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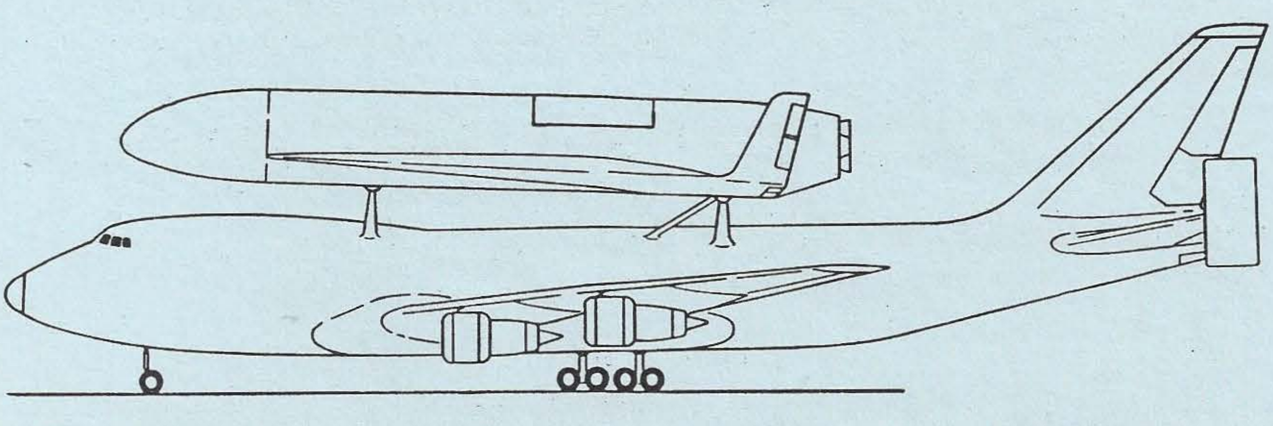
Engineering Firm Proposes Low-Cost Spaceplane

A new proposal for a reusable low-cost launch vehicle, an unmanned air-launched spaceplane, has come out of Teledyne Brown Engineering (TBE) of Huntsville, Ala. The vehicle, rather prosaically named the "TBE Spaceplane," is a concept that could be developed using existing technology and, in its basic configuration, could fly about 7,700 lbs. into low earth orbit, or about 2,870 lbs. into polar orbit (if rendezvous maneuvers are not needed, both payload figures can be increased by about 1,100 lbs.) Launch costs for the operator would be less than $5 million per flight, resulting in a cost per pound of about $570 for flights to low earth orbit, and about $1,260 for flights to polar orbit.

The TBE Spaceplane would be launched from the back of a Boeing 747 airliner (see illustration below). The Spaceplane itself--the "orbiter"--would be powered by liquid oxygen/liquid hydrogen engines consisting of one Space Shuttle Main Engine (SSME) and four uprated Pratt & Whitney RL-10 engines (the RL-10 is used on the Centaur upper stage of the Atlas rocket). The current Shuttle version of the SSME would be used, while the RL-10s would require an upgrade of performance from 15,000 up to 25,000 lbs. of thrust. The 747 would require modifications to its jet engines to increase the aircraft's thrust, possibly by the addition of afterburners.

The Spaceplane has a payload bay 15 feet in diameter and 21 feet long, which allows it to carry Shuttle-width payloads. The arrangement of the vehicle's propellant tanks is similar to that of the British HOTOL spaceplane (*C.S.R.*, Sept./Oct. 1987, pp. 1-8), with a liquid oxygen tank behind the payload bay, and a large, pressure-stabilized liquid hydrogen tank forward of the payload bay (strictly speaking, the hydrogen tank is not completely pressure-stabilized--the tank is sufficiently rigid on its own to handle all flight loads without internal pressure except those incurred during the actual touchdown on a runway during a landing). The location of other systems is shown in the diagram on page 3.



A typical TBE Spaceplane mission would go as follows:

T-30 minutes: The 747 aircraft, with the orbiter mounted on the back, takes off from an airstrip and begins a maximum-performance climb (the airstrip is located at or near the latitude where the orbital launch would take place, reducing the amount of jet fuel needed for the aircraft to get into position to launch the Spaceplane). During this portion of the flight, about half of the Spaceplane's liquid oxygen propellant supply is carried in a low-slung tank inside the 747 to improve the center of gravity of the assembly during atmospheric flight. Additional oxygen and hydrogen are also carried aboard the 747 to top off the orbiter's tanks before launch.

T-5 minutes: At an altitude of 38,700 feet, the orbiter's four RL-10 engines are started and throttled to about 11,250 lbs. of thrust each, effectively doubling the thrust provided to the assembly by the 747's jet engines. The 747 begins a steep climb, and propellant continues to be transferred from the 747 to the orbiter tanks.

