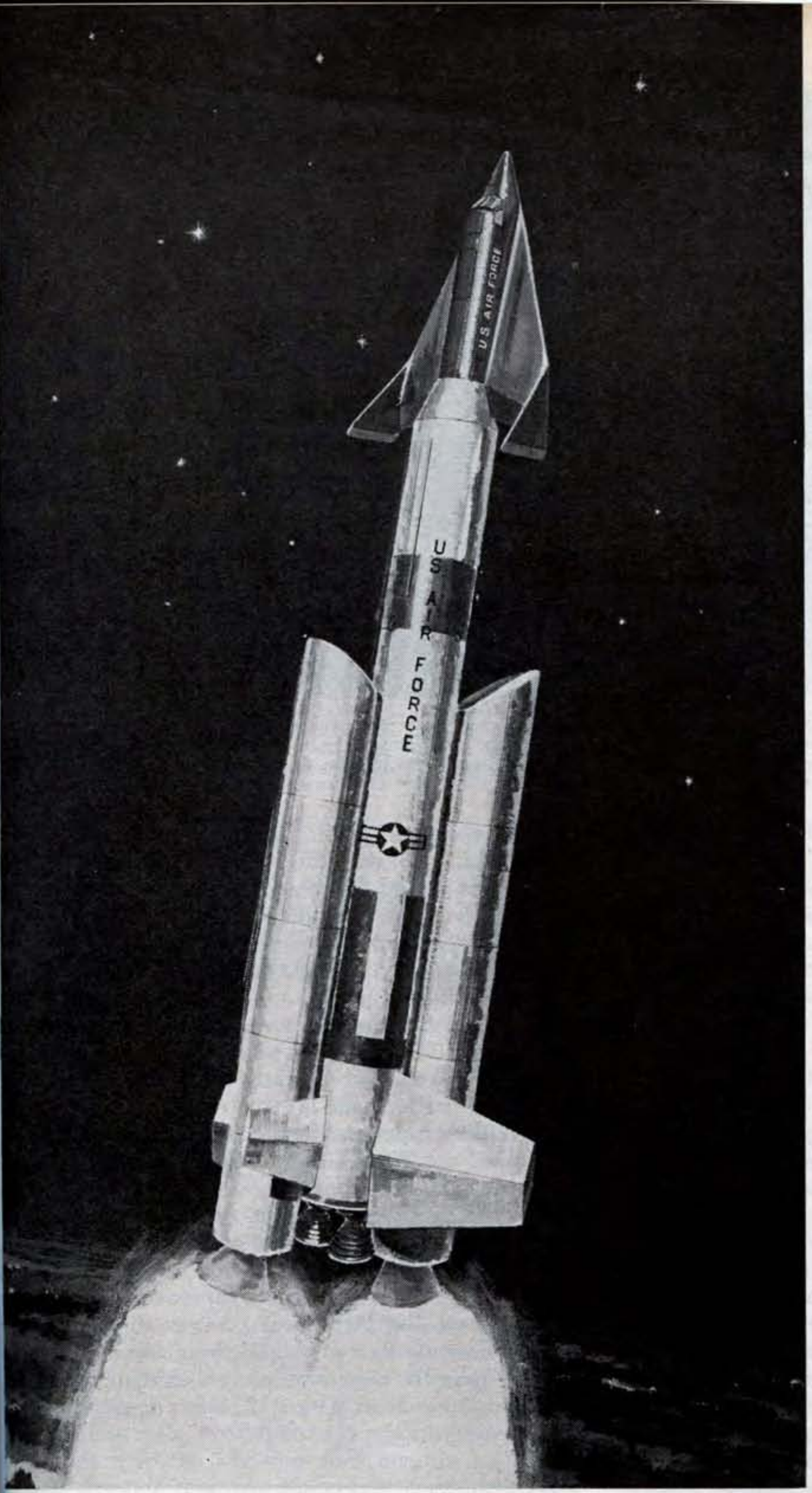
AIR FORCE
FEBRUARY 1962



The military space mission poses unique booster and vehicle requirements, not satisfied by any being developed for purely civilian purposes. Herein lies the importance of . . .

Dyna-Soar plus Titan III

By J. S. Butz, Jr.

