SP 43-27, VOL. 3

REQUIREMENTS AND CAPABILITIES FOR PLANETARY MISSIONS: Venus Orbiter Imaging Radar 1983

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(NASA-CR-148734) REQUIREMENTS AND CAPABILITIES FOR PLANETARY MISSIONS. VENUS ORBITER IMAGING RADAR 1983, VOLUME 3 (Jet Propulsion Lab.) 9 p HC $3.50 CSCL 22B
N76-30280
Unclas
G3/18 50448

August 1976

National Aeronautics and Space Administration

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. 43-27, Vol. 3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle REQUIREMENTS AND CAPABILITIES FOR PLANETARY MISSIONS: VENUS ORBITER IMAGING RADAR 1983		5. Report Date August 1976 6. Performing Organization Code
7. Author(s) D. H. Kindt, G. G. Ball, T. H. Bird		8. Performing Organization Report No.
9. Performing Organization Name and Address JET PROPULSION LABORATORY California Institute of Technology 4800 Oak Grove Drive Pasadena, California 91103		10. Work Unit No. 11. Contract or Grant No. NAS 7-100 13. Type of Report and Period Covered Special Publication
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Washington, D.C. 20546		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Two spacecraft will be launched in mid-1983 and inserted into a circular polar orbit around Venus about 6 months later. Elliptical orbits are also under consideration. The objective of the mission is imagery of the planet, at about the 200-m resolution level, with continuous altimetry and topographical studies. Science investigations will determine surface characteristics of the planet, study the surface/atmosphere interactions, and determine Venus' mass distribution. A plausible vehicle is based on a Mariner Jupiter/Saturn derivative; others being considered include a Lunar Polar Orbiter derivative and a Pioneer Venus Orbiter derivative.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Spacecraft Design, Testing and Performance Lunar and Planetary Exploration (Advanced)	Unclassified -- Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	6	

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Foreword

This volume represents one of a series of requirements and capabilities for planetary missions assembled from recent study activities at JPL. The purpose of this series of documents is to provide a summary of these studies which may be readily used in subsequent efforts. Emphasis is upon requirements and associated capabilities of the spacecraft and mission design as developed in the study. No particular priority of individual missions should be assumed from the sequence of these reports.

The other published volumes in this series are SP 43-27, Vol. 1, *Mariner Encke Ballistic Flyby 1980*, November 1975, and SP 43-27, Vol. 2, *Mars Polar Orbiter/Penetrator 1981*, March 1976. These volumes were prepared by the Mission Engineering Section of the Project Engineering Division.

Venus Orbiter Imaging Radar

Launch Date:	April–June 1983
Encounter Date:	October–November 1983
Injection Mass:	4335 kg
Net Mass in Orbit:	735 kg
Instrument Mass (radars only):	57 kg
Launch Vehicle:	Shuttle/IUS

Objectives:

Imagery of the whole planet, at about the 200-m resolution level, with continuous altimetry for determination of surface changes and features, and topographical studies. Some high-resolution imagery at about 50 m could be available.

Typical Science Investigations:

Synthetic aperture radar

Additional science investigations under study

Mission Description:

