Engineering Notes

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Integrated Launch and Emergency Entry Vehicle Concept

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Introduction

RECENT studies of space transportation architectures[1-3] have indicated the need for a heavy-lift launch vehicle (HLV) that could carry payloads to low-Earth orbit, would be partly reusable, and would provide lower operating costs than expendable vehicles. One popular concept for this vehicle envisions a winged booster, an expendable tank, and a propulsion and avionics module that, after ascent to orbit, would enter the Earth's atmosphere autonomously to return the expensive rocket engines and electronics needed for the ascent flight. The same studies have also shown the need for an advanced manned launch vehicle, which would operate in conjunction with the new HLV to carry personnel and other priority payloads to and from orbit. The booster of the HLV could possibly be used with the orbiter component of the advanced manned vehicle.

Studies of the safety aspects of the Space Station Freedom and the Challenger Space Shuttle accident have convinced many people that there will be a need for an emergency entry vehicle (EEV) on hand at the Space Station Freedom. In case of an emergency, the space station crew would be able to return safely to Earth in this vehicle. Because many of the possible emergencies could involve people with health problems or injuries, an EEV with a lifting shape would have several desirable features that are not available with an axisymmetric shape. For example, the higher lift-to-drag ratio of the lifting shape expands the available landing sites and allows control of deceleration loads. It could land horizontally at an airport with medical help nearby rather than splash down in water and then be picked up.

The purpose of this Note is to describe an integrated launch and emergency entry vehicle (ILEEV), a concept that could satisfy the needs for an advanced manned vehicle and an EEV as a component of an HLV. The primary advantage of this concept is that the same entry vehicle can be used to satisfy all three requirements, thereby reducing development and operating costs.

Entry Module

The primary element of the ILEEV system is the entry module, shown schematically in Fig. 1, in the advanced manned-vehicle configuration. The significant characteristics of this module are the payload bay and the aerodynamic shape. This vehicle would need on-orbit maneuvering and de-orbit propulsion, entry, and landing aerodynamics control surfaces, and avionics for returning and landing autonomously or with a remote pilot. In the EEV configuration, the payload bay would contain enough seats for the crew of the space station. In the advanced manned-vehicle configuration, the payload could be unmanned or it could consist of people with the required accommodations.

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Propulsion Module

To turn the entry module into a propulsion module, main engines are added, as shown in Fig. 2. Two engines would be used for each module. The engines would be below the module during ascent and would swing up into the payload bay for return. All of the major connections to the engine, feed lines, and thrust structure would be severed before placing the engines in the bay, so that swinging the engines into the bay would be relatively easy. A door in the base could provide a path for the engines to move into the bay. Because the engines are placed in a position near the center of the module for return, there would not be an aft center of gravity, which is a problem for many concepts. The engines should be dual-fuel, dual-mode systems that can burn methane early in the flight and switch to hydrogen later.

Launch Configurations

Four propulsion modules are used in the heavy-lift version of the ascent configuration, as shown in Fig. 3. They are identical, which simplifies operations. The expendable tank is the

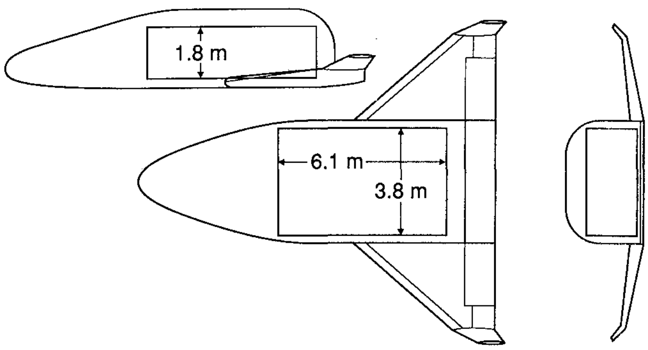

Fig. 1 Schematic of module in advanced manned-vehicle configuration.

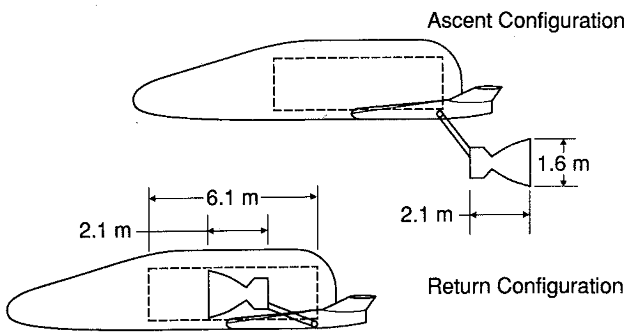

Fig. 2 Schematic of propulsion module.

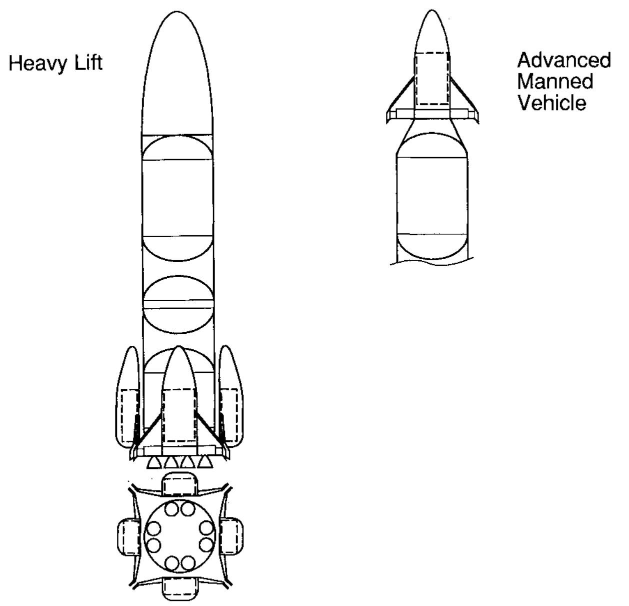

Fig. 3 Schematic of launch configurations.

largest element in the ascent configuration. It contains all of the ascent propellants, and the lines and thrust structure connect directly from the tank to the engines. As shown, the engines are located below the tank in the ascent configuration. The payload is placed on top of the tank, and all loads are very symmetric, which should allow the heavy propellants to be placed aft, minimizing the structural mass of the tank. The propellants are nearly equal to the Space Shuttle external tank in mass, but because some of the fuel is methane, the volume is about one-fourth less.

