Conclusion

There are distinct advantages of nonseparation of a payload from the apogee motor. However, certain unfavorable implications of this option should also be taken into account. One major problem that has been pointed out is that the apogee motor case may lose its rigidity, and this may lead to coning angle and finally a flat spin. Moreover, this may lead to satellite antenna dip and to thermal imbalance.

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A Shuttle Derived Utility Vehicle for Delivery of Small Payloads to Orbit

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Introduction

A DERIVATIVE of the Space Shuttle that results in a vehicle having less capability, but at a reduced cost per flight, is proposed. In this design, the two Solid Rocket Boosters (SRB's) are removed (Fig. 1). The two Shuttle SRB's weigh a total of approximately 2.6 million lb and constitute 57% of the launch weight. After removal of the SRB's, three Space Shuttle Main Engines are added at the rear of the External Tank (ET), and additional main engine propellant tankage is added in the cargo bay. This modified Shuttle is referred to herein as a utility vehicle. It should be noted that the three tank-mounted engines are modified for an expansion ratio of 40 to 1 compared to 77.5 to 1 for the present Shuttle. Only one tank-mounted engine is visible in Fig. 1, since the engines are in line in the side view.

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Mission Description

All six LOX/LH_2 engines are operated at liftoff, giving a thrust-to-weight ratio of 1.3 (Fig. 2). This value varies slightly, depending on the payload and amount of propellant stored in the payload bay. Throttling of the three tank-mounted engines is initiated 93 s after liftoff. Throttling and sequential shutdown of the engines continues until 245 s after liftoff, when all tank-mounted engines are shut down. At this time, throttling of the engines on the Orbiter is initiated while the electrical umbilicals and propellant lines on the tank-mounted engines are separated (a 30 s interval is available for this procedure). At 275 s into the flight, the ET is separated from the Orbiter and is allowed to reenter (Fig. 1). The Orbiter continues on the internal propellants stored in the payload bay. Throttling and sequential shutdown of the engines on the Orbiter proceeds until orbital insertion. After achieving orbit and delivering the payload, the hydrogen tank in the payload bay is discarded to reenter from low-Earth orbit.

The three ET-mounted engines are then retrieved with an extended manipulator arm which is stored in the payload bay. The ET thrust structure is then either collapsed and returned for re-use or expended. The Shuttle returns with the three engines and the cargo bay LOX tank.

In the event of an abort during ascent, the stored propellants in the Orbiter can be burned to depletion with the

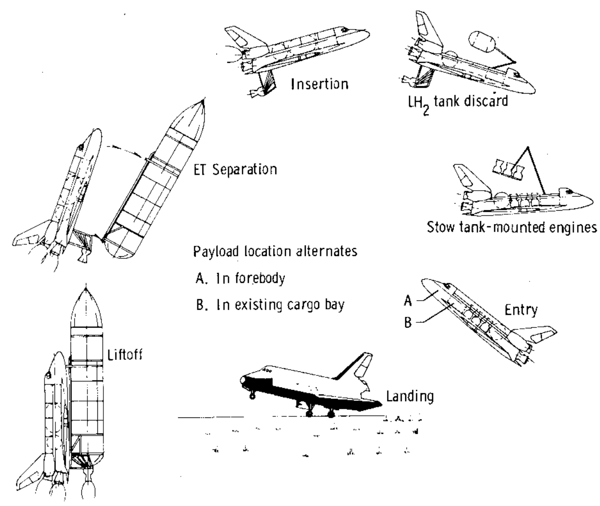

Fig. 2 Thrust, weight, and thrust-to-weight ratio vs time.

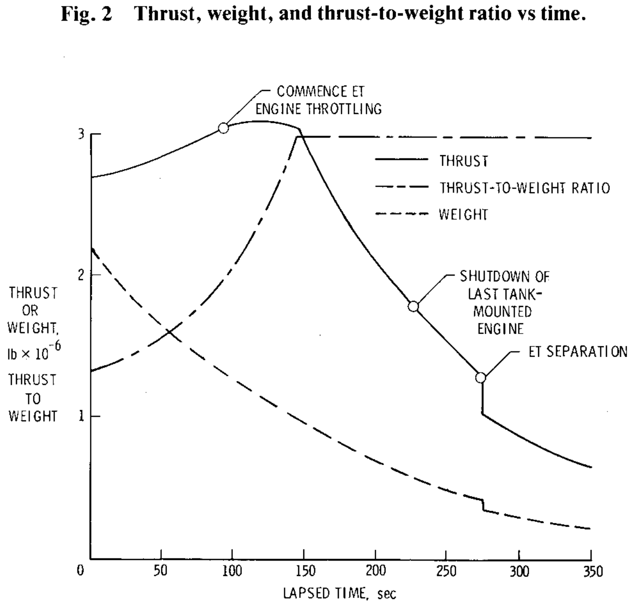

Fig. 1 Utility vehicle configuration and mission sequence.

engines vectored to give a return trajectory to a landing site. In an alternate mode, the oxidizer and fuel are dumped sequentially to avoid a fire hazard. By depleting the internal propellants, the maximum allowable landing weight of the Shuttle is not exceeded.

Payload Accommodation

In the baseline utility vehicle design, 15 ft of cargo space is allowed ahead of the internal LOX/LH_2 tankage. However, tank length can be varied. Results for trajectory studies show payload weight increases with increased propellant loading (Fig. 3). These estimates were obtained using methods from Ref. 1. For separate LOX and LH_2 tanks with 45 deg elliptical-end domes, the propellant loading limit is approximately 178,000 lb. This limit is shown as a vertical line at the right side of Fig. 3. For this case, there is no space available in the payload bay, and the Shuttle orbiter crew module is reconfigured to permit the installation of a payload. The existing space in the mid-section of the forebody and below the flight deck is substantial and could be increased by removal of the galley, the airlock, storage cabinets, provisions for extra crew, and any other items associated with longer duration missions involving space experimentation, more crew, and extravehicular activities. Some provisions would have to be made, depending on the size of the payload, for access to this alternate cargo space.

