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POSSIBILITIES FOR REDUCING HIGH-ENERGY PERFORMANCE REQUIREMENTS

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In recent years, techniques have been developed for utilizing gravity-assist effects from intermediate planets to improve performance and/or reduce flight time to difficult planetary targets. The first significant application of these benefits was accomplished by the highly successful MVM program which employed gravity swingby of Venus to reduce launch energy (and costs) for the initial flyby of Mercury. The same basic methods have been used to deflect the Pioneer 11 Jupiter flyby spacecraft to a Saturn encounter trajectory.

The current Planetary Mission Model is predicated on further exploitation of gravity-assist techniques. Remnants of the ambitious Grand Tour concent are evident in the Mariner Jupiter Saturn, Mariner Jupiter Uranus, and Pioneer Saturn Uranus mission designs. Also, the difficult Mercury orbiter mission will be possible with multiple gravity swingbys of Venus. In this case, the mission flight time of 31 months represents an operational price to be paid for the performance improvement over direct ballistic flight.

NEW FLIGHT TECHNIQUES FOR OUTER PLANET MISSIONS

A recent development has been identification of methods to utilize the gravity-assist potential of Venus and/or Earth to improve performance for missions to the outer planets. Two basic techniques have been verified, both of which offer the prospect of approximately doubling launch vehicle delivery capabilities over direct ballistic flight values for the price of increasing flight time by about 2 years (Ref. 1). The first of these techniques is predicated on successive Venus and Earth swingbys (dubbed VEGA for Venus-Earth Gravity-Assist) followed by a spacecraft velocity maneuver to achieve the final desired aphelion radius. The performance benefits originate in the low launch energy requirements ($C_3 \sim 20\ km^2/sec^2$) to initiate the planet encounter sequence.

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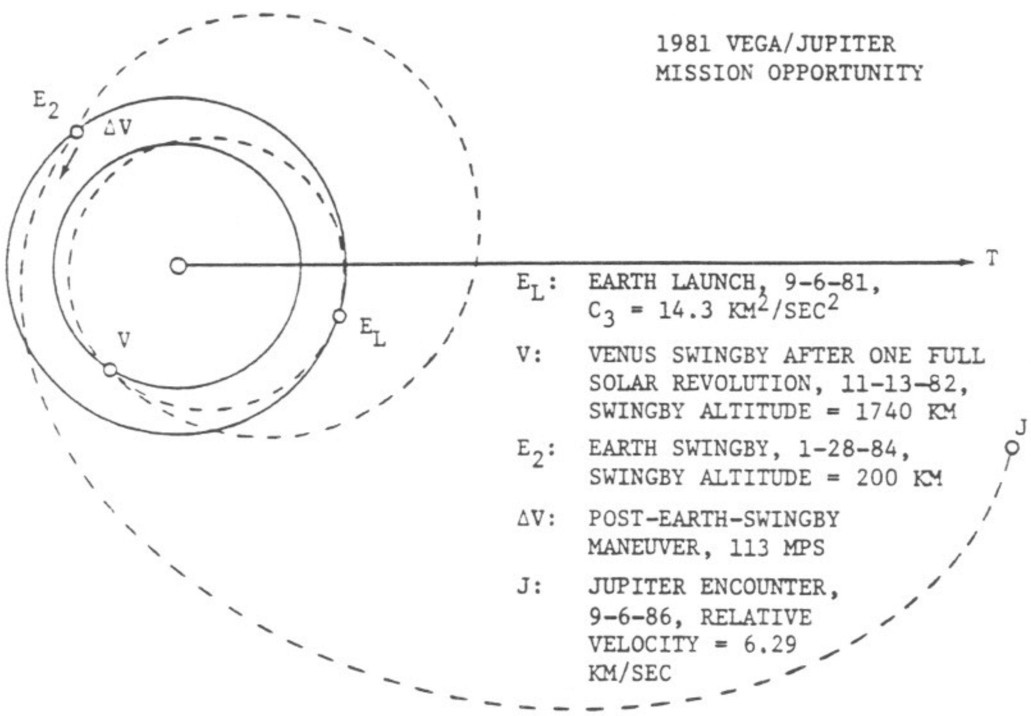

Fig. 1 Typical VEGA Flight Profile

The VEGA flight technique, illustrated on Figure 1, is characterized by initial perihelion radius inside the orbit of Venus. While this class of thermal environment should not be a major cost factor for a totally new spacecraft, modifications of existing Pioneer and Mariner designs could be quite expensive. For this reason, an alternate flight technique was developed which does not depend on Venus swingby.

