permitted to intervene in the case, but their fares will not be under review.

The purpose of the investigation, according to the CAB, is to explore the level of earnings of each of the 12 trunk airlines to determine whether the traveling public is being charged too much or too little. If the CAB decides fares should be changed, it will take across-the-board action to bring the general

fare level in line with a reasonable level of earnings.

The general fare investigation was ordered as the result of mounting pressure from Congress. The Board decided to study the general level of trunkline fares, but interested parties were given a chance to comment on the issues in the case (AW June 18, p. 32).

The airlines argued that the case should be expanded to include various issues. Primarily, the carriers wanted the CAB to look into the economics of the fare structure, including the differences between short-haul and long-haul charges.

The CAB decided to stick with its original plans for a limited investigation, but said it might go into the problems of the fare structure after the general revenue situation has been studied.

CAB Asks Suspension Of Four Irregulars

Washington—Suspension of the operating authority of four Large Irregular Carriers involved in the Trans American Airlines combine has been requested by the Civil Aeronautics Board Office of Compliance.

The Compliance Office said the carriers should be suspended for continued violations of a CAB order issued in July, 1955, which ordered nonscheduled airlines to stop operating a frequent or regular service.

The 1955 CAB decision revoked the airlines' operating authority and ordered them to cease and desist from operating frequent or regular service either together or individually. The Court of Appeals later stayed the Board's order, except for the portion prohibiting individual regular services.

Now the Office of Compliance finds that the nonscheduled airlines—Trans American Airways, Twentieth Century Airlines, Trans National Airlines and Hemisphere Air Transport—have operated frequent and regular service as individuals in violation of the CAB order during the last quarter of 1955 and the first half of 1956.

CAB Borrows B-57 For High-Altitude Study

Washington—The Civil Aeronautics Administration will receive a Martin B-57 jet bomber from the USAF sometime this month to help in its study of high-altitude air traffic control.

The B-57, which will be specially instrumented at the CAA Aeronautical Center at Oklahoma City, will be placed in operation around Oct. 1. It will be used to evaluate the effectiveness of navigation aids, communications equipment, radar and traffic-control procedures above 15,000 ft.

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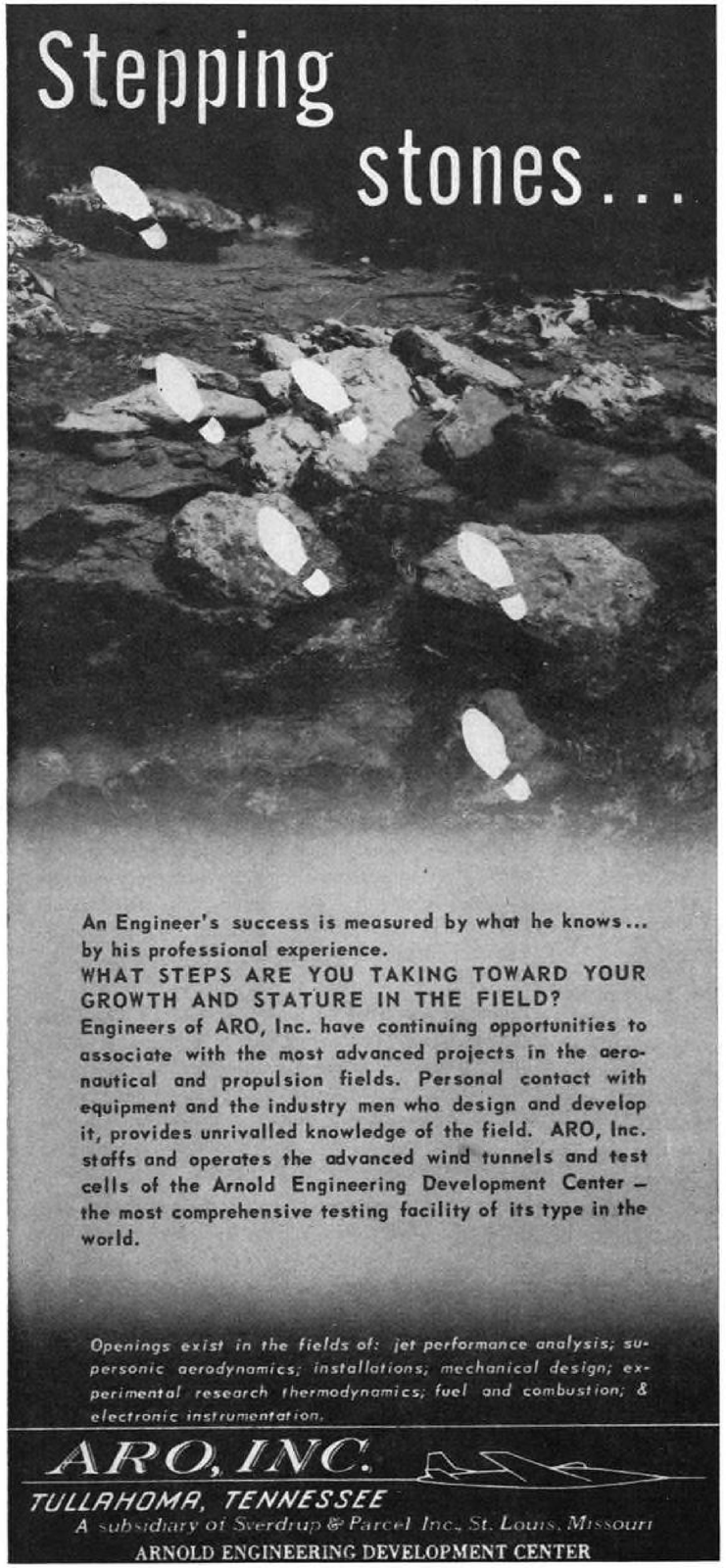

