Mariner Jupiter-Saturn 1977 Mission Support

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The Mariner Jupiter–Saturn 1977 Project has recently been formally established as a Flight Project. The mission calls for the launch of two Mariner-class spacecraft in 1977 to fly by Jupiter and Saturn. Flight times to Jupiter and Saturn are approximately 2 and 4 years, respectively. The primary scientific objectives of the missions are to explore Jupiter, Saturn, and their satellites, and to investigate the nature of the interplanetary medium. Engineering objectives include the demonstration of a Mariner-class of spacecraft in space for operational periods of 4 years, use of radioisotope thermoelectric generators as the primary power source, and communications and navigational accuracy out to 10 AU.

Support from the 26-m-diameter antenna subnet is required intermittently during the long cruise periods with 64-m support covering the encounters. Navigation support will require S–X planetary ranging, S–X doppler, and differenced range versus integrated doppler (DRVID) and will be planned around complete "cycles" of data. The number of "cycles" per week will vary with the phases of the mission.

The Office of Computing and Information Systems (OCIS) organization will be responsible for the hardware, software, and simulation needed by the Mission Operations System (MOS) to carry out the mission. This article provides an introduction to the mission requirements as presently understood.

I. Introduction

The primary scientific objectives of the *Mariner* Jupiter–Saturn 1977 (MJS77) Project are to explore Jupiter, Saturn, and their satellites. Exploration of the planetary bodies encountered includes the study of their interaction with the interplanetary/interstellar medium, ionospheric and atmospheric characteristics, as well as planetary fields, trapped radiation, and radio emissions. Physical characteristics of satellites, such as size, spin rate, ephemerides, surface configuration, etc., are also an important part of these objectives.

Interplanetary objectives include studies of energetic particles, solar wind characteristics, magnetic fields and particulate matter. Additional objectives are related to investigation of the boundary of the heliosphere and the interstellar medium.

The engineering objectives of this mission are to demonstrate the use of a *Mariner*-class of spacecraft in space for operational periods of 4 years, including the use of radioisotope thermoelectric generators (RTGs) as the primary spacecraft power source for long duration interplanetary missions.

A further engineering objective is to demonstrate interplanetary communications and navigational accuracy for distances out to 10 AU.

The material for this article was summarized from the comprehensive discussion of all aspects of MJS77 Mission Design contained in JPL Internal Document PD-618-4 (Ref. 1).

II. Mission Summary

Two identical *Mariner*-type spacecraft will be launched during the 1977 Jupiter–Saturn launch opportunity. Their flight paths will take them first to Jupiter and then on to Saturn. The mission has important scientific objectives related to each of the target planets, as many of the satellites as practical, and the interplanetary space between and beyond the planets. A *Mariner*-type spacecraft designed specifically for the outer planet missions will be launched by the *Titan/Centaur*/Burner II launch vehicle.

An MJS77 mission consists of a series of planetary encounters over intervals of several years. Time between planetary encounters is spent in traversing unexplored interplanetary regions progressively farther removed from the influence of the Sun. During the interplanetary portions of the mission, the science instruments will acquire data at a rate consistent with the combined retrieval capability of the project systems. The acquired data will be transmitted to Earth in real time on a nearly continuous coverage schedule. As a spacecraft approaches each planet, encounter operations associated with planetary science and approach guidance operations will begin. A trajectory correction will be performed at particular times prior to Jupiter closest approach. Optical measurements of the planetary satellites for approach guidance to the satellites will also be required.

About 2 months before Jupiter or Saturn closest approach, the imaging instrument will begin observations of the planets and their satellites. Measurement schedules of all science instruments will be varied as appropriate as the spacecraft nears each planet. Earth occultation is achieved for all planetary encounters. Flights encountering Jupiter must be compatible with the anticipated proton and electron environment.

The major characteristics of the two standard trajectories are summarized in Table 1, and heliocentric plots of the two trajectories are shown in Figs. 1 and 2.