Payload Estimates

In order to determine the deliverable payload, detailed weights for the modified Orbiter were obtained from Space Shuttle mass properties status reports. The Orbiter weight is from an operational vehicle designated OV-103[2]. Weight for structure must be added to the baseline Orbiter in the mid and aft fuselage sections to accommodate the much heavier loads of the internal propellants and tanks in the utility vehicle. (Other deletions and additions are listed in Table 1.) It is also necessary to estimate the weight of the modified ET. The 74,700 lb weight shown in Table 1 for a newer, lightweight ET at main engine cutoff was also obtained from a monthly mass properrties report.[3] First, the structure required for the SRB's is removed. Then, since the ET is normally supported by the SRB's on the launch pad, extra structure must be added to provide this support. Additional structure must also be added to the ET to accommodate the thrust of the three add-on engines. After removing the structure for attachment of the SRB's and adding that required for the LOX/LH_2 engines, the overall tank weight is 77,400 lb.

Estimates for deliverable payloads with the modified (or utility) Orbiter are shown in Fig. 3. If, for example, the entire Shuttle payload bay is filled with tankage and no technology improvements are made in the Orbiter (Point 1 in Fig. 3), then the deliverable payload is 2000 lb (to be carried in the forebody mid-deck area). For an additional payload, a reduction in Orbiter weight is achieved throught the application of advanced technologies. This process is already underway for the present Shuttle.[4]

For the utility vehicle application, this program would simply be intensified. In the field of avionics, the newer technologies which could be applied to reduce weight appear to be extensive. If all the Orbiter subsystem dry weights (including structure) could be reduced on average by 15%, then a payload of 17,000 lb could be realized for a 15-ft payload-bay space (Point 2 in Fig. 3).

Operations and Recurring Costs

By elimination of the SRB's, occupancy time on the Mobile Launch Platforms (MLP's) would be reduced because of the reduced stacking time. At present, once an MLP becomes available, the SRB's are stacked, the ET is attached to the SRB's, and the Orbiter is mated to the ET. For the proposed system, a support frame would be needed for the Orbiter and tank in the absence of the SRB's. For the utility vehicle, the pressurization and feed system would be more complex with the added engines and would require more elaborate checkout procedures.

However, by eliminating the SRB's recurring costs would be reduced by an estimated 25%. This reduction includes acquisition costs and all other operational costs associated with the SRB's, such as recovery and refurbishment, disassembly after use, reassembly, reprocessing, and inspection. The addition of the three engines on the ET would

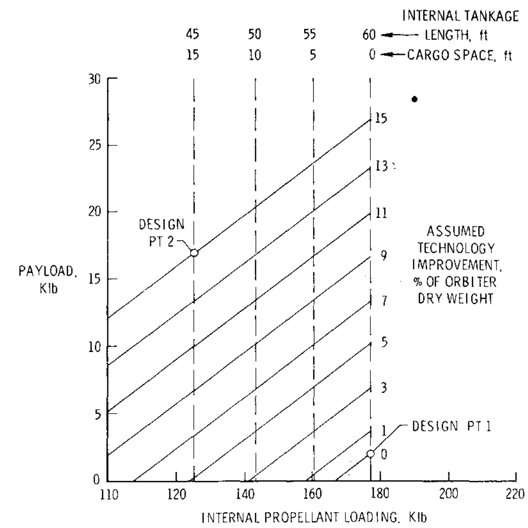

Fig. 3 Payload weight vs internal propellant loading for various technology improvements.

Table 1 Overall system weights

Item	Shuttle Orbiter, lb	Utility vehicle, lb	Comments
Shuttle dry weight	164,500	162,400	Eliminate galley, freon radiators, etc. Add structure for tankage.
3 Shuttle add-on engines	0	19,400	Shortened nozzles $\epsilon = 40$
Provisions for add-on engines	0	5,600	Thrust structure, pressurization and feed, and auxiliary systems.
Payload bay tankage	0	8,100	Tankage, tankage supports, insulation, and purge systems.
Personnel, payload accommodations, and miscellaneous fluids	32,900	25,000	Reduced personnel and maneuver propellants.
Payload	65,000	2,000	
Payload bay propellants	0	178,000	
ET weight at main engine cutoff engine cutoff	74,700	77,400	Less SRB attachment structure, plus add-on engine support.
ET propellants	1,596,000	1,589,300	
Booster	2,593,300	0	
Totals	4,526,400	2,067,200	

add an estimated 3% to the cost per flight, and the internal throwaway LH_2 tank and other systems would add another 6%. The net savings per flight are estimated to be 16%.

Summary Remarks

A modified Space Shuttle concept is proposed for use as a utility vehicle for delivery of small payloads to unique orbits. Although operationally more complex on-orbit, no new engine developments are required, and the external shape of the Orbiter is not altered. Launch costs per flight are reduced by an estimated 16% by removal of the SRB's. The use of a shorter nozzle makes storage of the engines in the cargo bay space left by removal of the hydrogen tank possible. As a result of the modifications to the standard Shuttle, a vehicle with lower recurring costs (but smaller payloads) could be made available.

Acknowledgment

Evans P. Brien died on December 11, 1983. He was employed by Kentron International, Inc/Aerospace Technology Division, under contract to NASA. We wish to make special note of his many contributions, particularly in the all-important field of design. Prior to employment at Kentron, he was employed by Martin Marietta and General Dynamics. He will be greatly missed both as a person and for his technical expertise.

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