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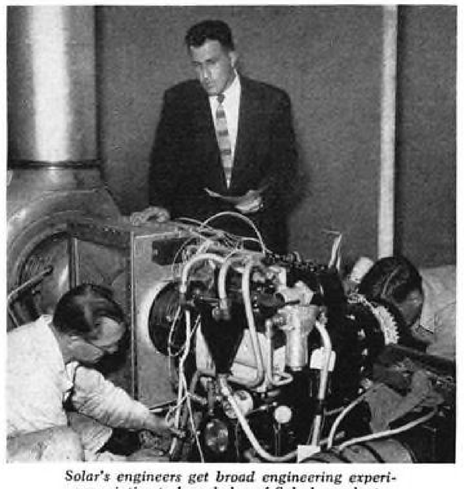

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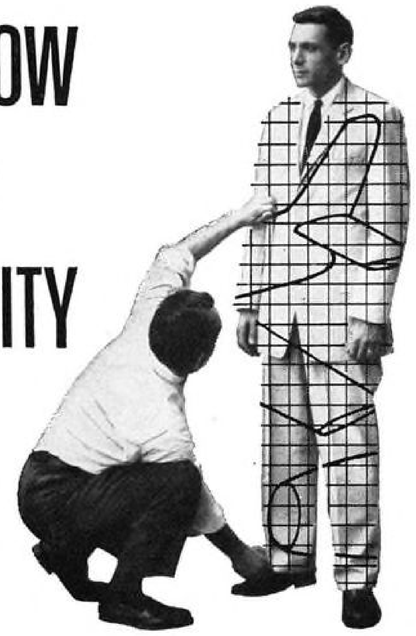

