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Future Science Cargo Requirements for the Shuttle

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SPACE SCIENCE PAYLOADS FOR SHUTTLE

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ABSTRACT

This paper presents a sampling of space science missions currently planned or under study at the Jet Propulsion Laboratory. Early use of the Shuttle for launching planetary exploration missions will not differ very much in principle from expendable launch vehicles. Future concepts which make use of the unique characteristics of the Shuttle in conjunction with other new technology open some truly fascinating prospects. Shuttle has other roles in space science as well, both for deep space and Earth-directed observations. A variety of payload concepts, ranging from highly conventional to "far-out," are under study. Increasing experience with Shuttle operations will broaden the spectrum of possibilities.

INTRODUCTION

As the Space Shuttle approaches operational status, that portion of the aerospace community which deals with planetary exploration faces an era of uncertainty. Two years ago, the planetary exploration plan for the remainder of the century showed a Venus Orbiter Imaging Radar launch in 1984; the first mission of the Solar Electric Propulsion System would have flown by Halley's Comet, dropping off an ESA probe on the way to rendezvous with comet Tempel II launching in 1986, 1988 would have seen the launch of an ambitious Saturn orbiter carrying probes of Saturn and Titan. The 90's would have seen a series of Mars Sample Return missions, Mercury Orbiters, etc.

Now, the bright future painted above looks dim. The VOIR mission has slipped in time and reduced in scope and is pretty much extinct in its original form. Halley's Comet will pass through the inner solar system unmolested by U. S. spacecraft (although the rest of the space-faring nations are in a fair way to produce a minor traffic jam). The Saturn mission (and the various excellent far outer planet opportunities in the early '90's) have drifted out of focus and the Mars Sample Return hovers (as always) just outside the current planning wedge. In truth, the plan has been thrown into disarray by the changing fiscal and governmental environment.

Recognizing this, the new administration within the NASA Planetary Office and JPL are working to develop a flexible, modest scope, planetary program which will achieve worthwhile goals while fitting within present constraints and building toward the future.

Other areas of space science have suffered some setbacks as well, especially the cancellation of the U. S. part of the Solar Polar Mission. Various options are being studied to salvage as much as possible of that mission. Other missions being developed in the Solar Physics and Astronomy area will take maximum advantage of the Shuttle capability.

PLANETARY MISSIONS

It seems to be a foregone conclusion that the planetary program faces lean times during the next several years. It will be some time before the missions which one might expect to be the logical successors of Viking and Voyager come to pass. Galileo remains in the stable, slipped 3 years from its original launch date and perhaps 5 or 6 years from the originally planned arrival at Jupiter. Despite the slips, redesigns, and redirections, Galileo remains true to its original goals of placing a spacecraft in orbit around Jupiter and sending a probe into the atmosphere of that giant planet. When the project started in 1978 it was planned for launch on a 3-stage IUS in 1982 with the orbiter carrying the probe. The much publicized Shuttle delays plus termination of the 3-stage IUS caused a slip to the 1984 launch opportunity (a very bad one) and a split into two launches, one of the orbiter and the other of the probe and flyby carrier. Even then it was only possible with a powered Mars flyby. A subsequent slip to 1985 and promise of the wide-body Centaur allowed the recombination of the mission into a single launch. The latest twist is the end of the wide body Centaur. We can still make the 1985 single launch but only by invoking the VEGA (delta-V Earth Gravity Assist) technique. This maintains the performance but at a cost of some two years in flight time. This program is truly an example of resiliency.

A Venus mission appears in the que for a 1984 new start. This mission is an orbiting radar mapper, but at a much lower cost level than VOIR. A good deal has been sacrificed from VOIR in terms of radar resolution and supplementary science in order to meet the tight fiscal constraints. Nevertheless this mission promises to give us our first detailed look at the surface of Venus. This mission will be launched from the Shuttle on a 2-stage IUS with a solid propellant kick stage and will enter an elliptical polar orbit about Venus. Data will be taken during the lower part of the orbit on either side of periapsis and played back during the higher portion (Fig. 1). Over a period of several months of operation the surface of Venus will be mapped with synthetic aperture radar techniques to a resolution of about 300 meters.