Artist's conception above shows the Dyna-Soar hypersonic glider being propelled by the Titan III military booster. First stage is two 10-foot-diameter segmented solid rockets mounted on the sides of a modified Titan II ICBM, which forms the second and third stages of the booster. The first-stage nozzles are canted outward so their thrust axes pass through the center of gravity of the complete system. After burnout the solid rockets are released and run back on short tracks before the heavy air loads on their sloping noses spin them rapidly outward and away from the upper stages. This staging idea is based primarily on the successful British Bloodhound ground-launched, antiaircraft missile design. Large fins on the aft end of the booster counteract the destabilizing effects of the nose-mounted glider.

FIRST firm recognition of a substantial military space mission has been given by the Kennedy Administration. The Air Force has been authorized to develop a Saturn-class booster with about two million pounds of thrust in the first stage.

The large three-stage rocket, still officially unnamed but usually called Titan III or Soltan, will have a maximum payload of about 25,000 pounds in a 300-mile orbit. More important, it satisfies military requirements that cannot be met by the Saturn or any of the

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Dyna-Soar glider is in its reentry configuration above. Large conical section on the aft end containing the abort rocket has been jettisoned. Protective shields covering the forward windshields are jettisoned after the period of maximum heating. Side windows are clear during flight. On first development flights glider fuselage will be mostly empty. Weight will be added later to determine effect of wing loading.

launch vehicles under development for nonmilitary space use.

The most crucial military need is for rapid launchings on very short notice. If satellite interceptors and many other systems are to be effective, they will need short countdowns, and will have to be ready to start into space with only a few minutes' warning.

The choice of propulsion systems is the key to low reaction time. Cryogenic propellants which provide fine engine performance for NASA missions are not suited to low reaction time systems. Such propellants cannot be kept aboard a rocket for long periods; their loading time is usually measured in hours. With current technology, only rockets using solid propellants or storable liquid propellants can be used in combat-type space boosters.

The Titan III uses solid propellants in the first stage and storables in the last two. Its first stage will be two 120-inch-diameter solid rockets built in segments. The number of segments can probably be varied from three to five. This will provide versatility of takeoff power to accommodate a variety of payloads, which is another military requirement. The maximum thrust of each of the solid rockets will be in the neighborhood of one million pounds. The propellant core will be of the regressive burning type so that the thrust will continuously drop to a final value of about 500,000 pounds at burnout.

A contractor for the solid-propellant engines is scheduled to be chosen in the near future. Applied research programs by the Air Force and NASA during the past couple of years have laid the foundation for these engines (*see* AIR FORCE, *October '61, page 33*), and there is little doubt of their feasibility. The building-block feature of segmented construction will allow a variety of large boosters to be tailored to specific military missions.

Second and third stages of the Titan III are essentially a modified Martin Titan II—the two-stage intercontinental ballistic missile. Modifications include structural strengthening and rigging of the first-stage engines for high altitude so they can serve as the second stage on the Titan III. The new rigging consists primarily of the addition of an altitude start system and a high-expansion ratio nozzle for efficient flow at high altitude. Each engine will develop about 250,000 pounds of thrust for a total stage thrust of 500,000 pounds. Martin has already begun modifying the Titan II for the space-booster role.

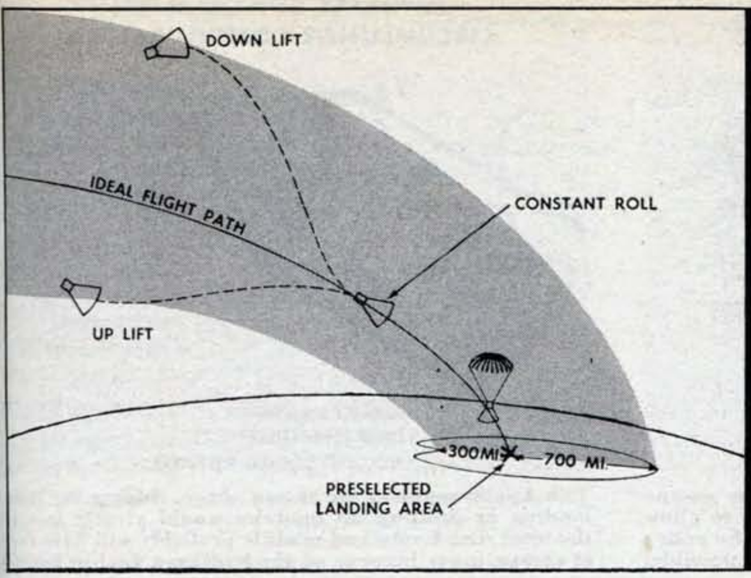
Storable propellants are called for in the ICBM version of the Titan II, and they are carried over into the space-booster configuration. In both stages the oxidizer is nitrogen tetroxide, and the fuel an amine-base mixture of hydrazine and unsymmetrical dimethyl hydrazine.

