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OTV IMPACTS AND INTERACTIONS

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ABSTRACT

The purpose of this brief paper is to identify the possible impacts to, and interactions with, the agency's planning activities for the Orbit Transfer Vehicle (OTV) that is tentatively scheduled for initial operational capability in the late 1990's. In general, the various Mars missions proposed elsewhere in this report require vehicles of significant size and performance far greater than that provided by any OTV configuration currently being seriously considered. Therefore, interactions and impacts on these current concepts are minimal. These impacts and interactions fall into categories of technologies, systems, and operations. Each category is addressed in the text.

INTRODUCTION

The civilian space agency is currently in the planning stages for the next step in the Space Transportation System (STS), a reusable OTV that can expand the range and capability of the Space Shuttle and Space Station. To accomplish preliminary definition of the OTV, Phase A development studies are in progress by three aerospace contractors. In addition, technology developments have been initiated in propulsion systems, aerobraking, and space servicing and operations. It is of value, if not the principal function of advanced program activities, to identify the impacts to, and interations with these current developments. It is in the best interests of this nation's future in space for the agency to define infrastructure and technology development programs that grow and evolve such that they enable, support, and promote these advanced programs. It is even more critical that the agency insure, through knowledge of these potential missions, that no developmental steps are made to support near-term needs at the sacrifice of the possible evolution into future missions. A particular point to be made here is that details of these future programs are much less important than how they interact with or impact current or near term space infrastructure element definition and technology developments. For the OTV, a useful breakdown of these impacts and interactions appears to fall into categories of technologies, systems, and operations. Each of these categories will be discussed in the following paragraphs.

OTV TECHNOLOGIES

Many times it is difficult to obtain public support for development of particular technologies when they are directly justified on the development of a single element. Advanced mission planning provides opportunities for broadening the base of support for technology development by enhancing the value of these technologies through a demonstration of how they can promote and support paths towards desirable future goals for the agency. For the manned Mars mission, supporting technologies are at least, but probably not exclusively: (1) Propulsion; (2) Life sciences; (3) Life support; (4) Robotics/automation/artificial intelligence; (5) Aerobraking; (6) Thermal protection; (7) Cryogenic fluids storage and handling; and (8) Power.

Propulsion

A manned Mars mission is a very demanding mission from the standpoint of propulsion. Concepts presented elsewhere in this report show departure masses of two million pounds or greater in low Earth orbit. Propulsion technologies in work that are primarily, but not totally, targeted for OTV development are the advanced space engine and propellant management. The advanced space engine, per se, will be of too low a thrust level for the Earth departure burn for a manned Mars mission but may be adequate for other portions of the mission. In addition, the technology developments that permit the increase in engine Isp may be applicable to development of a much larger Earth departure engine system. Other concepts presented in this volume rely on long term cryogenic storage (up to three years) and propellant transfer, not only between stages, but between fueling stations in space and the Mars vehicles. The most promising technology for enabling and enhancing manned Mars missions appears to be in-situ propellant production on the Mars surface, Mars moons, or even Earth's Moon. Some of these in-situ propellant production schemes will involve the transfer of cryogenic propellants in the "zero-g" environment of space.

Aerobraking

Analyses and conceptual designs for the agency's OTV that show aerobraking is a significant enhancing technology that can reduce the cost of transportation to Geosynchronous Earth Orbit (GEO) by almost doubling the delivery capability of an all-propulsive vehicle (reference 1). Analyses for manned Mars missions accomplished elsewhere in this report (reference 2), demonstrate a significant advantage of aerobraking in the performance of the Mars vehicle as well. However, there are significant safety problems involved with the concept of aerobraking either at Mars or at Earth on return. If these problems can be resolved, then the performance improvements offered by aerobraking are large enough for this technology to fall into the category of enabling. Reference 2, however, does make the point that current technologies for reusable Thermal Protection Systems (TPS) for the aerobrakes cannot tolerate the thermal environment for some masses and trajectories. Ablative TPS systems are more than adequate. Since ablative systems are non-reusable, the technology developments for the OTV must be pushed harder if they are to support reusable vehicle systems for manned Mars missions. Table 1 summarizes the impacts and interactions of manned Mars missions with OTV technologies.

Aerobraking technology developments are not limited to aero and aerothermal issues. Guidance through the atmosphere is another technology development receiving a significant amount of study at this time. To enter the atmosphere at a precise point, fly through a highly variable environment, and exit the atmosphere to fly to a precise point in orbit about a planet has proven to be a real challenge for Earth, where the atmosphere is known to a much higher degree than at Mars. Current efforts being devoted to development of guidance algorithms for the agency's OTV should include the requirement to enable aerobraking at Mars with little or no alterations. To address these technologies, the agency is planning a Shuttle launched Aeroassist Flight Experiment (AFE). The AFE will exit the Shuttle and fire a rocket motor to simulate an entry from GEO. The TPS concepts planned for the AFE will be reusable systems designed for the entry velocities encountered by a vehicle returning to Earth at or near the Earth relative parabolic trajectory. Conversely, vehicles returning from Mars will always be hyperbolic, with some trajectories having velocities as high as 55,000 ft/sec. As noted earlier, current state-of-the-art TPSs are not adequate for such a Mars return, hence this would require the AFE to consider the inclusion of

