Rx FOR Spaceborne Deterrence

- MILITARY MAN IN SPACE
- NUCLEAR KNOW-HOW
- LOWER COSTS
- MANEUVERABILITY
- RELIABILITY

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FOUR YEARS after Kitty Hawk, in another technical age, it was of small concern that scientists and governments couldn't see ahead eight years or so to the Spad or the Fokker D-VII. The unknowns of flight, let alone military operations, in the atmosphere were unfolding at a pace that compensated for a lack of decision and less than a maximum effort in preparing for the air age.

Today, less than four years after the Kitty Hawk of the space age, as technology continues to telescope time, we have a better view of the future but less time to prepare for it. The ultimate uses of space are as dim today as the future of aircraft was in 1908, but the small window that science and technology are opening on the universe leaves no doubt of the perils involved in occuping second place.

We know enough about space and the risks of wasted time to know that we must probe in several directions immediately and simultaneously to ensure that the future exploitation of space is indeed peaceful.

The critical areas, in which immediate decision and rapid action are required, are discussed herewith:

Nuclear Weapons Effects

Technological secrecy, especially about the effects of nuclear weapons, makes it difficult to fully and intelligently discuss the strategic systems which maintain the peace now and must do so in the future.

Any discussion of strategic weapons today must be heavy with conjecture. Even the most knowledgeable and experienced atomic scientists are not able to predict exactly what would happen if barrages of nuclear weapons were to be detonated in the upper atmosphere and in space itself.

However, a constantly increasing understanding of the laws of physics has allowed the general effects of such a barrage to be understood for several years. They are serious enough to have affected strongly the rate of development for some strategic weapon systems. For instance, some large multimegaton weapons, now considered feasible, can vaporize vehicles in space and in the upper atmosphere at distances well over fifty miles. They can have a lethal effect on unshielded space-vehicle crews up to several hundred miles away from the blast. And they can interfere with the operation of vital electromagnetic systems in the atmosphere and in space.

Obviously the prospect of the mass use of such weapons could have a controlling effect on the design and operation of such strategic systems as manned space vehicles, ICBMs, anti-ICBMs, and high-speed atmospheric weapons such as the RS-70 and Pluto nuclear-ramjet missiles.

Not all of these weapon systems may be useful in an all-out war. On the other hand, some systems could penetrate enemy defenses more easily after a nuclear bombardment in the upper atmosphere. In the case of RS-70, for example, the fact that it is manned has important implications as to its capabilities in a partially blanked-out electronic environment. In the world of the blind, a one-eyed man is king.

The nuclear-weapon problem is a complicated one, and it is clear that no one today knows what the eventual offensive and defensive implications will be.

The resumption of US atmospheric nuclear tests not only implies this, but President Kennedy stated it explicitly when he said, ". . . until we measure the effects of actual explosions in the atmosphere under realistic conditions, we will not know precisely how to prepare our future defenses, how best to equip our missiles for penetration of an antimissile system, or whether it is possible to achieve such a system for ourselves."

Only by testing can we obtain the experimental information necessary to free the whole nuclear weapon effects question from a morass of incomplete data and hypotheses. Only then can reasonable decisions, agreeable to both military men and scientists, be made on future weapon developments.

It is typically ironic that the nation is being forced into these vital tests. The Soviet test series last fall, which precipitated the US action, apparently did not reveal any fundamentally new physical effects or phenomenon. They primarily proof-tested new weapons and investigated in detail the complex interactions between nuclear blasts and the earth's magnetic field first revealed by US Argus and Hardtack explosions in 1958. These four-year-old US experiments demonstrated, in principle, that radar and radio communications could be disrupted by atomic weapons. However, they were limited in scope and raised more questions than they answered. They created an anxiety among government officials that has grown worse with time.

US monitoring indicates that the large Russian blasts made many types of radar and radio equipment inoperable at certain locations for long periods. However, quantitative data could not be gathered because the Soviets did not reveal precise data on the location of the explosions, their exact yield, and the time of detonation. So the US must get its own data by setting off weapons of varying yields at varying altitudes and latitudes.

In addition, the official announcements of the US test series have stated that a number of different types of warheads and weapons will be proof-tested.

Argus

The Argus experiments were the first to show that electrons from a nuclear weapon could be trapped in the earth's magnetic field just as extraterrestrial radiation is trapped in the part of the field known as the Van Allen belt.

Nicholas C. Cristofilos, who came from Greece to work for the Atomic Energy Commission, is generally credited with conceiving the experiments. Cristofilos theorized that electrons released by a bomb explosion at the right point above the earth would travel with almost the speed of light along the curved lines of force of the earth's magnetic field. As the electrons neared the magnetic poles, where lines of force converge, he believed that they would be reflected and reverse their direction. Consequently the electrons

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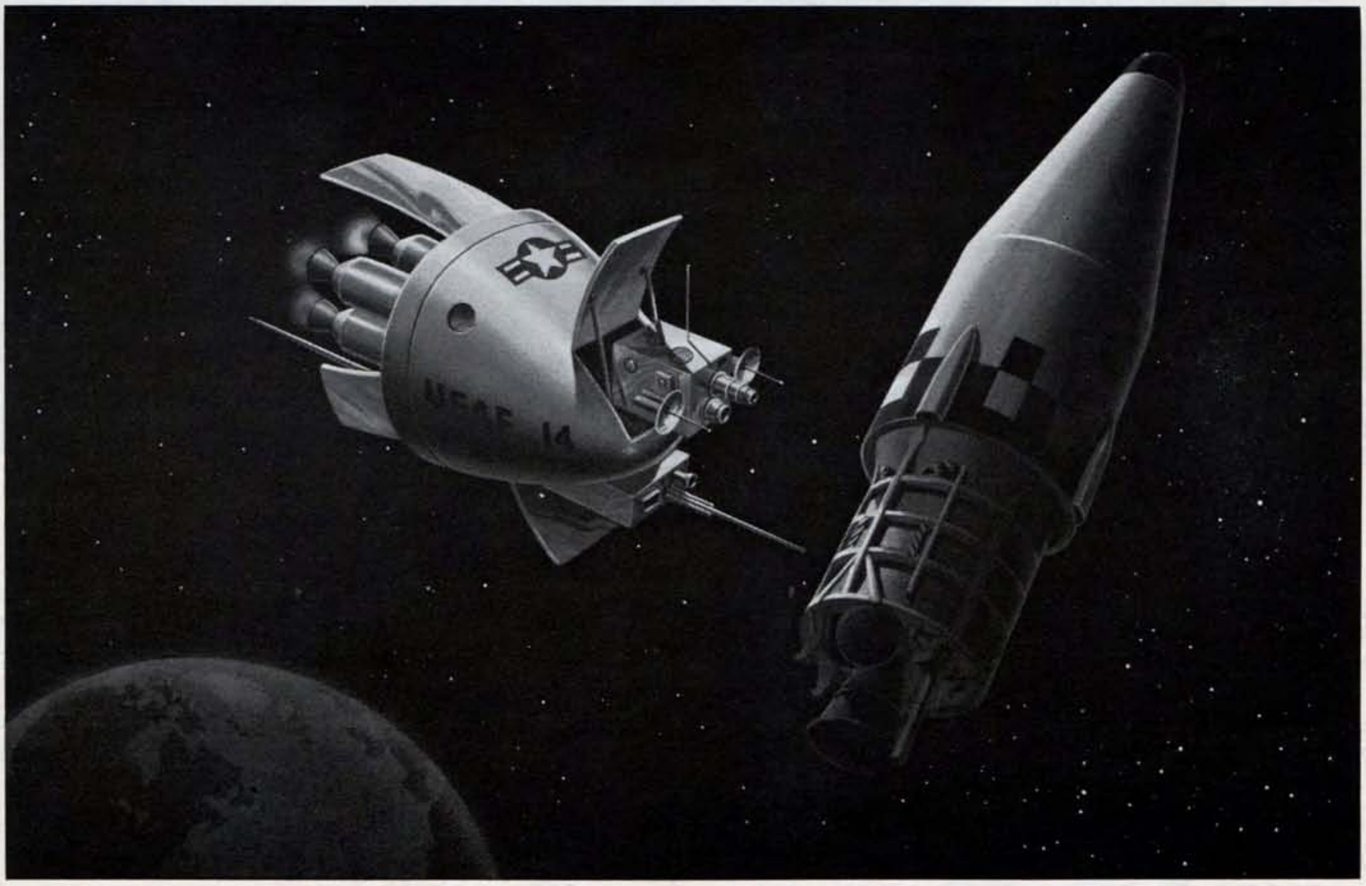
Satellite inspector vehicle is shown in artist's conception below, closing with an Agena-B in deep space. A variety of sensors are checking electromagnetic signals coming from the satellite or being sent to it from other points. Complete checks of hostile satellites require many sensors, and weight is saved if the inspector vehicle is manned.



would oscillate in a resonant fashion between the north and south magnetic poles and be trapped for extensive periods near the earth.