The first Titan III mission, announced by DoD, is to accelerate the Dyna-Soar program by moving the glider's first unmanned orbital flight ahead about two years. Under the new schedule, suborbital flights, powered by a modified Titan II, have been eliminated. High points in the new flight-test plan are:

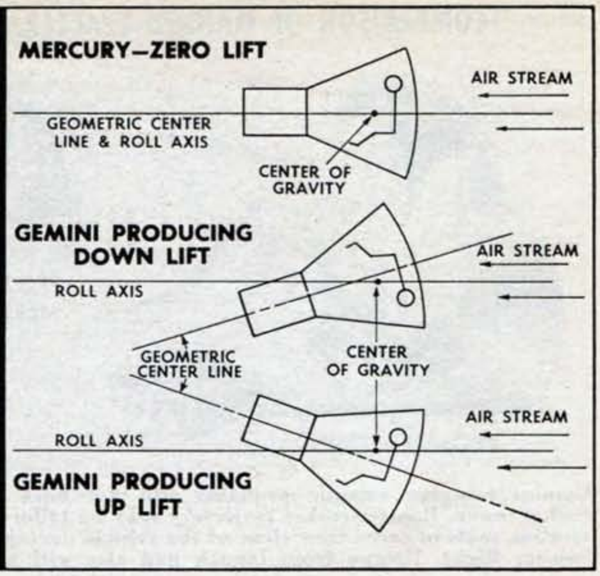
- First airdrop from a B-52—mid-1964, the first of a series of such flights, all manned. A dozen or more pilots thus will get experience in handling the Dyna-Soar at subsonic speeds and landing it.
- First unmanned launch of the glider into orbit from the Atlantic Missile Range by a Titan III—late 1964 or early 1965. Control of the glider will be maintained by an inertial-guidance system and through ground commands. Landing will be made at Edwards AFB, Calif. Two such flights are now planned.
- First manned orbital flight—mid-1965.

For the Dyna-Soar mission Titan III will have large fins on its aft end to counteract the large destabilizing moments created by the glider mounted on its nose.

But simply boosting the Dyna-Soar would not have



Reentry of a Gemini vehicle is shown conceptually above. A 300-mile undershoot, a 700-mile overshoot, and a lateral error of 150 miles from the predesignated landing area could be corrected. The Dyna-Soar's lifting ability will enlarge its "footprint" to a total length of about 6,000 miles and a width of around 3,000 miles. The flexible wing probably will be tested on the Gemini in place of the parachute in an attempt to enlarge its footprint even more.



Pure ballistic capsules of the Mercury type (top) will develop lift if the center of gravity is shifted. This design is planned for the Gemini and Apollo. Astronauts will be upside down when developing "down" lift relative to the earth. To counteract the lift force and follow a ballistic path the vehicle's crew will have to maintain a constant roll of about two rpm.

provided enough justification for the go-ahead on Titan III. The Saturn C-1 would have been adequate for sending the Dyna-Soar into orbit on purely development flights, and borrowing a few models of this NASA rocket for Dyna-Soar would have been much more economical than developing a completely new vehicle.

The only justification for the Titan III development can be its potential use as a combat booster and as the keystone of a military space program employing quite large orbital vehicles.

The second basic building block for a military space mission is the vehicle itself. Requirements in this area are not as clearly defined as those for the booster. However, both industry and Air Force studies point toward at least two vehicle requirements common to all military space missions.