TABLE 1

INTERACTIONS AND IMPACTS WITH THE OTV

INTERACTIONS

I. TECHNOLOGIES

PROPULSION

- O High Performance Cryogenic Engines
- O "Zero-g" Propellant Transfer

AEROBRAKING

- O Utilize OTV Developed Aerobraking Technology for a Significant Performance Enhancement
- O Application of Guidance Algorithms to Mars Aeroflight

II. SYSTEMS

PROPULSION

- O Cryogenic Advanced Space Engine
- O Pump-Fed Storable Engine
- O Cryogenic Propellant Storable and Transfer Systems
- O Aerobraking Systems

III. OPERATIONS

- O Propulsive Vehicle for a Manned Mars Flyby
- O Utilization as a Ferry Vehicle To-From the LEO Space Station and the Returning Mars Spacecraft
- O Utilization as a Ferry Vehicle in the Mars Vicinity

IMPACTS

I. TECHNOLOGIES

AEROBRAKING

- O Reusable Vehicles will Require Significantly More Advanced Technology Development than are Currently Needed for the OTV
- O Aeroassist Flight Experiment:
  - + Alternative Advanced Reusable or Ablative TPS Samples
  - + Higher Entry Velocities or Dedicated Flight

II. SYSTEMS

- O None Identified

III. OPERATIONS

- O May Significantly Impact the Design of the TPS to Allow an Option of Either Performing a Block Change to the OTV TPS for Mars Missions or Allowing the Application of Ablative TPS some test TPS samples of ablative or advanced technology reusable concepts. The thermal environment to the TPS during entry from GEO-type orbits will be dominated by convective heating, whereas the thermal environment for the upper limit of the Mars returning vehicles will be dominated by non-equilibrium radiation. To fully understand this thermal environent, it may be necessary to provide a much larger booster for the AFE to properly simulate the entry velocities encountered in a Mars return. It may be more appropriate to make a separate dedicated flight of the AFE for assessment of a Mars-Earth return. These impacts and interactions are also noted in the table.

OTV SYSTEMS

Propulsion

The Agency is planning the development of an advanced high performance cryogenic engine that is space maintainable, man-rated, and capable of multiple starts. As mentioned in the previous section, this engine is probably suitable for all propulsive burns except the Earth departure. Pump-fed, high performance, storable propellant engines are also under consideration. The concept of pump-fed storable engines not only results in improved specific impulse for the storable propellants, but permits much greater structural efficiencies in the design of the propellant tankage due to the greater densities of the storables over the cryogenics. Additionally, the use of pumps to directly feed the engines rather than to pressurize the propellant tanks allows lighter tankage designs. These two concepts compete with each other in performance vs. boil-off of cryogens vs. lighter and more efficient structures. The winner will have to await more sophisticated analyses which are in process.

OTV OPERATIONS

Manned Mars Flyby

As discussed in reference 3, it is conceivable to utilize at least one concept of the agency's OTV for the main propulsive stage for a manned Mars flyby mission. The proposal in the reference suggests using two of these OTVs mated to a Space Station module to provide the required velocity increment for the mission. In addition, the proposed command module for the OTV is also required for this mission. On the other hand, however, the proposal in the reference not only discusses the mentioned interaction, but also notes a significant impact to the OTV design that must be addressed early in the definition stages of the OTV. That is, the TPS design proposed for this OTV will not tolerate the entry environment at Earth on return, for some masses and trajectories, and may well have difficulty at Mars also. This short-comming of the TPS requires either more advanced TPS technology development than is required for the current planned near-Earth support, or we must incorporate into the design of the vehicle an option to replace the reusable TPS with an ablator. Alternatively, the final design could allow for a block change to an advanced technology TPS to support Mars missions, or it might be possible to spray an ablative coating directly onto the reusable TPS without physically removing it.

Mars Landing Programs

This category actually covers all cases of Mars missions that, due to significant mass or other reasons, choose to only carry enough propellant to place the vehicle into an elliptical orbit with a very high apogee at arrival back at Earth. This leaves the crew and scientific equipment and Mars samples in an orbit that is not accessible by the Space Station. The plan, as described in reference 4, utilizes the OTV to rendezvous with the Mars Spacecraft and return the crew and equipment to the Space Station in LEO. At first glance, this requirement does not seem to be any more demanding than the current requirement for the OTV to ferry payloads to and from GEO. Another concept for utilization of the OTV (not addressed by any of the papers in this report) is as a sortie vehicle in the vicinity of Mars. There are probably more efficient means to execute sortie missions from the main spacecraft, but this OTV should be given attention until that point is proven.

SUMMARY AND CONCLUSIONS

This brief paper has taken a casual look at the possible impacts and interactions with the agency's proposed OTV, its technology developments, and its major systems. Several impacts and interactions have been found and have been tabulated in Table 1. It is hoped that such a tabulation is useful to the development process for the OTV to make it a more useful vehicle. Since this paper is very cursory, it is recommended that the studies of the Mars missions, as they mature, continue to define possible impacts and interactions to the OTV.

REFERENCES

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2. Wallace and Hill, Mars Aerocapture, this report.

3. Roberts, B. B., Manned Mars Flyby, this report.

4. Stump, W., Earth Vicinity Trades and Options, this report.