Cristofilos also predicted that the oscillating electrons from a single burst would spread to the east and to the west until the earth was encircled (*see illustration pages 54 and 55*). No one could predict the energy intensity of the electron sheath or how long it would last.

To test the Cristofilos theory, three nuclear weapons of one- to two-kiloton yield were exploded, on August 27, August 30, and September 6, 1958. All of the shots took place in the South Atlantic Ocean over 1,000 miles southwest of the Cape of Good Hope.

In April 1959, Dr. Herbert York, then Director of Defense Research and Engineering, and Dr. Frank Shelton, Technical Director of the Armed Forces Special Weapons Project, described the Argus results to the House Committee on Science and Astronautics. The House report on the subject included the following statements, "Some of the electrons inserted into the magnetic field were not trapped, but plunged into the atmosphere, creating a temporary aurora at the two mirror points [reflective points near the magnetic poles] for an hour or so. . . . [The aurora] had the effect of interfering with local radio communications, but not on a worldwide basis. . . . In an hour or so the electrons spread to form the world-encircling shell. The effects persisted quite noticeably for a week or more, with some traces left even after a few months. . . . A nuclear explosion in space represents a way to interfere with local communications at the mirror point through the creation of an artificial aurora. Thus a weapon exploded near Tierra del Fuego would have the consequences of a natural magnetic storm in the New York area, or one exploded in the right point in the Indian Ocean could blanket Moscow."

The report also stated that manned space vehicles would not necessarily be harmed by the belts of man-made radiation because they could easily fly at different altitudes from the trapped electrons.

It was pointed out that the Argus tests gave no positive information on the possibility of creating an "umbrella" of radiation which could protect against ICBMs, or ". . . whether the nuclear warheads of such missiles would be 'cooked' to explode prematurely."

In conclusion the report made the obvious comment that the Argus experiments were made with very small test devices. They provided no way to predict the effectiveness of multimegaton explosions in causing widespread communications and radar blackout, in creating huge bands of lethal radiation near the earth, or in heating or damaging ICBM warheads. Theoretically, a large bomb would create many more electrons than could be trapped by the magnetic field at any altitude. It is believed that the excess electrons would leak out of the lines of force and possibly create disturbances over great areas of the atmosphere and space.

The Russians were the first to gather detailed data on very large explosions.

Hardtack Tests

Two "megaton devices" have been detonated in the stratosphere by the United States, part of the Hardtack series in 1958. Neither was in the right location to cause intense trapped radiation in the manner of Argus.

The first explosion, called Teak, occurred on July 31 at an altitude of 252,000 feet near Johnston Island, about 700 miles southwest of Hawaii and 1,000 miles north of the equator.

The Teak shot is officially described by the Atomic Energy Commission as, ". . . by far the most spectacular shot ever fired by the United States." More than ninety-nine percent of the atmosphere was below the detonation, and it can be considered in most respects a space shot. As such its visual and radiation effects were considerably different from those of nuclear explosions occurring near the ground.

The fireball reached a diameter of about eleven miles in 0.3 of a second, much faster than fireball growth in the atmosphere. In 3.5 seconds the fireball was more than eighteen miles in diameter. It retained its spherical shape and glowed brightly for about five minutes.

The fireball rose rapidly as it formed and reached an altitude of roughly ninety miles one minute after the explosion.

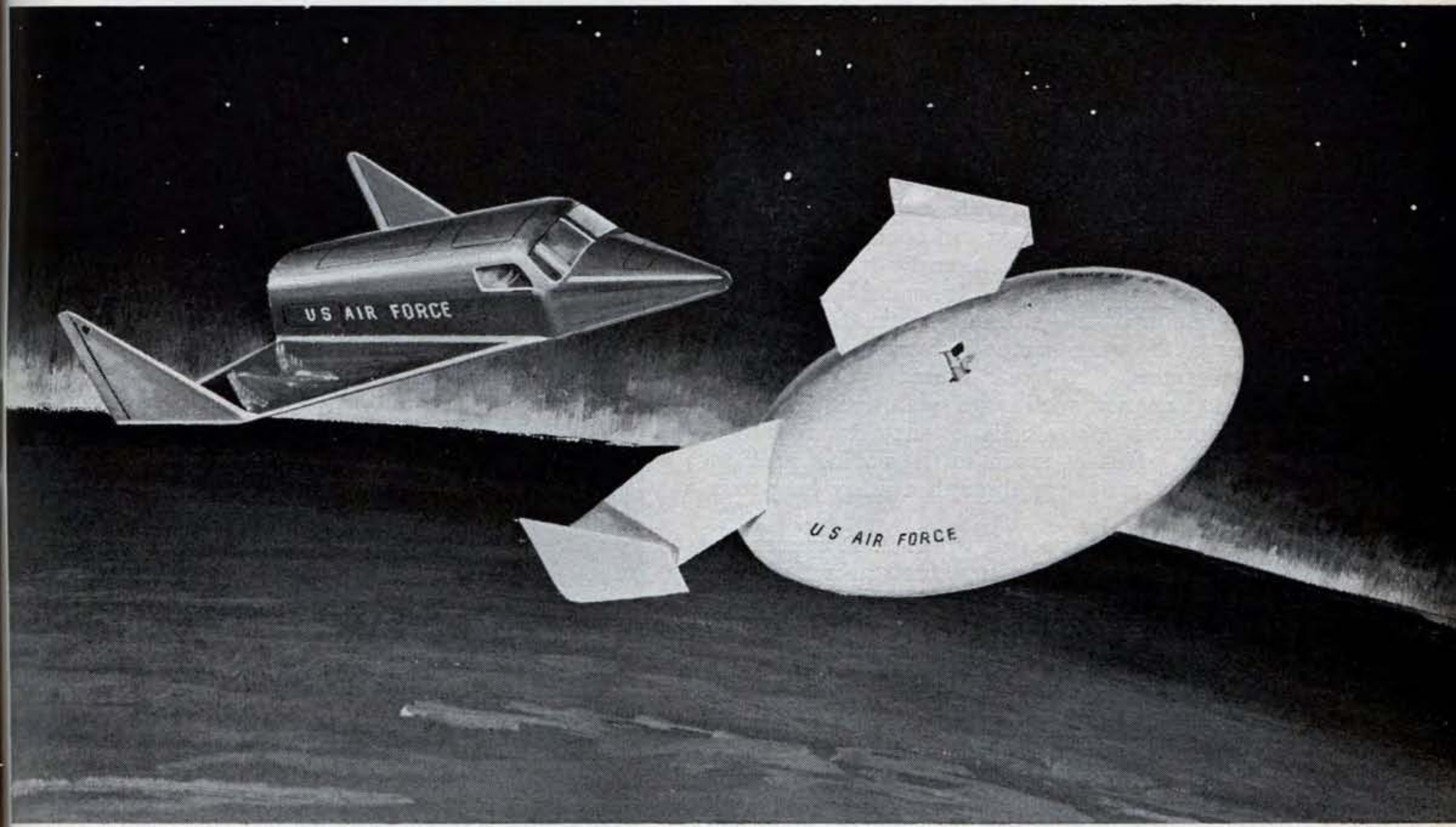
A red, luminous, spherical shock wave spread rapidly away from the fireball to a diameter of nearly 600 miles within six minutes after the burst. It is believed that this visible wave was caused simply by the passage of a shock front through low-density air. Observers stated that it gave the explosion the general appearance of a very bright light inside a red balloon.

Two other unusual and spectacular effects were clearly visible. An aurora developed on the bottom of the fireball and spread rapidly to the north. And a series of purple streamers left the fireball and streaked northward.

The second device, named Orange, was detonated in about the same location at 141,000 feet altitude. Its fireball did not develop as rapidly, and an aurora did not appear until the ball had risen for several minutes.