Large internal volume is a basic need. Any military task performed in space is going to take an array of electronic and mechanical systems and power-conversion equipment. Present technology indicates that these systems are going to occupy a sizable volume, especially if access pathways are to be provided for adjustment and light maintenance. Current design philosophy generally is to bypass modular construction such as planned for the Apollo moon vehicle. Virtually all of the equipment necessary for a given military mission will be housed in one unit—the reentry vehicle. Such design will allow complete recovery of very expensive equipment and undoubtedly will be an economic necessity when military spaceflights become commonplace.

The second vehicle requirement is the ability to return precisely from orbit. Military space vehicles must be able to reenter the atmosphere and land at designated airfields. Effective operations could not be conducted if vehicles had to be recovered over a wide area of land and sea on a regular basis.

Four manned US space vehicles are currently under development. It is pertinent to examine each from the standpoint of both their design mission and possible military usefulness:

- **Mercury**—weight and volume limited. Pure drag capsule intended simply to prove feasibility of manned orbital flight. No control over flight path or landing area. Capsule weight about 2,000 pounds. Advanced Mercury with eighteen-hour life-support system planned. No military value other than as trainer or research vehicle.
- **Gemini**—Two-man version of Mercury capsule, with capability to stay in orbit many hours, possibly as long as a week. Equipped with 500- to 750-pound rocket system for maneuvering in space. Center of gravity offset slightly to provide lift (*see illustration above*) and the option of changing the flight path during reentry and landing at a preselected point. Intended to prove rendezvous technique, study effect of prolonged weightlessness, and test the capability of a pilot to control his reentry path. Weight about 9,000 pounds. Extra volume available to test Apollo components and small systems, but marginal for military operations. Valuable as trainer. First flight scheduled for late 1963.
- **Apollo**—First US vehicle required to reenter the atmosphere at escape speed (about 25,000 mph). Design still fluid. Major changes possible to accommodate heavy radiation shielding for Astronauts or to protect against micrometeorites. Structural materials still in question. Offset center of gravity to produce lift. Four modules planned.

Command module for reentry, life-support system, quarters for three-man crew, mission control systems.

Service module containing power supplies for mid-course corrections during lunar flight, electric power, etc.

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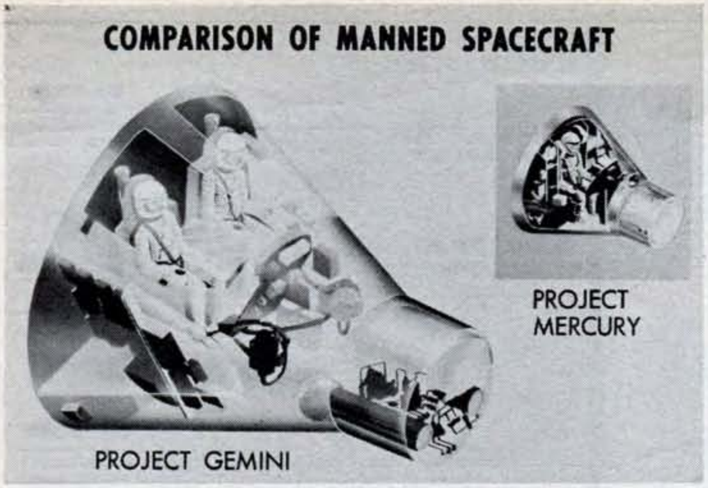
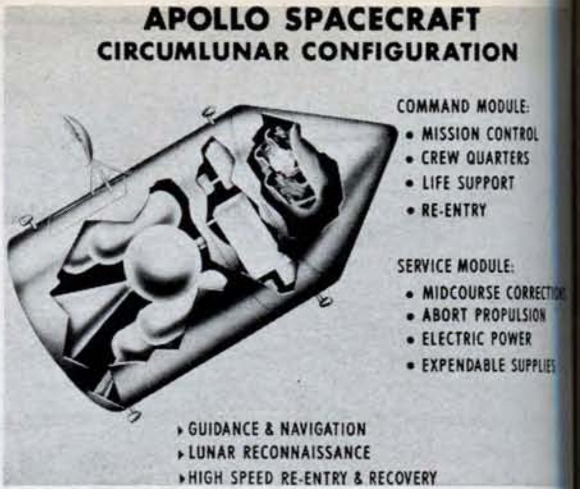


Gemini two-man capsule probably will not have an escape rocket tower. Booster-rocket trajectory may be tailored to allow ejection seats to carry crew clear of the vehicle during the entire booster flight. Escape from launch pad also will be possible.



