

MARCH 1966

Air Force/Space Digest



International

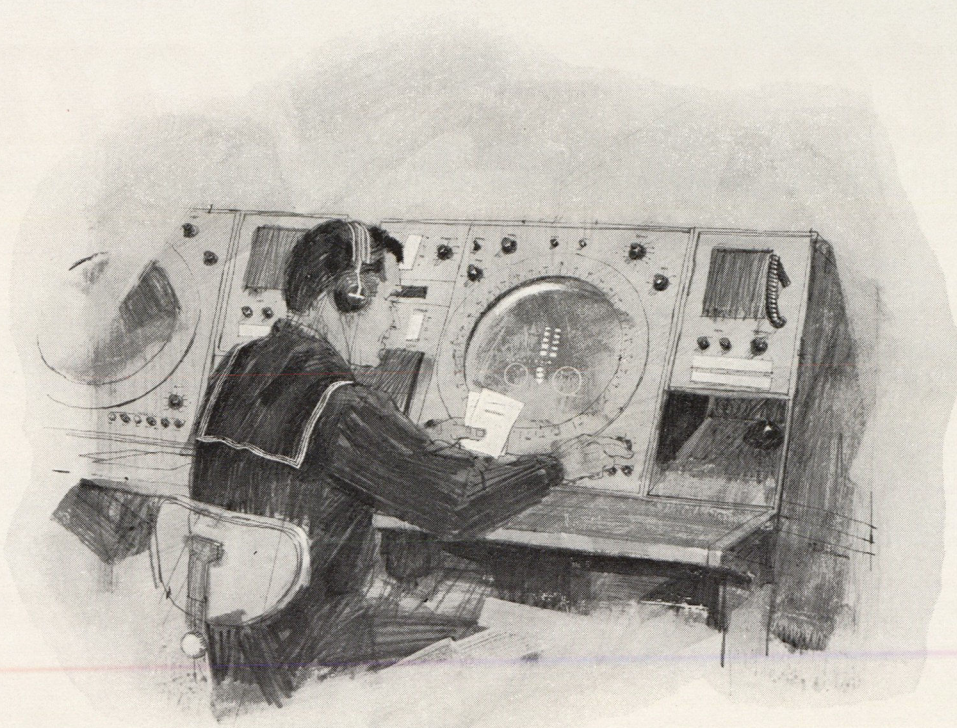
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C-5A

SPECIAL REPORT ON THE WORLD'S BIGGEST AIRPLANE

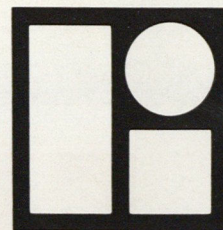
- The design and production challenges...
- The effect on US military capabilities...
- The effect on our global airlift...
- The implications for the civil airlines...



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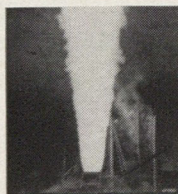
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NEW DIRECTIONS IN SOLID-PROPELLANT ROCKETRY..... 5

By Russell Hawkes



Many of the crucial technological questions about large solid-propellant boosters have now been answered, establishing them as the workhorses of the rocket age for both defense and space projects. A leading aerospace writer tells how technological pioneers are turning their attention to relatively small missiles. He describes the great potential for small solid tactical missile advancement in a time of increasing emphasis on "small" wars. These missiles could create new dimensions in tactical warfare.

CANADIAN AEROSPACE—A TIGHTENED BELT AND A CLEAR EYE..... 15

By Norman Avery

The aviation editor of a leading Canadian newspaper gives a comprehensive report on Canada's air arm and the Canadian aerospace industry from their moment of crisis in the late 1950s to the present era of service integration and diversification and export for the industry, which combine to promise a future of steady growth.

SPEAKING OF SPACE..... 23

By William Leavitt, Associate Editor

The National Aeronautics and Space Administration has suffered badly in fiscal planning for the coming year, because of belt-tightening due to the financial drain of Southeast Asian commitments. The Apollo and Gemini programs stay on schedule, but new starts have been deferred.

FB-111—A TECHNICAL DISCUSSION OF THE THIRD VERSION..... 26

By J. S. Butz, Jr., Technical Editor

Although the F-111 is an advanced design that promises excellent performance in a variety of missions, some of the claims released by the U.S. Department of Defense for the new strategic bomber version seem confusing and, perhaps, promise more than any aircraft, no matter how versatile and well-designed, can possibly live up to.

C-5A—EVEN MORE THAN MEETS THE EYE..... 28

By J. S. Butz, Jr., Technical Editor

The giant Lockheed C-5A transport has military and commercial potential far beyond current predictions. Not only will it revolutionize military transport and other large-aircraft requirements, but when commercial firms see its weight-lifting capacity and economy, they also will clamor to put the huge transport into service.

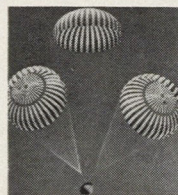
A-7A—A STATUS REPORT 34

By J. S. Butz, Jr., Technical Editor

At a showing attended by ranking military and civilian defense officials, the A-7A Corsair II demonstrated its weapons-carrying capability, handling characteristics, and maintainability. The U. S. Navy plans to buy 1,500 A-7As, and USAF is considering the purchase of LTV Aerospace Corporation's Corsair IIs for Tactical Air Command.

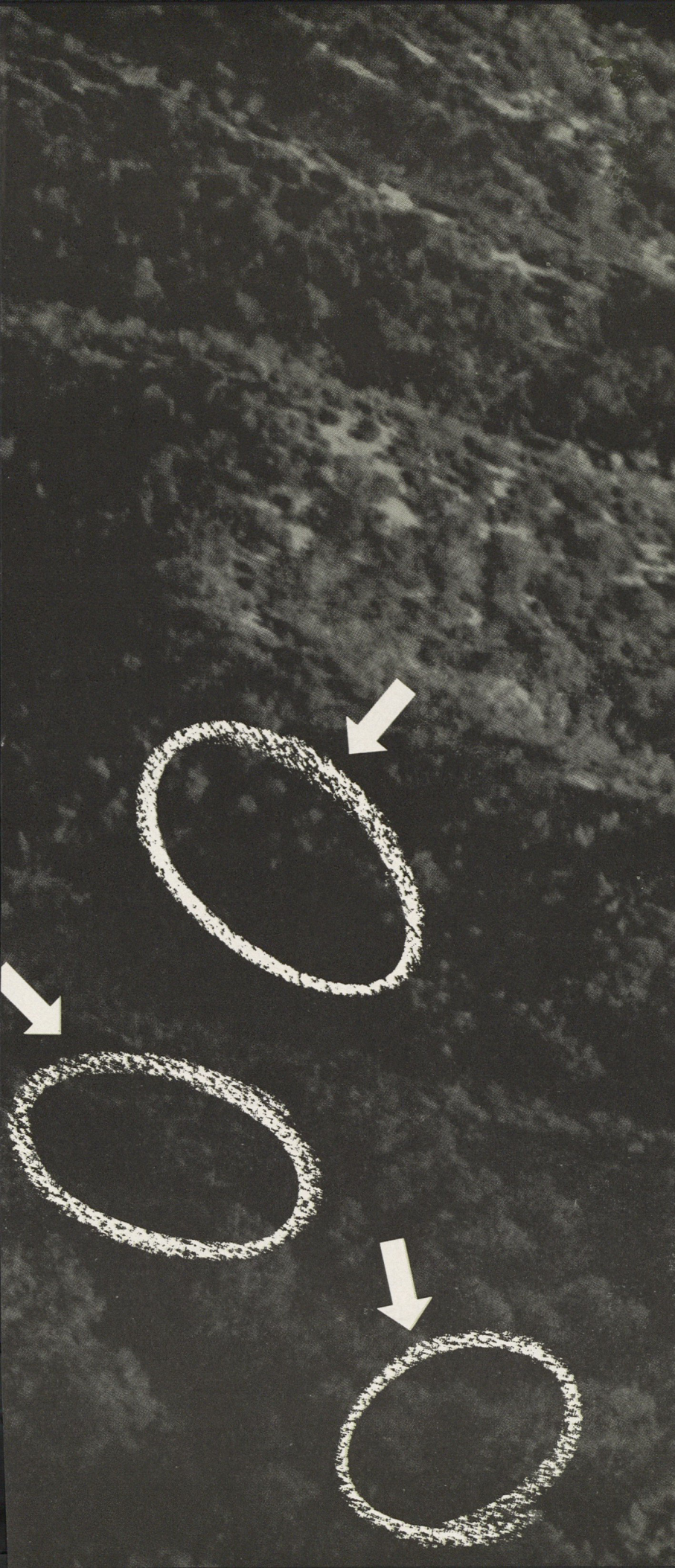
AEROSPACE REVIEW 36

By Allan R. Scholin, Associate Editor



The costs of the war in Vietnam are equivalent to one-eighth of the next year's entire U.S. Federal budget. . . . Five more Gemini flights in 1966 will pave the way for testing the Apollo lunar-landing vehicle by this time next year. . . . A second airmobile division is being readied for the U.S. Army. . . . Gravitational fields of other planets can be used to speed spacecraft to distant targets. . . . The Secretary of the Air Force reveals how he arrives at his decisions, in this month's report spanning Vietnam, the moon, and Mr. Brown.





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And a “zero-zero” Escapac seat is standard equipment.

Yet the Douglas Skyhawk costs less than half the price of comparable close-support jets.

And costs much less to maintain, too.



DOUGLAS SKYHAWK

Aircraft Division, Long Beach, California, U.S.A.

With many of the crucial technological questions about large solid-propellant boosters now answered, establishing solids as the workhorses of the rocket age for both defense and space projects, technological pioneers are turning their attention to relatively small missiles. There is great potential for small solid tactical missile advancement, which will stretch the boundaries of technology and create new dimensions in tactical warfare . . .

New Directions in Solid-Propellant Rocketry

BY RUSSELL HAWKES

The success of Polaris, Minuteman, and the big Titan IIIC space launch system gave notice, if any was needed, that solid-propellant rocketry is destined for a pivotal role in U.S. defense and space programs. The flawless performance of the United Technology Center 1.2 million-pound-thrust (544,320 kg), solid-propellant, zero-stage motors in the first flights of Titan IIIC ended a phase in the history of rocketry by supplying final proof that solids can perform the heavy labor of the rocket age.

With that fact established, the pattern of the next phase is beginning to emerge on the blackboards and test stands of the U.S. aerospace industry.

From now on, technological pioneers will concentrate more of their attention on relatively small missiles. This is not to deny that very large solid-propellant launch vehicles still have their most remarkable achievements ahead of them. It recognizes that recent accomplishments have made it possible and desirable to construct large solid rockets using what has become conservative technology. Dozens of U.S. defense officials and industry engineers polled by AF/SD INTERNATIONAL were in agreement with this conclusion.

The crucial technological questions about large solid-propellant boosters have been answered. It is time for them to leave the experimental milieu and move into the operational arena. In this movement, Government and

industry will be dealing with more economic and logistic headaches and fewer technological ones.

The problems of manufacturing giant motor cases, nozzles, and propellant grains that are consistently and predictably reliable and inexpensive, and providing them with satisfactory means of starting, terminating, and vectoring thrust have been solved. So precisely has the performance of recent large motors matched predictions that H. L. Thackwell, a leading solid-rocket design consultant, says it is now possible to build a solid-propellant motor of virtually any size with complete confidence that it will perform perfectly on the first test firing, provided that the state of the art is not stretched in any field except that of sheer size.

The brilliant future foreseen for enormous solid rockets is based on this assumption, now a safe one, that new motors can be built to the sizes dictated by their missions without inventing anything new. According to an old aerospace rule of thumb, a 5 percent increase in performance obtained by stretching technology adds 50 percent to the cost of developing a system and about as much to the risk that the system will be a failure. Since there is no longer an arbitrary limit to the size of a new solid-propellant booster, additional performance can best be obtained for the new design by a corresponding increase in size. The additional cost and risk are slight.

Colonel Harold W. Robbins of the

U.S. Air Force Space Systems Division contends that large solid-propellant boosters should be made under the same economic philosophy as canned food. That is, there should be essentially one motor design made larger or smaller according to the intended mission and packed in a throw-away can of appropriate size. Robbins holds that such motors will make space operations more economical than they would be with sophisticated launch vehicles capable of flying back to the launch site for repeated reuse.

In Robbins' opinion, about the only part of the large solid rocket in which technology has not completely matured is the steering or Thrust Vector Control (TVC) system. In other systems, progress will be slow, steady, and without much controversy.

Disagreement about TVC systems for large solid rockets now in development has narrowed down to a choice between liquid-injection systems and gimbaled nozzles. Liquid-injection systems deflect the rocket exhaust by jetting fluid into one side or the other of the rigid nozzle. Gimbaled nozzles redirect thrust by varying the structural geometry of the motor. Eventually, both methods are likely to be displaced by the hot-gas-injection technique now entering advanced development.

Hot-gas TVC works very much like the liquid-injection technique except that gases from the combustion chamber into the nozzle skirt are used to
(Continued on following page)



The successful static testing of the U.S. Air Force's Titan IIIC 120-inch-diameter (305 cm) solid booster, shown in this dramatic infrared photograph made at United Technology Center's facility at Coyote, California, helped to demonstrate the reliability of large solid-propellant rocketry. A brilliant future for large solid rockets has been predicted on the now-safe assumption that new motors can be built to sizes determined by their missions, with no need for basically new advances in technology, at costs that in today's terms are acceptable.

deflect the exhaust, rather than a special liquid for the purpose. The main technical stumbling block is the development of valves able to withstand the high temperatures of the chamber gas. Lockheed Propulsion Company and Aerojet-General Corporation have demonstrated promising solutions to this problem.

Colonel Robbins believes the ultimate TVC method for big launch vehicles will be nose steering, in which a top-stage motor does the job for all the stages and doubles as a trimming motor to make precise adjustments in the burnout velocity of the final stage. This would eliminate the weight and possibility of failure presented by separate TVC devices in each successive stage of a multistage booster. Nose steering has been used with considerable success on the U.S. Army's Nike-Zeus. More advanced versions are in early development by the Air Force.

Looking 10 or 20 years into the future, Robbins sees large solid rockets using 1965 technology to boost nuclear rockets to altitudes at which the reactors could be started without creating a radiation hazard on the ground. Thus, the large solid-rocket program is an important step in freeing the USAF from earth-orbit limitations.

As a measure of the decreasing cost of large solid rockets for such ambitious missions, Robbins points to the fact that the 45,000-pound (20,410 kg) Minuteman first stage cost \$125,-

000,000 to develop through its Pre-Flight Rating Tests, and the 500,000-pound (226,800 kg) Titan IIIC zero-stage booster was developed to the same point for the same cost. The 1,000,000-pound (453,600 kg), 156-inch (396 cm) motor will be brought to this point at a cost of only \$90,000,000. With development completed, even large motors weighing 2,000,000 or 3,000,000 pounds (907,200 or 1,360,800 kg) could be produced for about the same cost per pound as an automobile, Robbins believes.

While large solid rockets have developed to their happy status, development of small rockets has been languishing in their fiscal shadow. As a result, many qualified judges are convinced, every tactical missile motor now in the defense inventory is based mainly on pre-1955 propulsion technology. These judges predict that, if the Government will pay for aggressive research and development of small motors, it will be repaid with the biggest step forward in operational military capabilities since the first appearance of tactical missiles. The reason for this optimism is that fundamental advances in propellant chemistry, materials, and the nonpropulsion technologies now make it reasonable to try for tactical advantages that were clearly beyond reach in 1955.

The designer of small missile-propulsion systems cannot turn to sheer size to obtain the characteristics he seeks as can the designer of large

boosters. The designers of all tactical missiles, especially air-launched missiles, are rigidly constrained by the space available in launch vehicles.

They are also constrained by the harsh conditions under which tactical missiles must function. While big space boosters and ballistic missile motors can be provided a nursery-like environment, air-launched missiles must endure prolonged cold-soak at altitude, aerodynamic heating to high temperatures, intense vibration, and high accelerations.

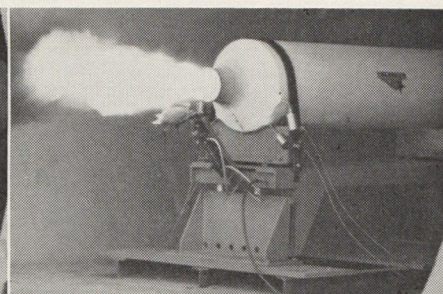
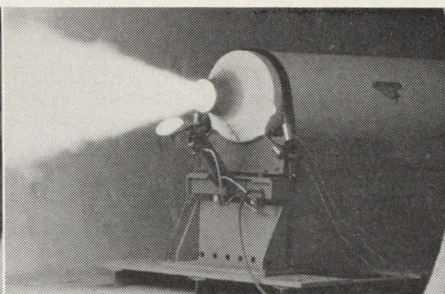
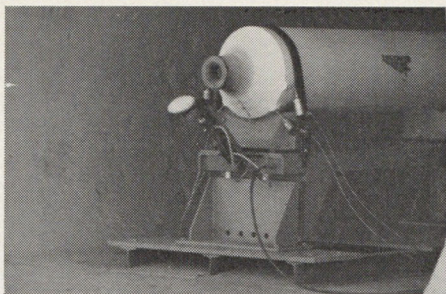
To the designer, these factors mean that he must get new military capabilities the hard way, by stretching the boundaries of technology.

One new capability sought by tacticians is a wide variability of acceleration and trajectory for air-to-ground missiles. When an offensive missile makes an unforeseen change in velocity or track, it invalidates the intercept calculations for defending missiles about to be launched or already on the way. The leading propulsion companies are now proposing methods of controlling rocket thrust to permit slow flight for reconnaissance flight phases and long-range cruise and speed segments to evade or penetrate defenses. In the cold-war arms race, the ability to deliver this change of pace means that the potential enemy must divert a sizable chunk of his technical and economic resources to development of super-sophisticated defenses.

At least a limited form of thrust control appears feasible for the next generation of missiles, and it is a requirement for the U.S. Air Force AGM-69A Short-Range Attack Missile (SRAM), which is to extend the capability of the aging B-52 and will also arm the FB-111, probably the F-4C, and, if it is developed, an Advanced Manned Strategic Aircraft (AMSA).

The U.S. Navy has several upcoming air-launched missiles that will also need advanced propulsion systems. The Condor air-to-ground missile and the ARM-1 and the ARM-2 antiradiation missiles would all reap tactical advantages from thrust control. The Air Force and Navy face the same problem of whether to choose now between throttleable, prepackaged liquid-propellant rockets and "wafer motors," which are the first and simplest form of thrust-controlled solid rockets, or to wait for more sophisticated throttleable solid rockets.

It is possible that the 2 services will reach different decisions. Industry officials report that many Navy research and development managers look very favorably upon prepackaged liquid-propellant rockets because of



Varying acceleration makes tactical missiles harder to stop. One method in solid rockets is to use "wafer motors." Above, sequence of 1 pulse of a 40-pulse motor being tested by Lock-

heed Propulsion Company during predevelopment work on USAF AGM-69A missile. From zero power, motor goes to full power, then dies down as wafer of fuel is burned out.

the success of the Martin (now Maxson) Bullpup, which has such an engine. Prepackaged liquid rockets have their propellants stored indefinitely in the missile tanks and, like solid rockets, can be launched on short notice.

Liquid propellants also offer higher specific impulse, which means more propulsive energy for each pound. In the past, command-guided missiles like Bullpup tended to use liquid propellants because their exhaust flames do not interfere with radio command signals as much as the exhaust flames of solid propellants. This factor is likely to be of decreasing importance because research by Lockheed Propulsion Company is producing better understanding of radio signal attenuation and reflection by solid-rocket exhaust. It is now possible for computers

to predict a solid propellant's attenuation characteristics before it is ever formulated and to make adjustments.

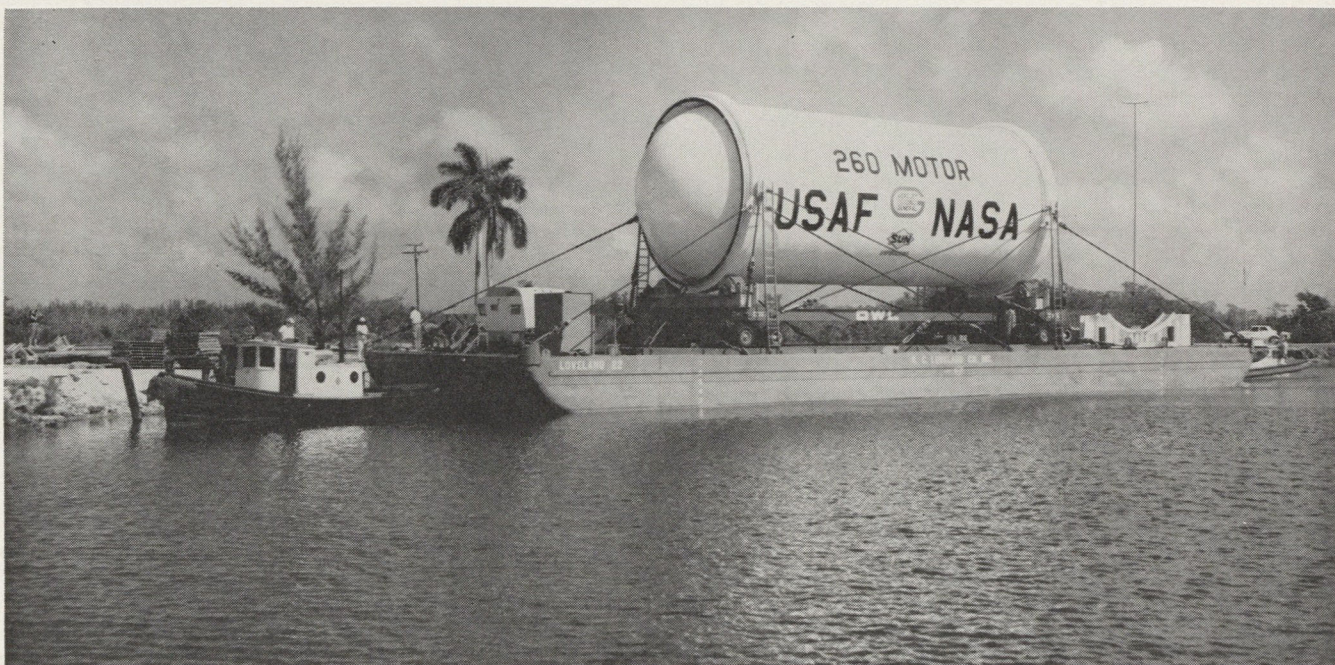
Complete thrust control or throttling is closer to operational reality in liquid-propellant rockets than in solids because engineers have known for centuries how to meter the flow of liquids. Controlling the rate of burning of a rigid grain of solid propellant, in which the necessary combustibles are already mixed, poses a tougher problem.

Both types of propulsion remain in contention for the AGM-69A assignment at this writing. The dominant thinking in the U.S. Air Force tends to favor a solid motor because of the factors that have made solid propellants the choice for most current air-launched missiles. Although liquids have an advantage in energy per

pound, room is an even more critical factor aboard combat aircraft than weight-lifting capacity, and more propulsive energy per cubic inch can be packed into the case of a solid rocket.

The solid-propellant wafer motor or pulse rocket does not permit control of thrust level but does allow the motor to be stopped and then restarted on command several times. The duration of coasting flight phases between the thrust pulses can be controlled so that the enemy faces dash, cruise, and coast segments at unpredictable intervals. Pulse durations are set irrevocably when the motors are cast, but they might not be the same for all missiles of a single type.

The first successful solid-propellant pulse rockets are "Cap Pistol" motors, (Continued on following page)



Large solid-propellant rocketry has reached such a high level of reliability that one expert has asserted it is now possible to build solid motors of virtually any size. Above, Aerojet-General

Corporation's huge 260-inch-diameter (660 cm) solid rocket is transported by waterway to Homestead, Florida, for test. USAF favors solid propellants, while Navy leans toward liquids.

which work like the toy guns they are named after. Curtiss-Wright makes a model which the National Aeronautics and Space Administration uses to control the attitude of Tiros weather satellites.

The wafer motor proposed for AGM-69A and other new missiles operates on a different principle. There are no moving parts, and all propellants are cast in the single case. A separate "wafer" of propellant supplies each thrust pulse. Each wafer and its igniter are protected from the heat generated in the preceding pulse by a thermal insulating barrier. At every ignition a barrier is shattered and spewed through the nozzle. A pulse motor for a missile such as AGM-69A would have 3 or more wafers and at least 1 would be a hollow, internal-burning propellant grain, with a large burning area to produce high chamber pressure and high thrust for rapid acceleration. Relatively low-thrust sustainer wafers may be end-burners with smaller burning area but more propellant per cubic inch than internal burning grains.

If wafer motors are indeed selected for AGM-69A, Lockheed Propulsion Company must be regarded as the leading contender for the propulsion contract. They claim a 2-year head start on competition on the strength of Air Force-funded predevelopment work, which has included testing of flightweight motors at simulated altitudes up to 100,000 feet (30,480 m)

after exposure to vibration and a 300° F range of temperatures. Aerojet-General and Thiokol have made and tested wafer motors and will provide first-class competition for the AGM-69A contract. Technical head starts of the type claimed by Lockheed have been known to evaporate in the face of economic factors.

A curious facet of the competition between prepackaged liquid-propellant rockets and the first generation of thrust-controlled solid rockets is the way in which technological progress is complicating the problem of choosing between them. While solid-rocket engineers have been striving toward specific impulse, environmental resistance, restartability, and controllability for liquid-propellant rockets, designers of prepackaged liquid rockets have been trying to overcome the advantages of solids with simplicity, reliability, ease of production, low cost, and impulse density. The liquid-propellant rocketeers have enjoyed comparable success. Indeed, liquid-propellant rocket engineers at Rocketdyne Division of North American Aviation insist that if procurement of AGM-69A is delayed a year, liquid propellants will have an excellent chance of winning the job.

Thrust control offers intriguing possibilities to tacticians for other than air-to-ground missions. Air Force is trying to drum up support in the Office of the Secretary of Defense for a

very large ballistic rocket capable of launching several warheads simultaneously. Each could have its own final-stage motor and terminal-guidance system to steer it toward its own particular target. Warheads with evasive-action capability and powered decoy reentry vehicles in the payload could pose a nasty problem for anti-missile defenses.