In general, electronic interference from the two shots was caused by modifications to the ionosphere so that some radio waves were absorbed or scattered and not reflected in normal fashion. The AEC reported that, ". . . serious absorption was observed . . . at Johnston Island for hours after the [Teak] shot, and lesser absorption was observed [at points 700 miles to the north and northeast]. . . . Orange gave numerous echoes long after the shot, but the effects appeared to be less than those for Teak. . . . High-frequency communications blackout occurs on some, but not all channels [after Teak]. . . . Some communication channels were open at all times. . . . Absorption on the order of minutes occurs near the shot even at ultra-high frequencies."

Radar operation was also disturbed. Both shots blanked out two types of airborne radar used as moni-



Dyna-Soar hypersonic glider (left) is scheduled for high-speed flight testing in 1964 to prove that highly maneuverable reentry vehicles can be operated. The saucer-shaped vehicle at right is under serious study because it has a high internal volume. It has more maneuverability than the Gemini and Apollo spacecraft but not as much as the Dyna-Soar.

toring devices. The blank out continued for nearly an hour and covered a large oval area in the directions of the explosions.

Detailed studies of the Teak and Orange fireballs were undoubtedly made to determine their possible effectiveness against ICBM warheads. Fireballs, created either by nuclear explosions or by other means, are believed to have potential as an ICBM defense.

Radiation Effects

Other effects of nuclear weapons in space can be described by reference to simple physical laws. Thermal effects in most cases probably will be minor compared to the radiation effects, and its primary damage would be done to the human eye. The absence of air means no blast effect. It also means that nuclear radiation will not be scattered and slowed down by air molecules. Therefore, nuclear weapons would be effective over much greater distances against space vehicles than against vehicles in the lower atmosphere or against objects on the ground.

In space, radiation particles from a burst travel out in straight lines. This terrific burst of radiation energy traveling near the speed of light can be visualized as an ever-expanding sphere with the radiation particles on its surface. While close to the burst the particles are packed tightly together, and their flux or the number of particles per square foot on the sphere's surface is very high. As the radiation front grows outward in all directions from the point of explosion, the particles spread out evenly, and their flux decreases. Therefore the greatest protection against nuclear explosions in space is to get great distances away, into areas where the number of particles per square foot is down to a safe level.

A twenty-megaton burst in space would kill a man in a light unshielded spacecraft at a distance of 400 miles. Closer spacecraft would be heated by the radiation, the intensity depending upon the construction materials of the vehicle and its distance from space zero. There would be a point relatively close to the burst at which a given vehicle would be vaporized. For example, a vehicle with aluminum sides 0.1 inch thick would be vaporized at more than twenty miles by a twenty-megaton explosion. Much larger weapons are feasible, and their vaporization, heating, and lethal ranges for relatively unshielded personnel would be correspondingly greater.

Two basic design approaches could provide protection against such weapons—shielding and maneuver.

The shielding state of the art in the US is far advanced, thanks to the now-defunct nuclear aircraft program. This technology has been widely applied to the spacecraft problem in industry studies. It appears possible to use shielding materials for basic structure in many cases to conserve weight. Thick ablation materials for reentry cooling can also serve as shields against certain types of radiation. Water, fuel, and other materials containing hydrogen can shield against heavy particles. Strong magnetic fields to deflect some types of particles have also been considered.

Virtually every shielding scheme adds great weight

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to a vehicle. It seems certain that operational military space vehicles will require much more shielding and consequently be much heavier than their civilian counterparts.

This shielding should provide a bonus in that it would allow military spacecraft to operate in the Van Allen belt and areas of high-intensity trapped radiation for considerable periods. It would also protect against radiation storms emanating from the sun.

Maneuver, the other method of protecting against nuclear weapons, also costs added weight. High-thrust rocket engines with large quantities of propellant are required. Many believe that this propulsion system might weigh as much as the vehicle itself to survive without refueling, through a fairly long-term hostile situation.

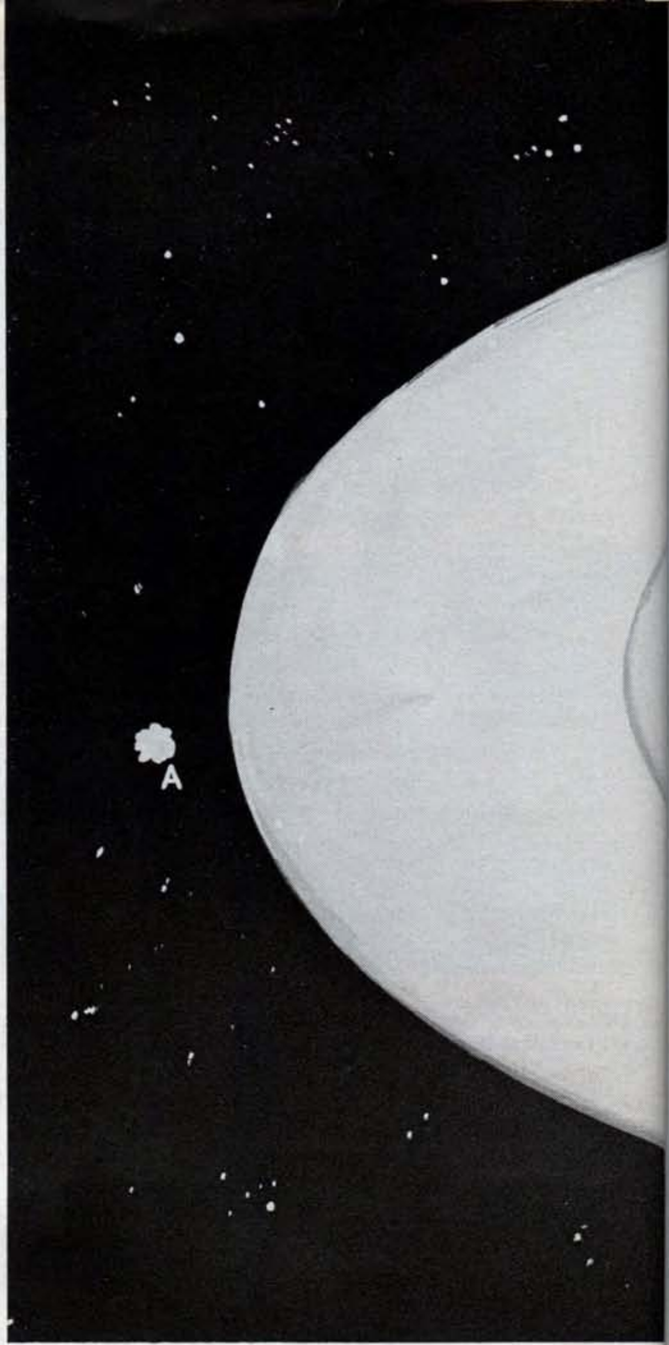
However, the weight seems worth it. It apparently will be relatively easy to hit spacecraft near the earth with large weapons from the ground but as a vehicle moves out the problem gets progressively more difficult. Space is a very large place. Space vehicles at 10,000-mile altitudes or more should be able to see weapons coming from the earth in time to evade them by several thousand miles. The warning time would be considerably longer than the thirty minutes' maximum for an ICBM attack on earth.

Most of the maneuvering probably will involve large changes in altitude for this requires much less fuel than changes in orbital plane. Under most circumstances it will be possible to go from a circular orbit near the earth to a highly elliptical orbit with a maximum altitude of over 200,000 miles for the same expenditure of propellant it would take to change the plane ninety degrees from an equatorial to a polar orbit.

There is no doubt that nuclear weapons would pose a grave threat to spacecraft, especially in their embryonic years. However, there may come a time when our deterrent systems will have to be moved out beyond the Van Allen belt.

Weapons that could force such a move have been discussed by Donald G. Brennan in a chapter contributed to the recent book *Outer Space, Prospects for Man and Society*. Mr. Brennan, a mathematican at the Massachusetts Institute of Technology's Lincoln Laboratories, said, "Another . . . system . . . more disturbing, would involve placing in orbit a limited number of devices of very large yield (a few hundred megatons or more) which would be detonated at orbital altitudes (say 150 miles) rather than be brought to earth before detonation. The thermal effects from such a high-yield device could set fire to a large fraction of a continent, the extent of which probably would be limited to only that which could be 'seen' from the point at which the device was detonated, except that areas protected by cloud cover at the time of detonation probably would not be ignited."

