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EVOLUTIONARY TRANSPORTATION CONCEPTS

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Abstract

Shuttle derivatives have been under study by the National Aeronautics and Space Administration (NASA) for a number of years. The Lunar/Mars Initiative has resulted in efforts to address additional requirements that must be met as we approach the turn of the century. These requirements include the need for higher reliability, lower cost, and the need for heavy lift capability. This paper will discuss some National Space Transportation System (NSTS) derived concepts that address these needs in the context of a "Block-II" system. These concepts will also be described in terms of an overall architecture which can be achieved with relatively modest up-front development.

Introduction

The NSTS is back on track and demonstrating capabilities in payload and crew delivery and payload servicing and payload return that are unprecedented in Earth to orbit (ETO) transportation systems. The basic design approach resulted in a system where upgrades to flight and operational elements can be introduced to meet projected long term requirements. These modifications may be installed as block upgrades as typified in the aircraft and launch vehicle industry where the lessons learned from flight experience are utilized.

Shuttle derivatives studied over the past 10 - 15 years have emphasized cargo vehicles. Shuttle Evolution assessments initiated in 1988 are attempting to address related issues for manned transportation systems. This paper will discuss some NSTS derivatives with particular application to manned missions, although cargo delivery must also be addressed in order to arrive at an architectural solution. Consideration of all three basic Shuttle hardware elements, the External Tank (ET), boosters, and Orbiter is essential to the evolution of an architecture which will meet long term requirements.

Requirements

The civilian space requirements are formulated in the Civil Needs Data Base (reference 1) and are augmented by the requirements postulated in the Human Exploration Study performed by the National Aeronautics And Space Administration in the fall of 1989 (reference 2). These requirements, although preliminary, enable determination of some fundamental, characteristic requirements. These can be broadly categorized into the transportation of crew, hardware, and propellant.

Extending human presence in space will require a considerable increase in the crew rotation capability beyond the maximum of 70 crew members per year. This is based upon 14 flights per year, 2 crew/5 passengers. The requirements approach 90 rotations per year in the 2010 time period with a Lunar/Mars initiative (figure 1).

Increasing the crew carrying capacity of the Shuttle to 10 (2 crew/8 passengers) is considered a viable option and becomes the first requirement for the Shuttle derived system considered in this study.

The cargo delivery requirement must be examined for both hardware, and propellant delivery as the two payload types can result in different delivery systems. Typical Lunar missions based on requirements in reference 2 result in a low Earth orbit (LEO) mass requirement for a single Lunar mission on the order of 450K lbs for an aerobraked, fully fueled LOX/LH2 transfer system. The capability for a direct Lunar launch is highly desirable for an early Lunar program and also enables initiation of more aggressive (e.g.,Mars) missions. This requirement sets the upper LEO mass requirement on the derived system.

Once the reusable, space based hardware is in place, propellant delivery becomes the key commodity. Propellant needs for a typical lunar mission run in the 300K lbs range for each mission again assuming a LOX/LH2 system. Examination of the inert (hardware) mass leads to a requirement on the order of 150K lbs and constitutes the lower bound for a modular delivery system. Consequently, 150, 300 and 450k incremental capability levels combined with the baseline Shuttle at 65000 lbs, provide a modular payload capability which meets a wide range of requirements well into the next century.

The other key characteristic parameter is the basic size of the systems to be launched into LEO. The dimensions for typical aerobraked configurations (fully deployed/assembled) is of the order of 45x90 feet; large by todays standards. Considering the desire to minimize on-orbit assembly early in the program, the last of the derivative system requirements is for a maximum payload envelope of 45x90 feet.

Shuttle Derived Building Blocks

Two Shuttle derived elements and a new rocket booster system are fundamental to the evolution strategy:
- the addition of a propulsion module to the base of a modified ET resulting in a new "core" stage
- a liquid rocket booster (LRB) system
- a Block-II Orbiter without a main propulsion system.

This combination of elements will constitute a transportation system which can satisfy civilian earth to orbit transportation needs well past the 2000 time period including a Lunar/Mars initiative. The rationale, description of the three elements, and the overall evolutionary strategy will be discussed in the following paragraphs.

Core Stage

The addition of a propulsion system to the base of the ET has been studied in the past (e.g., reference 3,4) and was selected as the basic core stage. There are several advantages in removing the launch vehicle propulsion function from the Orbiter. In addition to benefits to the Orbiter discussed below, there are advantages to the total system, including:
- in-line configuration performance gain due to reduced cosine losses, simpler load paths, aerodynamics

- more viable propulsion system recovery options
- the resulting core stage has potential application to other manned as well as cargo systems.

A three Space Shuttle Main Engine (SSME) concept configured with an optional propulsion return module is shown in figure 2. Standard SSMEs are employed with the 77.5:1 nozzles and operated at 100 per cent power levels. These engines were baselined based on the planned improvements and the extensive operating experience and reliability that will have been achieved by the time the evolved systems become operational. The derivatives under consideration do not preclude incorporation of advanced, low cost propulsion systems if/when they become available.