As the guidance experts perfect their art, it is becoming possible to develop truly long-range, accurately guided air-to-air missiles. The problem for the propulsion industry is to develop rockets that will reach out 20 to 100 miles (32 to 161 km) and yet fit within motor cases not substantially larger than those of present missiles with ranges of between 2.5 and 4 miles (4 and 6.4 km).

Thrust control can do much to extend range by permitting a relatively low-speed cruise or coasting segment of flight. Aerodynamic drag, and hence the thrust requirement, vary with the square of speed, so that slowing the missile cuts propellant consumption sharply.

Two or 3 years behind the development of the wafer motor are 3 types of solid rockets which permit thrust output to actually be throttled as it is in airplane engines. They can also be stopped and restarted like wafer motors.

All the throttleable solid rockets use propellants that burn more rapidly and

A LONG STEP FORWARD IN PROPELLANT

Many of the exciting prospects beginning to appear in the field of small missile design depend heavily on advances in solid-propellant chemistry made in recent years but not exploited in small missiles or in advances now in the pipeline from the chemical research labs.

While successive generations of Minuteman and Polaris ballistic missiles have had the benefit of the latest propellants their schedules allowed, U.S. Air Force Rocket Propulsion Laboratory scientists declare that currently operational small tactical missiles burn propellants formulated mainly from basic chemicals that happened to be on the shelves of the chemical industry at the dawn of the rocket age.

For instance, the nitrocellulose used is essentially the same as that developed for smokeless gunpowder, and the polysulfide rubber binders used in current composite propellants are little changed from polysulfides used for years to seal swimming pools and fuel tanks.

In 1941, solid propellants could be made with a specific impulse of 228 seconds, and 25 years later the figure for operational propellants has risen only to 248 seconds. Most of this 20-second advance can be attributed to the use of aluminum additives, which began in the middle and late '50s.

The next big advance is expected to push specific impulse beyond 310 seconds. It will be achieved with new classes of binders, oxidizers, and light-metal additives, which first began to be explored between the years 1958 and 1962.

Engineers at United Technology Center count no fewer than 7 new propellant combinations moving toward developmental maturity, and there is reason to believe there are 1 or 2 more that are not discussed openly. High-performance combinations are not moving as rapidly as those offering other advantages, but UTC engineers believe they will begin to be available for new missiles beginning in 1967. Lockheed Propulsion Company has developed a double-base nitroplastisol propellant for which it claims the highest specific impulse of any solid propellant yet tested.

The turn to custom-tailored chemistry has an appearance of almost revolutionary change. Actually, the change is the result of almost independent developments that have jelled rather suddenly. Propellant ingredients have evolved steadily and have only awaited the impetus of new missile programs to bring them through the final stages of development. The only propellant chemical to remain substantially unchanged has been ammonium perchlorate, now and for some time to come the most widely used solid oxidizer.

Even this ingredient has benefited from improved processing that makes possible precise particle-size control that improves the physical properties of the completed propellant grain.

Work on light-metal hydride additives has been pushed, and 2 or 3 are ready for application in 1966 and 1967. High-energy propellants being developed by UTC include 4 new oxidizers. Three of them are fluorine-based, and the

generate more thrust if the pressure in the combustion chamber is increased. They are throttled by restricting or opening the chamber exit or by injecting fluid from outside to pump chamber pressure up to the intended level.

The most easily produced within the limits of present technology is a type with 2 combustion chambers. The pressure-sensitive propellant in the front chamber produces a flow of partly unburned fuel vapor, which is valved through the exit and into the rear chamber at relatively low temperatures. There it is reburned with a solid propellant containing an extra supply of oxidizer to consume the unburned fuel vapor and release additional propulsive energy. The valve controls pressure in the first chamber to vary its burning rate and the rate at which it feeds fuel to the second chamber. A ring of igniters at the front end of the first chamber permits successive restarts. The dual chamber motor is being developed by Northrop Carolina Corporation, formerly known as Amcel Propulsion Company.

A simpler and lighter type of controllable-thrust solid rocket has only 1 combustion chamber. Pressure in it is varied by a control valve which partially blocks the thrust nozzle throat. The main problem with this simple device is the difficulty of finding valve-cooling techniques and materials that will enable the valve to

withstand the temperature of chamber gas that is not fuel-rich and, therefore, relatively cool, as it is in the front chamber of the Northrop-Amcel motor. Nearly all the major solid-rocket companies are working on this problem, and reports indicate that the single-chamber, throttleable solid rocket is on the road to operational feasibility.

Aerojet-General has partially sidestepped the valve materials problem by inventing a novel toroidal or doughnut-shaped single-chamber motor with the valve stem passing through the hole in the middle where it is not exposed to hot gas. Only the head of the valve is in the exhaust that issues from a circular slot in the side of the doughnut of propellant and funnels into the rocket nozzle. Aerodynamic drag limits the usefulness of this odd-shaped motor in the atmosphere, but it may find applications in space vehicles and in missile top stages.

Fluid injection chamber-pressure control as a means of throttling solid rockets has been tested by several of the major companies. It has been successfully demonstrated by Lockheed Propulsion Company and trade-named the RSVP (Restartable Solid Variable Pulse) motor.

A small amount of liquid is pumped into its combustion chamber at a controllable rate to vary chamber pressure, burning rate, and thrust produced by the high-energy, pressure-sensitive, solid-propellant grain.

Maximum thrust of the RSVP motor is 30 times its minimum thrust, compared to a maximum throttling ratio of 7 to 1 for Lockheed's version of the single-chamber valved motor.

In principle, just about any kind of liquid, including water, could be used to throttle the motor. Chlorine trifluoride has been used in demonstrations because it burns spontaneously when it touches the solid propellant and acts as a hypergolic igniter for any number of restarts, thus eliminating the need for pyrotechnic igniters. The RSVP motor is not to be confused with a hybrid rocket, in which one of the main propellants is a liquid and the other a solid.

The promising future of controllable-thrust solid rockets is owed in large part to advances in high strength-to-weight ratio materials that have occurred in recent years. These advances offset performance sacrifices that the designers have to make to obtain thrust control. If the performance of a rocket is to be varied in flight, it is obvious that it must operate at less than its best possible efficiency during part of its mission, since the motor design can be made optimum for only one set of performance figures.

Also, the hardware needed to control or pulse thrust takes up part of the weight allowance that could otherwise be used for additional propellant. (Continued on following page)

CHEMISTRY—CUSTOM-TAILORED SOLIDS

fourth is nitronium perchlorate with a higher percentage of usable oxygen than ammonium perchlorate.

Assuming no breakthroughs, 1 fluorine-based oxidizer should become available to missile designers in the next 3 years and the other 2 some time after 1970. Nitronium perchlorate is presently unstable at relatively low temperatures and is hard to formulate, but it ought to find applications between 1967 and 1970. The rule of thumb is that it takes from 2½ to 4 years from the beginning of serious development to ready a new propellant for application.

The energetic propellant combinations coming out in the next 2 to 4 years will be tricky to handle and use, compared to present combinations. They will be more sensitive, and there is a trend toward the use of toxic ingredients, which may raise production and ground-handling problems. AFRPL has built a remotely located test complex in which rockets with toxic combustion products can be operated and the hazards evaluated.

Solid-fuel binders have been improved substantially by new methods of organizing the structure of polymer molecules without changing the chemical formulas. The old-line chemical companies have been devoting more of their top-level talent to the problem of inventing polymers such as carboxy-terminated polybutadienes especially for use as propellants, and the recent accelerated progress is due partly to this. Further advances in binder chemistry are likely to be paced by development of other propellant components.

Development of high burning rates and good physical properties are getting more attention from propellant scientists at the moment than sheer specific impulse. Most industry officials regard this as a short-term trend motivated partly by the sizable resources the U.S. Army and Navy are bringing to bear on development of durable, reliable propellants for high-thrust, rapid-acceleration missiles to defend against aircraft and ballistic missiles. Another motive is the fact that most high-performance propellants now in development have rather poor physical properties compared to the common garden-variety propellants used in current operational missiles.

A new line of propellants based on cross-linked nitrocellulose with excellent physical properties at temperatures ranging from -75° F to 160° F (-59° to 71° C) is the source of much optimism at Hercules Powder Company, whose engineers regard Army tactical weapons and air-launched missiles as the most promising applications for new solid-rocket technology.

The Air Force is not pressing any major development or high-burning-rate propellants and will content itself with collecting the technological output of Army's Sprint program and Advanced Research Projects Agency's Hibex program. The pacing item in the field is the development of processing methods.

Among the foremost achievements in the drive toward better physical properties are the gun-launched High-Altitude Research Project (HARP) case-bonded solid-propellant rockets, which have withstood 8,000-G launches. ☆☆☆

lant. These compromises were not realistic until the advent of strong, lightweight cases and nozzles. Now, despite the weight of thermal barriers and igniters, Lockheed has been able to make wafer motors with propellant accounting for 87 percent of total motor weight, which is not too much inferior to early Polaris missile motors.

While most top engineers in the industry rank thrust control as potentially the most fruitful new venture in solid-rocket technology, those at United Technology Center are inclined to disagree. They believe that the hybrid rocket or the liquid-propellant rocket is better than any pure solid rocket for missions requiring thrust control. They contend that thrust control will deprive solid rockets of the simplicity that makes them best for so many missions.

As its name implies, a hybrid has 1 solid propellant and 1 liquid propellant. While the difficulties of throttling a hybrid are not negligible, it can be done by metering the flow of the liquid propellant. UTC engineers point out that this does not require the extra weight of high-temperature valves or special thrust-control fluid tanks.

Air Force scientists estimate that hybrids are now at about the stage of development liquid-propellant rockets had achieved in 1949 when the German V-2 engine was being scaled up for the Navaho missile system.

Military enthusiasm for hybrids has fluctuated widely over the years and at this moment is tepid. However, UTC management is confident that hybrids will have their day and has steadily funded independent research and development. One interesting concept is a high-energy hybrid burning nearly pure light-metal fuel and a fluorine oxidizer. Another ambitious UTC idea is to construct enormous hybrid space boosters in which the solid fuel consists of vast numbers of fuel bricks bonded together and strengthened by metal reinforcing rods.

The advantage of this is that the bricks can easily be shipped in bulk and loaded at the launch site into boosters that would be much too large to ship overland when completed. Brick-assembly hybrids would not require an elaborate casting and curing plant as do solid-rocket on-site manufacturing schemes. In the UTC brick-fueled hybrid, the oxidizer envisaged is liquid oxygen, but others might be used.

The brick-assembly method cannot be adopted for conventional composite solid propellants because the combustibles are premixed throughout the grain. Flame could propagate through the slightest crack between the bricks and the propellant grain would disintegrate.

In a hybrid, the absence of oxidizer particles in the fuel would make this impossible because combustion can occur only where liquid oxidizer meets the surface of the fuel.

Aerojet-General has a unique motor concept called CHARM (Consumable Hybrid Atmospheric Rocket Motor). It is an atmospheric research rocket which burns its own case in flight to prevent it from falling into inhabited areas. Another successfully tested Aerojet concept is a pulse-fired hybrid attitude-control rocket for spacecraft which generates 10 bursts of thrust per second.

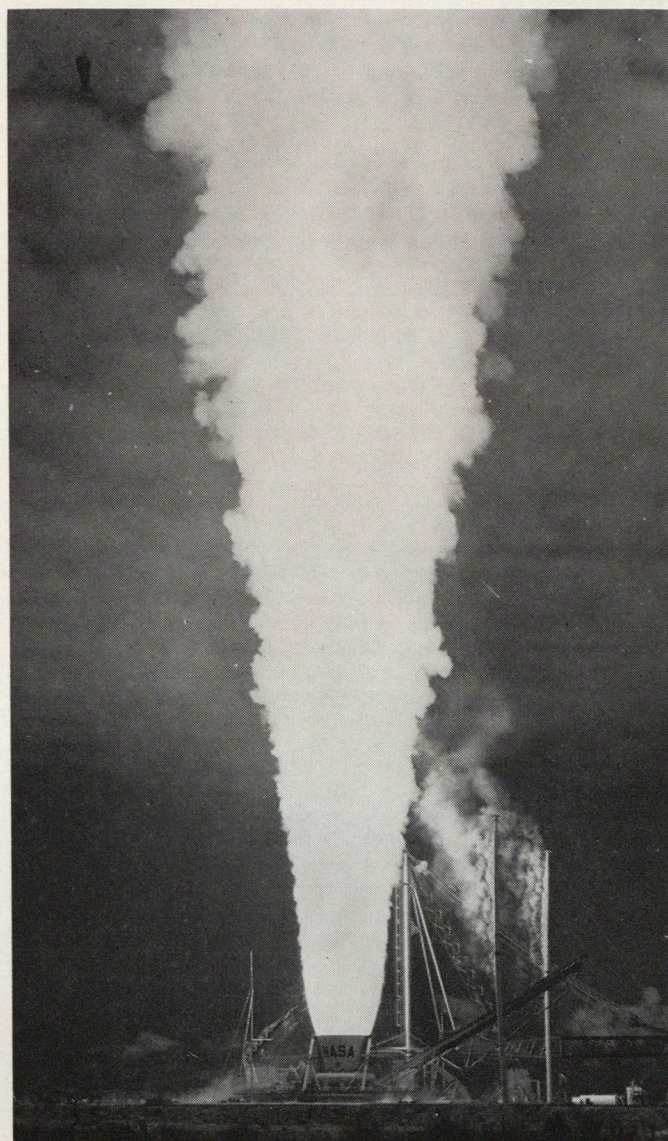
At the Air Force Rocket Propulsion Laboratory, scientists do not expect the hybrid business to boom until the most energetic usable chemical fuel is a solid and the most energetic usable oxidizer is a liquid. However, they expect that day to come eventually. Hybrids may find applications earlier if it becomes possible to make them very cheap. They have a poten-

tial for important cost reductions, but no one has shown how to realize them.

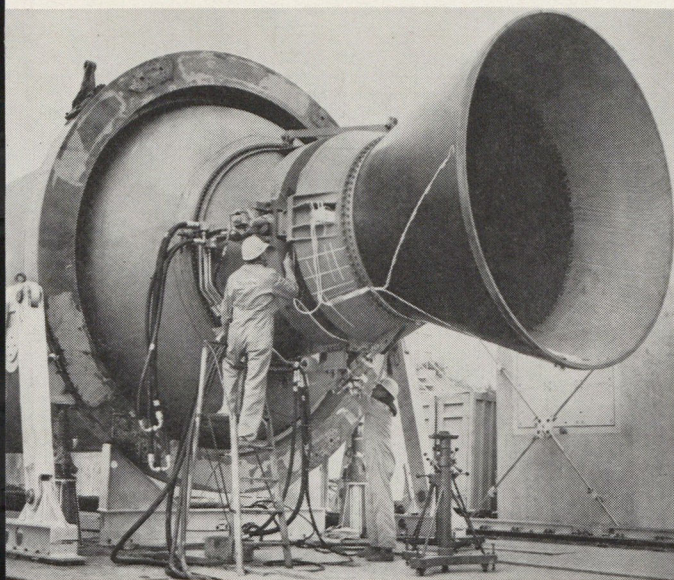
Still several years in the future are air-augmentation systems, which promise to double or triple the range of missiles that remain within the atmosphere. Burning indrawn air, in addition to self-contained chemical oxidizers, may make possible rockets with specific impulse equivalent to perhaps 1,500 seconds. Tests have already demonstrated 500 seconds.

In contrast, solid rockets, burning only the chemical oxidizers they carry, will do well to exceed 300 seconds. Martin-Denver and Thiokol have been conducting funded exploratory development of air augmentation, and practically every major rocket propulsion company has in-house programs under way. Of the solid-rocket engineers questioned, the few who did not rank controllable thrust as the most profitable area of new development accorded that honor to air augmentation.

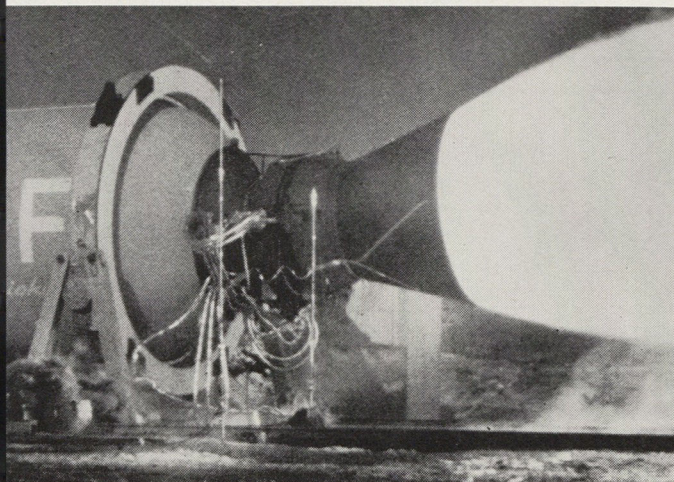
Air-augmentation methods range



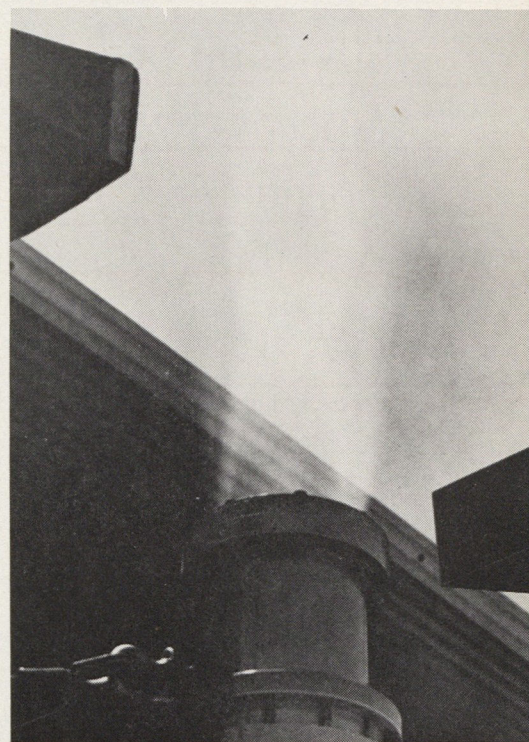
A plume of smoke hundreds of feet high rises majestically above the 260-inch (660 cm) solid rocket recently tested successfully by Aerojet-General. The huge rocket produced approximately 3,000,000 pounds (1,350,000 kg) of thrust for a period of 2 minutes during the dramatic test in early December of 1965. This striking technological achievement marked a true milestone in the advance of solids from their early doubtful days to today's reliability.



Above, the enormous movable nozzle on Thiokol Chemical Corporation's 156-inch-diameter (396 cm) solid-propellant segmented space booster is instrumented just before a static test. Below, in test at Thiokol's facility at Brigham City, Utah, booster produced 1,500,000 pounds (680,400 kg) of thrust.



Bracketed by microwave antennas to check attenuation of signal from exhaust plume, Lockheed Propulsion's RSVP motor performs static test. New motor combines features of solid and hybrid technology to allow unlimited restarts and an efficient wide-throttle range.



from elaborate ducted rockets, in which some or all of the propellant is burned with ingested air, to simple shrouds around the nozzle, in which heat and momentum from the rocket exhaust are imparted to the air in the duct. Air Force Rocket Propulsion Laboratory scientists predict that cost and reliability considerations will keep air-augmented rockets out of the defense inventory until it is proven that they can get along without complex variable-geometry air inlets.

Martin is developing a shrouded liquid-propellant rocket called RENE (Rocket Exhaust Nozzle Engine). Under contract from the Air Force Weapons Laboratory, Thiokol Huntsville Division will demonstrate a ducted rocket called SPARM (Solid-Propellant Augmented Rocket Motor). Beech AQM/37A target drones will be used as

flying test-beds for development motors. For the sake of economy, Douglas Littlejohn artillery missile motor cases will be used.

Ducted rockets like SPARM have secondary combustion chambers and must be accelerated to supersonic speed to operate efficiently. Thiokol will do this by loading the secondary combustion chamber with solid propellant and using it as a booster. At the end of the boost phase, the nozzle and forward closure will be jettisoned to clear the chamber for its air-augmented cruise role. Three SPARM flight vehicles are about to be flight-tested at the Naval Missile Center, Point Mugu, California.

Air Force and industry engineers are watching with interest an air-augmentation scheme developed by the California Institute of Technology Jet

Propulsion Laboratory. In the JPL concept, air is injected directly in the expansion cone of an otherwise fairly conventional rocket. It makes the nozzle adaptive to change of altitude, and valving the inflow of air provides a simple method of thrust vector control.

These characteristics make the JPL motor a promising candidate for ballistic missile and space booster first-stage motors, although the rapid changes of velocity and pressure make these less than ideal applications for air augmentation. A new generation of air-augmented boosters would probably use flatter ascent trajectories to prolong their advantage in energy per pound of propellant carried.

The propellant economy of air augmentation would be most welcome to designers of air-launched missiles. However, the presence of a large empty duct will tend to make missiles too large for the limited volume available aboard combat aircraft. Developers are contending with the problem of making a short, light duct, yet one which is long enough to permit thorough mixing of the air and the rocket exhaust. At present, it appears that liquid and solid rockets will derive equal benefits from air augmentation.

☆☆☆

QUESTION:

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Check:

the Turbo-Beaver (DHC-2 Mk III) and Twin-Otter (DHC-6)

See them at the 1966
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by de Havilland Canada, world leaders in STOL.

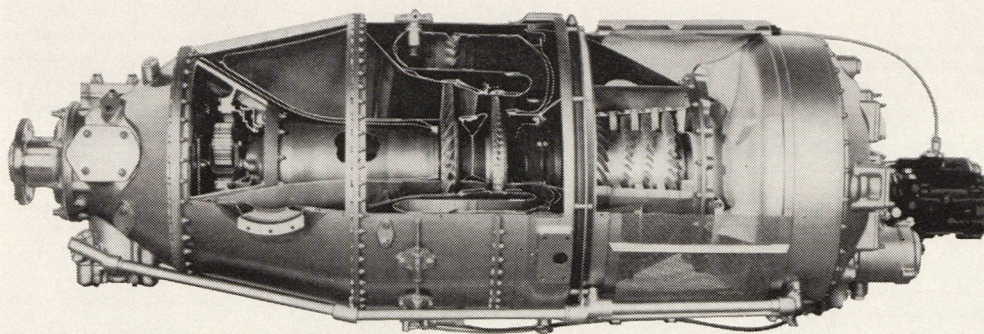


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Canada's military, and the aerospace industry that leaned so heavily upon it, experienced an economic crisis in the late 1950s. Both took bold, original steps to recover from that crisis. For the military, the answer for recovery without reneging on the country's major commitments was integration of the services. For industry, it was diversification and export. Today, after a long climb back—with money saved by the unification being invested in new equipment, and with Canadian aerospace products being used by many countries—the air arm and the industry can look forward, with confidence, to healthy, steady growth . . .

Canadian Aerospace

A Tightened Belt and a Clear Eye

BY NORMAN AVERY
Aviation Editor, Ottawa Citizen

In the late 1950s, Canada was trying to step ahead of the rest of the world in the supersonic interceptor field. The Avro Arrow was to fly higher and faster than any other aircraft in the Western World. But while its projected performance figures were attractive, its projected cost was not, and, with a new government in office, the program was ordered abandoned in February 1959. Costs had been estimated as high as \$2,300,000,000. The cancellation threw 14,000 out of work overnight and affected some 30,000 altogether.

The shock wave that followed the cancellation wiped out half of Canada's air industry, and Canadian manufacturers in the aerospace field still think back on that time with fear and bitterness.

The lessons of the Arrow were simple:

- Don't rely solely on a single defense contract.
- Diversify.
- Get out and compete for export trade.

For some, the transformation to di-

versified business came slower than for others. But the situation has righted itself, and Canada's maple leaf trademark now can be found around the world and in outer space.

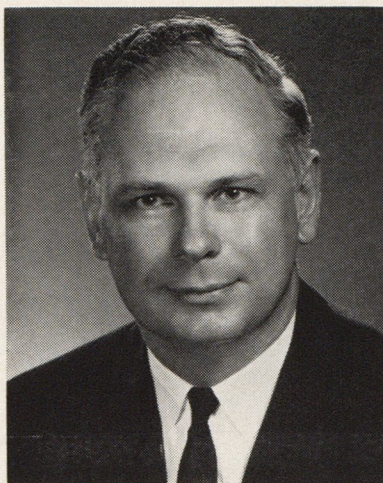
While the aerospace-industry men were learning their lessons, the military planners looked to a much more difficult task. In the post-Arrow days, they had reequipped home interceptor squadrons with the McDonnell F-101 Voodoo, and the North American F-86 Sabrejet squadrons on NATO duty in Europe with Lockheed CF-104 Super Starfighters. Increased firepower of the CF-104s over the Sabres abroad and the Canadian-built CF-100 Canucks at home allowed a substantial trimming of numerical strength. Canada's NORAD contribution was enhanced by 2 Bomarc-B squadrons and an accompanying SAGE system.

But an economic imbalance was developing in the relationship between funds spent for buying new equipment and those for operating it, and drastic measures were needed to head off bankruptcy. In 1954, approximately 43 percent of the defense budget went to buy equipment. It reached its peak of 57 percent during the Korean conflict. But this ratio had fallen so that in 1964 only 13 percent of Canada's

(Continued on following page)



RCAF units flying with NATO forces in Europe employ the Lockheed-designed, Canadair-built CF-104, comparable to F-104Gs flown by many other NATO air forces. Canadair has also built Starfighters for U.S. military aid program.



To cut costs without diluting military strength, Paul Hellyer, Canada's dynamic Defence Minister, planned and carried out complete integration of Canada's armed forces, now organized functionally into 6 interservice commands.

defense dollars went for equipment. It was calculated at this rate that zero would be reached in 1967—an embarrassing milestone for Canada's hundredth anniversary.

Defence Minister Paul Hellyer, whose first task in his new position was to unravel the defense puzzle, predicted that by 1967 "we'd be the best-dressed, best-fed, best-paid—but poorest-equipped—military force in the world."

His alternatives were few. He could pour another billion into defense. But with the country having experienced a series of deficit budgets and the cost of servicing the national debt rising, there was no overwhelming urge in this direction.

Another possible answer would be to cut back or eliminate one or more of Canada's major international commitments to NATO, NORAD, or the U.N. This was also rejected.