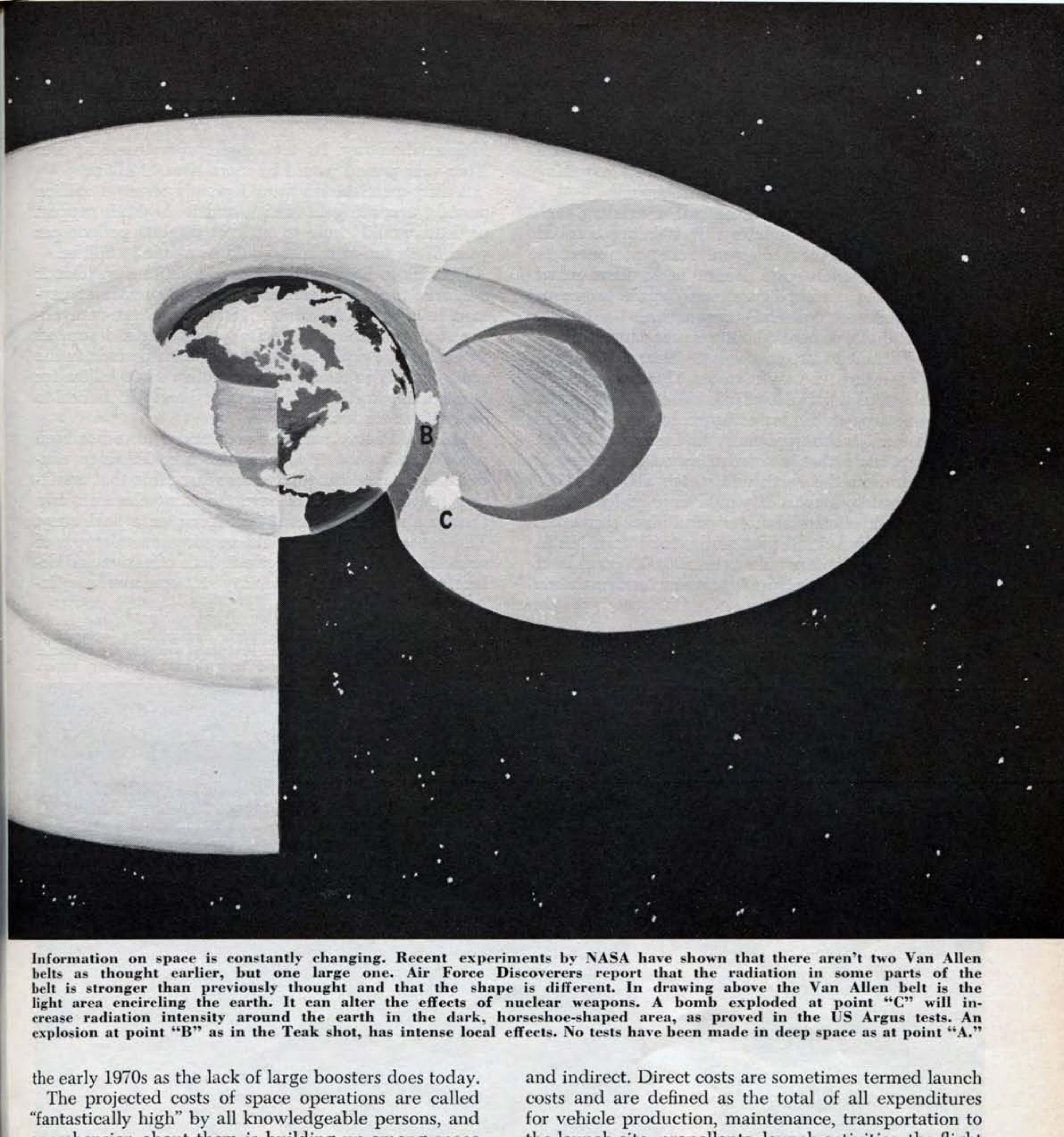
Further indication of the possibility of a forced move of strategic weapons in the future was given by Lt. Gen. James Ferguson, DCS/Research and Technology, USAF, in testimony before the Congress (*see page 71*). General Ferguson said, "Should the survivability of earth-based systems become marginal, deploying systems in deep space may be the only means of providing dispersal and remote location to ensure survival."



Launch Costs

The lack of large booster rockets has been the main technical factor which prevented the US from attaining unquestioned preeminence during the first four and a half years of the space age. Really big, reliable boosters could have launched large and versatile satellites. Projects that are now the subject of bitter argument could be handled easily as bonuses in heavy payloads.

The deficiency in booster power is being overcome. Four large launch vehicles, with first-stage thrusts ranging from 1.5 million to ten million pounds, are being developed. However, large boosters do not automatically guarantee success. Cost effectiveness is a critical item. Gross miscalculations on cost could hobble US space activity as much in the late 1960s and



Information on space is constantly changing. Recent experiments by NASA have shown that there aren't two Van Allen belts as thought earlier, but one large one. Air Force Discoverers report that the radiation in some parts of the belt is stronger than previously thought and that the shape is different. In drawing above the Van Allen belt is the light area encircling the earth. It can alter the effects of nuclear weapons. A bomb exploded at point "C" will increase radiation intensity around the earth in the dark, horseshoe-shaped area, as proved in the US Argus tests. An explosion at point "B" as in the Teak shot, has intense local effects. No tests have been made in deep space as at point "A."

the early 1970s as the lack of large boosters does today.

The projected costs of space operations are called "fantastically high" by all knowledgeable persons, and apprehension about them is building up among space planners. Relatively unsophisticated systems will cost billions over their useful lifetimes. Large-scale space operations involving numbers of vehicles, both manned and unmanned, will cost many, many billions. Cost estimates for the Apollo moon expedition ranging from $20 billion to $40 billion are not unique; they are indicative of the problem. Military operations are even more vulnerable to high costs because they are not one-shot expeditions. They cannot be intermittent. They must be conducted on a round-the-clock basis with many vehicles.

The space cost problem is many sided, but most analysts split it into two familiar categories—direct and indirect. Direct costs are sometimes termed launch costs and are defined as the total of all expenditures for vehicle production, maintenance, transportation to the launch site, propellants, launch activities, the flight crew, and all other recurring costs. Indirect costs includes research-and-development work on the spacecraft, boosters, and all other equipment; construction and maintenance of the range; ground-support equipment; construction of the launch facility, and all other nonrecurring costs.

For the next decade the split between direct and indirect costs is expected to be about fifty-fifty with the probability that in the early years indirect costs will absorb up to seventy-five percent of all space funds. As the necessary space technology is created and the base of launch sites and manufacturing facili-

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ties is completed, a growing share of the money will be devoted to operations, with launch costs requiring more than half in the early 1970s and beyond.

Thus a steady reduction in the cost of sending each pound into space is mandatory. It is being cranked into all long-range plans that are being presented to the public. If launch costs cannot be lowered many times below the current figure, many space programs now envisioned are financially impractical.