Other missions of modest scale appear among the future possibilities. The Moon and Mars figure large among planetary missions that "need doing." These bodies have in common the fact that they have seen fairly intensive exploration (Ranger, Lunar Orbiter, Surveyor and Apollo for the Moon and Mariner and Viking for Mars plus numerous Soviet efforts). This leads to an attitude of "What is left to do?" The answer is: "A lot." We have been stumbling around the surface of Earth in a (more or less) civilized fashion for some 6000 years yet we still find survey satellites of various types (GEOS, TIROS, Landsat, Seasat) very enlightening in our understanding of our home world. To say we know all about Mars from two landers and a few orbiters or of the Moon from several near equatorial landings and some rather limited orbiters is clearly ludicrous even if we assume that those bodies are less diverse than Earth.

In line with these considerations, two orbiter missions are under consideration; polar orbiters of both Mars and the Moon are strong candidates for future missions. The baseline for the Moon and a major consideration for Mars is a geochemical orbiter. That is to say, a vehicle which would concentrate on the surface and near-surface composition of the bodies. Such vehicles would provide data which would be of substantial interest not only to the pure scientist but to those who feel that space derived resources are of future importance. We have substantial compositional data concerning the equatorial regions of the Moon especially on the near side where the landings have taken place. Except for photographic data, we know little of the high latitudes and nothing of the poles which may hold deposits of cold-trapped condensables and the optimum sites for permanent bases. On Mars we have some knowledge of two landing sites and good photographic data for most of the planet. Much remains to be learned of this body before it lives up to its potential as a future home of humankind. Tables 1 and 2 present details of these missions.

The asteroids have long been the second class citizens of the solar system. Indeed one astronomer, no doubt "bugged" by their traces on his photographic plates, called them "Vermin of the skies." Far from this description, the minor planets form a very respectable part of the solar family. Although small in size (Ceres, the largest, is only 1000 km in diameter while the majority are much smaller) the asteroids present surprising variety and are of interest both to scientists and to those interested in space resources. The demise of SEPS has rendered rendezvous with main belt bodies difficult (albiet not impossible). However, several near-Earth or Earth-crossing asteroids are quite readily accessible. The best known of these are Anteros, a stony asteroid of 1 to 2 km radius and Eros, a relatively large body of 15-20 km mean diameter. The orbit of these bodies lie just outside that of Earth at the closest to the Sun and some distance beyond that of Mars at the farthest point. Table 3 summarizes the characteristics of the 1987 launch opportunity to Anteros. Similar opportunities occur in 1989 and 1992. The Shuttle and two-stage IUS can place a very substantial spacecraft in rendezvous with Anteros. Eros is more difficult and payloads are smaller. Other asteroids such as 1980AA and 1980PA (both unnamed as yet) offer similar attractive opportunities and new potential candidates are being discovered at a rate of perhaps two per year.

We have discussed a selection of missions for the relatively near future. How might these missions be implemented? Two programmatic options are presently being considered which recognize the probability that only modest cost programs may be acceptable to the administration over the next several years. The two options are dubbed "Pioneer" and "Mariner Mark II." The former looks at taking an existing Earth orbiting spacecraft design and modifying it just sufficiently to perform a deep space mission while the latter is a spacecraft designed for deep space missions but designed from the beginning to do a series of missions with high inheritance from one mission to the next. The Pioneer approach is probably the least expensive way to do planetary missions given certain constraints. These constraints can best be summarized as "Do the best mission you can within the capability of the spacecraft rather than pushing for the best possible mission." For example, a solar powered Earth orbit spacecraft can be modified fairly readily to operate at the Moon, Mars or Near Earth Asteroids. Sending it to Mercury or Uranus would require much more substantial (and costly) changes. Also the instrument complement must be selected to be compatible with spacecraft capabilities. Trying to push the system to achieve all the science goals which might be levied upon it will lose the cost advantage of an existing vehicle and may in fact cost more than a build from scratch.