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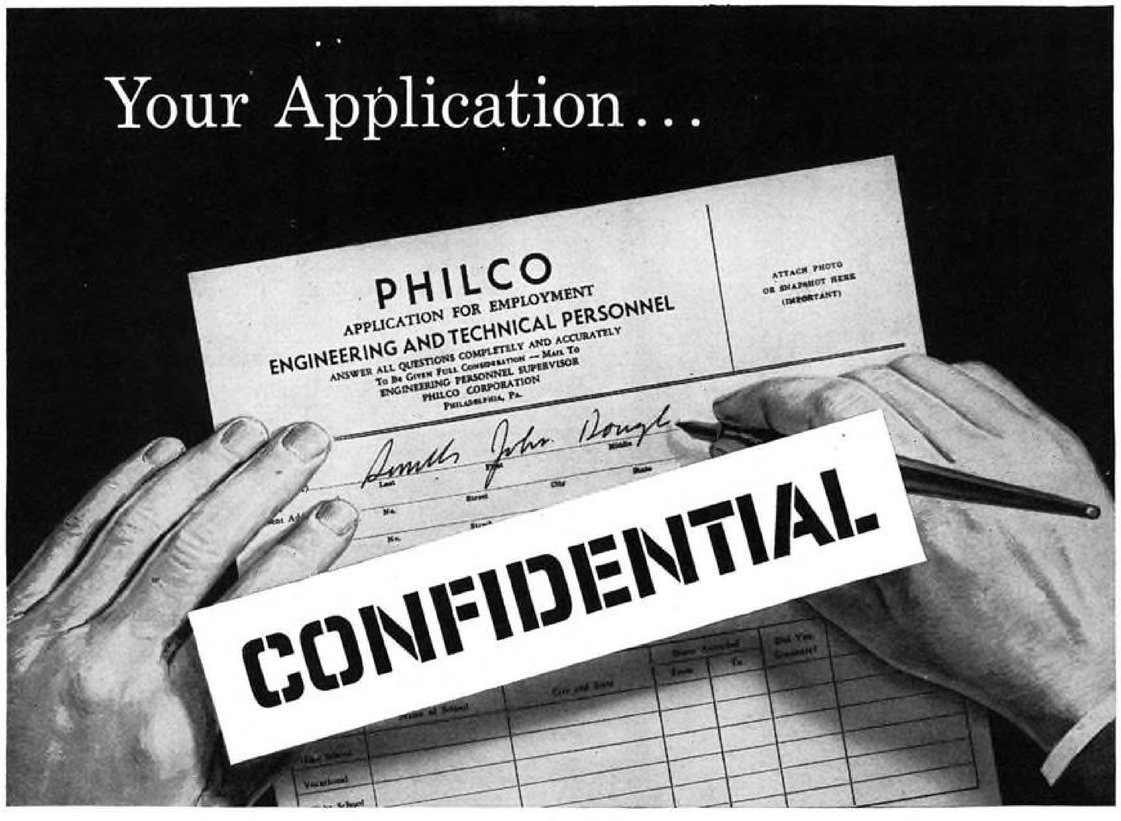

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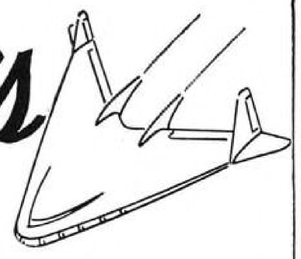

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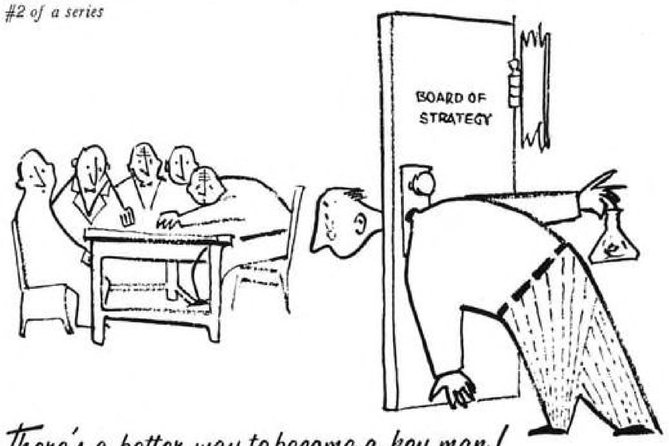