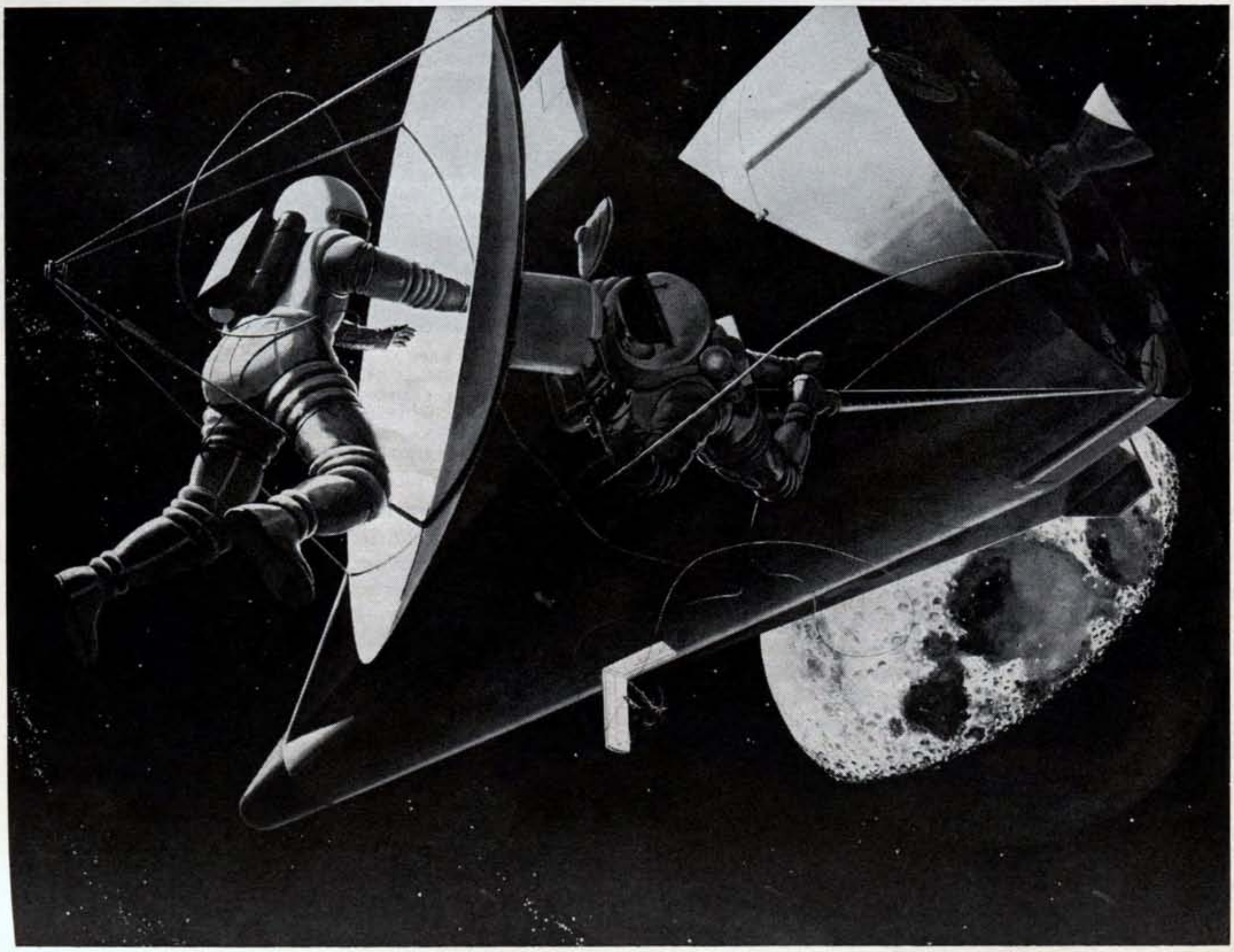
There is disagreement about current launch costs, and it is difficult to set an accurate figure. However, virtually all estimates vary between $1,000 and $2,000 per pound of payload placed in a 300-mile-high orbit. Even if one accepts the lower figure, it is obvious that current launch techniques must be improved. NASA planners estimate that a six-man space laboratory in a low orbit near the earth will weigh about 100,000 pounds. At today's rates it would cost at least $100 million to build such a laboratory and place it in orbit. And this is only a small part of the total cost. NASA also estimates that it would take 200,000 pounds of payload each year to resupply, recrew, and maintain such a laboratory. Its total direct operating cost over a ten-year period would be more than $2 billion.

A fifty-man station would weigh about a million pounds, according to NASA, and its logistics support payload would come to at least 500,000 pounds per year. So its ten-year cost would be about $6 billion.

Looking a little farther ahead, NASA says that it will take the equivalent of six million pounds of payload in a 300-mile orbit to establish a ten-man observatory on the moon. Its yearly logistic support would be the equivalent of 3.5 million pounds in the same orbit. The total cost would then be $6 billion for constructing the moon observatory and $35 billion to maintain it for ten years.

Military operational cost predictions have not been made public, but it is possible to make some educated estimates. First, it seems reasonable that a military space force would have the same elements as a theater air force, a naval task force, or a field army. The space task force would require several types of vehicles and weapons to give it both offensive and defensive power, the capability to communicate in-

Crewmen will have to make repairs to space vehicles or total reliability will never be high enough for operations lasting for many weeks or months. Hopefully men in relatively simple suits (as below) can maintain and repair external equipment. It appears that sizable stores of on-board spares will have to be carried in vehicles in deep space.



ternally, with other military forces, and with higher headquarters. Finally, it would need a resupply and logistics network in space in order to independently maintain its maneuverability and striking power over an extended period.

The cost of constructing, launching, and maintaining such a military force undoubtedly would equal that of ten fifty-man space stations, or at least $60 billion over a period of ten years. And the cost could be much higher.

The total cost of the civil and military operations cited above is more than $100 billion over a decade. Yet these figures do not include the R&D and other nonrecurring costs. And they cover only a small part of what must be spent operationally if the US expects to achieve and maintain true dominance in space.

Obviously many current space plans will prove academic, never to be implemented, if launch costs are not reduced drastically—by an order of magnitude at least. Most official spaceflight forecasts are based on a reduction to at least $100 a pound during the next ten to fifteen years. Some planners believe a concerted national effort should be made to reach $10 per pound over the same period, to ensure that at least $100 per pound would be attained.

The $10-per-pound goal is ambitious. But if it could be achieved there would be no doubt about US success in space. A multitude of operations would become feasible. And, best of all, arguments over the allocation of funds between civil and military projects would be minimized.

Here's what a reduction to $10 per pound would mean: The six-man space laboratory would cost only $20 million over ten years compared to $2 billion; the fifty-man station would be reduced from $6 billion to $60 million; the ten-man lunar observatory would cost $410 million instead of $41 billion. And a hypothetical military task force would have operating costs similar to those of SAC today.

Lowering launch costs 100 times, while not easy, is apparently technically feasible. A great joint DoD-NASA research-and-development effort would be required, but the objective is critical to an adequate and harmonious US space program.

The beginning of cooperation in this area was achieved last year. The Gollovin Committee, an *ad-hoc* group formed from DoD, NASA, and industry, met for several months to decide on a national booster program. The objective was to establish booster sizes for the moon program. In addition, a smaller launch vehicle for more repetitive military operations was considered. Plans for four vehicles were agreed upon, and they are intended to perform the majority of civil and military booster missions for the next decade or longer.

Current forecasts of launch costs for the four are listed below:

Saturn C-1—payload in the 25,000-pound range; cost per launch around $20 million; cost per pound of payload in orbit about $800.

Titan III—payload in the 25,000-pound range; cost per launch $8 million to $12 million; cost per pound of payload around $400.

Saturn C-5—payload around 200,000 pounds; cost per launch $50 million to $70 million; cost per pound of payload around $300.

Nova—payload around 400,000 pounds; cost per launch $80 million to $100 million; cost per pound of payload around $200.

The above costs are predicated on no failures of launch vehicles. If twenty percent of the boosters fail—a reasonable conclusion—operating costs will go up twenty percent.

From here it looks as though the US probably will have to live with average launch costs of around $500 per pound for another decade. Saturn C-1 and Titan III will be the main operational vehicles. Even though the Saturn C-5 and probably the Nova will be in service before the end of the period, it seems prudent to allow for a few failures of all of these boosters.

Some projects, such as the nuclear rocket and air-breathing boosters, which could dramatically lower launch costs, are in early stages of development and planning and won't be available before ten years. However, other systems, which possibly could lower costs before that time, are being abandoned by NASA to stay within the budget.

Basically, there are five ways to reduce launch costs:

- **Increase Reliability.** There are two fundamental ways to go about this. One is to fire a booster many times during development. In the past, this has been the only method that worked. US boosters and military rockets generally have not attained seventy-five percent reliability until they have been fired close to 100 times. The second approach is to learn more about designing rockets and to test systems more thoroughly on the ground. This is the approach being tried with Saturn C-5 and Nova. Hopefully, they will demonstrate more than an eighty-five percent reliability after only ten firings. It is also hoped that most of the early development firings can put useful payloads in space. Some NASA specialists point to the Titan II as a valid sign that boosters designed today can be much simpler, more efficient, and presumably more reliable.

- **Giantism.** Building boosters bigger increases the percentage of their total weight that can be carried as payload. This lowers launch costs. It is the only booster approach that could have been taken for the moon expedition if several rendezvous operations near the earth were to be avoided. A year ago many people argued against dependence on rendezvous operations for the moon expedition or for any purpose during the next ten years. Many people still hold to this position. But there is a growing belief that the hazards and difficulties claimed for rendezvous operations have been vastly overrated. Saturn C-5 and Nova use the giantism principle in part to get low launch costs. It will be interesting to see whether these vehicles have a much better initial reliability than rockets of the current generation.