"Instead," said Mr. Hellyer, "we decided to tackle the fundamental prob-

lem of defense organization. Knowledgeable military men throughout the world have been advocating for years the integration of the traditional services. People such as Field Marshal Montgomery, General Eisenhower and MacArthur, and Marshal of the RAF Sir Arthur (Bomber) Harris are all on record as favoring this approach."

Mr. Hellyer decided in mid-1964 that Canada should be the world's first nation to take the integration step. Accordingly, he placed a freeze on all procurement programs and ordered scrapping of some equipment programs. The only aircraft programs canceled were those to acquire additional Voodoos and Starfighters.

The armed forces were to be cut to 110,000 by August 1966. But the plan to drop 13,000 sailors, soldiers, and airmen was carried through a year ahead of schedule. Some 2,500 were compulsorily retired with a special cash settlement, and the rest were released at the termination of normal engagements. This is expected to provide administrative savings of \$100,000,000 by 1970.

The militia and reserve forces were cut drastically across Canada, and there was a sharp outcry from units with long battle traditions.

Integration of the 3 services began at the top. Duplicated and triplicated functions of the armed forces and the Defence Research Board were shuffled into a single headquarters organization. About 2,000 of the 6,000 headquarters personnel were cut.

Information services lost 161 of their 237 staff members for a saving of \$1,000,000 annually; 650 were to lose jobs in the various pay departments; and a one-third cut in recruiting staffs was expected to save \$1,200,000 annually. Canada's forces are recruited from volunteers only.

There were also savings by combining construction, engineering, communications, and intelligence services. It was found that about 20 percent of all materiel was duplicated.

When the dust settled, with the bulk of phase 1 accomplished, the department turned last fall to phase 2, the reorganization at command level. Canada's 11 major military commands were combined into 6 commands.

These are:

- **Mobile Command**—The largest of the 6, it will maintain combat-ready tactical air and ground forces capable of rapid deployment anywhere in the world.

- **Maritime Command**—To consist of sea and air maritime forces on the Atlantic and Pacific coasts mainly employed in antisubmarine warfare (ASW), but with provisions to supply sealift to Mobile Command.

- **Air Defence Command**—To maintain combat-ready air defense forces for NORAD.

- **Air Transport Command**—To provide strategic airlift of men and materiel necessary to give the forces the mobility required by their prescribed roles.

- **Training Command**—To be responsible for conducting a personnel selection and classification system for providing training at the basic, elementary, and advanced levels.

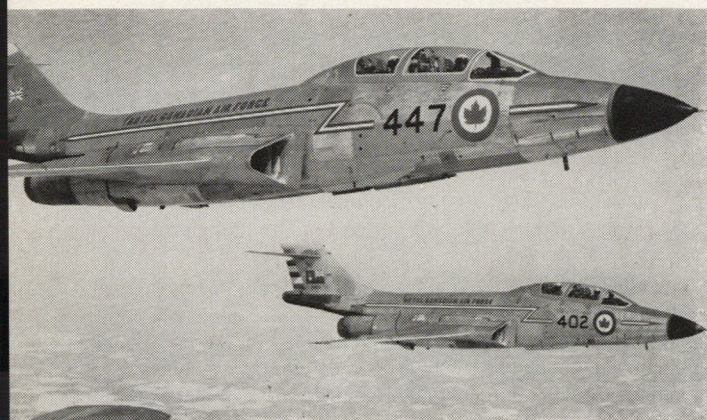
- **Materiel Command**—To provide logistics back-up for the forces and be responsible for materiel procurement, warehousing, distribution, and major repair and overhaul.

The Canadian Army brigade group in Germany and the air division with bases in France and Germany will continue their functions under NATO and report directly to Canadian Forces Headquarters (CFHQ). Administration of the militia, aid to the civil power, civil survival, and provincial representation will be provided by small regional offices reporting directly to CFHQ.

There will always be sailors, soldiers, and airmen, Mr. Hellyer has declared; they will merely all be in the same armed service. The question of a single uniform is still in the future and will not likely precede the final unification at the unit level.

Defense savings from integration will be spent on new equipment, the Defence Minister says. The equipment portion of the budget is expected to be back up to 25 percent within 4 years and could amount to \$3,000,000,000 over a decade.

"By establishing priorities and coordinated planning," says Mr. Hellyer, "we also intend to even out the peaks and valleys of equipment purchases. With a long-term plan and all concerned devoting themselves to that single plan, we should be able to establish quite clearly when and in what quantity we have to add or replace hardware."



In place of ambitious Avro Arrow interceptor, whose cancellation was a severe blow to Canadian industry, RCAF air defense units now are equipped with the McDonnell F-101 Voodoo.

Just over a year ago, Mr. Hellyer was able to put Canada's first 5-year procurement plan before Parliament. Terming it "not inviolable" in light of either disarmament progress or a worsening of the world situation, Hellyer set the cost at \$1,500,000,000.

Much of the hardware budget is going to update the equipment of Army personnel. On the air side, the order will include 4 additional Lockheed C-130E Hercules aircraft to bring the fleet of Air Transport Command to 24. To lend to the air mobility concept in the force, 15 de Havilland of Canada Buffalo aircraft will be included.

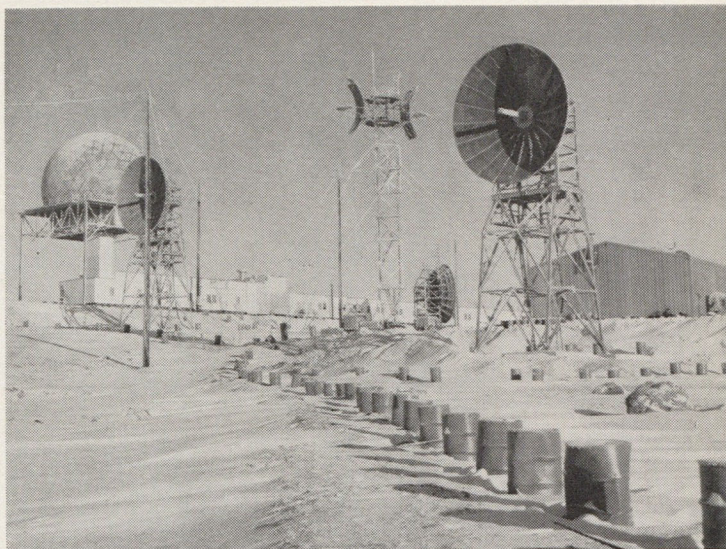
The new tactical support aircraft is to be the Northrop F-5 Freedom Fighter. It is to be built at the Montreal plant of Canadair Ltd., and equipped with J85-15 engines built at Orenda Engines Ltd. in Toronto. Total cost is to be \$215,000,000 for 125 aircraft. An improved version, it will be known as the CF-5 and will enter service in 1967.

The Navy is to get 6 new ships, 4 of them helicopter-equipped destroyers, using the CHSS-2 Sikorsky Sea King helicopter, which is produced by United Aircraft of Canada. The Navy has an order of 32 being delivered through 1967. These are used as ASW ship-helicopter teams, carrying both detection gear and armament.

Canada's only aircraft carrier is to be completely refitted this year, including improved accommodations for the Sea King helicopter. Other ASW elements to be improved are the Canadian-built Argus sub hunter, used by the RCAF, and the Navy's Tracker, which will be refitted with up-to-date detection systems.

The Defence Department will be shopping around the aircraft market-places of the world for some time. Some replacement is needed for the 3 ASW aircraft (the fleet also includes the Neptune), but this is beyond the 5-year term. Light jet transports are

Northernmost of radar networks to warn of impending bomber attack against western hemisphere is DEW Line, now supplemented by BMEWS in tracking ballistic missiles. Canada and U.S. share air defense in NORAD partnership.



under study to replace the Beech 18s now used for communications and training. Such a small jet would replace the C-47 Dakotas, still active in the RCAF, and the Canadian-built Cosmopolitans. The latter are being refitted with Allison engines, which are interchangeable with the Hercules powerplants for more economical maintenance.

Mr. Hellyer says his 5-year plan will enable industry to also make plans upon which to budget its technical talent and deter a mass exodus of engineers and skilled labor. This has been a problem since the Arrow collapse.

Meanwhile, industry has tackled its many problems with a solid front in an effort to keep plants working, particularly on exportable specialized products. Success is reflected in the Air Industries Association's 1964 statistics, which showed exports to the U.S. up \$26,000,000 and to other countries up \$33,500,000. Although final figures had not been compiled for

1965, it was generally expected that exports would again be high.

The exports ranged from complete aircraft, such as the de Havilland of Canada line of STOL Beavers, Otters, Caribou, and Buffalos, to avionics in U.S. spacecraft and turbine engines for a variety of purposes.

An example of the vigorous activity of industry is United Aircraft of Canada's small PT-6 turbine engine, which now powers more than 20 separate aircraft and helicopters. Its designers point out with some pride that President Lyndon Johnson has 2 aircraft in his fleet (King Airls) powered by the Canadian engines.

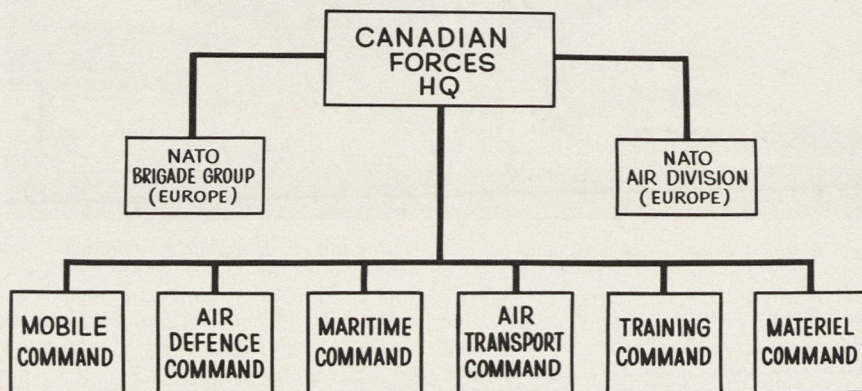
This company has, like many others in the country, diversified its developments into many other fields. Another version of the PT-6, called ST-6, powers a Norwegian launch and is the first turbine engine in its power class to be approved by the U.S. Navy's Bureau of Ships for marine use. Another application in lumber-conscious Canada is a bush operation in which it powers a machine that chews wood into chips for easier handling in paper production. It also powers a snowplow and is being used as the propulsion unit aboard an experimental light train.

A competing jet engine company, Orenda, is also finding side uses for its products. One of the most unusual is a 6,000-kw turbine electric generator that burns sewer gas. The U.S. Navy is also interested in Orenda's ship-propulsion units.

There is exciting activity in Canada's space industry as well. The country now has 2 satellites orbiting the earth, probing the mysteries of the ionosphere. Alouette I, which was sent

(Continued on following page)

CANADIAN FORCES COMMAND ORGANIZATION





Equipment of Air Transport Command, operated for armed forces by RCAF, includes fleet of 24 Lockheed C-130 Hercules transports. They will soon be joined by 15 de Havilland-built CC-115 Buffalo STOL aircraft.

into orbit in September 1962, has delivered excellent information in the Topside Sounder program with the U.S. And last November, Alouette B went aloft from Vandenberg Air Force Base, California, to fly a higher orbit for the same purpose.

Canada is vitally interested in the ion belts over her northern frontier because disturbances in the highly charged ionosphere cause frequent radio communications blackouts. The studies are carried out under the International Satellites for Ionospheric Studies, and the results are available to everybody.

Canada's involvement in space programs is relatively modest but effective. By 1970, the country will have spent \$11,000,000 on ionospheric studies. This figure, of course, is kept low by hitchhiking into space, courtesy of the U.S. National Aeronautics and Space Administration's Thor-Agena B rocket. The first Alouette, which made Canada the world's third nation in space, cost \$3,000,000 to design and manufacture under the guidance of the Defence Research Board of Ottawa. Its younger brother cost a bit more, but the long-range benefits will more than likely overbalance this modest outlay.

For one thing, it has meant a substantial step into space for RCA Victor of Canada, whose engineers designed the "innards" of the Alouette satellites, and for de Havilland of Canada, where the extendable metal tubes for antennas and booms were designed. This type of antenna has since gone into all U.S. Gemini spacecraft and the last 2 Mercury vehicles.

Canada has been involved in a couple of other space probes over the past few years. First of these is the Black Brant firings from Fort Churchill on the northwestern rim of Hudson Bay. The firings are being conducted by Pan American Airways personnel under the direction of the USAF Office of Aerospace Research, using

rockets developed by Bristol Aerospace Ltd.

Like the Alouette, the Black Brant is seeking an answer to ionospheric radio problems. Firing into the heaviest belt of the aurora borealis, the Black Brant V-B last June lobbed a 247-pound (112 kg) payload of instruments 235 miles (378 km) into the sky. This was almost twice the altitude of previous missiles of this type. Its 1 ton (.9 mt) of solid propellant burned for only 30 seconds and developed 17,000 pounds (7,700 kg) of thrust. More powerful Black Brants are being built. Mark III will provide a simple and economical means of lifting 40 to 100 pounds (18 to 45 kg) to an altitude of 100 miles (160 km) and Mark IV is designed for the 500-mile (805 km) altitude range. The latter is the first 2-stage Black Brant rocket.

Computing Devices of Canada, with Aviation Electric Ltd. building the space vehicles and a guidance sys-

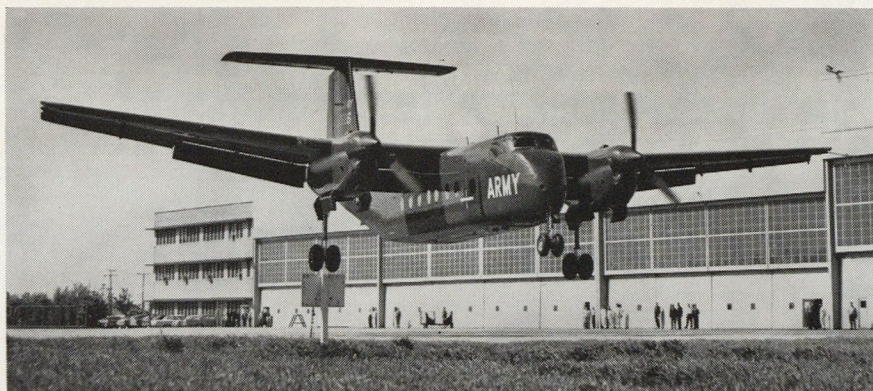
tem, have worked their way into space with a bang. Teamed with Montreal's McGill University Space Research Institute and the U.S. Army Ballistics Laboratories, they are engaged in HARP (for High-Altitude Research Project). This project sends missiles into the 75- to 100-mile (120 to 160 km) altitude range for about \$550 a shot, using a 16-inch (41 cm) naval gun at its Barbados launch site.

Purpose of the project is to develop space probes at low cost that will make use of the extreme accuracy of the system. Large self-propelled missiles are vulnerable to surface winds in their slow liftoff phase. The gun, on the other hand, fires the missiles at between 5,000 and 6,000 feet (1,525 and 1,830 m) per second and can achieve pinpoint accuracy in space. Work is progressing with powered missiles that are expected someday to toss a 50-pound (23 kg) payload into a low earth orbit for as little as \$50,000. The total HARP program has cost less than \$2,000,000 so far. (For more on this program, see "Trends and Developments," AF/SD INTERNATIONAL, January '65, page 38.)

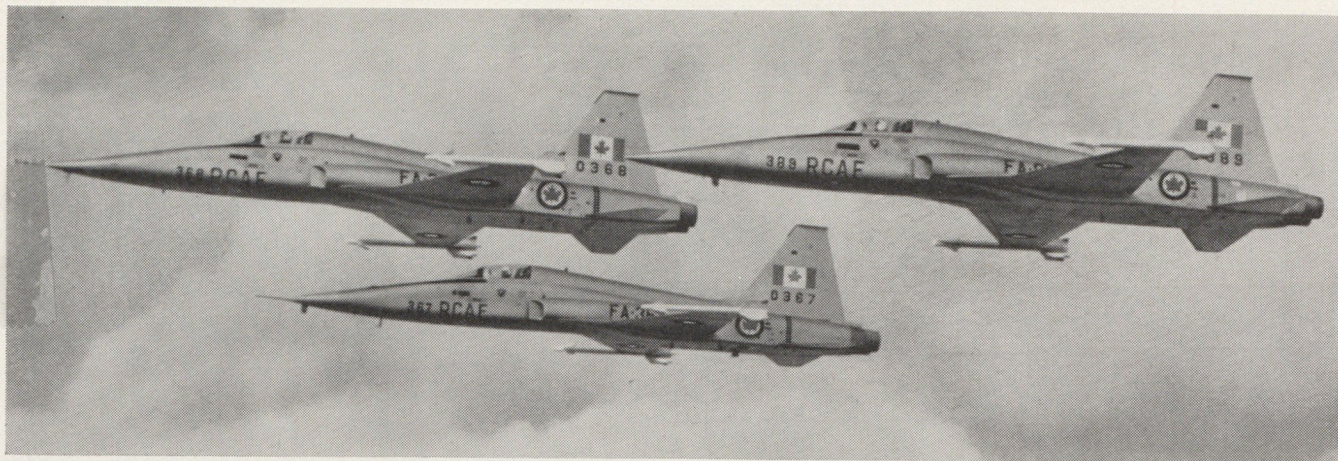
Practical application of the HARP system could be either accurate study of the ionosphere or possibly alteration of the nuclear particle contents of belts to achieve an electron balance.

Computing Devices is also involved in programs to study effects of meteoroid strikes on spacecraft and the phenomenon of intense light generated by hypervelocity impact.

Experience with HARP led the company to the production of solid-state electronic units capable of withstanding extremely high G shocks. This has



De Havilland Buffalo, shown on takeoff, carries the hopes of Canada's air industry for major U.S. production order. When Canada placed order for 125 Northrop F-5 Freedom Fighters last year, agreement called for the U.S. to buy comparable amount of materiel from Canada. Buffalo, whose development was financed in part by U.S., is now being tested in Vietnam by U.S. Army, which would like to get a substantial number to replace earlier CV-2A Caribou light transports. But Secretary of Defense McNamara, noting it would overlap USAF transport capability, isn't sure Army needs it.



Northrop CF-5A Freedom Fighters in RCAF markings. Canada is spending \$215,000,000 for 125 fighters to be built over a 4-year period by Canadair and powered by Orenda-built General Electric J85-15 engines. About 1 in 10 will be 2-place fighter trainers. With top speed of 1,000 mph (1,610 km/hr), the CF-5 will perform both as an interceptor and close-support fighter with ground forces.

helped growth of their export business.

Like other Canadian companies that have diversified and are carrying out their own research, CDC has benefited from the "spinoff" from space work.

One company with an interesting diversification program is Rolls-Royce of Canada Ltd. Mainly involved in engine overhauls at its Montreal plant, the scion of the British firm has formed a subsidiary to build a tracked truck that shows promise in trials of becoming the badly needed muskeg vehicle for military and commercial operators in Canada's north. Go-Tract Ltd. has established a new plant near Montreal to produce the Demon-100. This 7-ton-capacity (6.4 mt) vehicle has proven its ability to operate in 4 feet (1.2 m) of wet snow and to wade through 30 inches (76 cm) of water as well as over tree stumps.

Rolls-Royce Canada's principal installation caters to the servicing of all engine units working in North America. This includes a variety of industrial gas turbines and diesels as well as aviation engines. Forty percent of all civil airline engine time flown in North America is by Rolls-Royce units. The company operates a mechanics' school for North American users in conjunction with their Dart and Tyne overhaul facility.

The aerospace industry has often been accused of existing like a "kept woman" in Canadian economics. This accusation grew from the undulating aerospace economy that has lived from one defense requirement to another. There have been cases of heavy pressure to buy a product for the military, just to keep the industry alive. This day has nearly passed, and the 5-year equipment plan is helping to write the end of it.

There are several interesting proj-

ects on the boards in Canada, but their authors, with a better knowledge now of what chances they have of selling to the government, are updating present products to a broad range of uses before spending too much money on new ones.

Canadair Ltd. has a tilting wing machine, called the Dynavert, which is aimed at the military market for a small, fast V/STOL aircraft. The company has furnished over \$4,000,000 of the \$15,000,000 invested to date. The Government provided the rest.

Another item that has moved closer to success is the CL-89 reconnaissance drone that was begun in Canada and is now a joint project with Britain and Germany. The recoverable drone photographs enemy positions and returns, printing pictures on the way.

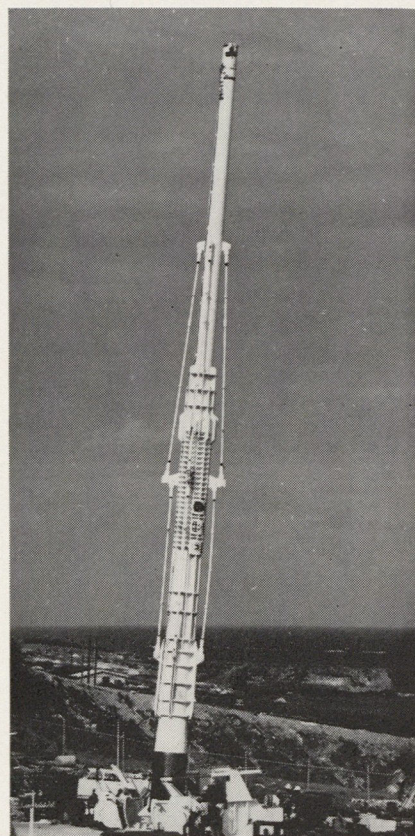
Avian Aircraft has developed an autogyro. Development took a few years, but certification is imminent, and the company has 104 firm orders for the 2-seat machines. It looks forward to 250 sales at \$17,500 per copy.

Douglas Aircraft of Canada recently switched from a monitoring role to active production of DC-9 wings and tails in Toronto, swelling the air-industry work force. De Havilland of Canada has built all wings and tails for the new jet but transferred their production to the expanded Douglas Company when faced with doubled orders. It has been called the first aircraft plant in Canada to be overcome by prosperity, but the transfer was made on a happy note.

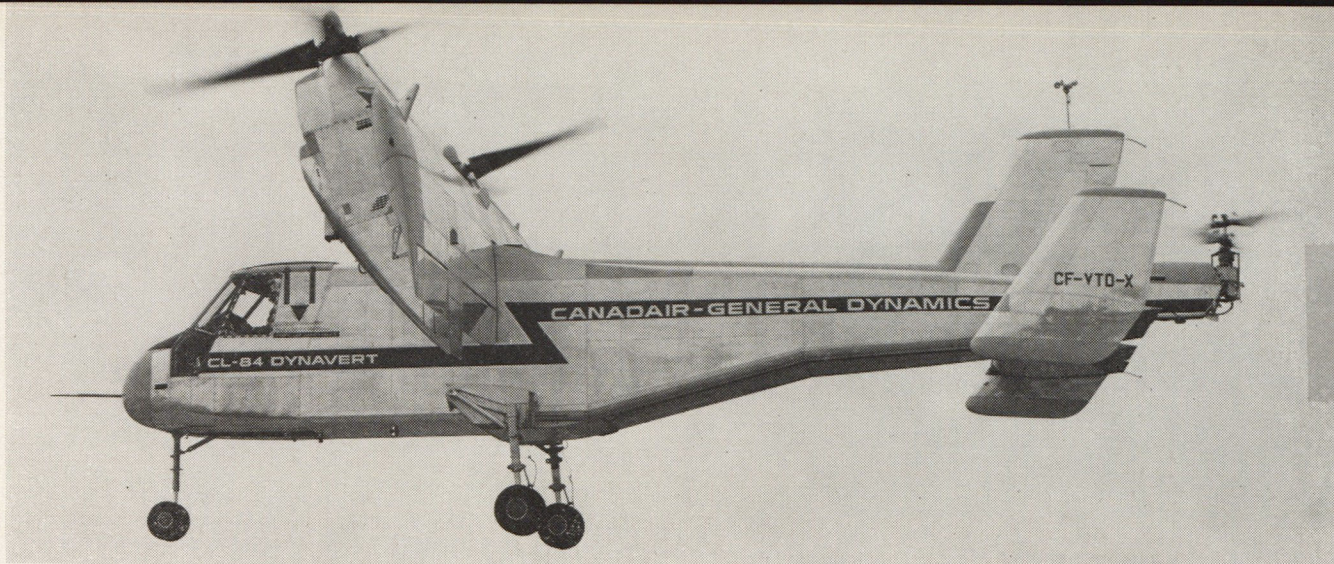
If the manufacturing side of Canada's aerospace industry is humming with activity, it can be matched on the transport side. Both of Canada's major airlines (Air Canada and Canadian Pacific Airlines) are showing marked increases in business and have heeded Government orders to bury the hatchet

and cooperate on international services.

Both were reporting passenger revenue increases in the area of 20 percent and both have announced plans (Continued on following page)



In Project HARP, a team made up of Montreal's McGill University Space Research Institute, Computing Devices of Canada, and U.S. Army Ballistics Research Laboratory, has fired missiles to 100-mile (161 km) height with this gun.



This tilt-wing, small, fast V/STOL aircraft, the CL-84 Dynavert, has been developed by Canadair with governmental financial support. The experimental Dynavert is capable of performing such roles as ground attack, assault transport, helicopter escort or destroyer, casualty evacuation, reconnaissance, and aerial command post. The V/STOL plane has a forward speed of 350 mph (565 km/hr).

to increase their fleets. Air Canada, a Government airline, will add the Douglas DC-9 to its fleet this year, 2 more DC-8s, and 4 of the enlarged 61-series DC-8s.

Canadian Pacific, whose routes reach through South America, the Orient, and Europe, takes delivery in May on its seventh DC-8, and a new 5-year procurement plan is in the works. The stretched DC-8 is a strong likelihood, and there are plans for 3 of the American supersonic transports.

The 2 airlines have often been at odds over competition, and CPA is restricted to a single transcanadian flight daily. The Government has ruled that Air Canada must not be forced into a deficit position by competition from CPA. But a long-awaited aviation policy for Canada should finally sort out the differences of the 2 lines.

The Government has ordered a study of over-all airline service and will deal in 3 phases with international, domestic, and regional services. A nagging problem in Canada is the need for short-haul lines as feeders to the main east-west trunk along which most of the vast country's 20,000,000 people live.

Such operations, however, are not profitable and require carriers who are ideally equipped and franchise-protected for the job. The current study is expected to blend the 3 areas of operation to produce a long-range policy upon which planning can be based.