T-15 seconds: The nose of the orbiter is raised hydraulically from a minimum drag position to its maximum-lift angle of attack.

T-0: At an altitude of 42,600 feet, the Spaceplane lifts free of the 747 and initiates the start sequence for the SSME. At this time, the RL-10s are throttled up to 100% thrust (100,000 lbs. total). The 747 throttles back and returns to base.

T+180 seconds: The orbiter's engines are throttled back to maintain a maximum acceleration of about 3.5 G's.

T+250 seconds: The SSME is shut down and the RL-10s are ramped back up to full thrust.

T+345 seconds: At an altitude of 43 nautical miles, all engines are shut down. The orbiter coasts to an altitude of 216 nautical miles, and two of the four RL-10s relight to circularize the orbit.

The Spaceplane could remain on orbit for up to seven days. Re-entry would involve relighting the RL-10s for a deorbit burn, and gliding back to a runway landing like the Space Shuttle.

The design of the TBE Spaceplane is intended to reduce development and operational costs to a minimum. Following are some of the low-cost features of this system:

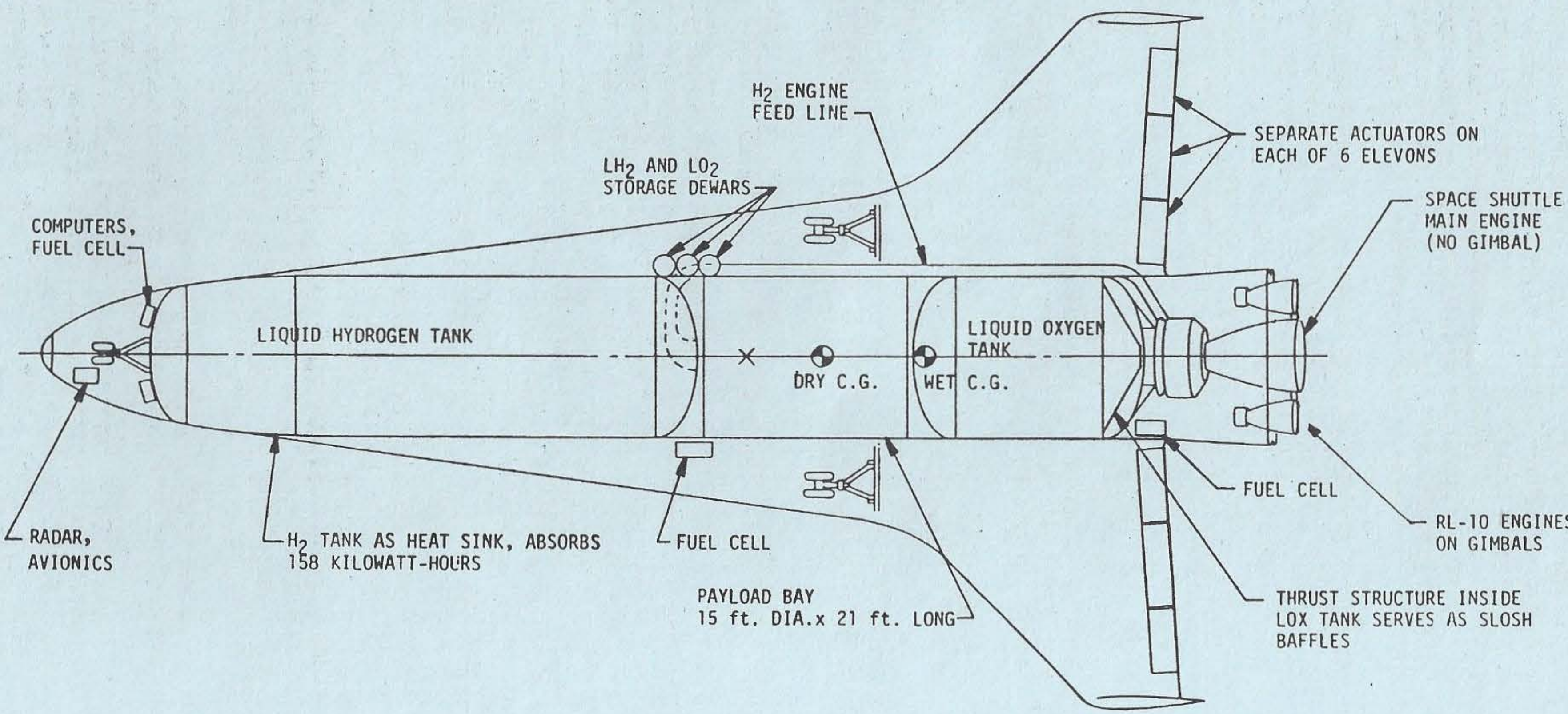
- The initial configuration of the Spaceplane would be unmanned, and optimized for freight hauling. This would result in lower up-front costs and a faster development schedule by initially avoiding the additional design, safety, and weight problems associated with a manned system. Development of a manned configuration could proceed at leisure, while the unmanned version would already be operational and flying payloads profitably.