- **Launch Efficiency.** Assembling and checking out

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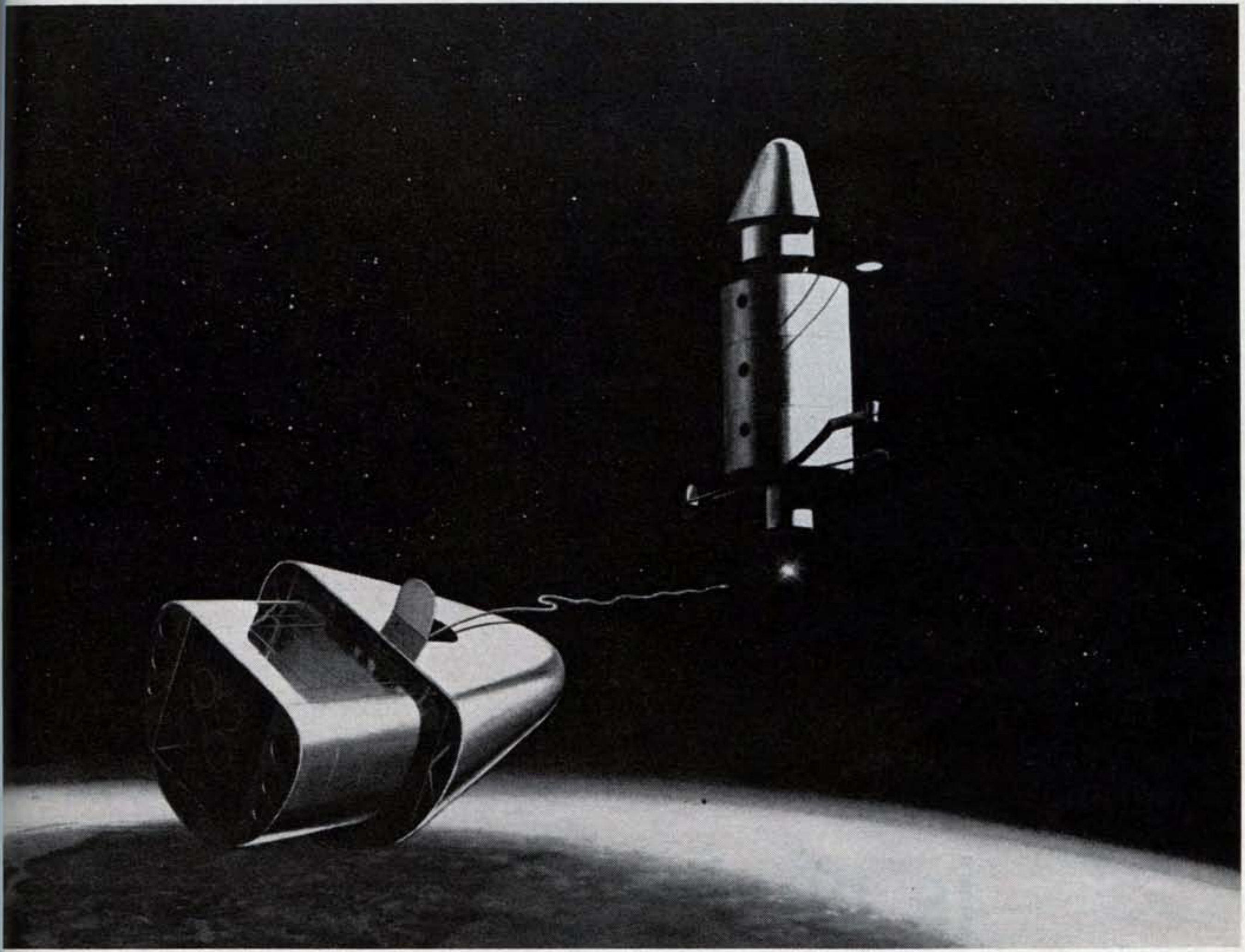

Orbiting, manned space laboratory (above) designed by the Martin Co., is one of many proposed by industry. It is the type requested by the Air Force as an immediate, joint project with NASA. The Gemini, two-man, reentry vehicle would be used to resupply and recrew the station. Inflated and doughnut-shaped stations are also being considered.

large rockets before launching requires thousands of man-hours of labor. It is an expensive business and great effort is being made to lower the assembly and "pad" time for each booster. The success of any given booster system will depend heavily on this effort.

• **Recovery.** If boosters can be recovered and reused, money will be saved as long as the cost of recovery and refurbishment stays below the cost of a new booster. NASA plans a year or so ago were predicated on the reduction of launch costs to about $100 per pound by about 1970. This reduction depended upon the recovery and reuse of the first stages of the Saturn C-1 and the larger vehicles, the C-5 and the Nova, which have only recently reached the final planning phase. However, in recent months these recovery programs have been all but abandoned, and most of their funds transferred to the booster development programs. The transfer of funds has helped keep the moon expedition on the track, but it has fundamentally altered the launch-cost picture a decade from now.

Several systems of rotating and extendable wings were considered to bring the first stage down to a soft landing on water or land, with the parachute and the Rogallo flexible wing (*see* Air Force, *July 1961, page 118*) receiving the most consideration. The work never progressed to the point that actual data on costs were assembled, so no one really knows whether recovery could save money. The few actual tests were more successful than had been predicted. In one, a rocket engine from the Saturn C-1 was fired the required length of time, dunked into salt water for a matter of hours, cleaned up with little effort, and fired again. This cycle was repeated several times on a single engine with no adverse effects. There have been reports that scaling problems would prevent the large flexwing needed for big boosters from performing as well as small ones. Some people working on the project say that so far they hadn't found this to be true. Their main concern was selecting an adequate material for the wing because it had to be deployed at speeds from 4,000 to 7,000 mph and experienced high aerodynamic heating. This problem appears possible to solve.

One step beyond this type of recovery is a first stage with a pilot and a permanent set of wings which could fly back and land at a conventional airfield. Studies show that this type of system could save a

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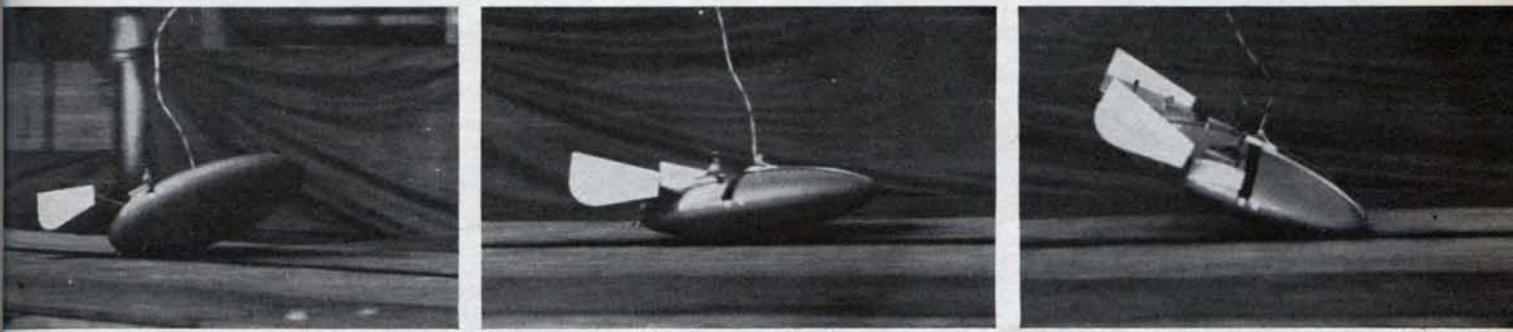
great deal of money once it was operational, but its development costs would be high.

The final step in recovery is a one-stage booster that could fly into orbit and return intact to a conventional landing field. Such a vehicle probably would be required to bring launch costs down near $10 per pound. NASA is asking for money in the fiscal 1963 budget to start the development of a research airplane which would serve as the prototype of this vehicle (*see page 64*).

• **Advanced Propulsion.** The use of liquid-hydrogen fuel in the upper stages is the primary factor in bringing down the launch cost of both Saturn vehicles and the Nova. Otherwise the vehicles would have to be several times larger than they are and their launch costs would be well over $1,000 per pound. Solid-fuel rockets in the first stage of the Titan III booster are generally credited with bringing the cost down to $400 per pound or less. When nuclear rockets enter service, they will be able to lift great loads into orbit at low cost. They might bring the cost as low as $50 per pound even without full recovery of the system. It is doubtful whether the nuclear rocket could be operational in less than ten years unless the program were given the highest national priority and pushed as rapidly as was technically possible.



Saucer-shaped vehicles can land on X-15 and Dyna-Soar-type, tricycle, skid gear. Or they can land on their curved bottoms as demonstrated by the NASA models above. If the occupants sit in the middle of the vehicle they experience about the same accelerations as they do in conventional aircraft. The weight savings possible by eliminating the landing gear is significant. Technically, the "rocker landing" works because it is possible to convert sinking speed energy into angular energy and dissipate it by aerodynamic damping. Wilbur Mayo of NASA thought of it.