Canadian carriers take in operating revenue in the vicinity of \$350,000,000 annually, and the profit margin has been increasing each year. It is now about \$20,000,000. This health is reflected through aviation, with flying clubs graduating more pilots and the

commercial graduates finding no difficulty getting jobs.

More aircraft are being purchased for both private and corporate flying, and some 20 business jets have joined or will join the Canadian scene. It is estimated there are 600 aircraft used for private business in the country.

While most of the small aircraft originate in the U.S., a Canadian manufacturer of light aircraft is making headway in a difficult market. Found Brothers Aviation has a bush plane, the FBA-2C, rolling off the line at 2½ per month. The aircraft is not handsome by pleasure-plane standards, but its spacious cabin will admit the odd-shaped cargo carried into bush camps and mining sites. Disposable load is 1,300 pounds (590 kg), and there are no wing struts to hinder loading.

Canada is heavily engaged in avionics and aircraft-simulator building. Canadian Aviation Electronics has

made a sound reputation building simulators.

With a variety of complex simulators operating in several countries, CAE has already sold DC-9 simulators to KLM and Swissair. Export sales over the past 3 years have totaled \$30,000,000.

The 93-company Air Industries Association met last November with collective red faces. A year earlier they had forecast extinction for many of their members' operations if Government orders were not placed immediately for defense equipment. The orders did not come and the industry did not die.

The companies' exports lifted sales and kept the plants humming. Now, with a long-range defense plan, they should emerge from 1966 with whopping profits, and the Defence Department should be helping by spending the fat trimmed from its structure.

☆☆☆



Canadair will deliver 2 of its new "400" transports to Loftleidir/Icelandic Airlines in March. The 400, or CL-44J, a stretched version of the CL-44D4 passenger/cargo aircraft, is 182 inches (462 cm) longer than the 44D and carries 189 passengers, an increase of 29 over the CL-44D. Here it departs from Cartierville Airport on an early test flight.



Surprise, neutralize, destroy

Guerilla warfare. Shifting, difficult, bitter—full of traps. How do you cope with it? Against the surprise of guerilla tactics, the U.S. Army can deliver its own brand of surprise—right out of its CH-47A Chinook transport helicopters.

To pin down the enemy, the Chinook can carry—into areas inaccessible to surface transport—a complete artillery section, including two howitzers, ammunition and gun crews. All in one load.

Hitting the enemy with troops where he least expects it, the Chinook can debark a fully-equipped combat platoon. And then lift away in seconds as the last man comes charging off the rear loading ramp.

Over 30 feet long and 7½ feet wide, the Chinook's cargo compartment can be loaded with Pershing Missile system components, or with infantry support weapons or the latest combat vehicles. Because of its large capacity, the Chinook reduces the number of helicopters needed for an air mobile mission, lessens traffic congestion and permits the use of smaller assault landing sites.

Now operating with the 1st Cavalry Division (Airmobile) in Viet Nam, the CH-47A Chinook has become the U.S. Army's standard medium transport helicopter.

The U.S. Army's foresight, guidance, and support, joined with the resources, man-

agement, and technical capabilities of the Boeing Company, have made the Chinook a performance-tested tactical transport.



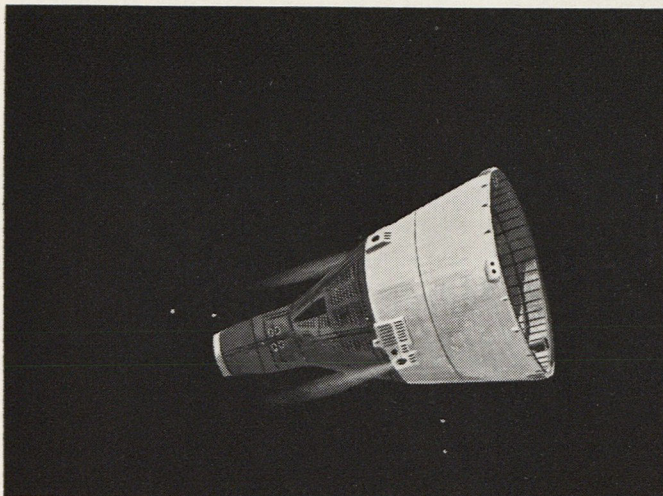
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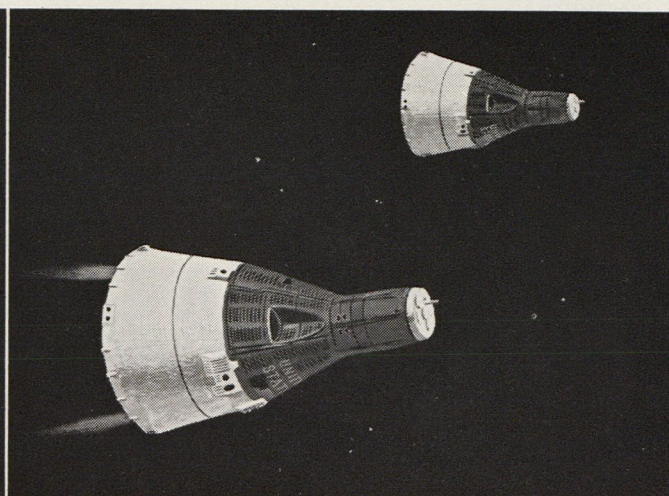
MORTON, PENNSYLVANIA

GEMINI RENDEZVOUS

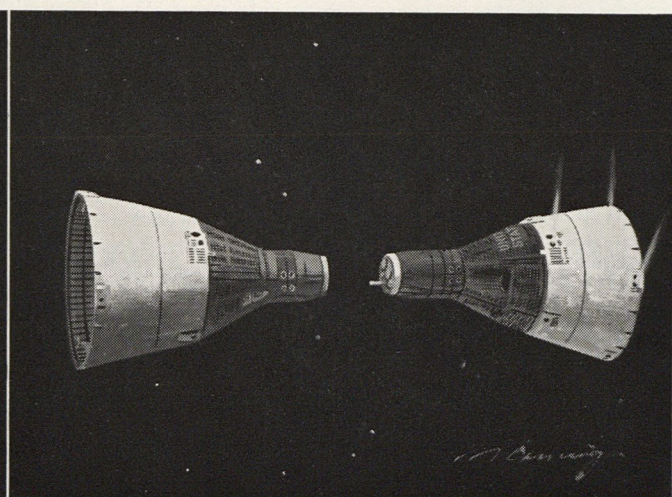
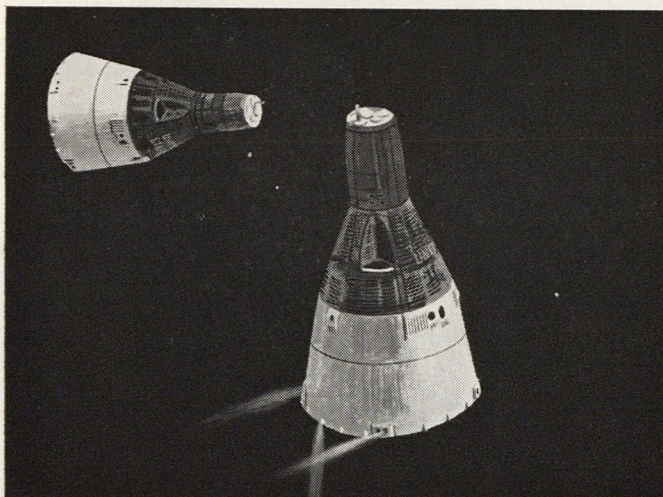
How North American Aviation rocket engines helped astronauts maneuver in space



- 1 Initial height adjustment was made with spacecraft traveling large end first with a boost from two 85-pound-thrust engines. This maneuver placed Gemini 6 in a higher orbit.
- 3 During the final stages of the rendezvous, eight 25-pound-thrust engines were used to turn Gemini 6 so both teams of astronauts were facing one another.



- 2 Forward boost from two 100-pound engines placed Gemini 6 at its final intersecting orbit with #7. This was after a series of maneuvers that took place during approximately $3\frac{1}{2}$ orbits.
- 4 The historic fly-around maneuver was made possible by 16 individual space engines in each craft, providing the control flexibility required in space flight.



The systems of small rocket engines that maneuvered the NASA Gemini spacecraft were built by North American Aviation/Rocketdyne Division. This division is also the Free World's leading builder of giant liquid rocket engines, and an important producer of solid-fueled rocket engines.

North American engines powered all the Mercury flights and will power Saturn and Apollo space flights. Pioneering new technologies such as space engines is but one way North American Aviation contributes to the Free World's growth and security.

North American Aviation 

European Headquarters: North American Aviation S.A., 29 Rue de la Coulouvrenière, Geneva, Switzerland

The National Aeronautics and Space Administration has suffered badly in fiscal planning for the coming year. The reason is the Vietnamese War. The Apollo program stays on schedule, the Gemini program is proceeding toward completion, but new starts on major space programs are being deferred. Slowed down is the schedule of the recently approved USAF Manned Orbiting Laboratory . . .

Wounded in the Vietnam War: The NASA Fiscal 1967 Budget

BY WILLIAM LEAVITT, Associate Editor

War's casualties are not only on the battlefield. The financial pressures of the Vietnamese conflict have taken their toll of future plans of the National Aeronautics and Space Administration, which spends most of America's space money and does most of the country's space project planning.

The Johnson Administration is asking Congress for a Fiscal Year 1967 budget authorization of just over \$5,000,000,000 for NASA. This sum is even less than what was actually appropriated by Congress for the previous Fiscal Year of 1966. In the U.S. Government fiscal planning system, the spending year begins July 1, 1966. Thus the \$5,000,000,000 Fiscal 1967 figure represents the amount of new money the Administration would like Congress to allow NASA to commit from July 1966 through June 30, 1967.

NASA's Deputy Administrator and General Manager, Dr. Robert S. Seamans, Jr., is candid in his explanation of the constraints under which the U.S. space agency is now operating. He describes his agency's new funding request as "extremely stringent," but still designed to achieve the Apollo moon-landing target date of 1969. But he warns that the NASA budget now provides "no funding to take care of major difficulties that might be incurred" in the moon program.

This remark may be interpreted as acknowledgment that NASA will probably have to play a perfect technical game in the achievement of its Apollo lunar-landing effort. This may be too much to ask of any research-and-development team. Therefore, it is quite possible now that the 1969 landing

may not be attainable and that Apollo will run over into the 1970s. No official in Washington, in or out of the space agency, will admit it publicly, but the fact is that if the Vietnamese War gets hotter and costlier, the priority of the moon-landing program, once inviolate, will be lowered. It is significant that President Johnson made no mention whatsoever of space in his State of the Union address to Congress and the nation.

This is not to say that he has lost interest in space. Rather it means that when he tells the nation that America can afford both wars in which it is engaged—the shooting war in Vietnam and his assault on poverty within the United States—he does not grant the U.S. space effort the same high priority. The NASA budget request reflects this view. There was consequent gloom at NASA's headquarters on the snowy Saturday afternoon on which correspondents were briefed on NASA's financial position for the coming Fiscal Year.

The sum of \$5,000,000,000 is still a lot of money, of course. But it does represent the lower end of the funding scale considered by the Administration in the hectic budget-planning effort that culminated with final appeals by Government agency heads at the LBJ Ranch in Texas, where the President held court during the Christmas holidays.

Dr. Seamans said that NASA proposed budget alternatives ranging from \$4,800,000,000 to \$5,800,000,000 for Fiscal Year 1967. The allotment they got from the President was nearly rock-bottom. And it is still possible

that the \$5,000,000,000 authorization request will be cut even further by Congress. That happened last year on Capitol Hill.

It all comes down to the fact that NASA is by no means out of business, but is essentially restricted in the manned spaceflight area to the liquidation of the Gemini program and the execution of the Apollo moon landing. The agency's proposed Apollo Applications program, which has been described in detail in earlier issues of *AF/SD INTERNATIONAL*, is budgeted for some \$100,000,000 in Fiscal 1967. But it continues to live in the limbo it has inhabited for more than a year.

This NASA proposal to use Saturn boosters and Apollo modules for a wide-ranging program of manned earth-orbital scientific studies as well as lunar-orbit and lunar-surface post-Apollo-landing missions has been the space agency's prime candidate for successor to the current Apollo program. NASA had asked for at least twice as much as it got for Apollo Applications. It received only enough to retain the program's study status.

To trim NASA spending plans, the unmanned space science side of NASA took rather a drubbing in the agency's new budget plan. Its Advanced Orbiting Solar Observatory project was canceled outright, and its planetary probe program slowed down.

In the latter case, financial restrictions combined with the discouraging report from Mars on the possibility of life on the red planet and indications of an extremely thin atmosphere to delay any Voyager orbiter or
(Continued on following page)

soft-landing probe on Mars until at least 1973. Voyager had been described by NASA as a \$1,000,000,000-plus program. The agency does plan to send a 1967 Mariner-type probe to Venus and 2 Mariner missions to Mars in 1969.

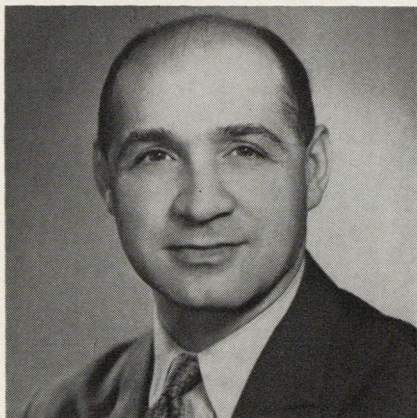
In addition, the nuclear space propulsion developmental effort in NASA was barely kept alive and the M-1 chemical rocket-engine project, designed for the 1970s, died.

In short, the civil space agency has been given the money to stay on the track to the moon, to keep advanced manned spaceflight programs alive enough to be dusted off and heavily funded, if the pressures of the Vietnamese War should abate, and to continue a modest but useful unmanned scientific space-exploration effort. At the same time, NASA will continue its efforts in communications, meteorological, navigation, and other "working" satellites. This is because such programs are paying off economically.

Military Space

On the military space side, the recently announced Air Force Manned Orbiting Laboratory (MOL) survived the budget ordeal and will get \$150,000,000 worth of Fiscal 1967 funding in the Department of Defense budget.

This is the same figure allotted to MOL in the last budget, although all the money authorized last year was not spent. Air Force MOL planners had hoped for a much larger authorization for Fiscal 1967 to get the long-delayed MOL project started. The Defense Department had previously indicated its intention to deploy manned MOLs starting in late 1968. Most observers, and some Administration officials, say that the new, low funding of MOL will cause at least a year's delay in the project. The Defense Department has not officially acknowledged this yet.



Congressman Emilio Q. Daddario of Connecticut directs Congressional hearings on science, research, and development.

Policy, Population, and Polymers

There was a time, not very long ago, when American Congressmen, except for a small band of specialists, took little if any interest in the relationship of science and technology to public policy-making. This has changed radically in recent years. In the face of the vast expenditures and sweeping decisions of the post-war atomic/space age, Congress is carefully examining the impact of science and technology on America and the world.

A number of Congressional committees have begun to analyze this impact from various points of view. Among the most highly respected by the scientific community is the Subcommittee on Science, Research, and Development of the House of Representatives' Space Committee. The subcommittee is headed by Congressman Emilio Q. Daddario of Connecticut, a Democrat first elected to Congress in 1958.

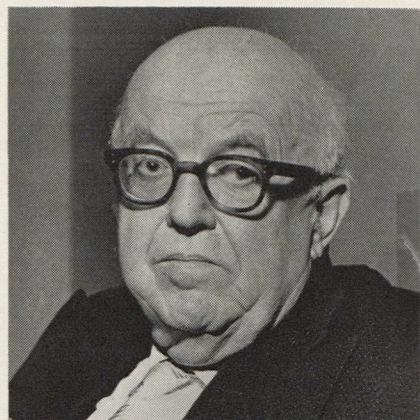
Mr. Daddario's committee has taken what political observers here call the "high road" in its continuing analysis of scientific and technological policy-making problems. There are no dramatic hearings, no recriminatory inquisitions of scientists and technologists. Rather, the technique is to have eminent scientists, technologists, and other specialists publicly present papers on science and public policy, after which a large panel of noted specialists in the various physical and social sciences discuss the various theses presented and question the speakers.

For the past couple of years the Daddario hearings, which should be more properly called seminars, have had an international flavor. Last year, for example, when the subject was the status of aeronautical research, Professor Luigi Broglio, Chairman of the Italian Space Commission and a distinguished aerodynamicist, was a guest speaker.

This year's international guest was the famous Lord Snow, British scientist-novelist and now Joint Parliamentary Secretary of the new British Ministry of Technology.

In his urbane style, he presented a provocative paper in which he described frankly not only the problems of scientific policy-making but also the problems and prospects of Britain in the international technological competition. While he was about it, he also predicted the emergence of mainland China as a major technological power by the end of the century.

"By and large," Lord Snow told the Congressional seminar, "[The British] technological position is uncomfortable, and we have got to change it before we get our economy sturdy



Lord Snow of Britain, noted scientist-novelist, now a major official in the Labor Government, addressed Daddario hearing.

again. That was why in October 1964, immediately the [Labor] Government came to power, we set up a separate Ministry of Technology. I know this step has puzzled well-wishers here and elsewhere; it has been criticized in England: It has seemed artificial and wrong to separate science and technology. The choice, however, was quite deliberate. It had been deeply considered for months before the election. In the British situation . . . it seemed necessary to give technology a special significance of its own. A Department of Science, Technology [and] Education would see technology, as usual, by the principle of maximum purity, emerging as very much the junior and unfavorite partner. So a Ministry of Technology was established, with a minister of cabinet rank, which . . . [in Britain] carries its own weight of meaning. . . . It will take 10 years to do all that has to be done. But it will be done. By the end of this decade our economic and democratic health will be a surprise to our enemies—and perhaps to some of our friends. . . .

"It is obvious," Lord Snow said, "that, in the fields of advanced technology, a country of limited resources cannot do everything. . . . Only [the U.S.] and the Soviet Union can do that; and I suspect, in the long term, China. We just can't. It is not pleasant to face, and act upon, that fact. But we have to. We have to make some hard choices, deciding where to invest and where not to."

In those areas where Britain's resources are too limited, Lord Snow said, the choice will be to make international arrangements for research and development.

"[Britain] can't do everything," Lord Snow declared, "but that doesn't mean that we can do nothing. Anyone who expects [Britain] to abdicate from all the fields of advanced technology is

making a mild misjudgment. . . . There is a feeling [in some quarters] that . . . research and development will become polarized, and that in the Western World, it will all flow to the United States. . . . [This] would not be acceptable to us. . . ."

Lord Snow said that in our time, "one thing stands out, as a warning and as a hope." The influence of computer technology "is going to be the biggest technological revolution men have ever known, far more intimate in the tone of our daily lives, and of course far quicker, either than the agricultural transformation to neolithic times or the early industrial revolution which made the present shape of the United States. . . ."

"We shall need," he said, "many people of different abilities who are at every step of the way studying, controlling, and humanizing [the computer revolution's] effects. . . ." He called this "mixed-uppedness" of personnel.

"I don't believe that anything can stop . . . the scientific and technical advance and material progress of all advanced societies—that is North America, nearly all of Europe, the Soviet Union, and a few more. . . . In short, the rich countries will get richer. Here my anxiety comes in. I wish I could believe that the poor countries—containing more than half our fellowmen—would not get relatively poorer. The more we look at our own scientific and technological problems, the more, perhaps, we comprehend the enormous effort that is required by societies which have not had our history and our luck. . . ."

"The world cannot survive in peace, half rich and half poor. It remains to be proved whether it can for long survive at all."

Lord Snow's concern was echoed in a paper by Dr. Roger Revelle of the Harvard University Center for Population Studies. He said that the technological revolution under way has in several ways dramatized for the underdeveloped areas of the world their status as poverty-stricken "fellow passengers on the spaceship" that is the world. He called for a massive U.S. Government-sponsored effort in political and social studies to search for policy answers to meet this problem.

To help meet the burgeoning problems of the "third world," he said, it is vital that population-control policies be adopted, matched with increased production of food, food aid by countries with surplus capacity, and production of dietary supplements containing high-quality protein and other food elements now lacking in the diets of many people in underdeveloped countries.

The Daddario hearings also fea-

tured presentations by such leading American technologists as Dr. Lee DuBridge, President of the California Institute of Technology; Dr. Charles Price of the Department of Chemistry of the University of Pennsylvania; and Dr. Guy Suits, former Vice President for Research of the General Electric Company.

Dr. Suits predicted that polymers, which not long ago—when they were called plastic—were barely strong enough to be used as toothbrush handles, are well on their way to becoming "the basic structural materials of our civilization.

"The polymer chemist has had a long uphill fight to bring order out of . . . atomic chaos, but he has succeeded in achieving a high degree of orientation and crystallinity in polymer structures with the result that these substances are becoming bona fide structural materials of real consequence. They are already replacing many metals in consumer products, to such a degree that in American industry as a whole, the volume of polymers used in manufacturing products already exceeds the volume of steel. This statement takes advantage of the fact that there is a density difference averaging about 7 times in favor of polymers. But relative growth rate of usage is such that polymers will soon overtake steel—even on a weight basis—and they may have already done so."

Dr. Thomas F. Malone, a meteorologist and Vice President of the Travelers (Insurance) Corporation in Hartford, Connecticut, another of the scientific panelists, told the legislators that the "most important problem of this century . . . is . . . applying science and technology to economic development."

He said the question of whether the developed world can transfer its skills to the emerging countries is "the crucible within which will be tested the superiority of [Western] cherished social, economic, and political institutions over those of competing ideologies during an era of rapidly accelerating change."

He called for establishment of regional facilities to stimulate innovation and creative technological solutions to the vexing problems of the underdeveloped countries. And he suggests that they might be complemented by an international institute patterned after the International Institute for Educational Planning. Such an institute would provide advanced training for professional staffs at regional institutions and research "leading to a better understanding of the process of applying science and technology" to problems of national growth.

One of the most provocative papers

presented at the Daddario hearings was given by Dr. Charles C. Price of the Department of Chemistry at the University of Pennsylvania, Philadelphia. He foresaw a scientific revolution based on the approaching ability of biochemical science to synthesize living systems.

It may even be possible, he said, to create living systems based on "entirely new and different kinds of chemical structures.

"In the same way that the chemist views nylon, orlon, and dacron as synthetic silk and neoprene, thiokol, and silicone rubber as synthetic rubber, it is fascinating to speculate that we may be able to devise living systems based on an entirely different set of chemical components. . . . Certainly one could envisage many useful returns to society from success in such a venture. We are today dependent on the remarkable 'chemical factories' in living systems for many of our essential needs—food, fibers, chemicals, antibiotics, to mention a few. We may exhaust our fossil liquid fuel, and it may be possible to develop microorganisms which could efficiently synthesize more for our needs," he declared.

Dr. Price urged more U.S. Government financial support for biochemical research to explore these and other potentials.

The proceedings of the Daddario hearings will be published. Inquiries as to their availability should be directed to the Honorable Emilio Q. Daddario, Chairman, Subcommittee on Science, Research, and Development, Committee on Science and Astronautics, House Office Building, Washington, D.C., U.S.A.

Erratum

In our report, "Spaceborne Video and the Revolution of Rising Expectations," which appeared in the February 1966 issue of *AF/SD INTERNATIONAL*, we erroneously attributed to Hughes Aircraft Company certain estimates on cost advantages of satellite television over other systems. Those figures listed in the article referring to "desired area of coverage between 300,000 and 500,000 square miles" (780,000 and 1,300,000 km²) should have been attributed to Lawrence C. Rosenberg of the George Washington University Program of Policy Studies in Science and Technology, Washington, D.C. Associated figures on costs of receivers for India are also those of Mr. Rosenberg. Mr. Rosenberg acknowledged with thanks the assistance of Hughes and others in his comprehensive study of the potential of direct broadcast television satellites. ☆☆☆

The F-111 is an advanced design that promises excellent performance in a variety of missions. It is already being built or is planned in fighter and reconnaissance versions, for both the U.S. Air Force and Navy, as well as other Free World forces. But some of the claims released by the U.S. Department of Defense for the new strategic bomber version seem confusing and, perhaps, promise more than any aircraft can possibly live up to . . .

FB-111—A Technical Discussion of the

BY J. S. BUTZ, JR., Technical Editor

In the view of Secretary of Defense Robert S. McNamara, it is now possible for a single basic airplane to serve as a strategic bomber, as an air-superiority fighter, and as a vehicle for interdiction attack, close support of troops on the battlefield, and long-range reconnaissance. In the judgment of the U.S. Defense Department the versatility of this single design is so great that it will meet the Navy's carrier requirements in these areas as well as those of the USAF and Free World air forces in Europe and Asia.

This airplane, of course, is the F-111, which, more than any other aeronautical enterprise, has become identified with the civilian hierarchy in the Department of Defense, rather than with the military services. The first 2 major versions—the General Dynamics F-111A for the Air Force and the Grumman F-111B for the Navy—have now been joined by a third configuration, the FB-111, which will be supplied to the USAF Strategic Air Command to replace aging B-52 strategic bombers.

There are only minor differences among these 3 aircraft. According to DoD there is an 85 percent commonality of parts between the Air Force and Navy fighter versions.

The Air Force's F-111A has a longer fuselage, 73 feet (22.2 m) as compared to 66 feet 9 inches (20.3 m) for the F-111B. The longer, slimmer fuselage has significantly lower drag during high-speed flight at sea level, and the Air Force needed this to attack well-defended ground targets. The Navy, which does not foresee heavy use of the F-111B as an attack aircraft, was willing to accept the higher drag penalty to gain the carrier-deck handling advantage which comes with the shorter fuselage.

The other major difference is that the Navy's F-111B has a slightly longer

wingspan—70 feet (21.3 m) with the wings extended and 33 feet 11 inches (10.3 m) with the wings pulled all the way back to a sweep angle of 72 degrees 30 minutes, as compared to 63 feet (19.2 m) and 31 feet 11 inches (9.7 m) for the F-111A. The Navy wanted the increased span and larger wing area to raise wing efficiency at high altitude and during loiter, to improve the aircraft's performance in the carrier air defense mission.

The FB-111 bomber version is widely assumed to consist basically of the Navy wing married to the Air Force fuselage. Consequently, the bomber should have slightly longer range at high altitude and slightly shorter range at low altitude than the F-111A. Apparently, there will not be a significant stretchout of the fuselage to increase the fuel capacity of the FB-111.