Dubbed ΔVEGA (for ΔV-Earth-Gravity-Assist), this latter flight technique, depicted on Figure 2, involves initial launch outward from Earth orbit, a retrograde velocity maneuver at aphelion to produce an Earth-crossing orbit, and gravity swingby of Earth at either of two optional locations. Performance capabilities and phasing time requirements for this technique are comparable to the VEGA method. However, the minimum perihelion which must be experienced by the spacecraft is about 0.85 AU. A secondary characteristic of ΔVEGA missions is the existence of two distinct launch periods for each launch opportunity to any specific outer planet. The two launch periods are separated between centers by about 12 weeks and could prove of significance to operations in the Shuttle era.

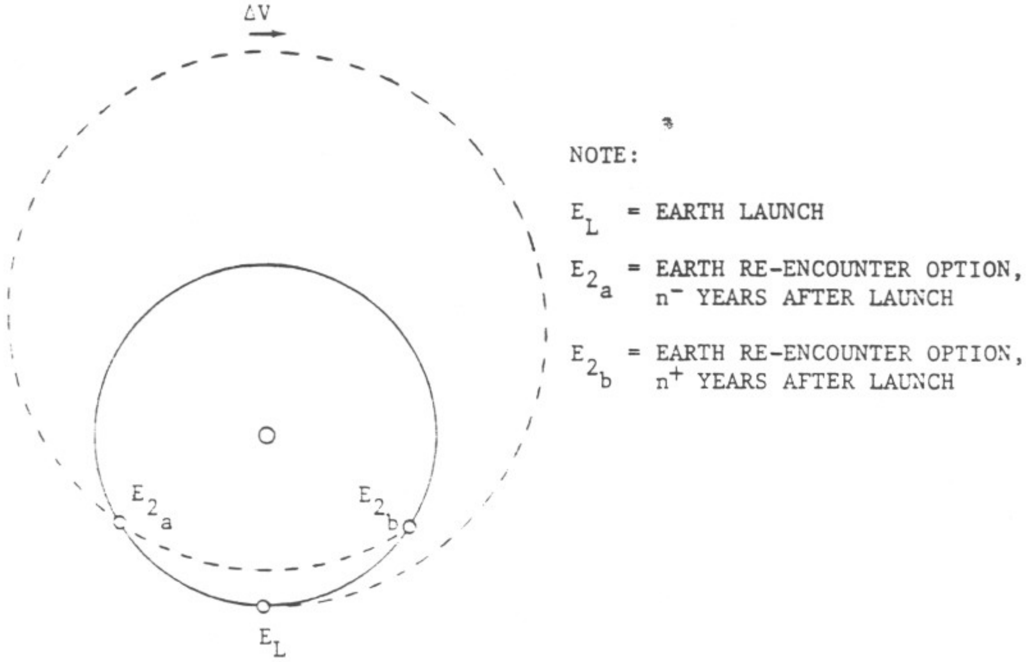

Fig. 2 ΔVEGA Heliocentric Geometry Options

LAUNCH VEHICLE CAPABILITIES

The performance advantage factors offered by the new flight techniques apply to all planetary launch vehicles. For example, the difficult Mariner Jupiter Orbiter and Mariner Saturn Orbiter missions, which substantially exceed the direct launch capabilities of Titan IIIE/Centaur/TE364-4, can both be performed by this launch vehicle if the VEGA or ΔVEGA techniques are employed. Of course, the mission flight times are increased by the necessary planet phasing interval of about 2 years. This latter consideration must be weighed in context with the value of increased spacecraft mass and/or reduced launch vehicle requirements.

Current mission plans for Mariner Jupiter Orbiter and Mariner Saturn Orbiter are based on launch in 1985 and 1987 respectively. Therefore, capabilities of the Titan IIIE/Centaur launch vehicle are probably academic. Of more significance, the new flight techniques affect the requirements imposed on the Interim Upper Stage operating in conjunction with Shuttle. As shown on Figure 3, only a few of the competing IUS candidates can deliver the Jupiter Orbiter spacecraft with conventional ballistic flight. The Saturn Orbiter mission, which is currently planned for launch after availability of the Space Tug, is within the capabilities of a single IUS configuration. If the VEGA or ΔVEGA flight techniques were employed, both of these demanding missions fall within the capabilities of even the lowest-performing IUS candidates. Combining the new flight techniques with a high-performance stage such as Space Tug would result in delivery capabilities to the outer planets sufficient to support consideration of totally new types of massive spacecraft and a wide range of new options for scientific exploration.