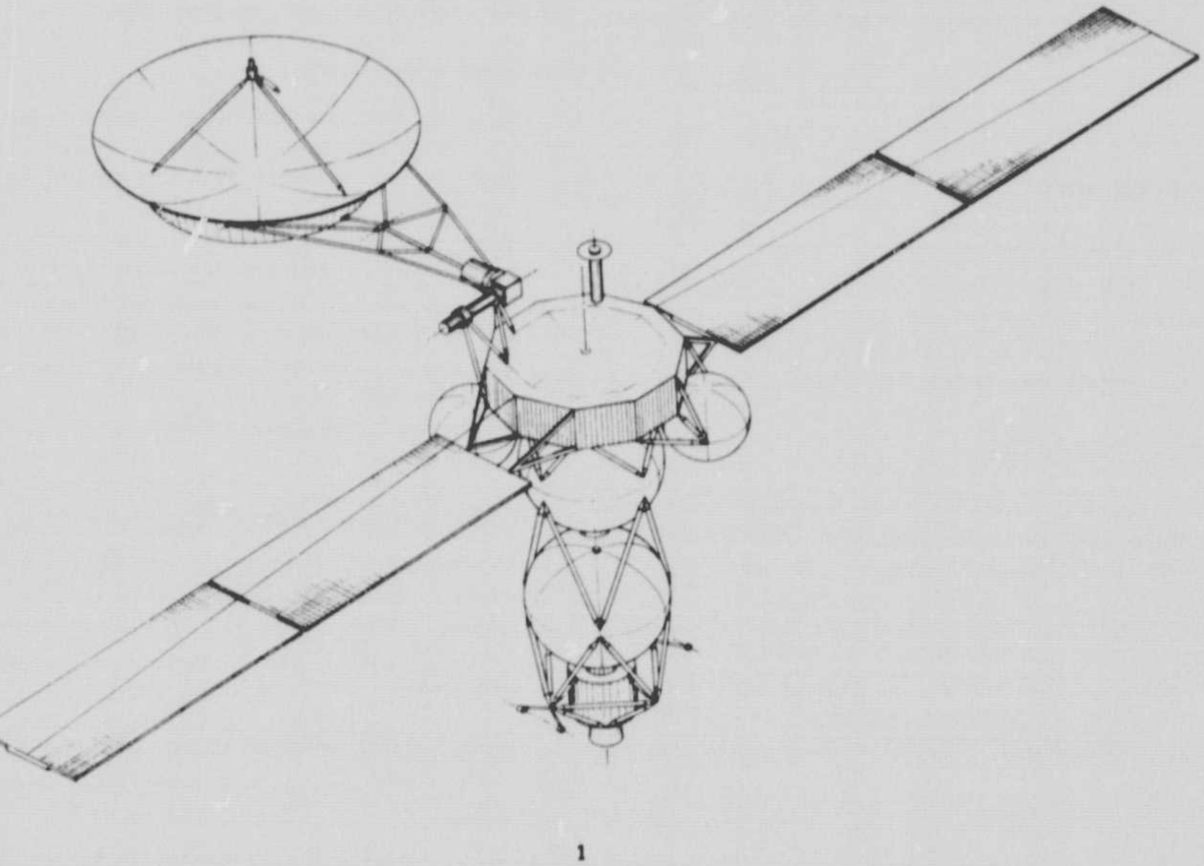
Two spacecraft are inserted into a 97-min, 500-km circular polar orbit. Elliptical orbits are under consideration, the tradeoff being propulsion system requirements vs. radar system complexity and performance. Imaging occurs on specific defined orbits, while other activities such as nonradar science, altimetry, and telecommunications take place on nonimaging orbits. The circular orbit allows complete planet mapping within 120 days. A plausible vehicle for a Venus Orbiter Imaging Radar (VOIR) mission is based on a Mariner Jupiter/Saturn (MJS) derivative, with some design inheritance from Viking and other Mariner spacecraft. The VOIR spacecraft has solar panels.

Other spacecraft concepts being considered include a Lunar Polar Orbiter derivative with a Seasat-type antenna and a multiantenna Pioneer Venus Orbiter derivative with some despun parts.

I. Science

A. Rationale

Imaging and mapping of the surface of Venus significantly beyond the capabilities of Earth-based observations would be a major step in the exploration of the terrestrial



planets. The VOIR mission represents a practical, realizable means of meeting this need in the 1980s using side-looking radar.

B. Objectives

Science objectives appropriate to this mission are:

(1) To determine surface characteristics such as texture, crustal structure, topography, and morphology.

(2) To study the surface/atmosphere interactions of Venus.

(3) To examine meteorite impact effects on the surface and phenomena such as cratering, brecciation melting, erosion, and regolith formation.

(4) To determine the mass distribution of Venus.

C. Typical Experiments

The synthetic aperture radar (SAR) is the only proposed science instrument carried on the VOIR spacecraft in this study. This radar could be similar in concept to the one to be flown on Seasat-A in 1978. The SAR would operate at L-band frequencies (1 to 2 GHz), at an altitude from the surface of 500 km, and would be used for imaging as well as altimetry.