A high degree of commonality will be maintained among all 3 aircraft. All will use the same main structural parts, the same Pratt & Whitney TF30 turbofan engines, the same auxiliary power systems, and so on. A number of differences in electronic systems will be necessary. A strategic bomber, for example, normally carries more elaborate communications, navigation, and electronic-countermeasures equipment than do air-superiority fighters or tactical fighter-bombers. Packaging this strategic bomber equipment so it will fit into the obviously limited internal volume of the FB-111 and rigging it so that it can be operated effectively by a 2-man crew, while they are also flying the aircraft, will be one of the major development tasks with the FB-111.

Considerable public discussion can be expected in the U.S. during the next several months about the suitability of the basic F-111 design for

such a broad range of military missions. The military and appropriations committee of both Houses of Congress are keenly interested. A number of Congressional leaders believe Mr. McNamara has gone too far. Most Congressmen appear to support the views of top USAF officers who believe that a completely new long-range bomber of the AMSA (Advanced Manned Strategic Aircraft) type is needed to replace the B-52. The Air Force accepts the FB-111 as an interim strategic aircraft. But the need to go into the program-definition phase on AMSA no later than July of this year has been emphasized by General John P. McConnell, USAF Chief of Staff, and by Lieutenant General James P. Ferguson, USAF Deputy Chief for Research and Development.

Currently, the situation is a confusion of history, mystery, and uninformed reports. Very few people, if any at all, have a clear idea of what the total cost of the development and production program for the several versions of the F-111 will be. It has been reported that some Senate critics are prepared to charge that the cost may ultimately be more than double the original estimates.

Very few people have enough information to judge what the aircraft's performance finally will be. It is known that there have been development troubles with the engine and with the engine air-inlet system, which must be unusually sophisticated because the aircraft must operate in an unusually wide range of speed and altitude conditions. Weight and drag problems likewise have been reported. These are common in the development of new aircraft, and particularly when a truly advanced design is being undertaken, as is the case with the F-111.

USAF will get 210 of these General Dynamics FB-111s to offset in part the loss of 345 B-52 and 80 B-58 bombers from the inventory by 1970. Deliveries are scheduled to begin in 1968. Pylons under variable-sweep wings carry conventional or nuclear weapons, auxiliary fuel tanks to boost range, or both. Pylons swivel to point externally carried stores in directions of flight regardless of wing angle.



Third Version

Few answers to these questions have been made available. On the subject of costs, a defense official reported last fall to a meeting of U.S. and British aeronautical specialists that "projected costs [for the F-111 program] have increased about 15 percent beyond those initially anticipated. Newspaper reports of excessive costs have been allowed to stand largely unrefuted, both because this is a highly classified program and because the Department of Defense cannot release daily reports to the press on cost analysis."

On the subject of performance, it was said that the F-111 has flown successfully at Mach 2.18, and that "the expectation of current configuration performance is just short of the Mach 2.5 requirement and the improvement programs, normal to military aircraft development, will bring the speed unquestionably up to Mach 2.5." The over-all development progress with the F-111 was described with great confidence, as follows: "We have in the F-111 program unquestionably the most flexible, the most capable, and the most versatile multi-purpose aircraft in military history—one designed to satisfy not only the [USAF] Tactical Air Command and the U.S. Navy requirements initially envisioned, but of the Royal Air Force and the Royal Australian Air Force."

The program was characterized in the following terms: "The F-111 must expect to live in 2 worlds; namely, the world of fact, much of it classified and unreportable to the press, and the world of rumor, in which all kinds of allegations will be voiced, many of them unknowledgeable and bordering on the irresponsible."

Of course, the Defense Department is the agency with the facts and the authority to explain them, so that the

avoidance of further controversy would seem to lie in its hands. Congress will be pressing for a more thorough explanation. The pressure for more information will be strong for it will come from men in Congress who have been severely critical of Secretary McNamara's overruling of military wishes in the writing of the F-111 specifications and the selection of a contractor. Senator John L. McClellan, from the state of Arkansas, Chairman of the Senate Investigations Committee, who has been highly critical, will reopen hearings this spring.

It will take a great deal of explanation to clear the air. For example, the material released on the expected performance of the FB-111 can charitably be characterized as confusing. Secretary McNamara has said that "the FB-111 . . . will replace the B-52, series C through F. It will have twice the speed of those aircraft, approximately, with approximately the same range. It will be faster, both at low altitude and high altitude, and it will have capabilities for penetrating enemy defenses far greater than the plane it replaces. . . . The FB-111 will carry both nuclear and conventional bombs. It will carry 50 750-pound [340 kg] high-explosive bombs."

Obviously, in this recitation, the aircraft's capabilities as a fighter are being mixed with its capabilities as a bomber, without explaining which is which.

The FB-111, with 50 750-pound (340 kg) bombs loaded under its wings, is not going to have fighter performance anymore, and it is not going to be twice as fast as the B-52. It will have about the same high subsonic speed. As for range, the F-111A, under the best circumstances—that is, with nothing but 2 large fuel tanks slung under its wings and cruising at sub-

sonic speeds—can be ferried 4,100 miles (6,600 km).

With 50 750-pound (340 kg) bombs under its wings and carrying only internal fuel, the aircraft couldn't exceed 2,500 miles (4,025 km). In the nuclear delivery role, with 3 small SRAM-type (Short-Range Attack Missile) low-yield nuclear missiles carried internally in the fuselage bomb bay, the range is going to drop well below 4,000 miles (6,440 km) if the aircraft's high speed is used in the target area, since fuel consumption climbs rapidly at supersonic speeds.

In short, it is difficult to understand the statement that the FB-111 has "approximately the same range" as the B-52. Even the early B-52s of the C through F variety will fly more than 6,000 miles (9,660 km), fully loaded with more than 10 tons (9 mt) of bombs. So the range of the bomber version of the F-111, with any useful sort of load, will have "approximately" 50 to 60 percent of the range of the aircraft it replaces.

The F-111 design is an advanced one. Its basic concepts, such as the variable-sweep wing and turbofan engine, combine to give it excellent performance over an unusually wide range of flight conditions. Theoretically, its performance and versatility should be superior to any existing operational fighter.

If General Dynamics completes the second half of the development program with as much success as in the first half, when the company met all major deadlines and most performance guarantees, then the F-111 undoubtedly will become a widely admired aircraft. However, even the soundest engineering and development program could be spoiled if too many claims are made which the aircraft cannot possibly fulfill. ☆☆☆

The giant Lockheed C-5A transport has military and commercial potential that goes far beyond current predictions. The airplane's main features are well within the state of the art. The C-5A will not only revolutionize troop and equipment transport, but may also serve important command-and-control functions, in aerial refueling, and even naval assignments, among many others. When commercial aviation firms see its weight-lifting capability and recognize how the C-5A could meet increased freight and passenger needs just around the corner, they also will clamor for the huge transport . . .

C-5A—Even More Than Meets the Eye

BY J. S. BUTZ, JR., Technical Editor

The announcement that the C-5A transport would be produced for the U.S. Air Force by the Lockheed-Georgia Company, Marietta, Georgia, stimulated an unusual flood of optimistic predictions about the aircraft's importance and the revolutionary effects it will have on U.S. military effectiveness and on commercial aviation.

Few airplanes have received such praise and so many votes of confidence from so many sources—before they even reached the drawing boards. U.S. Secretary of Defense Robert S. McNamara, high civil officials in the Air Force, USAF general officers, newspapers, national magazines, television, radio, and the trade press all have given the C-5A a much bigger buildup than they normally afford a new aircraft.

Wide recognition has been given to the C-5A's unprecedented cargo-carrying capacity—100,000 pounds (45,360 kg) of payload for 6,300 miles or 10,140 km (San Francisco-Tokyo or Honolulu-Saigon) or 250,000 pounds (113,400 kg) of cargo for 3,700 miles or 5,955 km (New York-Paris). This is about 3 times the work capacity of the Lockheed C-141, the smaller brother of the C-5A, which is now entering service.

The C-141 itself is a prodigious worker. One C-141 StarLifter is the equivalent of 7 piston-driven C-124 aircraft over long hauls, such as the transpacific routes. And a fleet of 280 C-141s, which will be available in the next few years, will quadruple the present U.S. military airlift capacity to Southeast Asia.

The C-5A has an important added virtue that no other transport can claim. It can carry virtually any of the Army's heavy equipment, including the 50-ton (45.3 mt) Main Battle Tank. Another key feature is the aircraft's relatively low operating cost. According to DoD estimates, the C-5A will cost about 50 percent more to operate than the C-141. But it will do 3 times the work so that the direct operating costs in cents per ton-mile should be about half of the C-141's. Since the C-141 is expected to carry cargo under optimum conditions at 4 to 5 cents per ton-mile, the C-5A apparently has a real chance of getting this figure down to 2 cents.

The truly revolutionary implications of such economics are obvious, but also difficult to comprehend completely. Essentially, the C-5A will allow the U.S. to place formidable land

forces on any trouble spot in the world within 24 hours. These Army units will not be "token" light-infantry forces of the type that are now rushed in by air in emergencies. The C-5A will move heavy mechanized infantry and armored divisions, complete with tanks, trucks, artillery, and combat supplies.

A force buildup that would take more than a month with current sea- and airlift could be achieved in a week with a fleet of 100 C-5As. A comparative example is provided by Operation Big Lift in 1963, which required 204 transport planes to airlift 15,000 un-equipped troops to Europe in 63 hours. Once at their destination, the men picked up tanks, trucks, ammunition, and other supplies which had been pre-positioned. Fewer than 100 C-5As could move the same number of troops plus their tanks, equipment, and supplies the same distance within 24 hours.

Current plans call for Lockheed to develop the C-5A and deliver 58 aircraft under a contract valued at approximately \$2,000,000,000. This contract is unique in that it covers the engineering design, testing, and development, plus the tooling-up and production of



The Lockheed C-5A, now in production, is designed to supplement the C-141 and other military transports by carrying heavy military equipment over intercontinental ranges.

Because of its range and payload capacity, the C-5A may be suited for other military roles. And the same characteristics make it attractive also as a commercial transport.

the 58 aircraft and their spares. It is expected that contracting for the complete package will save the Government substantial amounts of money.

The Defense Department has an option to buy 57 more aircraft. Many sources are estimating that the military will purchase at least 200 C-5As. This would be enough to completely modernize the U.S. global logistics pipeline during the 1970s. In addition to operations in emergencies, these aircraft would be kept busy, day in and day out, moving men, equipment, and supplies. The relatively low operating cost and the prodigious capacity of the C-5A would mean that many more types of supplies would move by air. The amount of materiel in the logistics pipeline would be reduced substantially, with major savings in dollars and personnel. Some experts foresee the C-5A taking over virtually the whole overseas logistics job with only bulk cargoes moving by sea. If this happens, the trend toward increasing numbers of support personnel per fighting man may turn sharply downward.

Estimates of the C-5A's high productivity and low operating cost have generated many predictions of rapid

success in commercial aviation as well. In passenger service the C-5A is expected to cut operating costs in half and to bring air fares down to about the equivalent of traveling by bus.

Whether or not this is desirable is a matter not entirely agreed upon. Economists disagree about the size of the new market that will be generated by such a fare structure. Also, there is concern about the great size of the C-5A and its 700-passenger capacity which, according to many experts, would make it useful only on current high-density routes such as the North Atlantic and New York-Los Angeles. However, there can be little doubt that some airlines will have the C-5A hauling passengers shortly after it becomes commercially available in the early 1970s. The airline business is too competitive to allow the C-5A's potential to go untested for long after it is certificated and ready for service.

Another certainty is that the C-5A will be used as soon as possible in civil air freight service, which offers unprecedented opportunities for inventory reduction and dollar savings. Air freight business now is growing at a rate of almost 25 percent per year

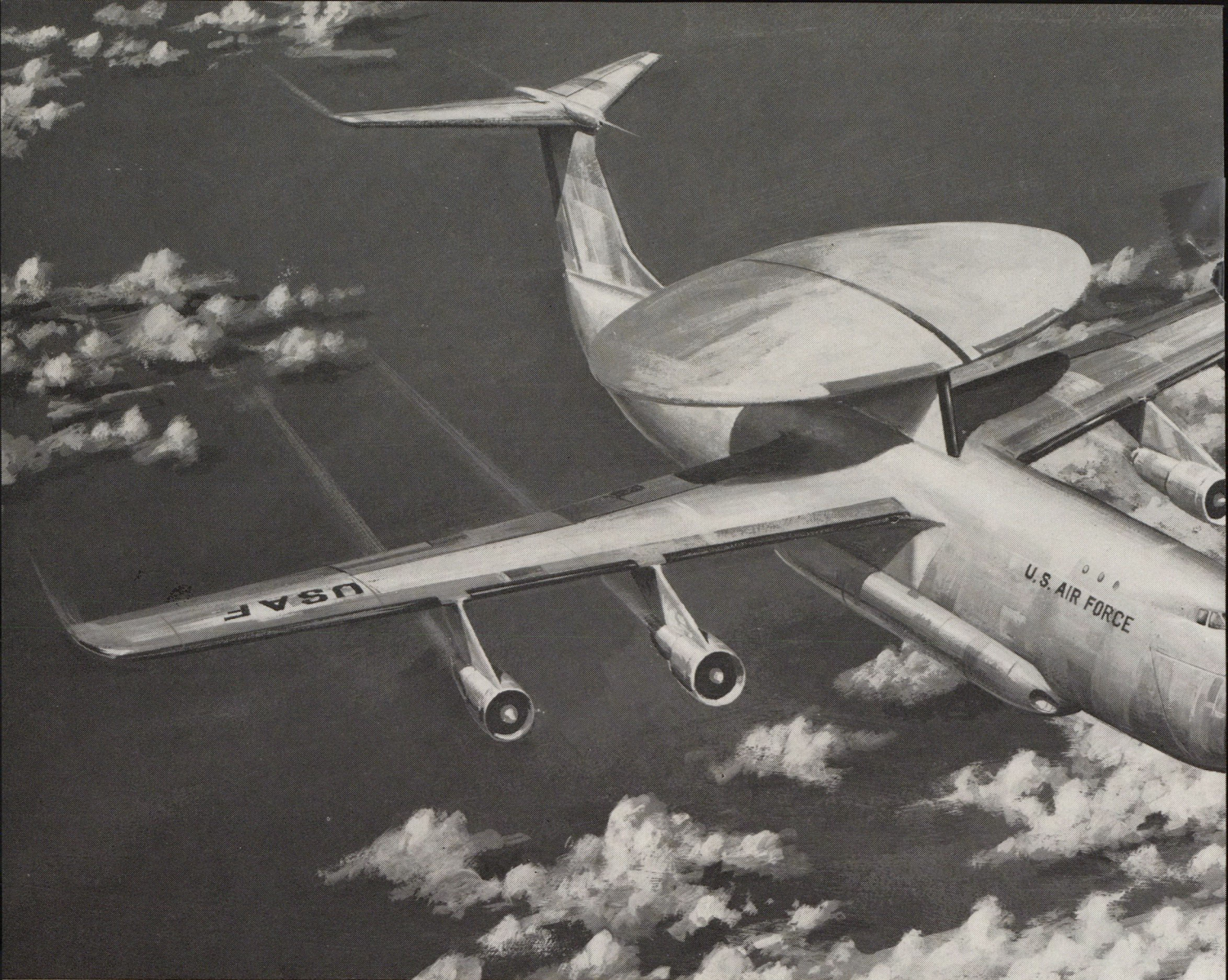
and shows no signs of slowing down. With the impetus of the C-5A's low direct operating costs—about half that of the best transports in civil service today—added to the already strong attractions of air freight service, the industry could reach almost explosive growth conditions.

Currently, Lockheed estimates a market of 100 C-5As among airlines for both passenger and freight service. So, if one accepts the 200-airplane market estimate for the military, the total market estimate is 300 aircraft. In dollar terms this is impressive—\$5,000,000,000 plus.

Such a prediction reflects an unusual degree of confidence on the part of Lockheed and all of its potential customers.

However, despite the unusually optimistic predictions made on all sides for the C-5A, it seems worthwhile to take a closer look at the project and its limitations and potential. The C-5A is a big step forward in many respects, but no one has yet come up with a good crystal ball for predicting the future in aviation. Overoptimism often was the problem in the early days, but since the Korean War the tendency

(Continued on following page)



has been to underestimate the potential generated by the technological revolution.

One good example is the performance improvement of the jet engine. In 1958, top officials at the National Aeronautics and Space Administration declared that gas-turbine engine research wasn't needed any longer, that all possible future improvements could be made by industry using technology then available. In the intervening 7 years a veritable revolution in knowledge has taken place. It has been proven conclusively that the jet engine's unused growth potential is far greater than that which has already been exploited. Major advances include new lightweight materials and design techniques and cooled turbine blades, which allow the engines to run at significantly higher temperatures. Thus, the new generation of jet powerplants is much lighter than existing engines of similar power.

Without this new technology, the

C-5A's fine performance would not be possible. Its General Electric GE 1/6 turbofans produce 40,000 pounds (18,145 kg) of thrust each, have a considerably higher thrust-to-weight ratio than any large engine in use today, and have a lower specific fuel consumption.

In this same vein, no one in or out of the engine business anticipated the improvement that has been achieved in jet-engine life. Today, some models are operated by the airlines for more than 5,000 hours between overhauls, and still longer life apparently is a certainty. These engines are largely responsible for the low operating costs of turbojet and turbofan transports, as compared to piston-driven aircraft, which have less than half the engine overhaul life.

Another key area in which the expert prognosticators miscalculated badly, at least in their public statements, was the size of the jet transport market. Ten years ago arguments

were still raging over the relative merits of the turboprop vs. the turbojet engine, and there was great concern about the economics of large jet aircraft in airline service. No one felt confident enough to predict that by 1965 around 900 U.S.-built jet transports would be in use by the airlines and that around 300 would be on order with enough new purchases anticipated in the near future to put the industry in a mild boom condition.

Many other examples of faulty prognostication in aviation can be cited. However, the main point is that the estimate of a 300-aircraft market for the C-5A probably is grossly in error. If the estimate proved to be correct, it would be unprecedented.

Looking toward a large market is quite stimulating. The total dollar values rise rapidly, and, if 1,200 airplanes were sold, the total price would be in the neighborhood of \$17,000,000,000, or nearly the equal of an Apollo man-on-the-moon program.



—ILLUSTRATION BY RICHARD SCHLECHT

The C-5A will become attractive for a wide variety of military missions if it fulfills expectations and becomes a highly reliable, durable workhorse. The artist's conception at left shows a possible air defense configuration. A search radar is enclosed in the disc-shaped radome above the fuselage and a height-finding radar in the strut supporting the disc. On the C-5A these radars can be larger, more powerful, and have much greater range than airborne installations of this type which are now operational. Elaborate communications and computer installations can also be carried in the cavernous interior to allow the C-5A crew to control other air defense aircraft over hundreds of thousands of square miles. In addition to performing early-warning and intercept-control functions, the C-5A could become a potent missile-launching platform. It will have a sufficiently large fuselage and payload capacity to carry a large number of air-to-air missiles. For example, it could carry about 30 Hughes AIM-47 missiles developed as armament for the Lockheed YF-12A interceptor. The AIM-47, which flies at Mach 6 over a range of 100 miles (160 km), weighs 800 pounds (363 kg) and is 12 feet (3.65 m) long. The C-5A could carry the 30 AIM-47 missiles in addition to radar and command-and-control equipment. The missiles could be stored in racks in the fuselage and fired through openings in the enlarged wheel fairings as shown in the drawings. Larger missiles with much more range could be carried so that the C-5A would have the capability of defending effectively against supersonic bombers, thus making it a valuable supplement to the supersonic interceptor force. And the C-5A's great range would allow it to attack invading bombers long before they and their standoff missiles would come in range of major North American population centers.

Initially, such thoughts seem entirely out of line. However, there are good reasons for believing that the final sale of the C-5A and its derivatives will be closer to 1,200 than 300.

First of all, the C-5A is technically well within the state of the art. There is nothing in its design or production plan that hasn't been done before. It rides a strong backlog of experience in the development and operation of high subsonic-speed transports.

Some design problems have new orders of magnitude. For example, the aircraft's 712,000-pound (322,960 kg) gross weight is better than twice that of the C-141; its 222-foot (68 m) span is 40 percent more than the C-141's; and its 236-foot (72 m) length is 65 percent longer than that of the C-141. As a result, the C-5A's natural control response is relatively sluggish. However, automatic control and stability system technology has advanced to the point where the C-5A will have a relatively low minimum speed in the

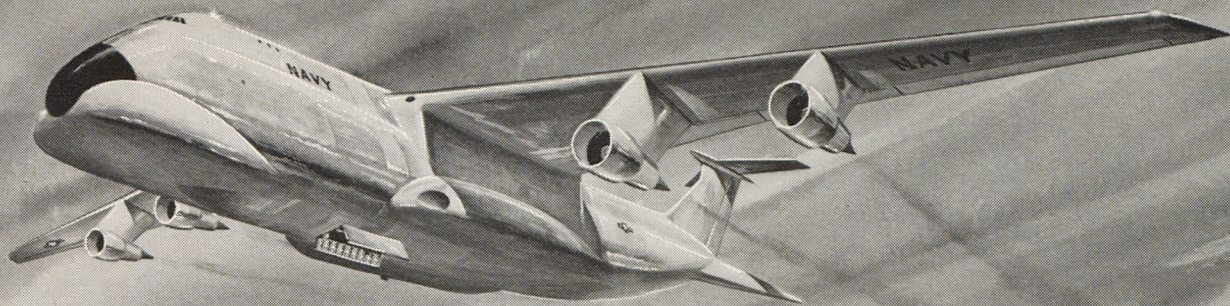
115- to 130-knot range, depending upon weight, and a short-field capability comparable to current civil jets.

It is to take off fully loaded in 7,850 feet (2,393 m) and land at its normal landing weight in less than 5,000 feet (1,524 m). The 28 low-pressure tires in its landing gear will allow the C-5A to operate from sod fields. Its eyelid-type door on the nose, and the clam-shell doors on the rear of the fuselage, will allow drive-through loading. That is, the cargo being delivered can be hauled or driven out of one end, while a new load is brought in at the other. With this design, the turnaround time on the ground, including fueling, for the C-5A will be about an hour under normal circumstances. Integral rail and roller systems will allow aerial delivery of heavy cargo.

Production of the C-5A will be manageable with current knowledge, just as the performance requirements, such as those discussed above, are within the technology. The basic tool-

ing will be similar to that used on the C-141, 707, B-52, and other large aircraft. That is, the tooling will accommodate sheets of skin measuring approximately 3 feet by 50 to 60 feet (.9 m x 15 to 18 m). It would be preferable to go to larger sheets to reduce the number of joints in the skin, because the joints with their necessarily heavy backup structure, rivets, etc., weigh considerably more than continuous skin. Achieving low structural weight on any metal aircraft depends largely on reducing the number of skin joints, and, on an aircraft the size of the C-5A, this is of critical importance. However, as things stand today, it would take a major effort to produce and ship larger aluminum panels. So far, such a facility expansion has not been considered economical. However, if larger aircraft than the C-5A are constructed, this might become worthwhile.

The final major assembly procedure, (Continued on following page)



—ILLUSTRATION BY GORDON PHILLIPS

Antisubmarine warfare roles could also be performed by the C-5A, as depicted in this artist's illustration. Its large internal volume and heavy payload capacity would allow it to carry a more extensive and sophisticated load of submarine detection equipment than in aircraft now performing such missions. In addition, it could accommodate an unprecedented load of depth charges and homing torpedoes.

Modifications for the ASW mission would probably include an extended wingspan to improve flight efficiency at speeds of 150 to 200 knots (275 to 375 km/hr). Changes in engine design could be made to improve fuel consumption at reduced throttle. However, range and endurance would be outstanding, because the C-5A could be operated with 2 engines shut down during much of the sub-hunting mission.

the attachment of the 63-foot-high (19 m) vertical tail, will have to be accomplished out of doors, because the high bay area of the Lockheed plant will not accommodate the completely assembled aircraft. Otherwise, the C-5A production line and subassembly areas will resemble those currently seen.

Improved management is the second reason why the C-5A market should be large. If there is any breakthrough connected with the C-5A, it is in the area of management.

The past 10 years have seen great improvements in 2 prime phases of management. One is the ability of the top echelons to keep track of and effectively control the work of thousands of people. The other is the ability to collect detailed data on the performance of all operational systems, to analyze this data, and to effectively use this information to improve the design of new systems. A corollary ability of importance in this second area is to effectively feed information from advanced research and test programs into the design cycle.

These are traditional tasks of engineering management. In recent years they have become troublesome because aircraft and their systems have become increasingly complex and great masses of data must be processed on a timely basis if management is to be effective.

The use of PERT (Performance

Evaluation Review Technique) and similar computerized systems to manage the U.S. strategic missile programs have been well recorded. They are credited with making these complex developments tractable and with making it possible to produce them in a relatively short period and within reasonable budgetary limitations.

What hasn't been so well recorded is that the management systems have been continually strengthened, and now they are much more powerful than the original PERT. For the C-5A effort Lockheed has tailored a system called Sentinel. It combines 4 older systems. One is the original PERT-Time which was primarily good for monitoring a schedule. Another is PERT-Cost, which allowed a close check on many cost elements. A third system was aimed at monitoring 60 to 80 technical parameters, such as weight and drag, to make it possible at any time to determine how well the total system was meeting the performance requirements. The fourth system is designed to evaluate overall cost/effectiveness.

The Sentinel is designed to allow a continuous check on how well the company is meeting schedules, costs, performance, maintainability, and reliability requirements, and it even shows how much of an incentive profit can be expected. Program changes can be evaluated rapidly and thoroughly. For

example, if there is some question about the desirability of incorporating new numerical control techniques in wing construction, Sentinel will answer these questions rapidly and completely. It will indicate the most advantageous time at which to begin using the new process, and how much savings it will provide, its effect on aircraft performance, the change it will make in the cost of a wing 2 or 3 years hence, the incentive profit it would generate, and so on.

A great many such questions must be answered. Numerical control, for example, is in a period of rapid innovation. Major improvements in the methods of employing these automatic machines are being demonstrated constantly. There will be significant opportunities for altering the C-5A design and production plans during the next 2 years, with dollar savings for both the Government and the company. The C-5A development is so complex that it would be virtually impossible to take maximum advantage of such opportunities without a system such as Sentinel.