To address the orbital insertion and maneuvering requirements typical of propellant delivery missions, an orbital maneuvering/reaction control system package is considered in addition to the primary propulsion system. The weight and performance numbers (table I) reflect this option as well as the impacts to the ET consisting of: structural beefup, particularly in the intertank area, added aft skirt, thrust structure and feed lines, subsystems including avionics, thrust vector control (TVC) and electrical power. The weight estimate reflects incorporation of aluminum-lithium (Al-Li) materials.

Moving the engines from the Orbiter to the base of the ET will also require modifications to launch site facilities, particularly the Mobile Launch Platform. This and other impacts have been defined in the Shuttle Derived studies referred to above.

Liquid Rocket Booster (LRB)

A LOX/LH2 LRB sized to deliver 65K-70K lbs to LEO is a natural extension to the STS launch system. The improved performance, abort options/engine out capability, environmentally clean exhaust, and the reduction in ground processing time, all add up to a viable option requiring further consideration. In addition, the LRB has considerable synergism with the Advanced Launch System (ALS), and alternate access options with a Personnel Launch System (PLS). Eventual development of a "Shuttle-II" vehicle with fly-back boosters will necessitate the development of such a propulsion system. The booster system can be designed to meet the current STS interface and performance constraints enabling some degree of resiliency by the ability to fly either the LRB or the Solid Rocket Booster if one experienced major problems.

The LRB baselined for this study is a LOX/LH2 concept based on studies performed in 1988-89 (reference 6,7). The desire for common propellant and engine systems was key to the selection.

Modified Orbiter

Some fundamental changes to the Orbiter's primary function are proposed as a result of the projected long term requirements and current space policies. Specifically, if it is assumed that cargo delivery will be accomplished primarily by unmanned cargo vehicles, a "Block-II" Orbiter will be free to evolve to enhance crew related capabilities. In this scenario, a derived Orbiter can emphasize enhanced on-orbit operations, Earth observation missions, servicing/retrieval missions, in addition to increased crew carrying capability. These requirements do not require robust lift capability; on the contrary, lift capability can be traded for flight margins and enhanced safety systems. An enlarged crew compartment is a candidate for improving on-orbit operations in addition to meeting crew delivery requirements (figure 3). The upper and lower flight decks are extended 15 ft. aft allowing considerable on-orbit work space. The shortened payload bay is consistent with payload length requirements for payloads in the 40000 lb range based on typical payload densities and dimensions.

The second major change would be the removal of the main propulsion system offering several advantages:

- separates the launch propulsion function from the spacecraft with associated reduction in vehicle complexity
- additional volume due to removal of propulsion system is available for other uses (e.g., additional orbital maneuvering system propellant)
- orbiter weight reduction with subsequent down weight capability enhancement
- faster turnaround at the launch site

In addition, enhancements defined in recent Shuttle Evolution studies were included. These enhancements (table II) strive to achieve higher reliability/safety, reduced turnaround time, cost, and increased capability, although not in terms of enhanced payload. As the data in table-II indicates, the resulting weight is greatly impacted by removal of the propulsion system and the addition of a Crew Escape Module (CEM) if implemented. The center of gravity (CG) shift is considerable and is currently under study. Potential CG management strategies include: abort dumps, payload manifesting, delete forward RCS, wing fillets, extending the elevons, and as a last resort ballast.

This Orbiter concept is illustrated in figure 4, and the total stack for this candidate Block-II vehicle is illustrated in figure 5. The overall performance capability (table III) assumes the enhancement weight changes are converted to performance. However, performance is not the primary goal, and should be traded for margins to the extent possible. A candidate trade list is also shown in table III.

The above modifications to the Shuttle elements result in a manned transportation system derived from current hardware/technology with significant improvements to warrant a Block-II designation. But the overall architecture is the most important attribute. A phased implementation of the above three building blocks allows significant architectural options with proper mixing/matching. Utilization of the core stage with six to eight LRBs results in a Heavy Lift Launch Vehicle (HLLV) that is capable of launching an entire Lunar mission stack, meeting the first cargo (450K) requirement. This vehicle can satisfy Lunar mission needs with minimum required on-orbit assembly, reconfiguration, and checkout, and also allows reasonable capability for initiation of a Mars program. The propellant delivery requirement (300k) can be met with tanker vehicles consisting of the basic core stage and two or more LRBs (figure 6).

The overall architecture is illustrated in figure 7. It is an STS derived architecture with no technology break-throughs required, but incorporating currently available technologies. The architecture will meet civilian requirements well into the 2020 time period, and could overlap operation of the current Shuttle fleet past the 2010 time period.

Conclusion

The results of this assessment indicate that Shuttle derived elements and a LRB system can be defined which can meet long term requirements. Although lacking the excitement associated with new technologies, derived systems offer enhanced capabilities at minimum risk and lower up-front development costs. Furthermore, the Block upgrade approach is more amenable/flexible to changing mission needs. It is hoped that the basic building blocks discussed herein foster further study, particularly from a total architectural standpoint. The STS offers a sound set of hardware and operations experience base upon which to grow our space transportation capability.

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