Mariner Mark II offers the possibility of spacecraft which, like their namesakes of the 60's and 70's, return good science but which have their goals and number of experiments constrained to a modest level. This contrasts with the Voyager/Galileo approach of trying to do as much as possible on one mission. (Note: This comment is in no way derogatory to these missions. There is little doubt that these bigger missions are most cost effective in terms of total data per dollar but modern concerns are with year-to-year cost, not cost effectiveness.) The major difference between MMII and earlier Mariners is that the early missions were not designed with future missions in mind. The amount of inheritance was happenstance. The MMII would be designed from the beginning with the idea that a series of several missions would be flown by derivatives of the first spacecraft. For a slight increase in cost of the first mission, substantial savings are possible on the later ones. Tables 4 and 5 present potential missions for Pioneer and Mariner Mark II respectively.

Beyond the rather lean near future, some fascinating prospects beckon. Evolving technology offers new approaches to accomplishing some long time goals.

The concept of aerocapture is most promising. This technique uses a moderate lift over drag (approximately 1.0 to 1.5) aerodynamic shape maneuvering in the atmosphere to go from a hyperbolic flyby to a circular orbit without use of propellant except to trim the final orbit. For a given approach mass at Mars, for example, only about 80 to 85% is required for the aeroshell and related systems versus 50 to 75% which would be expended to do the same job propulsively. For a Saturn mission, higher payloads and/or shorter flight times are possible for a Saturn orbiter using the atmosphere of Titan for braking. The same technique enables a Titan orbiter, currently achievable by no other means. The same vehicle technology allows improved payloads for Venus orbiters and precision landing on Mars plus having applications to the Orbit Transfer Vehicle. The major potential use at Mars would be in the sample return mission (Fig. 2).

A somewhat less mature but very promising technology is that of in situ propellant manufacturing. Again Mars is the target of initial interest partly because of potential utilization and partly because of ease of application. The atmosphere of Mars itself offers an excellent source of raw material. The atmosphere can be gathered simply by compression and passed through a cell, now operating in the laboratory, which decomposes the carbon dioxide into oxygen and carbon monoxide. The oxygen is liquified and stored while the carbon monoxide is dumped. The oxygen provides the oxidizer for methane brought from Earth to be used for propulsion of a sample return vehicle. Actually the carbon monoxide could be retained and used as a fuel but the performance is substantially lower than methane. The methane has the added feature of functioning in the refrigeration loop which liquifies the oxygen. It may be asked, why not collect and electrolize water to obtain hydrogen and oxygen for still higher performance. The answer lies in the uncertainty of finding water anywhere but the polar caps plus the very substantial difficulty in liquifying and storing hydrogen. This type of operation is definitely of interest but as a second or third generation system, especially in conjunction with a manned mission or base.

Propellant manufacturing shows future promise for the satellites of Jupiter and Saturn. This would be an application of the water electrolysis mode making use of the ice which is a major constituent in these bodies.

Various combinations of aerocapture and propellant manufacturing may well enable missions launched by the STS and its derivatives which were once thought to require nuclear propulsion and/or enormous launch vehicles. While detailed analysis has yet to be conducted, manned Mars missions may be far easier to accomplish than once believed.

EARTH ORBIT MISSIONS

The Shuttle will dominate missions in Earth orbit for years to come. The number and variety of missions is such that no one paper can cover them all. In fact, it has already begun with the OSTA-1 payload on STS-2 which carried, among other things, the SIR-A radar which returned many excellent images of Earth. The future will show many payloads of similar nature ranging from the small "Getaway Special" class up to large, highly complex systems. The SIR-B radar mission is scheduled for 1984.

One attached payload of substantial interest is SIRTF, the Shuttle Infrared Telescope Facility. This large infrared astronomy facility is expected to add significantly to our astronomical knowledge.

To most people, however, Shuttle related astronomy means Space Telescope. The launch of this facility will mark a milestone in astronomy. While by no means as large as the largest Earth-based telescopes, the perfect "seeing" afforded by operating outside the atmosphere and away from the lights of Earth will allow this instrument to far exceed the capability of the largest of its Earthbound predecessors. Revolutionary discoveries can be predicted with great confidence once it becomes operational.