On paper, air-breathing systems offer even greater efficiencies than nuclear rockets and ultimately nuclear-powered air-breathing systems will top them all. There is a long development road to such vehicles, but apparently the US is ready to take the first step.

Many Air Force and NASA observers regard the Titan III (*see* AIR FORCE, *February 1962, page 33*) as about the best booster in its class that can be built within the current state of the art. Every effort has been expended to see that launch costs would be low and development time short.

First, the Titan III was sized to allow it to perform a wide variety of missions so that its reliability could be increased through frequent use. Second, all components on the booster are conservatively designed. This is especially true of the solid-propellant first stage which is formed by two one-million-pound-thrust rockets, the largest ever flown. The specifications call for slightly less performance excellence than was achieved in the Minuteman and Polaris programs. The case material, the insulation, the nozzle construction, the propellant, the propellant bonding material, and the amount of propellant carried in the case are all on the conservative side. This adds a little weight, but past experience has shown that it will yield high reliability—high even for solid rockets which have the highest reliability of all rocket engines.

A modified Titan II ICBM forms the second and third stages of the Titan III. It has a significantly lower number of parts than first-generation boosters. This is expected to provide high reliability.

By the time this magazine is mailed the Air Force probably will have contracted for the development of the large solid rockets. First flight of these engines is scheduled for the third quarter of 1964. The complete Titan III will be fired during this test. Shortly thereafter another Titan III is scheduled to launch an unmanned Dyna-Soar glider around the world from Cape Canaveral to a landing at Edwards Air Force Base, Calif. Regardless of the outcome, this flight will be a turning point for military aviation.

Reliability

It isn't generally recognized yet, but the most successful astronauts and spacecrewmen of the future probably will be the most ingenious mechanics and repairmen. There is a good chance that the first requirement for future astronauts will be ability to repair complex systems. Proficiency in piloting a maneuverable reentry vehicle or in handling engineering test pilot chores may be second on the astronaut's rating sheet.

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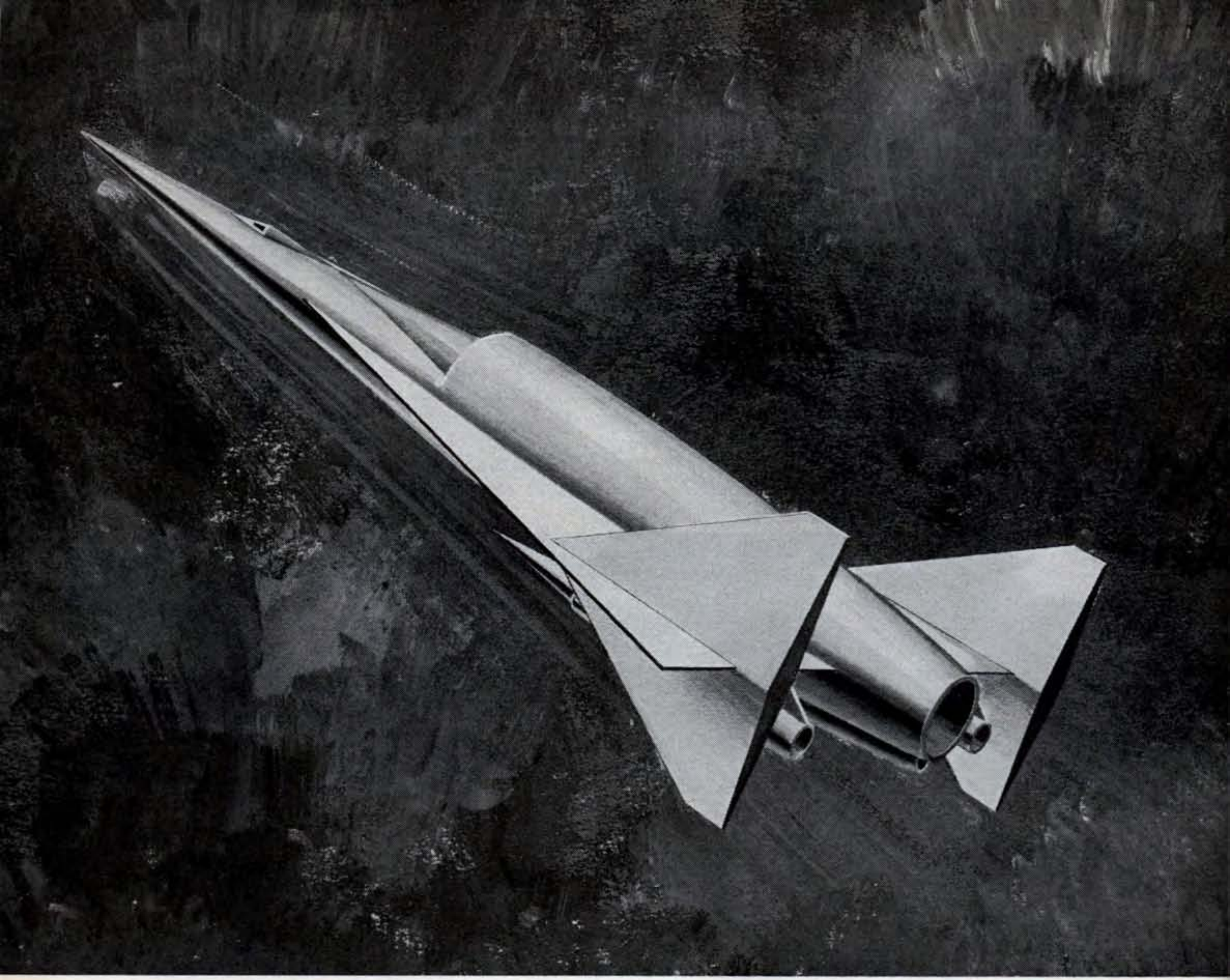

Orbital research airplane shown above in artist's conception is being proposed by NASA as a follow-on to the X-15. It will be about ninety feet long and weigh about 100,000 pounds. The engines in pods are turbo-ramjets, and the air-collection, rocket system is located in the fuselage. The plane's final design will probably have variable-sweep wings.

The reason is that virtually all civil and military missions in space will last for very long periods compared to those common on earth. Many systems in space vehicles will have to operate continuously for many weeks and perhaps months. When the exploration of the near planets comes around, the trip time probably will be a year or more away from earth bases.

The simple fact is that no one knows how to construct complex electromechanical systems that will operate reliably over such long periods. No one predicts that it will be possible to build "perfect" machines of this type in the foreseeable future.

Only one basic solution is being offered to the reliability program. In-flight inspection and maintenance must be done by human crews. The maintenance tasks being visualized today go well beyond the exchange of modular-type black boxes or the tuning or adjustment of malfunctioning equipment. Many believe that on the longer missions, more distant from the earth, the crew will have to be able to do some fabrication work and renew failed elements in a system.

To cite one vehicle-construction program, North American's design of the Apollo moon vehicle calls for the crew to replace faulty modules of electronic equipment. A more elaborate on-board-spares program is now under study, but it is too early in the program for anyone to say just how much crew maintenance will eventually be required.

Without crew maintenance or inspection manned space vehicles probably would have about the same reliability as the unmanned satellites and outer-space probes launched during the past four years. Even if this rather spotty reliability record were doubled, it would not be satisfactory for manned vehicles. A corollary is the premise that complex military systems will never be reliable enough to perform vital missions, such as command and control and triggering of weapons, unless they are at least visited by men at short periods to perform inspection and maintenance.

The earth-bound operation most comparable to manned spaceflight is a cruise by a nuclear submarine, which operates independently of any maintenance base for periods longer than a month. The on-board maintenance and repair experience on these craft is under close study by space vehicle designers.

Great strides in systems reliability have come in recent years through more stringent selection of parts,

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closer inspection of assembly, the use of solid-state electronics and system redundancy. The only likely way to get the total reliability of very complex systems up near 100 percent over long periods is to use all of these techniques plus inspection and maintenance by the crew.

The presence of man in a spacecraft can decrease its complexity by several orders of magnitude if he handles many logic functions, serves as a switch between redundant systems, and is trained as a repairman to renew systems operation after a wide variety of the most probable failure modes.

Determining the optimum relationship between astronauts and the basic machines in spacecraft obviously is an involved problem, and it is not expected to be resolved for many years.

Reentry Vehicles

Manned military space vehicles probably will come in a few standard shapes. Possibly there will be one basic reentry vehicle shape and one shape for vehicles which are to remain in space over their lifetime.