Sentinel also will allow changes to be made on the basis of operational experience with older transports such as the C-130 and the C-141. A major library of data, describing in detail the malfunctions of all types of military transport systems, is being built up. In the past, without a computer sys-

tem, it has not been possible to assemble operational data in such detail, or to make full use of it in designing more reliable systems. Sentinel should greatly improve the situation.

Another vital service performed by Sentinel is to illuminate trouble spots in a program long before they reach crisis proportions so that orderly corrective action can be taken.

All major firms have similar advanced management systems. Sentinel is not unique. But Lockheed gives it a major part of the credit for winning the C-5A competition.

Another indicator is that Lockheed has quoted some rather low prices for the C-5A. The current agreement is unique in that it combines development and initial production into a single contract worth around \$2,000,000,000. This is about \$35,000,000 per aircraft or \$115 per pound (.45 kg).

The Government also has an option to buy 57 more aircraft in the second production order for a total price of less than \$800,000,000, a per-aircraft cost of about \$14,000,000 or \$47 per pound. This is close to the \$30 to \$40 per pound common for fully equipped, high subsonic-speed jet transports today. Since most of these aircraft are well out on the learning curve, with several hundred already produced, the C-5A prices indicate great confidence. These prices should be reduced substantially as the production passes 300 aircraft and Lockheed takes advantage of the learning curve.

The Sentinel management system is largely responsible for these low prices by keeping wasted effort to an absolute minimum.

The third reason for believing that the C-5A market will be large is the relatively large number of possible military uses. It is difficult to imagine that the C-5A will be used solely for logistics purposes. If the aircraft does as well as is expected and becomes a thoroughly reliable workhorse, then it is inevitable that it will be pressed into a variety of services.

One ideal mission would be command and control. The C-5A's great internal volume and heavy payload would make it much more effective than current command and control aircraft which can carry only a small percentage of the desired communications, computation, and data storage and display equipment.

Air defense is another mission that would come under discussion. An artist's conception of a C-5A modified for air defense is presented on pages 30 and 31, along with a discussion of its advantages and disadvantages.

The Navy also has missions which a slightly modified C-5A could satisfy handsomely. One is mine-laying. No other aircraft could approach the C-5A in mine capacity or operational radius.

Undoubtedly, an aircraft with the C-5A's payload and range characteristics could strengthen the Navy's antisubmarine warfare capability if its costs were right. An artist's conception of such a C-5A modification and a discussion of the mission are on page 32.

It also is difficult to imagine a better aerial tanker than the C-5A. The current tanker fleet is not going to last forever, and replacements will be necessary in the latter 1970s. And, even if bombers are completely passé in 10 or 15 years, a significant number of tankers will be necessary for fighter operations. The C-5A will be the logical choice to replace the KC-135s as they are retired.

All in all, the military market seems considerably larger than 200 aircraft for the type of C-5A that is being forecast today—that is, a highly reliable aircraft with relatively low purchase price and an outstanding low operating cost on the basis of pounds of payload delivered. It appears that the Sentinel management system will allow the aircraft to be modified at relatively low cost so that the cost/effectiveness would remain high.

The rapidly growing civil market is the fourth reason for believing that

the total demand for C-5As will be high. Great arguments are being made about the passenger and freight traffic that will materialize in the 1970s and 1980s, when large aircraft such as the C-5A will be needed. The basic trend is toward more optimistic predictions as both the passenger and freight growth rates continue to remain high.

The freight growth situation has reached the point that C-5As will be needed in the mid-1970s if no totally unexpected change takes place. One Pan American World Airways, Inc., vice president reported recently that ton-miles of cargo moving over the Atlantic in 1964 were 22 percent higher than in 1963, and that his company, during the first three-quarters of 1965, was 45 percent ahead of that figure. On Pan American's total system, he said the freight business was up 60 percent so far this year. He concludes that something spectacular is beginning to happen.

If the future is less spectacular than this executive imagines and the growth rate returns to about 25 percent per year, then the airlines will need 6 times as many jet cargo transports of 707 and DC-8 size in 1975 as they have today. In such a competitive situation, there would be a good market for an aircraft such as the C-5A, which had a direct operating cost well under that of its contemporaries. A Sentinel-type management system which can keep modification costs low should produce a competitive civil version of the C-5A, which would not have the heavy floor, tie downs, rollers, etc., needed to carry and drop heavy military loads.

The passenger service potential is less clear, but if the civil air freight operations go well, it seems inevitable that the C-5A would be modified rapidly to carry passengers.

In the final analysis, there are strong indications that the total civil/military market for high subsonic-speed jet aircraft is going to be much larger in the 1970s than it was in the 1960s. The main requirements of all operators of such aircraft, whether civil or military, will be lower operating cost, and increased productivity—the ability to carry more payload over longer distances each day. As the C-5A will set new standards in both of these areas, it is certain to be a solid choice for a large portion of this market.

The market potential seems so great that the C-5A probably will not long remain an oddity much larger than its contemporaries. Other jet transport manufacturers probably will rise to the challenge and steadily increase the size of their aircraft so that by the mid-1970s they will be ready for the C-5A.

☆☆☆

C-5A VITAL STATISTICS

Length	236 ft. (72 m)
Wingspan	223 ft. (68 m)
Height of tail	63 ft. (19 m)
Cargo compartment floor area	2,743 sq. ft. (254.8 m ²)
Empty weight	approx. 300,000 lb. (136,000 kg)
Basic mission weight	712,000 lb. (323,000 kg)
Cruising speed	500 mph (805 km/hr)
Delivery of first production model	—early 1968
Operational date	—early 1969
Commercial availability	—mid-1970s
Currently planned production rate	—10 to 12 per year

At a showing attended by ranking military and civilian defense officials, the A-7A Corsair II demonstrated its weapons-carrying capability, handling characteristics, and maintainability. The U.S. Navy plans to buy 1,500 A-7As and USAF is considering the purchase of Corsair IIs for Tactical Air Command . . .

A-7A Development— A Status Report

The new mainstay of the U.S. Navy's carrier attack force, the A-7A Corsair II, has been shown publicly and in great detail by its manufacturer, the LTV Aerospace Corporation. Several hundred U.S. Department of Defense dignitaries, high-ranking military officers, politicians, and newsmen gathered at Dallas, Texas, recently to watch an impressive low-level flight demonstration and observe mechanics in a rapid-maintenance demonstration, and later were given the opportunity to thoroughly inspect the aircraft.

John Konrad, the company's chief test pilot, and Robert Rostine, an experimental test pilot, flew 2 A-7As in simulated bomb runs, low-level passes, precision rolls, and maximum performance takeoffs.

Konrad's aircraft was loaded with more than 7,500 pounds (3,035 kg) of bombs while Rostine's was clean. Except for takeoff, there was little noticeable difference in the handling characteristics of the 2 aircraft. Konrad reports that the A-7A's turning capability is superior to that of the F-8U Crusader, the supersonic Navy fighter from which much of the A-7A design was taken. He also says that the A-7A is "much more comfortable than the F-8U" at high speed and low altitude, and "the pilot does not feel turbulences or excursions in the flight path." The Corsair II is a 7-G airplane, and there are no limitations on its maneuverability envelope. It can pull 7 Gs without buffeting, under all flight conditions.

During the maintainability demonstration, a crew of 4 mechanics removed the engine in about 20 minutes. A 20-mm cannon was removed in 2 minutes. Most of the aircraft's 35 large access panels were removed to expose electronic, hydraulic, and electrical equipment in neatly packaged arrangements, most of which can be comfortably reached by a mechanic standing on the ground. The Navy expects to operate the A-7A with only

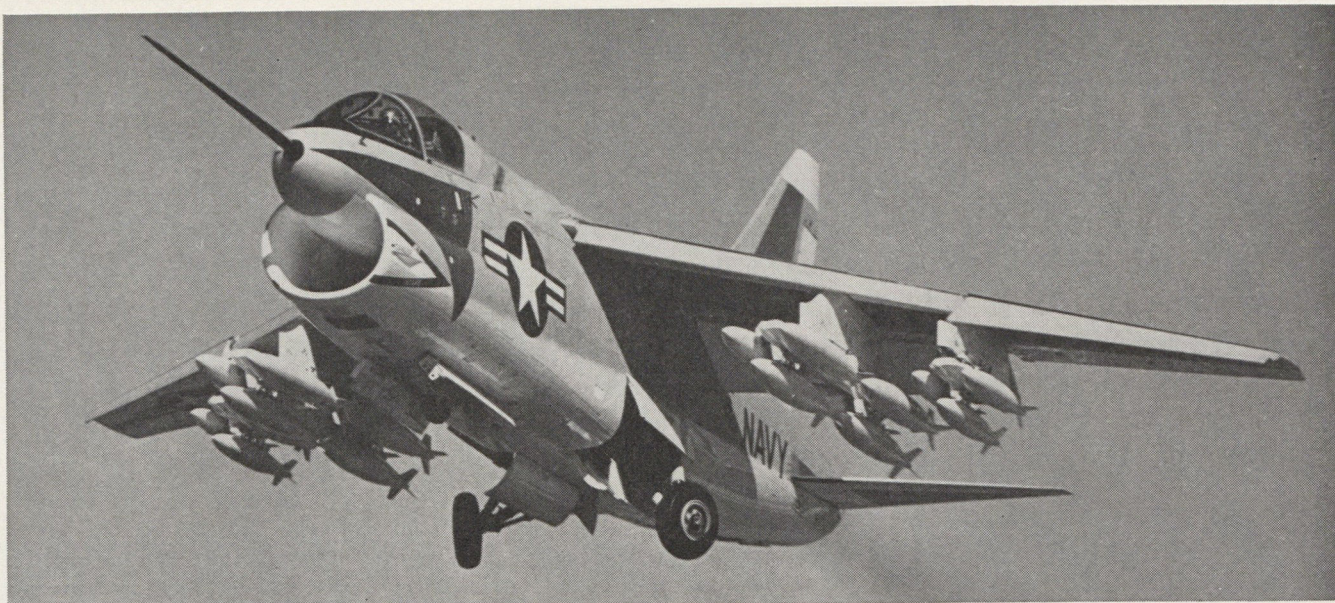
11.5 direct maintenance man-hours per flight hour.

Currently, the Navy plans to purchase about 1,500 Corsair IIs. Existing contracts total \$239 million and cover the development program and the delivery of 189 aircraft. As the learning curve takes effect in production, the per-copy price is expected to drop to about \$1.5 million, fully equipped.

The contracts between the Navy



The large speed brake extended from the lower fuselage of the A-7A Corsair II is important in giving the aircraft exceptional maneuverability at low and high speeds near the ground. It allows the angle of descent to be steepened during bombing runs and improves turning performance considerably. A-7A is built by the LTV Aerospace Corp.



This is the bomb load configuration used by John Konrad, LTV's test pilot, during the Dallas flight demonstration. The 2 inboard pylons carry 6 500-pound (227 kg) bombs each. The 2 outboard pylons are loaded with 3 250-pound (113 kg) general-purpose bombs.

and LTV are of the incentive-fee type, with the company guaranteeing many aspects of flight performance and maintainability. Currently, all of these guarantees are being met, and many of them exceeded by a large percentage, with the exception of empty weight, which is about 400 pounds (181 kg) heavy. However, range, payload capability, and all of the key performance characteristics are proving to be better than estimated, and the overweight condition is causing no concern.

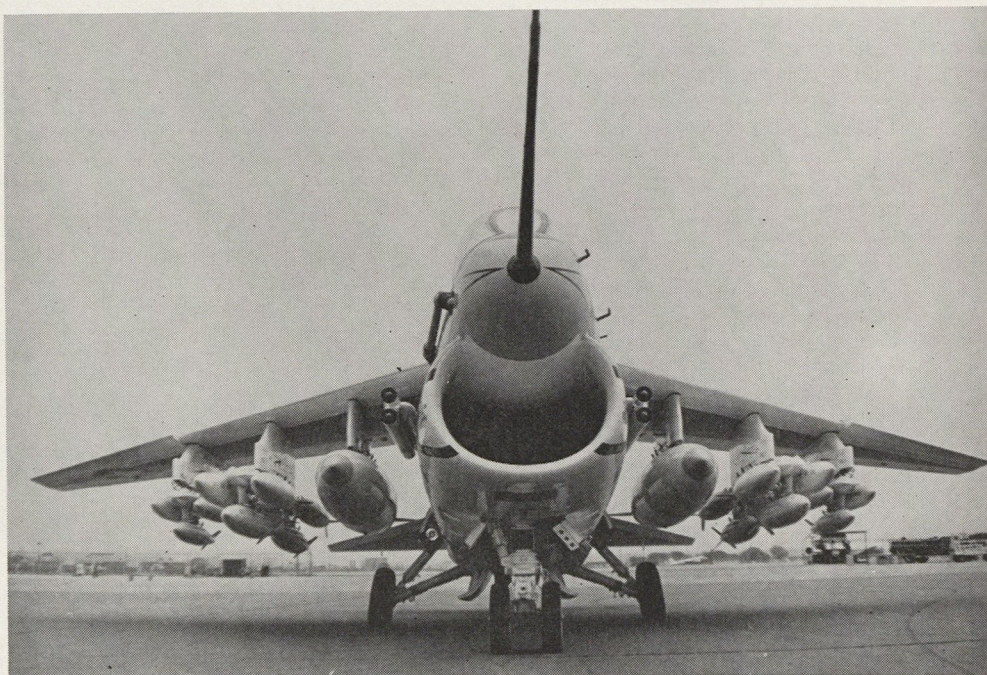
First deliveries of the A-7A to the fleet have been scheduled for the fall of 1966.

The Fiscal 1967 budget, as sent to Congress by the Defense Department, provides for initial purchase of A-7As for USAF's Tactical Air Command. It is understood that few changes will be required to make the aircraft suitable for the close-support mission. The main one being considered is the addition of a short afterburner to reduce the takeoff run by around 40 percent.

The aircraft's major selling points are the very low fuel consumption of its Pratt & Whitney TF30 turbofan engine, its 20,000-pound (9,070 kg) maximum bomb load, and its great range (said to be twice as long as any operational jet attack aircraft). If the Air Force decides to purchase the A-7A, it is reported that LTV has the production capacity to deliver Air Force and Navy aircraft from the same line with essentially no delay to either service.

—J. S. BUTZ, JR.

Loaded with bombs, rockets, and droppable fuel tanks, the new A-7A Corsair II attack bomber carries a load more than double that of the B-17 of World War II. Together with pylons, racks, and launchers, the plane shown here has 14,750 pounds (6,730 kg) hanging from its wings and fuselage. The Corsair II itself weighs only 15,000 pounds (6,804 kg) empty.



The costs of war in Vietnam are equivalent to one-eighth of next year's entire U.S. Federal budget. . . . Five more Gemini flights in 1966 will pave the way for testing the Apollo lunar-landing vehicle by this time next year. . . .

A second airmobile division is being readied for the U.S. Army. . . . Gravitational fields of other planets can be used to speed spacecraft to distant targets. . . . U.S. airlines will carry 160,000,000 passengers by 1971. . . . And the Secretary of the Air Force reveals how he arrives at his decisions. . . .

Vietnam, the Moon, and Mr. Brown

BY ALLAN R. SCHOLIN, Associate Editor

A program calling for expenditures of \$13,760,719,000 to support the war in Vietnam was presented to the U.S. Congress by President Johnson on January 19. Congressional leaders in both political parties expressed their support.

About one-third of the total amount represents a supplement to funds previously appropriated for the Defense Department in the current Fiscal Year, which ends June 30. The other two-thirds will be spent in Fiscal Year 1967, beginning July 1. Thus the Vietnam requirement was the first specific request in the Administration's 1967 budget, which President Johnson noted will total almost \$113,000,000,000.

"We are currently engaged in a major effort to open a road to a peaceful settlement," President Johnson declared. "Whether the present effort is successful or not, our purpose of peace will be constant; we will continue to press on every door.

"But until there is a response, and until the aggression ends, we must do all that is necessary to support our allies and our own fighting forces in Vietnam. That is the purpose of the present request."

Major portions of the funds will be used to increase U.S. Armed Forces by 113,000 men, and to buy an estimated 2,000 helicopters, 900 fighter and transport planes, and almost 5,000 tactical missiles—principally Hawk anti-aircraft weapons and Bullpup air-to-ground missiles.

In addition, \$2,100,000,000 will go to replenish stocks of equipment and ammunition borrowed from other U.S. military units to support the force buildup in Vietnam.

The increase in military personnel will enable the Marine Corps to form a complete new division, its fifth. Two Marine divisions are in Vietnam or other points in the Far East, one is divided between the U.S. and other areas around the world, and the fourth is made up of Reservists not on active duty. The Reserve division will not be called at this time, but is undergoing intensified training to be ready for mobilization on short notice, if needed later.

Strength of the U.S. Army will be

increased, primarily to augment existing units and to create more support elements, but not an additional division. These manpower increases will raise the total military strength of U.S. Armed Forces to more than 3,000,000 men.

A sum of \$1,238,000,000 is allocated to building ports, airfields, roads, and other military facilities in Southeast Asia.

Another \$152,000,000 will be devoted to research-and-development projects directly related to the war in Vietnam,



Two 500-pound (227 kg) bombs are released by U.S. Air Force F-100 Supersabre fighter against Viet Cong target in Mekong delta in South Vietnam. President Johnson has asked Congress to provide \$13,760,719,000 to cover costs of war in Southeast Asia. Funds will go toward purchase of an estimated 2,000 helicopters, 900 fighter and cargo aircraft, and 5,000 tactical missiles, and to increase U.S. Armed Forces by 113,000 men.

and \$415,000,000 will go to the Agency for International Development in assisting the Governments of South Vietnam, Laos, and Thailand to improve economic and social conditions of people in rural areas.

* * *

With its Gemini-8 spacecraft on the pad at Cape Kennedy, Florida, scheduled for launch sometime in March, the National Aeronautics and Space Administration hopes to wind up its Gemini series of orbital missions in 1966 and move on to early Apollo flights leading to a manned mission to the moon by the end of the decade.

Aboard Gemini-8 as capsule commander will be the first U.S. civilian astronaut, Neil Armstrong, who, before he was selected for the space program, flew a number of missions as a NASA test pilot in the U.S. Air Force's X-15 rocket-powered research plane. Mr. Armstrong's partner in Gemini-8 will be Major David Scott of the U.S. Air Force.

The highly successful 2-week endurance flight of Gemini-7 and its rendezvous with Gemini-6 in December cleared the way for U.S. astronauts in 1966 to concentrate on the mechanical operations they must perfect in space to ready themselves for flight to the moon.

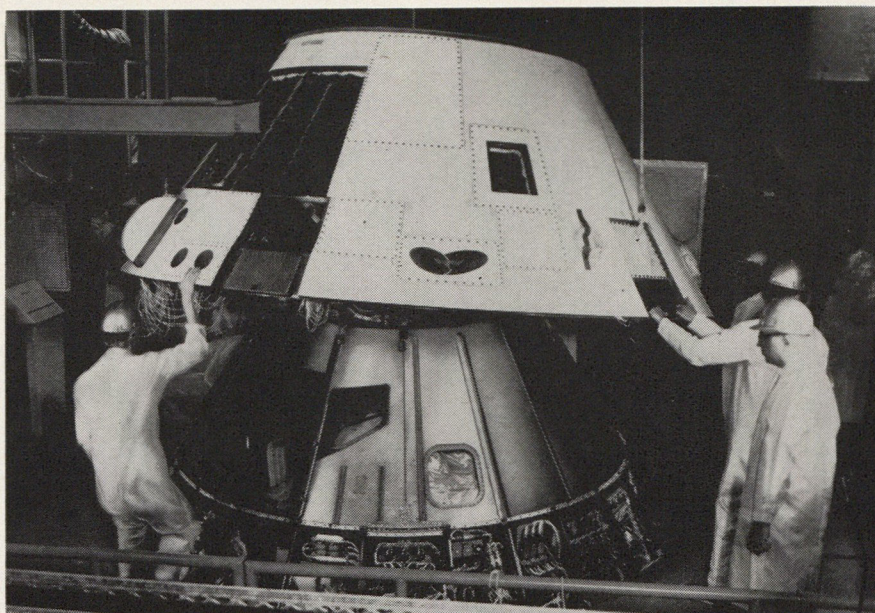
The Gemini flights have proved that trained astronauts can function effectively in a space environment for more than the time required to reach the lunar surface and return to earth, that design and fabrication of space vehicles and on-board equipment has so far proved adequate for the tasks, and that rendezvous of 2 or more vehicles in space is attainable.

The 5 Gemini flights scheduled this year will be devoted to exercising these demonstrated capabilities and to giving astronauts more practice in working in and around their vehicles in space. Each of the 5 missions will include attempts at docking, with at least 1 member of the crew leaving the capsule on each flight to familiarize himself with the sensation of walking in space and with performing chores outside the spacecraft.

Meanwhile, this year will see the first tests of the 3-man Apollo lunar vehicle linked to its Saturn booster, leading to the first manned Apollo orbital mission early in 1967.

The Gemini-7 and -6 missions established 11 space records for the U.S., of which the first space rendezvous was the most dramatic. The USSR twice put spacecraft within 4 miles of each other, but apparently in different orbital planes.

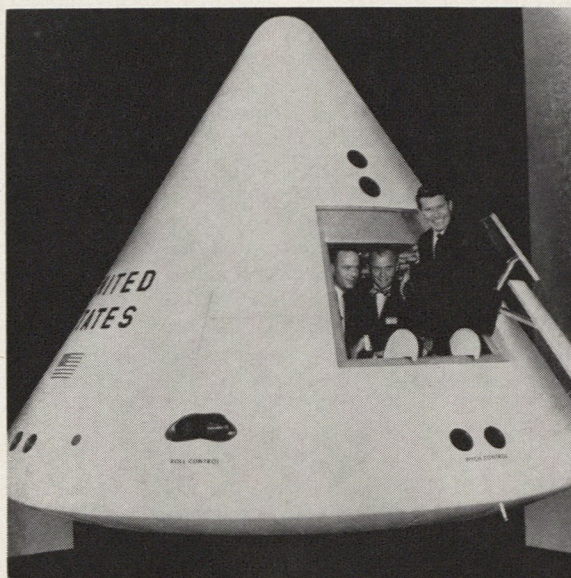
By remaining aloft in Gemini-7 for 330 hours 35 minutes, Air Force Colonel Frank Borman and Navy Captain



Workmen at Aeronca Manufacturing Co., Middletown, Ohio, lower heat shield onto inner crew compartment of Apollo spacecraft 009, destined for unmanned launch late this year to test capsule's ability to withstand 5,500° F (3,000° C) temperatures on re-entry. Prime contractor for Apollo vehicle is North American Aviation, Inc., Downey, California. Heat shield of stainless steel honeycomb is produced by Aeronca, with ablative coating supplied by Avco Research and Development Division, Wilmington, Mass.

Apollo 3-man capsule is tried on for size by 3 of the original 7 U.S. astronauts, all of whom completed orbital flights in NASA's Mercury program.

Framed in hatch, from left to right, are M. Scott Carpenter; John H. Glenn, Jr.; and Walter M. Schirra, Jr. Carpenter and Schirra are U.S. Navy officers. Glenn was a colonel in the Marine Corps before retirement in 1964. Schirra guided Gemini-6 in December rendezvous with Gemini-7.



James Lovell set records for the longest spaceflight, longest multimanned flight, most orbits for a manned vehicle (206), most miles traveled on a single flight (4,129,400 miles or 6,644,205 km), and most time in space for individual astronauts. These records had been held by Air Force Colonel Gordon Cooper and Navy Commander Charles Conrad for their 8-day Gemini-5 mission last August.

Gemini-7 and -6 also brought the cumulative total of man-hours in space for America to 1,352 hours 42 minutes, compared to 507 hours 16 minutes for the USSR; most men sent

into space (16, to 11 for the USSR); and most manned flights (11, to 8). The 5 Gemini flights in 1965 also set new records for the most manned flights in a year, topping the 3 Mercury missions in 1962, and the most men sent into space by 1 nation in a year—10, compared to 3 by the U.S. in 1962 and 3 by the USSR in 1964.

* * *

How to get along with the boss was explained recently to members of the U.S. Air Force Headquarters staff by the boss himself, Air Force Secretary Harold Brown.

(Continued on following page)



"I probably ask a lot of nasty questions," Secretary of the Air Force Harold Brown told members of U.S. Air Force Headquarters staff recently, "but this is the way to learn." He emphasized that studies prepared for him must include "all the arguments and all the answers," not just those which support a particular view.

"There are probably thousands of ways to do any job, and among those thousands there may be hundreds which will work well," Secretary Brown said. "My own way is to dig deeply into the most important questions, the studies and proposals presented to me and the ones which I dream up myself, and then to carry out a rather detailed dialogue with the people who make these presentations or do the work. I also like to work out some of my own ideas part way myself, and then bounce them off others.

"In listening to your results, I probably ask a lot of nasty questions, but this is the way to learn—and I have a lot to learn. Furthermore, this is the way to improve the quality of our studies so that they will be able to stand up to the kind of searching

examination they will get at the OSD [Office, Secretary of Defense] level. As you know, studies play an important part in the decision-making process, and we want our studies to encourage favorable decisions. To do so, they have to include **all** the arguments and **all** the answers—not just some, but all.

"Once in a while, we tend to leave out some of the arguments, maybe because we fear subconsciously that if we look at all the facts we may come up with an answer we don't like. But that's a chance we have to take. And you never know; often we come up with an answer we do like, too. Whatever the answer, it will be a lot easier to defend before the Secretary of Defense, the President, and the Congress if we know all the arguments, pro and con.

"When a study is presented to me, I like the conclusions and recommendations put in the following way: 'If you think **this** way, **this** is what you ought to do. If you think **that** way, **that** is what you ought to do. Of course, if you take the second choice, you will be making a bad mistake, but that's the choice you should take if you believe the second premise.'

"In other words, gentlemen, I like a set of conditional recommendations. But these recommendations ought to flow from an analysis of the arguments, not from a preconceived conclusion based on doctrine or intuition. The only way to understand something, no matter how you come out on the answer, is to go through all the arguments.

"Of course, it's also very important for everyone to feel that he has a chance to present his arguments and to press his viewpoint personally, especially if he feels strongly about something and wants to talk to his superiors about it. So far as I'm con-

cerned, this is an extremely important principle to maintain. When I've reached a conclusion, I'm still open to persuasion. I've reached some wrong conclusions in the past, and I've always let people try to argue me out of them. Quite often they've been successful, too, and I expect to keep using that technique. This is something you should expect of me, just as those who work for you expect it of you."