III. Flight Phases

A flight phase is defined as a period during the flight when the mission operations of all the project systems are similar during that period. The MJS77 mission requires special considerations for each of the flight phases in terms of data retrieval and processing as well as spacecraft tracking and control functions.

A. Launch Phase

The *Titan/Centaur*/Burner II launch vehicle will inject first into an Earth parking orbit and then reignite to provide the mission injection velocity. The spacecraft will maintain communications via the S-band link and the launch vehicle telemetry system during the ascent. Following separation, deployment of all structural appendages will be completed prior to beginning celestial acquisition. Cruise science begins during the acquisition and a science roll sequence will occur. Upon completion of celestial acquisition, the spacecraft will be configured for cruise. DSN coverage during this phase consists of a 26-m subnet and a 64-m subnet.

B. Cruise Phase

The cruise flight phase is defined to include portions of a flight during which the spacecraft is in a relatively quiescent state. The purpose of cruise operations is to continuously acquire science data, monitor the engineering status of the spacecraft, and to accumulate radio metric data for navigation. The typical navigation tracking requirement will be 1 "cycle" of a DSN 64-m network tracking every 2 weeks as discussed in *Section IV-C*. The DSN coverage includes a full 26-m subnet and ¼ of a 64-m subnet until encounter minus 100 days when the 64-m coverage will increase to ¾ of the subnet. During the cruise phase, specific science and engineering sequences will be required, such as instrument mapping of the celestial sphere, instrument calibrations, and high-gain antenna mapping. Some of these sequences will require controlled turn maneuvers of the spacecraft for extended periods of time.

C. Trajectory Correction Maneuver Phase

At designated times during flight, the spacecraft will be required to perform trajectory correction maneuvers to improve navigation. The amount of DSN tracking required will depend on the navigation data needed for the maneuver and will typically include a full 26-m and a full 64-m subnet. The mission operations activity will increase significantly during this period.

D. Encounter Phase

The encounter phase will begin about 40 days before the time of closest approach to the planet when the frequency of activities and observations becomes very high. It will last until 40 days following closest approach. DSN and MOS coverage will be increased to monitor the spacecraft operations. Observations will include high-resolution planetary imaging and observations with the non-TV instruments, atmospheric scans by the spectral instruments, and planetary fields and particles data acquisition from close range. As much of the scientific data as possible will be relayed in real time. However, there will be data rate limitations as the spacecraft approaches Jupiter and Saturn due to "hot target noise."

Following closest approach, an Earth occultation period will occur during which all data must be recorded for later playback when the downlink has been reestablished. The near-encounter phase will also include the closest approach observation of many of the planetary satellites.

IV. Telecommunications Requirements

The requirements for the MJS77 telecommunications system fall into four general areas:

(1) Command data.

(2) Telemetry data.

(3) Radio metric data.

(4) Radio science data.

The capability in each of these areas, except radio science, is discussed in the following paragraphs.

A. Command Data

Command reception will be provided via S-band throughout the mission at 4 bps. Command data will be received at the spacecraft uncoded. The command link will be inhibited when no uplink signal is present or when synchronization is lost.

Reception of commands via the spacecraft high-gain antenna requires the spacecraft to be Earth-oriented. Reception via the low-gain antenna requires the antenna cone angle to Earth to be less than 30 degrees.

When the spacecraft has acquired the uplink RF signal at S-band and is in the two-way mode, it will achieve synchronization with the command signal within 1 min after receipt of the first symbol of the command acquisition sequence.

B. Telemetry Data

Telemetry transmission will be provided at selected times throughout the mission via S- and X-band. Telemetry data generated in the spacecraft will be transmitted via a single channel per carrier. The transmitters of the spacecraft will, in general, share the downlink power between the RF carrier, the ranging channel, and the telemetry channel. The telemetry data sent simultaneously via the S- and X-band channels will be identical, with the capability existing to remove telemetry modulation from the S-band link.

All telemetry data transmitted from the spacecraft will be time-multiplexed together. Prior to time-multiplexing, the non-imaging data may be coded with an error-correcting binary code. All data transmitted from the spacecraft to Earth will be convolutional coded.