Two configurations for manned reentry vehicles are currently receiving serious attention in the Air Force. Both meet the military requirement for maneuvering in the atmosphere, being able to fly to and land at any designated jet-bomber-size air base and make a more or less conventional horizontal landing. Both also meet the military requirement of having an appreciable internal volume to carry nonexpendable equipment back to the earth.

One of these configurations is the Dyna-Soar glider which has clearly discernible wings. The other would be called a flying saucer by most people and is technically termed a lenticular shape.

The primary advantage of the Dyna-Soar design is its relatively high lift to drag ratio (L/D), or aerodynamic efficiency, which will provide it with more maneuverability in the atmosphere and allow it to make a more conventional runway landing. The Dyna-Soar will have an L/D of 1.5 to 2.0 depending upon the flight speed. Flight experience is expected to show that the glider can be lengthened and given a shorter span to provide a higher L/D and greater maneuverability.

Saucer-shaped vehicles have an L/D of about 1.0, and there isn't much that can be done in the way of shaping and cambering to improve it. Therefore they would be able to maneuver about 400 miles to either side of their initial flight path after making a reentry at 18,000 mph. They would be able to vary their path longitudinally, in straight-ahead range, by around 1,500 miles. This compares to a lateral capability of about 1,500 miles to each side and 6,000 miles in range for the Dyna-Soar.

Landing a saucer on a runway would not be as easy as a Dyna-Soar. However, the saucer offers the possibility of saving weight by eliminating the landing gear. A three-point skid system, similar to that planned for the Dyna-Soar, could be used. But tests have shown that "rocking-chair" landings on the curved bottom are possible (*see models on page 63*).

The main advantage of the saucer is its high-volume efficiency, sometimes referred to as structural-weight efficiency. This is extremely important on a spacecraft. It indicates how much structural weight a vehicle must have to enclose a given internal volume. Weight is much more critical on spacecraft than on aircraft and will continue to be so for many years because of high launch costs.

The basic geometric shape with the highest volume or structural efficiency is the sphere. It has the lowest possible surface area to enclose any given volume. However, it is impossible to fly a sphere in the atmosphere, and the saucer is the nearest thing to it which is acceptable aerodynamically. The prospect of carrying large weights of radiation shielding makes the volume efficiency of the saucer doubly attractive. This is true regardless of whether the shielding travels into or out of orbit with the vehicle, or whether it is kept in space and attached to vehicles as they begin an operational tour. In addition the constant unbroken lines of the saucer make its structural design relatively simple.

Time enters the picture. Dyna-Soar is in development with much of the detailed design work complete and a flight program scheduled with orbital shots in 1964. The saucer is only in the study phase, well behind Dyna-Soar.

The Dyna-Soar flights will prove the concept of the radiation-cooled, hot structure and most of the technology of highly maneuverable reentry vehicles. If Dyna-Soar is successful, there should be little doubt about the saucer, for its structural problems are somewhat less severe. Also the Dyna-Soar experience should indicate whether high L/D or high-volume efficiency is most desirable in a reentry vehicle.

There is little doubt that the first Dyna-Soar is only the first step to useful military reentry vehicles which have the ability to maneuver in deep space. Such maneuverability will entail the addition of a large propulsion system and possibly a basic change in structure. If a vehicle goes into deep space, to the vicinity of the moon, its reentry speed into the atmosphere rises from the 18,000-mph low-orbit speed to around 25,000 mph, or escape speed.

A vehicle designer has two choices of ways to accomplish a reentry at these speeds. First, he may use the maneuvering rocket to slow him down to 18,000 mph so the Dyna-Soar-type radiation-cooled structure can be used during the reentry. This method requires large quantities of propellants. The second choice is to change the structure to withstand the 25,000-mph reentry. This will involve the attachment of ablation material to the outer surface for cooling. Or some more exotic form of cooling such as spraying gas over the hottest portions of the surface might be used. As the state of the art in high-temperature structures stands today, most specialists believe ablation material would be used, just as it will be on the Apollo moon vehicle. It is an open question whether this material would be applied over the Dyna-Soar hot

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structure and allowed to burn completely away as the vehicle slowed to a speed of about 18,000 mph, or whether a completely new, all-ablation structure would be used.

Space vehicles which are never to return to the earth probably will be spherically shaped. At least the crew quarters and other areas which have to be shielded will be spherical to get maximum structural efficiency. Artificial gravity probably would be provided by connecting two or more spherical vehicles with tubes and spinning the whole system. The sphere is also a suitable shape for space storage tanks for fuel equipment and supplies. In a hostile situation it it probable that manned and unmanned vehicles of these types would need maneuvering capability just as the reentry vehicles would.

Orbital Research Airplane

The outstandingly successful US series of "X" (for experimental) aircraft apparently will not end with the X-15. NASA has asked for money to start development of a single-stage airplane which can take off from Edwards AFB, Calif., cruise at hypersonic speeds, accelerate itself into orbit using a combination of air-breathing and air-collection engines, reenter the atmosphere, and land under power at Edwards. Strictly a research airplane, it also is the prototype of the long-heralded Aerospace Plane, a completely recoverable operational booster. This research airplane will undoubtedly be a joint venture with the Air Force and the Department of Defense.

A number of loud technical voices are being raised against this program. Its ultimate usefulness is questioned. Great propulsion and structural problems are cited. The situation is reminiscent of the X-1 and the doubts about flying faster than sound. The orbital research airplane is being pushed by the same ex-NACA group that has been instrumental in all "X" series work. John Stack, who conceived the X-1 program and has been active in this area since, is heading the NASA effort on the orbital airplane.

The exact layout of the engine system has not been decided, but the basic operation is known. A conventional turbojet system will be used up to about Mach 3. From Mach 3 to Mach 8 or 10 power will the provided by subsonic combustion ramjets. At the same time large quantities of air will be taken aboard the aircraft and the oxygen separated out and stored. When the air-collection process is complete the inlet duct will be closed off and the stored oxygen will be burned with hydrogen in a rocket to accelerate up to orbital speeds.

The first air-collection and liquification system probably will use large radiators, with liquid hydrogen as a refrigerating agent. Another system, employing a chemical cycle to separate high-purity oxygen from the air, has the potential of being smaller and lighter, and it may be tested at a later date. The technology of burning fuel on the external surface of hypersonic vehicles to produce lift and thrust should be sufficiently advanced in five years or so to allow this type of engine to be tested on the orbital research airplane. If this method provides high thrust at all Mach numbers, the air-collection system and rocket could be completely eliminated on an operational orbital airplane.

The new "X" airplane will be about a ten-year project and cost about $1 billion. Total cost on the X-15 has been $225 million to date. Under current plans, a contractor for the orbital research airplane will be selected by July 1963 after exhaustive design studies and a competition during the next year.

Three projects are high on the Air Force space capability timetable—manned military test station in orbit, a satellite inspector, and an observation and surveillance satellite.

The proper testing and development of subsystems and systems for space vehicles can only take place in space. A manned space station is absolutely necessary to the study of human factors, electronic equipment, machinery, power supplies, instrumentation, etc.

A satellite inspector, which can maneuver in space, rendezvous with an uncooperative target, and determine its intentions, is a unique military requirement. No civil program can develop this capability.

A space reconnaissance system employing every known type of sensor and data-recording system is a prerequisite for military space operations. Any spacecraft, civil or military, which cannot constantly scrutinize the earth and space for many thousands of miles around will be extremely vulnerable.

The first inspector and reconnaissance satellites will be unmanned. But to be truly effective such systems will have to be enlarged to take a crew. Once these three vehicles are in operation they will have a catalytic effect on the whole military space program.

In turn, the intimate knowledge of space that the large-scale operation of space vehicles will engender can only shorten the time until the next great scientific-military objective is reached. This is the mastery of a completely new physical process which will bring the sort of military supremacy that the atomic bomb provided in its early days. There can be little doubt that such a breakthrough will occur again as knowledge in every field broadens too rapidly for assimilation by any individual. Perhaps the nuclear stalemate will never be broken until some nation achieves another true breakthrough.

As space operations speed the accumulation of knowledge the possibility of a breakthrough increases. Space offers a completely new laboratory in which to make studies on such subjects as: plasma, the fourth state of matter which constitutes more than ninety-nine percent of the universe, but which man is only beginning to understand; the relationship between gravity and magnetism; and, the use of focused, coherent radiation.

There is good reason even now for believing that such studies eventually will produce completely new types of propulsion systems and radiation rays which could operate over great distances and make nuclear weapons as we know them today obsolete. Whoever achieves these breakthroughs first will govern the shape of things to come.—End