* * *

A second airmobile division is now being assembled by the Army in the U.S., following the satisfactory performance of the 1st Cavalry Division (Airmobile) in Vietnam combat. Helicopters are being collected from industry production lines and wherever they can be spared from other Army units.

The airmobile division is authorized 428 helicopters, primarily Bell UH-1 Iroquois and Boeing Vertol CH-47 Chinooks in both armed and troop-carrying versions, and 6 Grumman OV-1 Mohawk fixed-wing attack and reconnaissance aircraft.

This equipment is a limiting factor in readying the new division, not only because rotary-wing aircraft represent the key to the division's mobility, but because helicopters must be available for training exercises.

Production of helicopters for the U.S. Army has reached the rate of 160 a month, enough to replace damaged and worn aircraft in Vietnam and still supply the new division by late spring. The Army, meanwhile, is training rotary-wing pilots at the rate of 300 a month to cover replacement of pilots returning from Vietnam and to man the new airmobile unit.

The cadre of the second airmobile division will include many veterans from the 1st Cavalry Division, whose combat experience is invaluable in indoctrinating new men and instilling high esprit in the unit.

Three major questions, unanswered when the 1st Cavalry Division went to Vietnam, were:

1. Can helicopters be maintained adequately in forward areas despite intensive operations?
2. Can they be refueled promptly during a wide-ranging campaign?
3. How vulnerable are they to enemy ground fire?

Combat experience has provided answers to all these questions—answers that show the airmobile concept is proving feasible.

The in-commission rate of 1st Cavalry Division helicopters has been higher than anywhere else in the Army, at home or overseas, even though they fly an average of 50 hours a month. This is attributed to the fact

(Continued on following page)



Portable "laser" ranger, developed at General Electric Company's electronics laboratory in Syracuse, New York, may be employed as a surveying tool. The range-finder weighs less than 30 pounds (13.5 kg) and has an accuracy of plus or minus 1 foot (30.48 cm) at distances up to 50,000 feet (15,200 m).

that division personnel were handpicked and well trained before leaving the U.S., and are determined to make good.

Refueling in the field has been facilitated by collapsible rubber tanks, carrying as much as 500 gallons (1,890 l), capable of being carried inside or underneath CH-47 helicopters. When empty, the tanks are flattened and hauled back to rear areas along with casualties or other personnel or cargo.

As for survivability, the Army reports helicopter losses in combat have averaged only 1 in 12,000 sorties. With noncombat operations included, the loss rate is 1 in 16,000 sorties.

Contributing to the low loss rate are Sikorsky CH-54 Skycranes, 4 of which had been assigned to the airmobile division. In 3 months, the Skycranes recovered 45 disabled helicopters, ranging from the small Bell OH-13 Sioux to the Boeing Vertol CH-47, plus a de Havilland Caribou transport and even a Douglas A-1E Skyraider fighter. The value of recovered aircraft is estimated at \$15,000,000—more than double the cost of the Skycranes themselves.

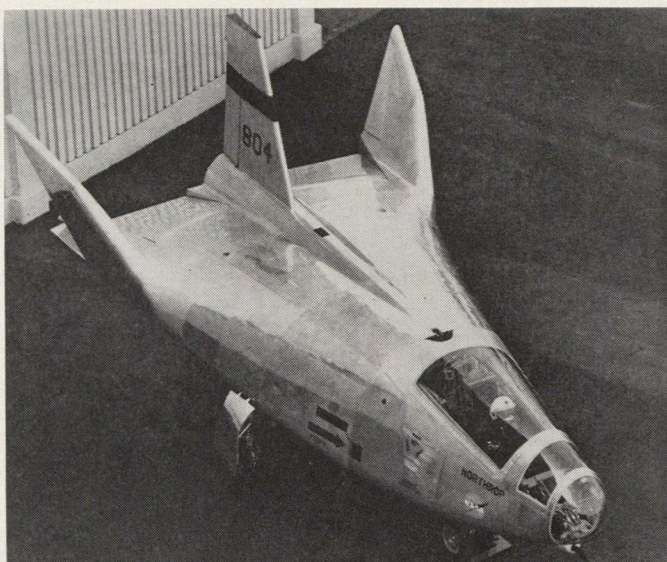
Although 1 CH-54 was shot down early this year, the Sky Crane has proved its value and the Army has requested a small production quantity to augment those in Vietnam and to equip its second airmobile division.

* * *

A wingless, tri-finned flight-research vehicle, designed to help solve control problems of future manned spacecraft entering the earth's atmosphere, has been delivered to the National Aeronautics and Space Administration by its manufacturer, the Northrop Corporation of Hawthorne, California.

Designated HL-10, it is a 22-foot-long (6.7 m) lifting body vehicle, the second such craft to be delivered to

This HL-10 experimental lifting body built for NASA by Northrop Corporation, Hawthorne, California, will be flown within earth's atmosphere to gather data for designing vehicle in which astronauts can return to earth from orbiting spacecraft. In first unpowered flights it will be released from wing of B-52.



NASA by Northrop within 7 months. Its predecessor, the M2-F2, has been undergoing extensive testing since last June at both NASA's Flight Research Center, Edwards Air Force Base, and Ames Research Center, California. It is scheduled to make its initial flights sometime before the middle of this year.

Both vehicles will ultimately be dropped from beneath the wing of a B-52 bomber, flying at an altitude of 45,000 feet (13,725 m), with NASA and Air Force pilots gliding and maneuvering them at high speeds to landings on Rogers Dry Lake in California. They will be dropped at speeds of approximately Mach 0.8. Both craft are also designed to accommodate rocket engines for even more advanced future flight experimentation.

Lift and flight will be achieved by the bodies of the vehicles alone, which are designed aerodynamically

to eliminate the need for wings. Both of the shapes are NASA-developed and are basically configured as half cones with their noses blunted and vertical and horizontal surfaces added for control.

NASA's Milton Thompson is chief pilot of the flight programs for both the M2-F2 and the HL-10. He gained fame as a pilot of the X-15, the Paraglider Research Vehicle, and the M2-F1, a plywood version of the Northrop-built metal M2-F2 lifting body. He will be joined in flight tests by Captain Jerauld R. Gentry of USAF's Flight Test Center.

* * *

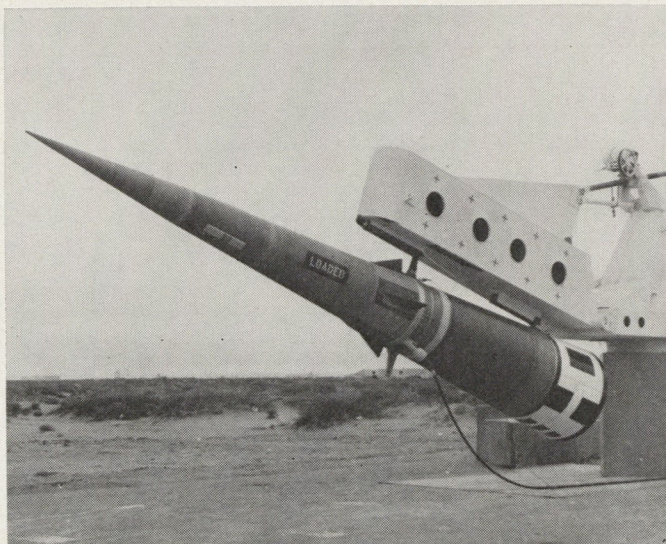
U.S. domestic and international scheduled airlines will carry nearly 160,000,000 passengers an average of 700 miles (1,127 km) each by 1971, according to the Federal Aviation Agency's latest 5-year aviation forecasts.

This predicted airline activity is almost twice that of Fiscal Year 1965, when U.S. air carriers flew 95,000,000 passengers an average of 660 miles (1,063 km) each.

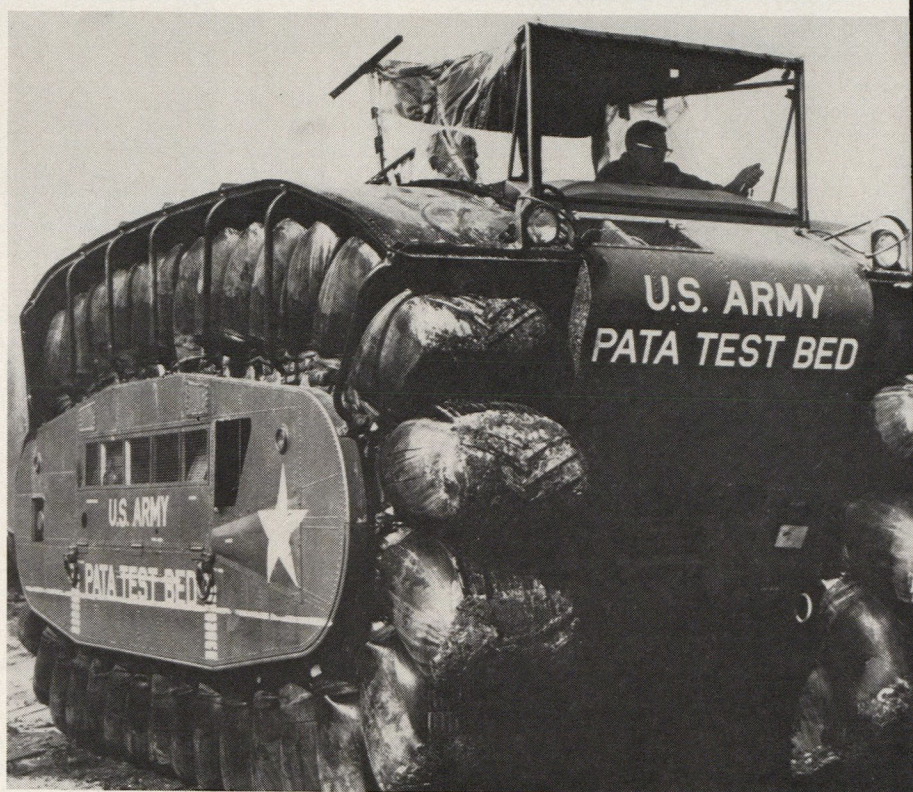
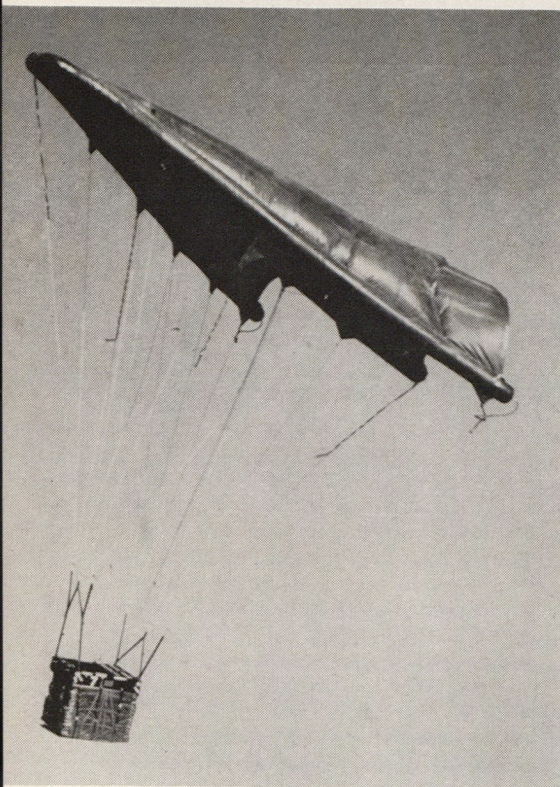
Other areas in civil aviation also show significant growth trends. The total U.S. airline fleet is expected to increase from its January 1965 level of about 2,100 aircraft to about 2,400 in 1971, with jets tripling from 564 planes to 1,690. Among the jets, 2- and 3-engine types will increase from an inventory of 180 to nearly 950. Local service carriers will generally convert to turbine equipment by 1971, in contrast to local service operations today, which are primarily with piston-powered planes.

General aviation (nonairline) active aircraft will increase from 88,742 as of January 1965 to 123,400 by 1971. Most of the increase will be in the (Continued on page 42)

Key element of U.S. Army's Nike-X system for defense against ballistic missiles is this Sprint missile, capable of extremely fast acceleration to intercept warheads which elude longer-range Nike-Zeus antiballistic missile. It is shown here being readied for test launch at White Sands Missile Range.



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CLOSING DATE FOR SPACE RESERVATIONS APRIL 22

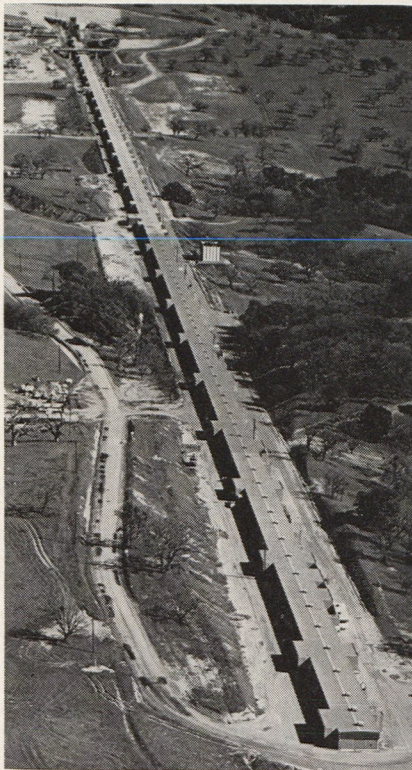
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Linear atom smasher now being built for U.S. Atomic Energy Commission at Stanford University, Palo Alto, California, is 2 miles (3.2 km) in length, and will be the most powerful in world when completed late this year. It was designed by Aetron Division of Aerojet-General Corp.

large single-engine aircraft, which will grow from 45,777 aircraft to an estimated 69,700. Multiengine aircraft will increase from 10,644 in 1965 to 18,800 in 1971, and turbine-powered general aviation aircraft from 306 to 1,850. General aviation will log 22,800,000 flight hours in Fiscal Year 1971, in contrast to the 16,200,000 logged in 1965.

Total annual civil aircraft production is expected to increase from 11,050 in Fiscal Year 1965 to about 13,900 in 1971.

* * *

Development work on the United States/Federal Republic of Germany Main Battle Tank Program will be carried to completion under a \$43,728,000 contract signed by the U.S. Army with General Motors Corporation, Indianapolis, Indiana.

The negotiations leading to the current contract were based upon design, configuration, and major component selection decisions announced last June by the defense ministers of both countries.

This successful contracting effort guarantees uninterrupted progress for the new Main Battle Tank and marks a major milestone in the life of this unique, international materiel development effort.

The contract provides for \$11,700,000 of the award to go to 2 subcontractors, Continental Aviation & Engineering Corporation, Detroit, Michigan, for a high-horsepower engine, and National Waterlift Corporation, Kalamazoo, Michigan, for a new-type suspension system.

General Motors was selected as the U.S. contractor in July 1964 and since that date has completed its contribution to the initial phases of the MBT Program. The current contract covers Phase III that terminates with the fabrication of pilot models as provided under the basic agreement between the U.S. and the Federal Republic of Germany, signed August 1, 1963.

The U.S. portion of the MBT Program is headed by Major General Welborn G. Dolvin of the U.S. Army Materiel Command in Washington, D.C. General Dolvin directs the technical effort located at the Army Tank Automotive Center, Warren, Michigan, and maintains contact with his German counterparts through a liaison office in Bonn, Germany.

* * *

Ships from 4 NATO nations are again operating under NATO's flag in exercise Match Maker II, which began January 11.

The exercise is being conducted by the Commander in Chief, Eastern Atlantic, Admiral Sir John Frewen, KCB, RN, from his headquarters in Northwood, England. Captain Parker B. Armstrong, U.S. Navy, commands the squadron.

Precedence for the exercise was set last year when the first Match Maker squadron operated for 5 months. Canada, The Netherlands, the United Kingdom, and the United States participated in Match Maker. These same

countries have assigned ships for the 1966 exercise Match Maker II.

Ships participating in Match Maker II are the radar picket ship, HMS AGINCOURT, and the destroyer escorts, HMCS ANNAPOLIS, HNLMS DRENTHE, the USS GARCIA, the HMCS RESTIGOUCHE, and the HMCS SKEENA.

Match Maker II is basically designed as an antisubmarine warfare exercise, but includes gunnery, communications, fueling, and other operations. Many of these maneuvers are being carried out while the Match Maker ships are integrated into previously scheduled exercises under NATO and the U.S. Atlantic Command.

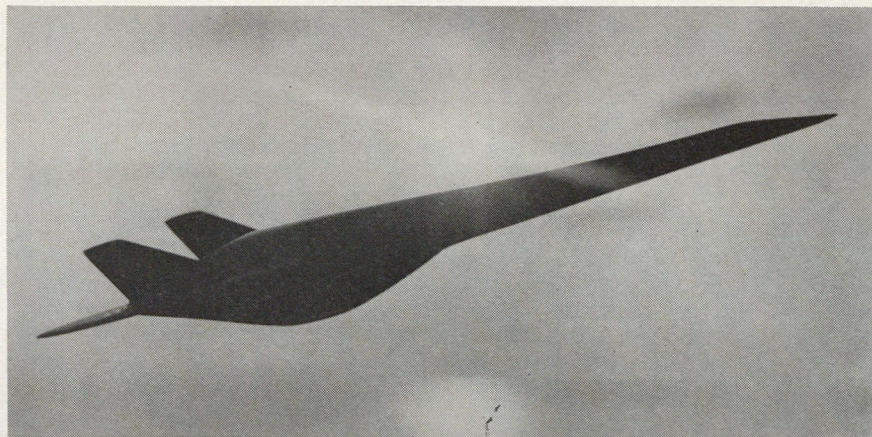
As with Match Maker I, this second international squadron will visit ports of many NATO countries. During these stops they will evaluate supply and logistics operations under standardized NATO procedures, and have the opportunity for recreational visits.

* * *

Appointment of Willis F. Chapman, retired U.S. Air Force brigadier general and veteran pilot, as director for aerospace programs in Europe of the LTV Aerospace Corporation has been announced by its president, Paul Thayer.

General Chapman will make his headquarters in Paris, where he formerly served duty tours in such positions as senior Air Force member of the Mutual Weapons Development Team, charged with contracting for joint military research-and-development efforts with NATO countries.

A native of Jackson, Michigan, and a 1935 graduate of the U.S. Military Academy at West Point, he has been a flying officer since he earned his wings in 1936. General Chapman was assigned to Air Force Headquarters



A generation beyond the supersonic transport is the hypersonic plane, which will fly at speeds of Mach 6—7,200 km/hr—or more. The design above was developed by the Lockheed-California Company, Burbank, California. Hypersonic aircraft are a natural evolution from conventional aircraft development, says E. R. Schuberth, head of Lockheed's spacecraft and hypersonic design department, which has been conducting research on the subject as far back as 1958 at the company's research laboratory.

in Washington, D.C., in 1951 as Chief of the Tactical Weapons System Group in Research and Development, and, from 1956 to 1959, served in Paris. He returned to the Pentagon in 1959 as Assistant for Foreign Developments, in the Office of the Deputy Chief of Staff for Research and Technology, leaving in 1962 for another Paris tour of duty.

He was promoted to brigadier general in 1961 and retired from active duty in 1965.

* * *

The Swiss Government and Hughes Aircraft Company have signed a multimillion-dollar contract for a modern tactical air weapon system to provide Switzerland with an electronic network of early warning and military defense control. The program, called "Project Florida," has been approved by both houses of the Swiss Parliament.

The contract—for production and delivery of Hughes equipment over a 3-year span—was signed by General Fred Kuenzy, Chief of Switzerland's Defense Supply Agency, and Clarence A. Shoop, Vice President of Hughes Aircraft and an executive of Hughes International.

Shoop said Swiss personnel are scheduled to start training on the system later in 1966 at the Hughes Company's Fullerton, California, plant. The system will comprise a network of military radar stations and air defense direction centers throughout Switzerland in combination with that country's advanced surface-to-air missiles and Mirage IIIS interceptor aircraft.

The system has also been chosen by the Governments of Belgium, The Netherlands, and West Germany.

Hughes also is producing a tactical air weapon control system for Japan, under a contract with the Japanese Government.

* * *

A television camera like the one astronauts will use to broadcast live pictures from the surface of the moon to earth-bound TV receivers has been delivered to the National Aeronautics and Space Administration.

Built by the aerospace division of the Westinghouse Defense and Space Center, Baltimore, Maryland, under contract to NASA's Manned Spacecraft Center at Houston, Texas, the camera is a prototype model of the unit to be used on the first manned Apollo lunar exploration mission.

Stanley Lebar, Westinghouse program manager for the lunar camera, said pictures produced by the unit during the moon exploration mission will be relayed to the earth and processed and distributed by the Apollo

When U.S. astronauts reach the moon they will transmit pictures to earth with this television camera built for National Aeronautics and Space Administration by Westinghouse Defense and Space Center, Baltimore, Maryland. Views of moon exploration will be relayed by NASA to world TV networks.



Three new Swedish military vehicles using Boeing Company turbines as boost powerplants are (from left) the Royal Swedish Army's turretless S tank, a self-propelled 155-mm gun, and a self-propelled 40-mm antiaircraft battery. Each vehicle will carry a Boeing 553 vehicular gas turbine of 450 brake horsepower in addition to a reciprocating engine. Both engines drive into a combining gear. The reciprocating powerplant is used for cruise, the Boeing turbine providing additional power for high-speed maneuvering. AB Bofors builds the vehicles, AB Volvo the reciprocating engines and transmissions.

ground system to the world's television networks.

"The primary objective of the Apollo lunar television camera," Mr. Lebar said, "is to provide real-time, or live, television pictures of the moon mission that can be viewed by scientists and the public on standard television receivers. The quality of the pictures produced by the system will be virtually as good as those usually seen on home television receivers."

Mr. Lebar said the camera will also provide a means of observing the astronauts and instruments in their spacecraft and their activities on the lunar surface. Mission control will thus be able to obtain operational information useful to the mission and to future missions. In addition, the camera will be used to gather scientific information of a general nature.

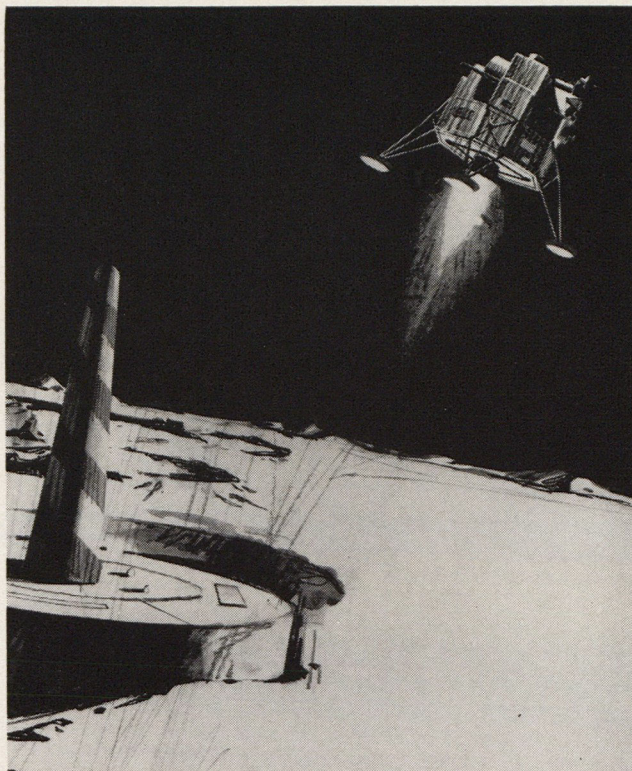
Heart of the camera is the SEC (Secondary Electron Conduction) imaging tube. This type of tube was invented and developed by the Westinghouse Research Laboratories at Pittsburgh, Pennsylvania. It has the ability to obtain good pictures at the very low light levels of earthshine during the lunar night.

Four lenses are provided for the camera. A wide-angle lens with an 80-degree field of view will be used inside the Apollo spacecraft. A telephoto lens will be used for pictures of the earth from the spacecraft and for other pictures outside the Apollo vehicles.

Two other lenses, a narrow-aperture lens for lunar day and a wide-aperture lens for lunar night, are for use on the moon. Automatic features of

(Continued on following page)

Astronauts could be guided to preselected landing point on moon by this lunar transponder designed for NASA by space electronics engineers of Ryan Aeronautical Company, San Diego, California. Device would be positioned on moon by an unmanned spacecraft in advance of a manned lunar landing. It would employ 2 frequencies, one to communicate with earth, another for astronauts approaching lunar surface.



the camera will allow the astronaut to perform the camera mission with no mechanical, electronic, or optical adjustments.

* * *

Moon-bound astronauts could be guided to preselected lunar-landing sites by a homing device in much the same manner that airplanes now follow homing beacons, according to Ryan Aeronautical Company space electronics engineers.

A preliminary study for the design engineering of such a device is under way by Ryan Electronics for NASA's Manned Spacecraft Center, Houston, Texas.

The ultimate plan is to place the device—called a transponder—on the surface of the moon well in advance of a manned lunar landing. Design engineers say the transponder could be positioned on the moon by an unmanned Surveyor-type spacecraft, or by a roving vehicle which would be carried to the lunar surface, then detached from the "mother" craft for reconnaissance.

Investigations by the Ryan engineering staff, led by Robert L. Ogram, indicate that it is feasible to place the transponder on the lunar surface in such a position that it would be subjected to electronic commands from earth.

Two electronic frequencies are envisioned for the transponder system: An S-band (about 2,200 mc) to communicate with the NASA Deep Space Instrumentation Facility (DSIF) on

earth; and an X-band (about 10,000 mc) for communication with the orbiting or descending lunar spacecraft.

Antenna design and DSIF and spacecraft receiver sensitivities are such that 30 milliwatts (.030 watt) of radiated power suffices for reliable operations, according to Ogram.

The NASA requirement in this study is for the device to be ready to operate at any time during a 3-year period after installation on the moon.

Design requirements are being dictated primarily through man's existing knowledge of lunar environmental conditions. Ogram points out that lunar surface temperatures fluctuate sharply—perhaps as greatly as 300° F per hour during eclipse—with a day peak of 275° F (135° C) and -250° F (-157° C) at night.

In addition, the lunar surface is subjected to extremely high-energy nuclear radiation from the sun, which could destroy unprotected electronics components in a period of several hours. Anticipating these hazards, Ryan engineers plan a sufficiently thick coat of "armor" to protect the transponder from these elements.