For the advanced manned-vehicle launches, a fifth entry module replaces the payload of the heavy-lift version. It has no engines and is delivered to orbit in the same way as the payload of the heavy-lift vehicle. Because the payload capability of the advanced manned-vehicle version is greater for ascent than entry, some ascent payload could be placed behind the advanced manned-vehicle module in the conical adapter.

Launch Operations

Two of the four propulsion modules (Fig. 2) separate at a Mach number of 3. During the high-altitude coast before they start to enter, the dynamic pressure is low, and the engines can be stowed. These booster-propulsion elements then glide back to the launch site. The other two propulsion modules go into orbit and return to the launch site later. The external tank goes into orbit, and it can be disposed of by entry in a safe area or used in orbit. The payload could be delivered to the space station or contain propulsion for ascent to a higher orbit.

Sizing Parametrics

Some analyses of the ILEEV concept have been completed. An optimized trajectory has been used to estimate the propellant consumption, and mass estimates have been calculated for the various subsystems in the entry module. The results are shown in Fig. 4 for various vehicle sizes. The return payload of the advanced manned-vehicle configuration was assumed to be equal to the mass of the engines in the propulsion module (4 Mg), and the entry module was sized to return the engine masses. The resulting module dry mass does not change rapidly with gross mass. The heavy-lift payload changes much more rapidly. At the lowest gross mass shown, the manned-vehicle ascent payload is less than the manned-vehicle return payload, and this would probably not be a reasonable size to select for the vehicle. The smallest reasonable selection would be where the advanced manned-vehicle payload is the same for ascent and return, near 600 Mg gross mass. At high values of gross

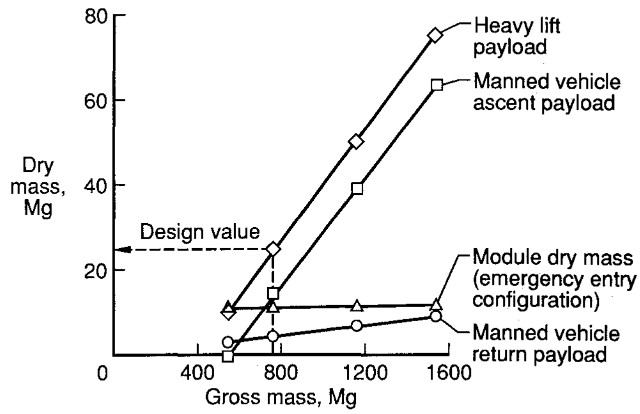

Fig. 4 Sizing parametrics.

Table 1 Mass statement

System element	Mass, Mg
Module dry mass (emergency entry configuration)	11
Fluids (maximum)	2
Return payload or propulsion	4
Module gross mass	17
Heavy-lift payloads	25
Total, four boost modules	68
Expendable tank	22
Propellant, including reserves and losses	647
Gross mass	762

mass, the advanced manned-vehicle ascent payload exceeds the return payload by large amounts. Since the operating costs of the system are largely determined by the expendable tank, which is proportional to the gross mass, a selection of a very large gross mass would probably be unacceptable economically. The data point with a heavy-lift payload of 25 Mg appears to be a reasonable compromise and was selected for the design value. The schematics (Figs. 1-3) show a vehicle sized for this selected payload. The payload bay volume is sufficient to provide the same payload density as the Space Shuttle (98 kg/m^3).

Mass Statement

The masses of system elements are given in Table 1. The selected heavy-lift payload of 25 Mg results in a gross mass of 762 Mg. The advanced manned-vehicle return payload is 4 Mg. The module dry mass, 11 Mg, is a good indication of the development cost of the system, which should be considerably less that that of concepts using internal-propellant boosters. The operating costs would be driven by the cost of the expendable tank, which has a mass of 22 Mg.

Conclusions

The integrated launch and emergency entry vehicle (ILEEV) is a concept that can satisfy the need for a heavy-lift launch vehicle, an advanced manned vehicle, and a Space Station Freedom emergency entry vehicle. It could have relatively low development costs because only one small entry vehicle would need to be developed. It would have reasonable operating costs because the expendable tank would be smaller than that of the Space Shuttle and all expensive parts would be reused.

References

[1]Holloway, P. F. and Talay, T. A., "Space-Transportation Systems Beyond 2000," 38th Congress of the International Astronautical Federation, IAF-87-188, Oct. 10-17, 1987.

[2]Durocher, C. L., Inby, T. M., Jenkins, J. C., and Gorski, R. J., "National Space-Transportation Studies," Society of the Automotive Engineers Paper 86-1681," Oct. 1986.

[3]Holloway, P. F. and Zersen, W. F. H., "Future Space-Transportation Options—Overview," AIAA Paper 86-1210, June 1986.