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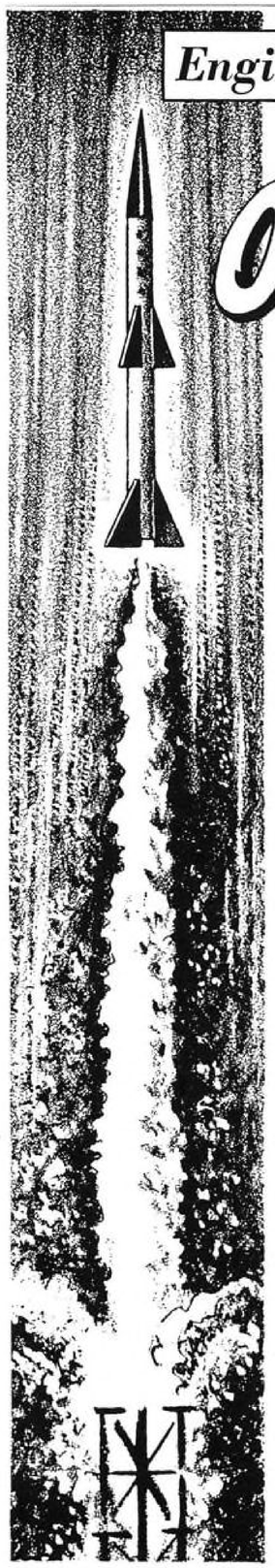

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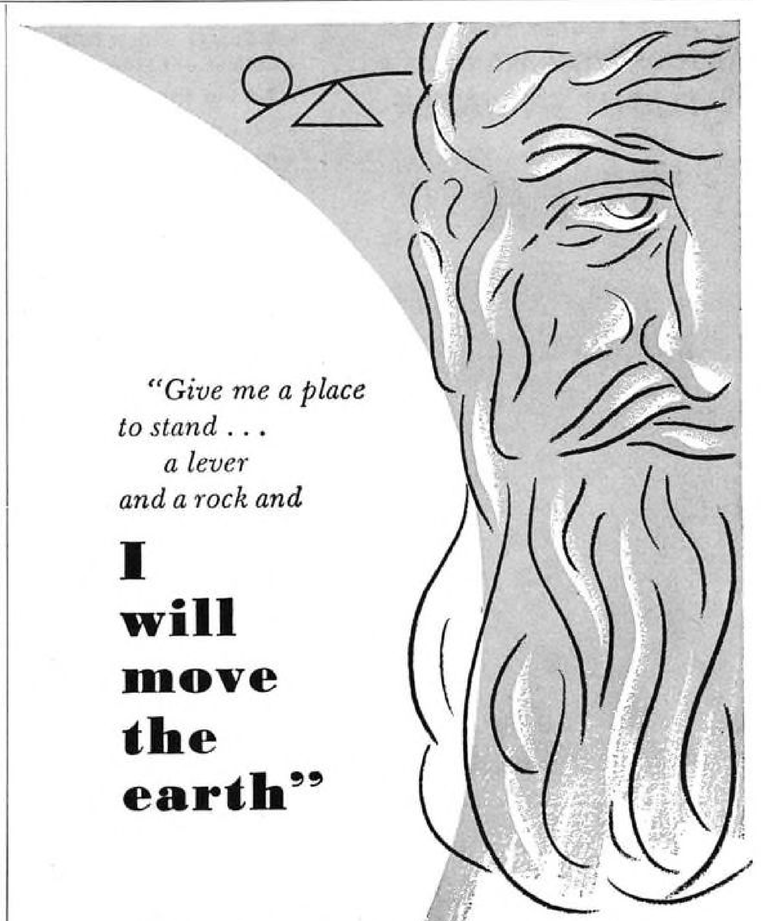