Two Apollo modules are shown above. Adding the lunar landing or orbiting-lab modules would greatly increas the total size. Command module probably will have rock et escape tower because of the hydrogen fuel in booster

Orbiting-laboratory module with large volume for experimental equipment. This would be joined with command module to support crew when the laboratory was manned. Expected to be in operation by 1967.

Lunar-landing module with propulsion system and shock-absorbing gear to land on moon.

Apollo reentry vehicle will weigh about 15,000 pounds according to current specifications and will have relatively low internal volume. Valuable as a trainer and research vehicle but of limited operational usefulness.

• **Dyna-Soar.** Winged, reentry, orbital-speed vehicle with ability to return to jet-sized airfields. Current mission is to serve as a research vehicle to obtain hypersonic flight data and prove the concept of boost-glide aircraft. The glider has a substantial volume available for equipment. Weight of the research configuration is about 10,000 pounds for the glider, plus about 5,000 more for the abort rocket section. It is considered feasible to push the total weight up to nearly 30,000 pounds through the addition of operational equipment.

Of these four, only Dyna-Soar fits the requirements outlined for military space vehicles.

Dyna-Soar is a young project but a relatively old concept. Detail design work on the aircraft is less than two years old, and in that time remarkable progress has been made. However, its genealogy can be traced back to the Sänger-Bredt studies of antipodal bombers conducted in Germany during World War II. These unpowered winged vehicles were to achieve global range by skipping in and out of the atmosphere after being boosted to high suborbital speeds by large rockets.

Since then many theoretical studies and a great deal of experimental work on similar types of aircraft have been conducted in the US by the Air Force, NASA, and industry. Serious agitation to construct orbital airplanes began in the early '50s. It reached a crescendo as increasingly favorable experiments were performed in the mid-1950s and when Sputnik I heralded the space age.

The Department of Defense loosened the purse strings for a development program in 1958. In April that year the Air Force selected Boeing and Mart from about nine interested companies to compete f the Dyna-Soar contract. This competition ended i November of 1959 when Boeing was selected to design and construct the glider with Martin receivin responsibility for the booster.

Immediately following, a "Phase Alpha" was injected into the program. The object was to revie Boeing's design proposal thoroughly before begi ning development—to make certain the best possib design approach and configuration were being used.

During Phase Alpha, many aerodynamic configur tions were reevaluated. These included: Mercury-typ shapes, with and without extendible drag device "Eggers" shapes, that is, flat-topped, high-lift, hig drag shapes; gliders with varying lift/drag ratios an wing loadings; gliders with wings that would fold ont the top of the vehicle during the period of maximu heating; inflatable gliders; and lenticular or sauce shaped vehicles.

Structural design was also reconsidered. The mai choice was between two basic types of constructio One was the hot structure on which the outer sk reached temperatures of 2,000 degrees F and mor It would be cooled by radiating heat to the atmo phere.

The other type was the double wall, or "cool," stru ture. Most of its reentry heat would be absorbed int a load of water that eventually would boil away.

Most of the high-speed experts in industry and th government had their say during this reevaluatio Phase Alpha ended in April 1960 with a go-ahead o the development of Boeing's original glider propos

Boeing's glider is flat-bottomed with about a sevent five-degree sweep on the wing leading edge. It approximately thirty-five feet long, with a span about twenty feet. The aerodynamic goals are mode ately ambitious. Design lift/drag ratio will vary fro 1.5 to 2.0 depending upon Mach number. Many expe predict that the Dyna-Soar experience will allow th second generation of winged reentry vehicles to hav a higher L/D, and consequently improved mane verability and greater range in the atmosphere.

Dyna-Soar's wing loading will be relatively low during its development flights, around thirty pounds per square foot. This is in the Cessna 310 class and well below that of modern military aircraft. Low wing loading decreases the aircraft's rate of descent at high speeds and eases the structural-heating problem. As would be expected, this feature also improves handling characteristics during low and slow flight. The glider is designed to land on a 10,000-foot runway with a lower sink rate than that of the X-15.