The spacecraft can transmit data at 16 different rates between 20 bps and 115 kbps to take advantage of the prevailing link capability at different phases of the mission.

C. Radio Metric Data

The telecommunications system will provide the capability for generation of radio metric data including single- and dual-frequency ranging at planetary distances for selected times throughout the mission. Single-frequency ranging will be provided with a 64-m station at S- or X-band. Dual-frequency ranging will be provided at S- and X-band with a 64-m station. The uplink will be at S-band only and the downlink at S- and X-band, or both. The capability to make range measurements required sharing the uplink and downlink power with other channels. As such, ranging performance is dependent on, and impacts with, carrier tracking, command, telemetry, and radio science performance.

For orbit determination purposes, solutions will be performed using radio metric data which are taken simultaneously from two stations. For this reason the MJS77 tracking coverage is based upon a "cycle" of data which consists of continuous horizon-to-horizon passes from DSSs 14, 43, 63, and 14 again, as illustrated in Fig. 3. Almost full doppler and range coverage is required from encounter minus 40 days to plus 40 days. Because of the need for simultaneous data and large round trip light times, it is necessary that the quality of the three-way data be equivalent to current two-way data. This will probably require the use of hydrogen masers. The requirements on instrumentation-induced data noise and calibration capabilities for quantities affecting the data (e.g., station location and transmission media) are equally stringent. If the quality of the data can be made to satisfy the "design goals," the orbit determination result could possibly be significantly improved to yield better navigation accuracies of interest to the project.

V. Deep Space Network

The MJS77 mission will take advantage of the planned Deep Space Network (DSN) capability which is designed to support the NASA Mission Set planned for 1975–1980. It is expected that the spacecraft will incorporate additional capability to match the planned DSN performance improvements during the mission lifetime.

The DSN plans to support the MJS77 flight operations with the following facilities:

(1) Deep Space Stations (DSSs), including a subnet of three 64-m antennas.

(2) Data circuits to handle real-time radio metric, telemetry, and command data between Deep Space Stations and the Mission Operations Center. Data circuits will also be provided to handle real-time data between Remote Spacecraft Assembly Facilities and the Mission Operations Center.

(3) A Network Control function to control the DSN, and to validate the DSN data.

(4) A capability for participating in MJS77 simulation activities.

(5) Compatibility Test Area 21 (CTA 21) at JPL and DSS 71 at the Air Force Eastern Test Range for supporting spacecraft and system compatibility tests.

VI. Interfaces

The DSN will interface with the MJS77 spacecraft via the standard RF telecommunications link, the design and control of which will be the subject of an RF Interface Control Document.

The DSN interface with the MJS77 Mission Operations System for real-time data will be via the GCF high-speed and wide-band data lines to the Mission Control and Computing Center.

For operations control purposes an additional interface will be established between DSN Operations Control and the corresponding flight operations control function in the MOS.

VII. Concluding Remarks

The basic outline for the MJS77 mission and requirements for DSN support have been described above. As the mission design progresses, DSN plans for management, documentation, network configuration and capabilities, interfaces, and mission support will be developed and implemented. Future articles will describe significant achievement in this process.

Reference

1. *Mariner Jupiter/Saturn 1977—Mission Requirements*, JPL Document PD-618-4, May 25, 1972 (JPL internal document).

Table 1. Example trajectories for the MJS77 mission

Parameter	Flight 1 JSI77	Flight 2 JST77
Launch:		
C_3	110	100
Launch date	8/17/77	9/4/77
Jupiter:		
Periapsis radius	7.2 R_J	5.8 R_J
Arrival date	5/25/79	4/18/79
Flight time	1.7 yr	1.6 yr
Satellites	Ganymede or Callisto	Io
Satellite distance	~20 × 10^3 km (or greater)	~50 × 10^3 km (or greater)
Occultations	Jupiter	Jupiter
Saturn:		
Periapsis radius	3.2 R_S	2.3 R_S
Arrival date	5/4/81	2/16/81
Flight time	3.7 yr	3.4 yr
Satellite encounter	Iapetus after Saturn	Titan before Saturn
Earth occultation	Saturn Iapetus	Saturn Titan