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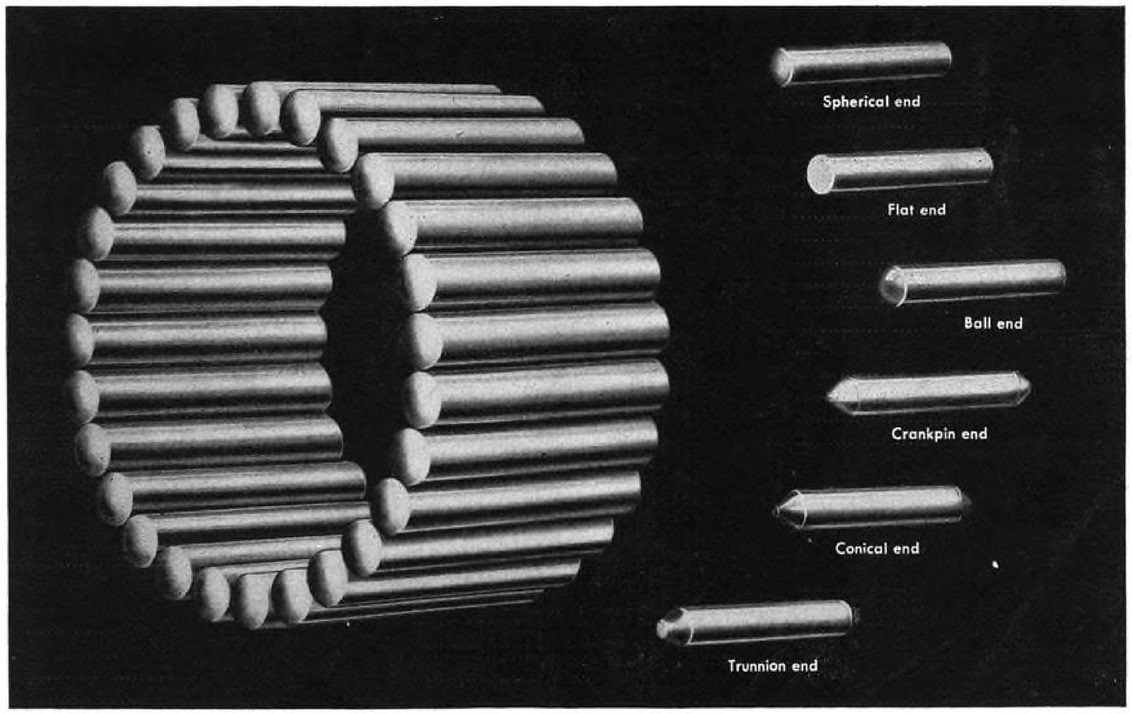

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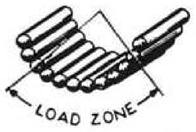
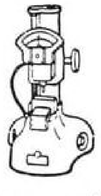
High radial capacity in minimum space stems from full complement of small-diameter rollers. Load zone contains maximum number of contact lines.

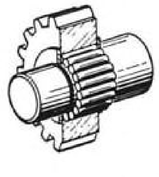


Fine finish contributes to efficient anti-friction performance. Needle Rollers are usually polished to 4-6 rms, but finishes as fine as 1-3 are available on special order.

High carbon chrome steel is carefully hardened, ground and lapped to make each Needle Roller a precision part for long-life performance.

Close tolerances on Needle Rollers are assured by stringent quality controls. Standard OD tolerance is .0002" but rollers can be supplied with OD tolerance of .00005." Tolerance on length dimension depends on end formation.





Mounted without races between hardened shaft and hardened housing (RC-60 recommended), Needle Rollers allow largest possible shaft diameters.

Torrington Needle Rollers provide the lowest cost, highest capacity anti-friction bearings obtainable. They are manufactured in a complete line to meet SAE and AFBMA specifications. Available in the inexpensive spherical end type or in other end shapes, they provide maximum retainment and fillet clearances or greater lip retainment. Needle Roller standards for material, heat treat, tolerance and finish are the highest in the industry.

Good operating results with Needle Rollers require careful design of mating parts furnished by the user. The Engineering Department of The Torrington Company, with broad experience in applications of Needle Rollers, will be glad to give you technical advice on your needs.

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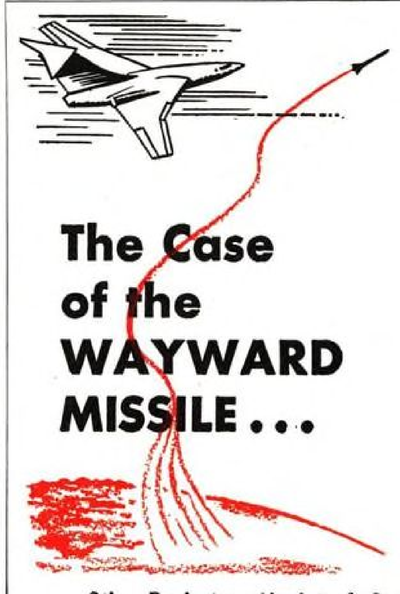

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