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Among free-flying spacecraft which the Shuttle will deliver to Earth orbit, we find the Extreme Ultraviolet Explorer. EUVE is intended to perform a thorough and detailed sky survey in the very high frequency ultraviolet range which is not visible on the surface of Earth. This spacecraft will be released by the Shuttle in low circular orbit and will use on-board propulsion to position itself in the final 550 to 700 km orbit. EUVE will carry multiple U.V. telescopes to provide the survey function and will operate in Earth orbit for at least one year in order to obtain the full global survey. The 1300 kg EUVE is expected to be launched in 1987.

Rather than peering into space, the Ocean Dynamics Topography Experiment (TOPEX) (Fig. 3) spacecraft looks toward Earth, more specifically at the oceans. The spacecraft will operate in a 1300 km orbit of about 64° inclination. Spaceborne remote sensing techniques have demonstrated that global synoptic measurements of the ocean can be made at sufficiently frequent intervals and fine enough spacings to permit the study of temporal and spatial variability of ocean currents and their influence on climate and the transport of pollutants and nutrients. The TOPEX mission will use a satellite carrying a radar altimeter to measure globally the height of the satellite above the local sea surface directly beneath the satellite for a five year time period. By combining these measurements with those of satellite height above the Earth's center (the orbit) and the height of a static ocean relative to the Earth's center (the geoid), sea surface slopes can be derived from which surface geostrophic currents can be inferred.

CONCLUSION

This has been a brief and woefully incomplete summary of some currently planned missions and future possibilities for space science missions launched by the Space Shuttle. As Shuttle operations become commonplace and we fully comprehend its capabilities and its limitations, new possibilities will arise which we have not even considered previously. The Space Transportation System offers capabilities of a different type than we have been accustomed to in the past. When we learn to properly use these, we will indeed have entered a new era of space science.

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Table 1

Typical Lunar Mission

$C_3 \left(\frac{km^2}{sec^2}\right)$	- 2 to 0
Time of Flight (days)	3 to 5
Orbit Insertion $\Delta V \left(\frac{km}{sec}\right)$	0.8 to 1
Operations at Target (months)	12

Science Payload
- Gamma-ray spectrometer
- Multispectral mapper
- X-ray spectrometer
- Radar altimeter

Table 2

1988 Launch Mars Mission

$C_3 \left(\frac{km^2}{sec^2}\right)$	12
Time of Flight (days)	207
Orbit Insertion $\Delta V \left(\frac{km}{sec}\right)$	2.1
Operations at Target (months)	12

Science Payload
- Gamma-ray spectrometer
- Multispectral mapper
- Radar altimeter
- Magnetometer

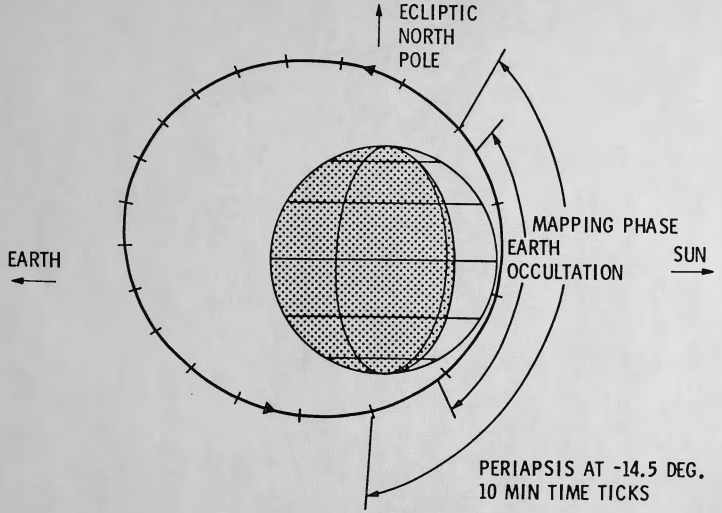
Table 3

1987 Anteros Mission

$C_3 \left(\frac{km^2}{sec^2}\right)$	29
Time of Flight (days)	430
Rendezvous $\Delta V \left(\frac{km}{sec}\right)$	1.6
Operations at Target (months)	3

Science Payload
- Imaging
- Gamma-ray spectrometer
- Multispectral mapper
- X-ray spectrometer
- Radar

VENUS MAPPER
MAPPING ORBIT

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