- The Spaceplane's structure would consist of aluminum and graphite epoxies. These are materials currently used in aircraft construction and are well-understood.

- No auxiliary boosters or throwaway drop tanks would be needed. Although drop tanks would theoretically improve performance, they would add to vehicle operational costs and increase the difficulties involved in abort situations.

TEXT CONTINUED ON PAGE 4

SPACEPLANE SYSTEMS LAYOUT



- The relatively low heat loads during reentry require no exotic thermal protection systems. These low heating loads are the result of the Spaceplane's large ratio of planform area to vehicle weight: empty, as it would often be on return from orbit, the Spaceplane has a wing loading of about 22 lbs. per square foot, compared with 75 lbs. per square foot for the Space Shuttle. This results in Spaceplane heat loads that are about one-third of those experienced by the Shuttle. Under these circumstances, thermal protection could be accomplished by conventional metal surfaces of titanium and Inconel, with reinforced carbon-carbon on leading edges (this large planform area also results in better glide performance during landing operations compared to the Shuttle).

- The engines, both the SSME and the RL-10, are currently in production, with little or no additional work needed to adapt them for the Spaceplane. The SSME assembly would actually be simpler, since the Spaceplane does not require the gimballing of the SSME that the Space Shuttle does. This would result in less complex and more reliable engine mounting and propellant feed systems than would otherwise be required. The RL-10s (which are gimballed) would need to be upgraded in thrust, but Pratt & Whitney spokesmen claim that this would be a relatively inexpensive adjustment.

In addition to lower costs, the design of the Spaceplane is also intended to improve system reliability, safety, and--in an era of high launch risks--insurability. The system has no solid rocket motors, and all engines for both the orbiter and the carrier 747 are fully flight-tested. If the 747 suffers an engine failure, the propellants are dumped and the aircraft returns to base for a landing with the Spaceplane still attached. During a normal launch procedure, the four RL-10s are started and checked out before spacecraft separation. If there is a problem, the airplane again returns to land with the orbiter. If the SSME fails to start after separation, or shuts down prematurely, the RL-10s alone have sufficient thrust to power the orbiter subsonically more than 600 miles to a safe landing.

Modifications to the basic Spaceplane design would allow for future growth, while keeping initial development costs to a minimum.

The first and most obvious modification would be the addition of a pressurized cabin to permit manned operations. Like the British HOTOL, manned operations of the TBE Spaceplane would most likely involve a passenger capsule in the payload bay with executive control over the vehicle, while the minute-to-minute flight details would be handled by the automatic flight control system. If a pilot's cabin turns out to be absolutely necessary, it could probably be added to the nose compartment.

Other modifications would permit increased payloads to orbit. These could include replacing the SSME with an improved Pratt & Whitney design, replacing the 747 carrier with a supersonic boost aircraft, or developing an alternative orbiter design using drop tanks for some of the hydrogen. These changes could increase payloads dramatically--up to five-fold in some cases--but would have to be traded off against increased development costs and vehicle complexity.

The TBE Spaceplane is targeted towards a large variety of missions, involving both launching payloads into orbit and returning payloads from orbit back to Earth. These missions include launching and retrieving satellites from low earth orbit (geosynchronous satellites with their own orbital transfer motors could be launched from the Spaceplane payload bay in the same way as they are from the Space Shuttle payload bay), refueling and refurbishing satellites, and space station support missions.

The space station missions for the Spaceplane's unmanned configuration would consist of logistical flights, delivering supplies, raw materials, and construction components into orbit; and returning products, old hardware and waste back to Earth. Later manned configurations would permit personnel transportation to and from the space station, in both routine and emergency situations. One configuration of the Spaceplane could be parked at a manned orbital facility, and used in an emergency as an escape vehicle (the SSME would be replaced in orbit by a deorbit engine using storable propellants). In all cases, the relatively small Spaceplane payloads are offset by low costs and frequent flights.

Teledyne Brown estimates the cost of building and operating a Spaceplane launch system at about $2.3 billion, approximately the price of a single Space Shuttle orbiter. Although, as mentioned earlier, the cost per flight is about $5 million, higher launch fees can be charged which would still be competitive but would allow the vehicle operators to recover the development costs of the system in about five years.