Conventional power sources, such as currently used solar panels, cannot provide power during the lunar night. Instead, power may be provided by long-life atomic sources known as radioisotope-thermoelectric generators.

While the basic application of the transponder would be to serve as a beacon for lunar-landing vehicles or orbiting astronauts, the study reflects

additional uses for the device of long-range values in the telemetry fields.

Data related to seismology, atmospheric composition and pressure, temperatures, micrometeoritic bombardment, and radiation levels in space could be relayed via the transponder communications systems.

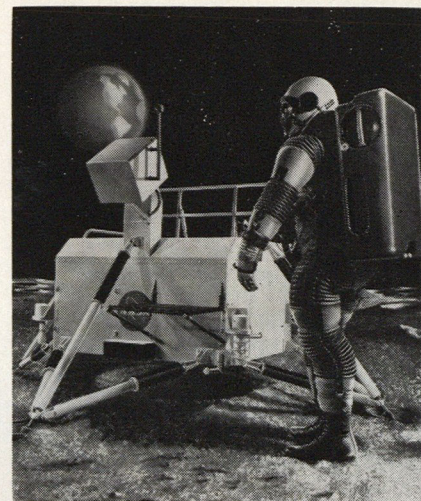
* * *

A new International Programs and Policy Division has been established in the Federal Aviation Agency's Office of International Aviation Affairs. It is headed by Howard W. Helfert.

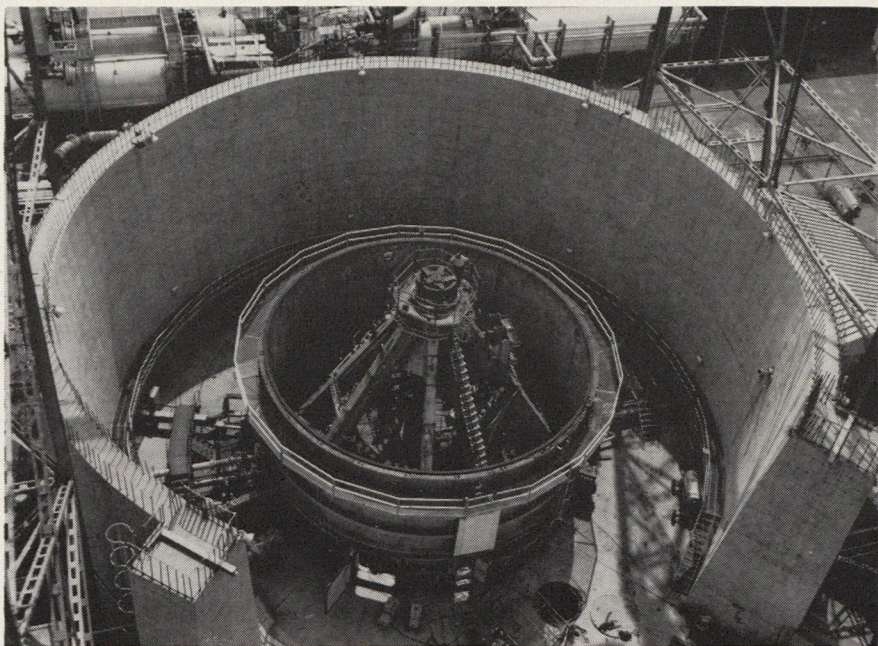
Major function of the new division is the development and coordination of FAA's international aviation objectives within the framework of over-all U.S. foreign policy. The new division also is the focal point for FAA representation at international meetings and advice to other FAA offices and services on international activities having political or national security implications.

Helfert joined the FAA in 1940 as an air carrier inspector after serving as a pilot with United Air Lines. He interrupted his civilian Government career during World War II to join the U.S. Air Force and returned to the Agency following his release from active duty.

He has worked in international activities with the FAA at Washington headquarters and field posts since 1946, when he opened the Agency's Paris office. He remained in Paris 4 years and returned to the U.S. in 1950. He later spent 3 years in Montreal as Alternate U.S. Representative to the International Civil Aviation Organiza-



To explore lunar terrain inaccessible to spacecraft, this manned flying system has been designed by Textron's Bell Aerosystems Company, Buffalo, New York, and built by NASA's Marshall Space Flight Center at Huntsville, Alabama. A cluster of 5 100-pound (45 kg) thrust rockets at base of vehicle provide propulsion affording a moon range of 15 miles (24 km).



Chamber to test S-IVB (third) stage of Saturn launch vehicle, which will boost the Apollo 3-man spacecraft on flights culminating in landings on the moon by 1970, is being readied at U.S. Air Force's Arnold Engineering Development Center, Tullahoma, Tennessee. The S-IVB stage, with 200,000 pounds (90,700 kg) of thrust, is ignited at 400,000 feet (121,000 m). The chamber will duplicate near-vacuum at that height.

tion (ICAO), a Presidential appointment, and as U.S. member of the ICAO Air Navigation Commission. He became chief of the FAA's Field Service Staff in the Office of International Aviation Affairs in 1959, a post he held up to the present time.

* * *

America's largest high-altitude simulation rocket test cell will soon test a section of the nation's biggest space vehicle under altitude conditions.

The test cell, known as J-4, is 1 of 2 high-altitude test cells in the Large Rocket Facility at the U.S. Air Force's Arnold Engineering Development Center, Tullahoma, Tennessee. It has an underground exhaust chamber 250 feet (76 m) deep by 100 feet (30.5 m) in diameter.

The vehicle to be tested is the S-

IVB stage of NASA's Saturn 5 booster, designed to put the nation's astronauts on the moon and to orbit information-gathering spacecraft around Mars and Venus.

The S-IVB, 58 feet (17.7 m) long and more than 21 feet (6.4 m) in diameter, serves as the top stage of both the Saturn I-B and the Saturn 5 vehicles. It is powered by a North American J-2 engine generating thrust of 200,000 pounds (90,700 kg). In its Saturn 5 application, the stage burns briefly to place itself and the Apollo spacecraft into earth orbit. Then, following a coast period, it reignites to increase its velocity from about 17,000 mph (27,370 km/hr) to about 25,000 mph (40,250 km/hr)—enough to send the Apollo craft to the moon.

The tests, to be conducted by ARO,

Inc., operating contractor of the Arnold Center for the Air Force, are expected to run from 6 to 9 months. Fifteen tests, in which the sun/shade environment encountered by a space vehicle will also be simulated, will be made to check the altitude performance, restart capabilities, and over-all reliability of the system.

* * *

The U.S. Army's PATA (pneumatic all-terrain amphibian) vehicle pictured on page 43 of our January 1966 issue is a product of the Ling-Temco-Vought Michigan Division at Detroit, Michigan, and not of the Firestone Tire and Rubber Company. The latter fabricates the vehicle's unique rubber tracks.

LTV began its PATA development at its Dallas, Texas, plant in 1961, constructing a one-man scale model



U.S. Army's PATA (pneumatic all-terrain amphibian) vehicle, shown on page 43 of the January issue, was preceded by this one-man scale model built and tested by its designer, Ling-Temco-Vought Co.

(see cut). The project was later transferred to LTV's Michigan plant. We are indebted to Robert A. Fisette, LTV's Director of European Operations in Paris, and Arthur L. Schoeni of the corporation's Dallas headquarters for calling the error to our attention.

* * *

Seven allied medical officers from 5 countries are attending a 6-month advanced aerospace medicine course at the USAF School of Aerospace Medicine, Brooks Air Force Base, Texas.

Enrolled in the course, which runs until June, are: Captain Wen-wu Shen, Republic of China; Colonel Hansheinz (Continued on following page)



First firing tests of U.S. Army's Chaparral surface-to-air antiaircraft missile system were conducted recently at the Naval Ordnance Test Station, China Lake, California. The Chaparral, a modification of the Sidewinder air-to-air missile, is mounted on an M548 self-propelled vehicle of the U.S. Army.



Seven medical officers from 5 countries are participating in 6-month advanced courses at U. S. Air Force's School of Aerospace Medicine, Brooks Air Force Base, Texas. From left to right, they are: Captain Wen-wu Shen, Republic of China; Colonel Hansheinz Kohler, Lieutenant Colonel Rudolf Schmidt, and Major Hugo Hembach, Federal Republic of Germany; Lieutenant Colonel Isao Kuroda, Japan; Major Hung Bae Park, Republic of Korea; and Lieutenant Colonel Perfecto J. Barcelona, Republic of the Philippines. All are graduates of an earlier basic course in aerospace medicine at the school. They will spend part of the course working at other Air Force bases in U. S.

Kohler, Lieutenant Colonel Rudolf Schmidt, and Major Hugo Hembach, Federal Republic of Germany; Lieutenant Colonel Isao Kuroda, Japan; Major Hung Bae Park, Republic of Korea; and Lieutenant Colonel Perfecto J. Barcelona, Republic of the Philippines.

The officers were previously graduated from a primary course at the

school. In this advanced course, after refresher education, they will observe aerospace medicine in operation by spending a portion of the course on duty at U.S. Air Force bases.

* * *

An advanced Boeing turbine engine has been ordered as a powerplant for a series of military vehicles being produced by AB Bofors of Bofors, Sweden, for the Royal Swedish Army.

The engine is the Boeing 553 vehicular turbine. The 553, an advanced turbine which has been under development at the Boeing Turbine Division for the past 3 years, weighs 385 pounds (165 kg). It has a normal rating of 400 brake horsepower and a maximum rating of 450 brake horsepower.

The turbine engines have been ordered by AB Volvo of Gothenburg, Sweden. Volvo is producing the powerplant and transmission package for

the Swedish vehicles. The number of engines involved in the order was not disclosed.

The turbines are used in a dual powerplant package for the Swedish 37-ton (33.5 mt) S tank, a 155-mm self-propelled gun, and a self-propelled 40-mm antiaircraft twin gun. The vehicles utilize a reciprocating engine for cruise power and the Boeing turbine for boost power in high-speed maneuvers.

The Swedish order for the 553 engines will be administered by FN-Boeing Turbines, S.A., a European firm owned jointly by Boeing and Fabrique Nationale d'Armes de Guerre of Belgium. FN-Boeing Turbines will arrange for manufacture of the 553 powerplants at Fabrique Nationale's own Belgium facilities.

* * *

Most promising aircraft of the future is a helicopter that folds its blades during flight and changes into a swift fixed-wing plane, a Lockheed-California Company engineer recently told the aviation advisory unit of the North Atlantic Treaty Organization.

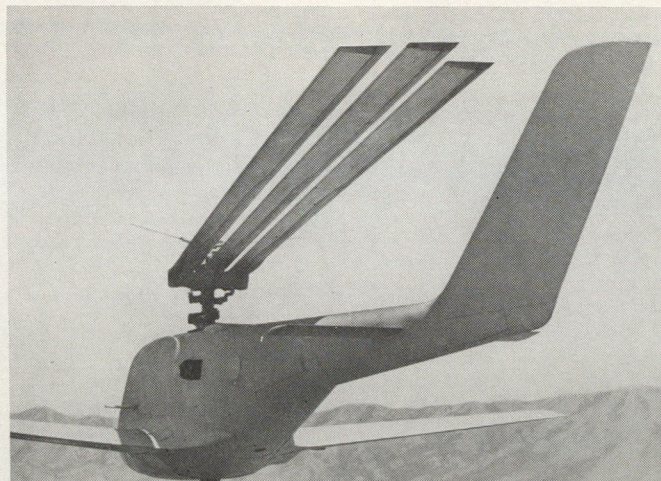
After taking off vertically, the winged helicopter would stop its rotor blades and fold them back and then continue as an airplane with speeds up to 500 miles per hour (805 km/hr), Dr. Richard M. Carlson reported at the meeting of the NATO Advisory Group for Aerospace Research and Development (AGARD).

He said feasibility of the proposed stopped-folded rotor aircraft has been determined by Lockheed engineers in U.S. Government-sponsored and independent studies and in whirl-stand tests using full-scale rotor blades mounted on a 32-foot-long (9.7 m) helicopter test model.

The stopped-folded rotor aircraft, which would extend its blades to hover and land like a helicopter, has outstanding potential in both the com-



To inspect interior of hydrogen tanks in Saturn S-1VB stage, accessible only from 18-inch (45.7 mm) aperture, Goodyear's Aviation Products Division fabricated this inflatable ladder. Deflated, it rolls into 12-inch (30.5 mm) bundle. Inflated with nitrogen, it extends to 11 feet (335 cm), and is strong enough to support 2 men.



Shown in whirl stand test is this test model of a helicopter designed by Lockheed-California Company, which can fold its blades in flight and operate as a fixed-wing aircraft at speeds up to 500 mph (805 km/hr).

mercial and military fields, he pointed out.

As a short-haul transport, it could efficiently fly 60 passengers from city center to city center over a 500-mile (805 km) range. "Direct operating costs appear to be highly competitive with those of short takeoff and landing aircraft," Dr. Carlson noted.

Lockheed studies indicate even greater potential for the stopped-folded rotor aircraft in antisubmarine warfare missions and as a low-altitude military tactical transport, Dr. Carlson said.

Problems associated with stopping the blades in flight are minimized with a rigid-rotor system, according to Dr. Carlson, because the blades are fixed rigidly to the mast—not hinged or teetered as they are on most conventional helicopters.

"Design and analysis studies have indicated," said Dr. Carlson, "that conventional articulation (movement) present in flapping (hinged) or teetering rotors must be mechanically removed when such rotor systems are stopped in flight."

* * *

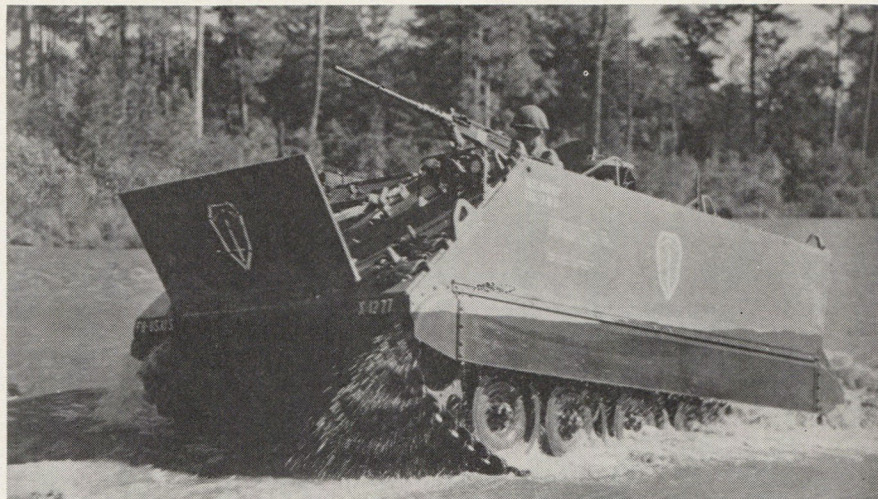
Another approach to the problem of combining effective helicopter VTOL capability with high forward speed is a hot-cycle rotorwing aircraft developed by the Hughes Tool Company under a \$297,000 study contract from the U.S. Army.

An unusual feature of the rotorwing design is that the center is a solid triangular hub with a 13-foot (4 m) radius. At 3 points of the hub are mounted wingtips 10.5 feet (3.2 m) long, making a combined blade sweep diameter of 47 feet (14.3 m).

Power is supplied by 2 General Electric 1/J1 jet engines mounted high on the T-tail, reminiscent of the F-104 and C-141 tail. To power the rotorwing, engine exhaust is piped forward through the rotor shaft and out the blade tips. The aircraft would take off vertically, applying rotorwing. When it achieves horizontal flight speed of 150 mph (240 km/hr), the rotor is stopped with the forward blade resting along the fuselage. The triangular hub and remaining 2 blades then form a delta wing measuring 42 feet (12.6 m) from tip to tip. No mechanism is required to fold or stow blades. GE engines, operating conventionally, then enable the plane to reach speeds above 400 mph (640 km/hr).

Dimensions of the proposed craft are 70 feet (21.3 m) long, 21 feet (6.4 m) high, with empty weight of 12,800 pounds (584 kg), and maximum take-off weight of 28,400 pounds (12,882 kg).

The hot-cycle rotor drive, say Hughes engineers, eliminates need for



This is U.S. Army's versatile M-113 armored personnel carrier, which also serves as a mobile command post, a cargo carrier, a self-propelled flamethrower, and a carrier for several types of weapons. M-113, built by FMC Corporation at San Jose, California, is also being coproduced for Italian Army by OTO Melara, La Spezia, Italy, under an agreement with FMC Corporation, supervised by defense ministries of U.S. and Italy.

a power turbine, thus providing twice the payload to empty-weight ratio of conventional shaft-driven helicopters.

* * *

A 2-phase program to assemble Cessna Aircraft Company's Model 150 in Reims, France, was recently announced by Del Roskam, Cessna President.

The 2-place, single-engine Model 150 will be produced by Reims Aviation, a Cessna affiliate which has been producing the F172 for sale primarily in European and United Kingdom markets since 1963. The 4-place, single-engine F172 is the French version of Cessna's Model 172.

Production of the Model 150 is being developed in 2 integrated phases, Mr. Roskam said. The first phase consists of the assembly at Reims of major subassemblies shipped from Cessna's Commercial Aircraft Division in Wichita, Kansas, while major assembly jigs are fabricated by Cessna for Reims. When the jigs are delivered, Reims Aviation will construct aircraft from detail parts and subassemblies produced by Cessna and its subcontractors.

Engines for the French-produced Model 150s will be procured by Reims Aviation from Rolls-Royce, which also builds engines for the F172.

Most of the French-produced Model 150s will be sold in Europe and the United Kingdom by dealers operating under Cessna's wholesale distribution zone centered in Brussels, but Mr. Roskam explained that Reims-built aircraft will be available for delivery anywhere in the world.

* * *

Spacecraft destined for solar system targets, including the sun, can

be given an effective "kick" en route by a swing through the gravitational field of another planet.

Termed "gravity-assisted trajectories," the technique can make certain space missions feasible which otherwise would not be practical until advanced propulsion systems are perfected, according to John C. Niehoff of IIT Research Institute, Chicago.

The gravity-assist technique is under study for the National Aeronautics and Space Administration's Lunar and Planetary Programs Office, Washington, D.C.

Direct missions to planets more distant than Jupiter will tax the capability of current launch vehicles, making returns on a launch investment questionable in view of the flight times involved. Direct missions passing close to the sun present formidable energy demands which cannot be met with current launch vehicles.

Niehoff explains how gravity-assisted trajectories can alleviate these problems. For example, a gravity assist from Venus on a 115-day Mercury mission launched by an Atlas-Centaur rocket would permit a payload increase from 400 pounds (181 kg) to 1,200 pounds (544 kg), Niehoff said.

A Saturn 1B-Centaur rocket could propel a lightweight spacecraft to Uranus in 4.75 years with a Jupiter assist. Without the assist, the flight would take twice as long.

Niehoff pointed out that Jupiter, with its large mass, is the most effective planet from the standpoint of gravity-assist performance. His analysis reveals that a gravity assist from Mars or Venus to a Jupiter target provides little or no improvement over

(Continued on following page)

direct flight. Jupiter assists, however, will aid missions to outer planets.

In fact, he said, it has become apparent that post-Jupiter objectives are almost limitless, extending from trajectories which will return a spacecraft to earth to trajectories which carry the spacecraft completely out of the solar system.

* * *

A solid-state computer with an expected reliability 20 times as great as in the computer now used in F-106 interceptors is being designed by Hughes Aircraft Company for the U.S. Air Force.

The new system, HCM-204, is a general-purpose digital computer of less than half the weight and size of the vacuum tube computer now used in the MA-1 navigation and weapon control system of the Mach 2 Delta Dart jet interceptor. The design development is being conducted under contract with the Aeronautical Systems Division of Wright-Patterson Air Force Base in Ohio.

The 20-to-1 increase in computer reliability will improve the rate of mission success, will lower maintenance costs, and will make possible a wider tactical use of the F-106.

The transistorized circuitry of the HCM-204 uses etched printed circuit boards linked together by an automatic wire wrap process. This technique is also used by Hughes in conjunction with the Polaris missile Mark 84 fire-control system. Heart of the new computer is an air-bearing memory drum, 3 inches (7.6 cm) in diameter and 3.25 (8.2 cm) long, which will provide storage for more than 600,000 bits and will have a memory capacity of 33,000 words, triple the capacity of the present system.

* * *

A new infrared guidance system will soon be tested and evaluated at the U.S. Army's Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland.

The Army will study this concept as a possible guidance technique for a third-generation airborne antitank weapon for helicopters. Developed by Aerojet-General Corporation of Azusa, California, as part of a proposed missile called Teton, the infrared system directs an invisible beam of light onto its target, and the missile rides the beam from the helicopter or aircraft to the impact point. A stabilized sight allows the gunner to follow his target even though the helicopter or aircraft maneuvers to evade enemy fire. If the missile is pursuing a moving vehicle, Teton gunners score a hit by holding the infrared beam on the target, the missile chasing the vehicle like an enormous curve ball.

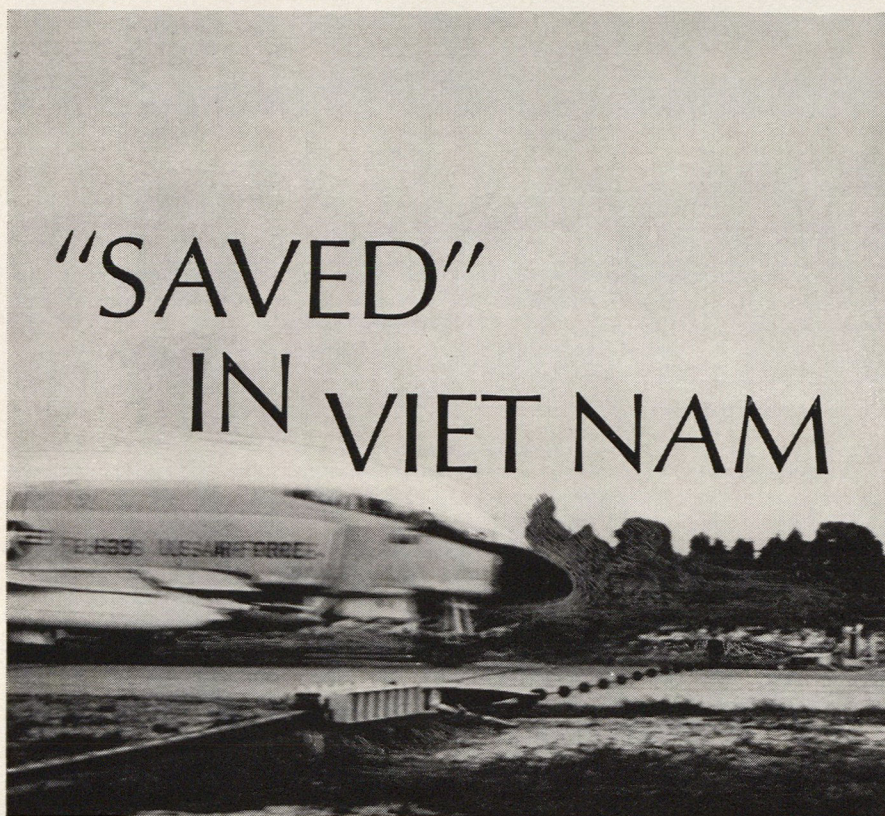
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Greece is receiving radar equipment to modernize its air-route traffic-control center at Athens from the U.S. Federal Aviation Agency.

Included are a radar bright display system (RBDE), a video mapper to be used with the existing Athens radar system, and a microwave link (RML) to bring radar data into the center from the radar site located some distance from Athens.

The RBDE is the same as that used in FAA's air traffic control facilities. The system involves a storage tube which converts raw radar data into a television-type display which can be used in ordinary daylight or lighted rooms. It also provides target trail history which tells air traffic controllers not only where an airplane is but also where it has been, the direction it is going, and gives a rough estimate of speed. Rates at which the stored information fades can be changed by the controller to suit the needs of the air traffic situation.

The microwave link was formerly used by FAA and was to be completely refurbished at the Collins Radio Company, Cedar Rapids, Iowa, prior to shipment to Greece. ☆☆☆



The United States is doing its best to make sure that the gallantry of its fighter pilots isn't squandered in preventable landing and takeoff accidents. Large numbers of Bliss BAK-12 portable runway arresting units are in service at Vietnamese air bases. One fighter squadron



Vietnamese prepare ground to receive Bliss BAK-12 unit.

reports no less than sixteen emergency arrestments in a single month! For detailed information on the BAK-12 and other Bliss arresting gear units, write E. W. Bliss Company, 101 Chester Road, Swarthmore, Pa. In Europe: E. W. Bliss, 54 Boulevard Victor Hugo, St. Ouen (Seine), France.

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3. Dominican Republic.....40 minutes	11. Lebanon.....9 hours	19. Guatemala.....35 minutes
4. Berlin.....5½ hours	12. Greece.....7 hours	20. Algeria.....5 hours
5. Laos.....13 hours	13. Chinese Invasion of India...12½ hours	21. Korea.....9 hours
6. Congo.....10 hours	14. Indonesian Revolt.....13½ hours	22. Chinese Reds take over China 10 hours
7. Cuba.....5 minutes	15. Muscat-Oman.....11 hours	23. Israel Blockade.....9 hours
8. Tibet.....12½ hours	16. Hungary.....7 hours	24. Viet Nam.....13 hours

This global capability was demonstrated in an 18-hour, 10,000-mile non-stop flight of four Tactical Air Command Phantoms from MacDill AFB, Fla., December 1-2, 1964.

Fully loaded Phantoms operate easily from hard surface 5,000-foot runways, even with bombloads of more than 7 tons. Hundreds of serviceable asphalt runways, already built, can now be used for combat operations of the Phantom

now entering service with the United States Air Force. Few other jet fighters can now even operate from short runways like these. None can match the Phantom's capability for bringing Mach 2 multiple-mission, all-weather, heavy load carrying air power to advanced fighter strips.

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ST. LOUIS



What's an F-5 doing here?

The F-5B with RCAF markings is crossing the U.S.-Canadian border at Niagara Falls. Canada is among the twelve nations which have selected versions of the supersonic F-5. These versatile fighters are now flying

or will fly soon in the air forces of four NATO nations, two SEATO nations, and six other nations of the free world.

NORTHROP F-5
NORTHROP CORPORATION, BEVERLY HILLS, CALIFORNIA, USA