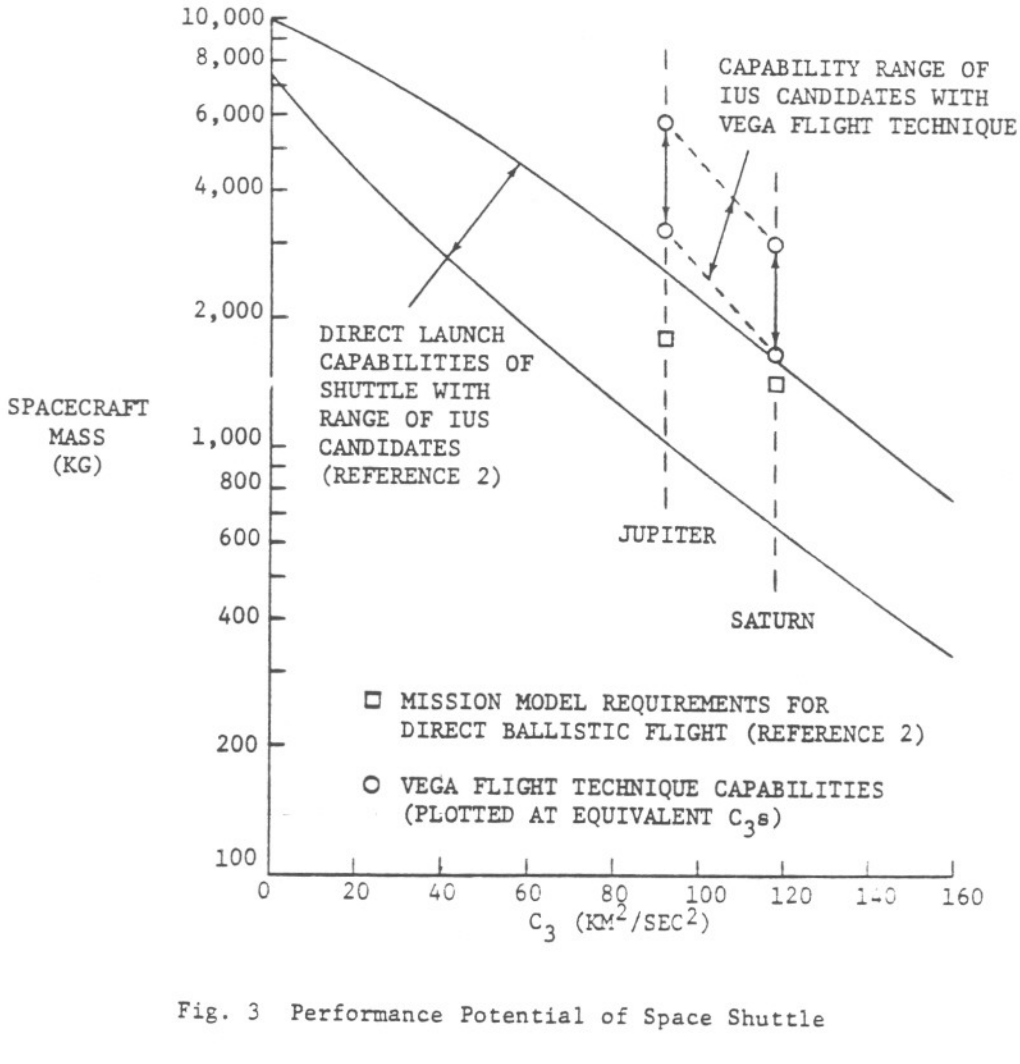

Fig. 3 Performance Potential of Space Shuttle

CONCLUSIONS

The most demanding performance requirements in the current Planetary Mission Model are those associated with the Mariner-class Jupiter Orbiter and Saturn Orbiter missions. The high launch energies required for conventional ballistic flight, in combination with the large spacecraft masses desired, exceed the capabilities of most of the competing candidates for the Interim Upper Stage planned for use in conjunction with the Space Shuttle.

New flight techniques have been developed which redistribute performance requirements between launch vehicle and spacecraft. With the low launch energies involved, net delivery capabilities to the outer planets can be approximately doubled for the operational prices of increased complexity and extended flight time.

With the new flight techniques, the difficult Jupiter and Saturn Orbiter missions fall within the capabilities of even the lowest-performance IUS candidates. For high-performance upper stage configurations, the current spacecraft mass requirements could be tripled and doubled for Jupiter and Saturn missions respectively.

The new flight techniques offer program options for reconciling conflicting IUS requirements as well as providing growth potential for future planning. In conjunction with orderly evolution of upper stages, the Space Shuttle could support the objectives of outer planet exploration through the remainder of the century.

REFERENCES

1. New Flight Techniques for Outer Planet Missions, Paper No. AAS 75-087, July 1975, G. R. Hollenbeck, Martin Marietta Corporation.

2. Shuttle/IUS Performance for Planetary Missions, Paper No. AAS 75-273, August 1975, M. J. Cork and J. M. Driver, Jet Propulsion Laboratory and J. L. Wright, Battelle Columbus Laboratories.

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