Teledyne Brown is not the first to propose a 747-launched spaceplane. In the early 1980s, studies sponsored by the Air Force and NASA produced ideas for a wide variety of such systems. There was an Advanced Military Spaceflight Capability (AMSC) study, an Air-Launched Sortie Vehicle (ALSV) study, a Trans-Atmospheric Vehicle (TAV) study, and an Orbit-On-Demand Vehicle (OODV) study. Proposals were received from companies such as General Dynamics, Rockwell International, Boeing, and Pratt & Whitney. Proposals included different kinds of orbiters using different kinds of propulsion--usually high-performance engines specially designed for each vehicle, although some used RL-10s (a Boeing/Pratt & Whitney design for the study used nine RL-10s in its orbiter, and seven more in the tail of the 747 for additional thrust! Only to be expected, I suppose, in a Pratt & Whitney design). Some contractors added drop tanks to their orbiters. Some used an off-the-shelf 747, some modified the aircraft extensively. All had one thing in common: their designs were complex, used advanced technology, had large payloads, and were hideously expensive. Why do the engineers at Teledyne Brown think they can do better?

Teledyne Brown's Spaceplane differs from the Air Force and NASA proposals in several important ways. First, its mission requirements, commercially-oriented, are far less severe than those of a military system. All of the military and NASA concepts were manned, and were designed for missions requiring larger payloads and more exacting launch and reentry capabilities than would be required for a commercial launch system. Second, and more important, the majority of the government programs were biased towards new and exotic technologies rather than "off-the-shelf" solutions. Some studies, such as the AMSC, specifically *demanded* new technologies, rejecting concepts using existing hardware and components.

A better parallel to the TBE Spaceplane would be another commercial venture: Third Millennium Inc.'s Space Van. In its original configuration, the Space Van orbiter was also designed to be launched on the back of a 747 (*C.S.R.*, Nov. 1981, p. 1-2, June 1985, pp. 2-5). Unlike the government proposals, and like the TBE Spaceplane, Space Van was designed for low cost and maximum use of existing technologies (the most recent version of the Space Van design is smaller, and uses a specially-designed, vertically-launched booster instead of a 747. More on this in the following article).

Unfortunately, the development of the TBE Spaceplane seems to have stalled out. Teledyne Brown, having taken the idea this far, is apparently not interested in following it up any further, even to the extent of supplying a small amount of additional study funding to further refine and validate the concept. NASA, for its part, has examined the idea of a small, cheap, reusable launch vehicle and, not surprisingly, has pronounced it unfeasible. From what I have seen, I think NASA is wrong.

Unless the supporters of this concept can locate private funding, this Spaceplane design may end up on the same dusty shelf on which all of the aforementioned Air Force/NASA spaceplanes now reside.

For further information on the Teledyne Brown Spaceplane, contact Teledyne Brown Engineering, Space Programs Division, 300 Sparkman Drive, Huntsville, AL, 35807, or call Dan DeLong at (205) 532-2849 or Dr. Ernst Stuhlinger at (205) 532-2832. Articles on the TBE Spaceplane appear in the March, 1987 issue of *Analog* magazine (pp. 56-65) and in the December, 1987 issue of *Spaceflight* (pp. 413-416).

MMI Space Van: New Subcompact Model

Third Millennium Inc. (MMI), Washington D.C., has adopted a compact version of their Space Van called Micro Van. Similar in concept to the previous design (orbiter mounted on vertically-launched booster), Micro Van is considerably smaller, with a payload to low earth orbit of about 3,300 lbs. compared to the larger Space Van's payload of 6,200 lbs. Where the Space Van had eight RL-10 engines on its orbiter, Micro Van has only three. The reusable boost vehicle would be reduced in size as well, and would be powered by a single Rocketdyne H-1 rocket engine (the H-1 was used as a first stage engine for the Saturn 1B launch vehicle).

The primary reason for the reduction in size was to reduce development costs. Micro Van's estimated cost of development is about $320 million (1987 dollars) compared to about $750 million for the larger Space Van system.

Micro Van's smaller payload capacity is still sufficient to address many payload launch requirements. Use of an orbital fuel depot and an Orbital Transfer Vehicle would increase the system's flexibility, allowing Micro Van's 3,300 lb. payload to be transferred into geosynchronous orbit.

Tentative launch prices to low earth orbit are set at about $175 per pound depending on traffic level--about a third the price of Teledyne Brown's Spaceplane.

* * *

Update: American Rocket Company

The American Rocket Company (AMROC) of Camarillo, Calif. has received new funding permitting them to continue operations at a reduced scale. AMROC representative James Bennett reports that the company has re-hired about 40 people, or about half of the employees laid off when the stock market crash derailed AMROC's earlier fund-raising plans.

Season's Greetings,

Tom Brosz

The Commercial Space Report (C.S.R.) is published monthly, and endeavors to report and analyze developments in the field of private initiatives in space transportation and exploitation.

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