The main uncertainty with Dyna-Soar, however, was not aerodynamics. It was high-temperature structure. Boeing's original idea of a hot structure, with a skin that glowed red and white during reentry, was okayed during Phase Alpha. This decision was based on a mass of laboratory data which gave good reason to believe that the hot structure would be successful. It was also expected to be the lightest and least complicated construction system for 18,000-mph winged vehicles. But many questions remained that could only be answered through the development and testing of a full-scale glider.

The most encouraging news about the Dyna-Soar program to date is the fine performance of the full-scale hot structure during ground tests. Boeing spokesmen report that for the past year the Dyna-Soar structure has withstood full simulation of the maximum reentry heating conditions. All the questions about the hot structure have been answered, and the company now has "high confidence" that each glider will be able to withstand "several" reentries.

Two major structural innovations have been made on Dyna-Soar to handle high temperatures. First, it uses a design concept employed on fabric-covered airplanes. The outer skin is very lightly stressed, resisting only local aerodynamic and thermal loads, which are quite low. All of the main loads, the accumulation of aerodynamic and heat loads, are borne by a heavy internal truss work. On most modern, low-temperature aircraft the truss has been eliminated, and weight is saved by carrying part of the main bending and torsion loads in the skin.

A special feature of the Dyna-Soar is the use of pinned connections between all of the truss members. This is an ideal connecting method to allow a structure to expand evenly without warping during severe heating. However, it is sometimes difficult to achieve in practice.

The second structural innovation is new materials. A ceramic, zirconium graphite, is used for the nose cone to withstand maximum temperatures in excess of 500 degrees F. Two materials have been successfully tested for the leading edges, the next hottest spot with a maximum temperature of about 2,000 degrees F. These are the refractory metals, molybdenum and columbium, both with good strength at high temperature. But they required an extensive development effort to find surface treatment that would keep them from rapidly oxidizing away in a hot air stream.

An adequate surface treatment has been found for both metals. There is a greater background of experience with molybdenum at present, but columbium may still be used during flight because it appears to be less brittle. To accommodate thermal expansion the Dyna-Soar's leading edges are built in sections that overlap, shingle fashion.

The remainder of the Dyna-Soar's skin is made of Rene 41, a tough steel alloy originally developed for turbine blades in jet engines. It can now be rolled into thin sheets. No expansion joints are needed in this skin, which is attached in large sheets.

Somewhat surprisingly, the glider has been provided with a large windshield area. The pilot will have excellent visibility. A protective shield is used on the front windshield during reentry when maximum temperatures are encountered.

Cooling is required in only two locations on the Dyna-Soar. The pilot's compartment is kept below 100 degrees F. To accomplish this, the compartment has a double wall filled with water which is kept from sloshing by a wicklike filler material.

The equipment bay is also cooled but to a higher temperature than the pilot's area. Most of the heat entering this bay is dumped through heat exchangers into the fuel supply for the auxiliary power system.

The power system is needed to operate flight controls, flight instruments, test instrumentation, and electrical systems aboard the glider. Liquid hydrogen and liquid oxygen are burned on demand to run a turbine-generator set.

Landing gear on the Dyna-Soar is also especially designed to resist heat. Rubber tires and the standard shock-absorbing oleo struts had to be discarded because they deteriorated at high temperatures. Landing shock on the glider is absorbed by metal straps which support the gear leg and yield and stretch under impact. Many tests have proved this design which is very light and worth the inconvenience of replacing the yield straps after every landing. A smooth dishpan-type skid serves as the nose wheel, and two wire brushes with very high friction coefficients are used on the main gear at the rear of the glider.

The pilot-safety system on the Dyna-Soar is built around the idea that the entire glider is the escape pod. At very high speeds it is not considered possible to build a capsule or mechanism that could protect the pilot if the glider failed. The escape problem, then, is to get the man and the glider away from the booster in case of failure. This would be accomplished by a large solid-propellant rocket located in the adapter section behind the glider. If an emergency occurred on the pad at launch, the rocket would have enough power to propel the glider to an altitude of several hundred feet. The pilot could then land the aircraft on a strip at Cape Canaveral. The alternative would be for him to use his standard Mach 2 ejection seat to clear the glider and make a parachute landing. Once booster had separated and the glider had reached the desired speed, the abort rocket and the adapter section would be jettisoned.

Dyna-Soar's handling qualities at all speeds have beeen thoroughly checked out in flight simulators. Little remains to prove the concept before actual flight tests.—END