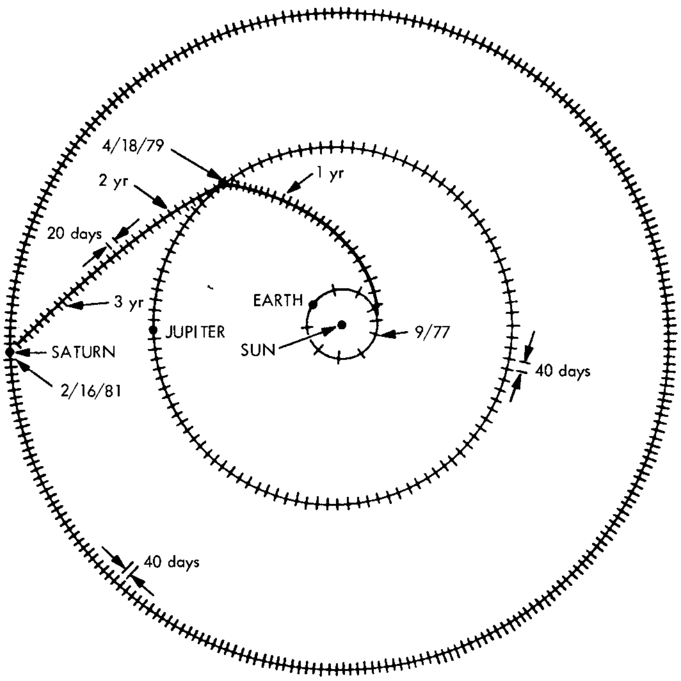

Fig. 1. JST77 heliocentric trajectory (ecliptic plane projection)

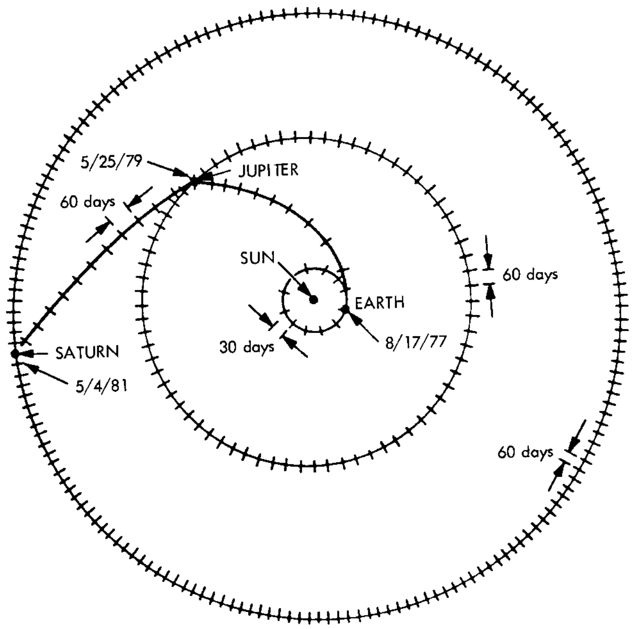

Fig. 2. JSI77 heliocentric trajectory (ecliptic plane projection)

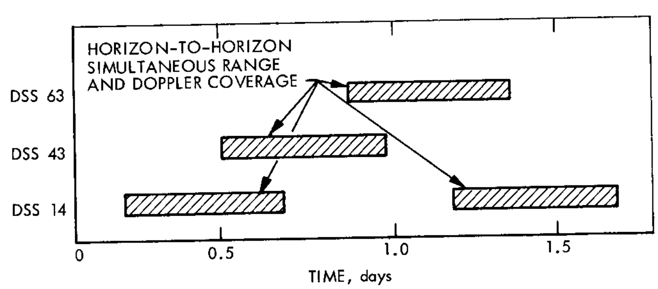

Fig. 3. A navigation "cycle" of data