Other scientific instruments could be flown and are under investigation.

II. Mission Description

A. Launch and Arrival

The VOIR mission involves two spacecraft being inserted into a 500-km circular polar orbit around Venus. Launch opportunities open in April 1983 for arrival in late October and early November 1983. For this period, C_3s of less than 12.0 km^2/s^2 are required over a 70-day injection period beginning in April.

The spacecraft is launched using the Shuttle/IUS, with an expected injection capability from 5500 to 6200 kg over a 6.0 to 12.0 km^2/s^2 C_3 range.

Launching the two spacecraft with a single set of launch equipment may be considered even with coincident launch and injection periods. A 22-day launch period is adequate if dual sets of launch equipment are available; 52 days are required if a single set of launch equipment is used.

The cruise period to Venus after injection by the Shuttle/IUS takes about 4 months. The arrival speed of the spacecraft at Venus ranges from 2.9 to 4.1 km/s, depending upon when the launch occurs in the April 1983 launch period.

B. Venus Orbit

The nominal orbit selected is a 500-km-altitude polar circular orbit, which has the following advantages:

(1) The radar doppler shift requirements are minimized by the circular orbit.

(2) No undue navigation and atmospheric uncertainties are encountered at the low orbital altitude; hence the radar design requirements are eased. (A more extensive analysis would be required to justify any significant further reduction in altitude.)

(3) The circular polar orbit allows complete planet mapping within 120 days.

An alternate circular polar orbit could be achieved by increasing the altitude to 1000 km. More radar power and a somewhat longer time would be needed for Venus mapping. However, this type of orbit would also provide some relief of the orbit determination problems associated with the lower circular orbit. A 500 × 1000 km elliptical orbit could be utilized but would have a serious impact on radar design complexity and data analysis.

C. Data Management

The data collection philosophy for this mission assumes that the radar mapping objectives will be accomplished during the first half of a Venusian rotation period. The revolution-to-revolution shift of the spacecraft's ground trace is less than the typical radar swath width, permitting complete mapping of the surface in one half of a Venusian rotation period. Optimization of system operations could be achieved by having the radar operate continuously over this period. After the mapping requirements were satisfied, the remaining orbits could be used for collecting other science data and data transmission.

III. General Spacecraft Characteristics

The baseline VOIR spacecraft that has been studied is a three-axis stabilized design based on existing MJS technology (Figs. 1 and 2). This spacecraft is solar powered and has a relatively large propulsion system, with radar added as the main science experiment.

The spacecraft structure consists of an MJS'77 ten-sided bus. It supports all appendages and provides a structural

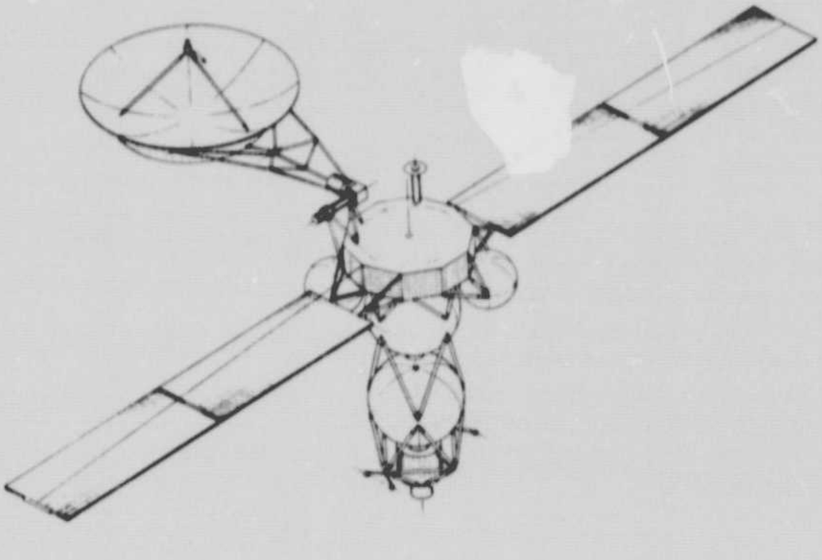


Fig. 1. VOIR spacecraft (Earth-storable propellants)

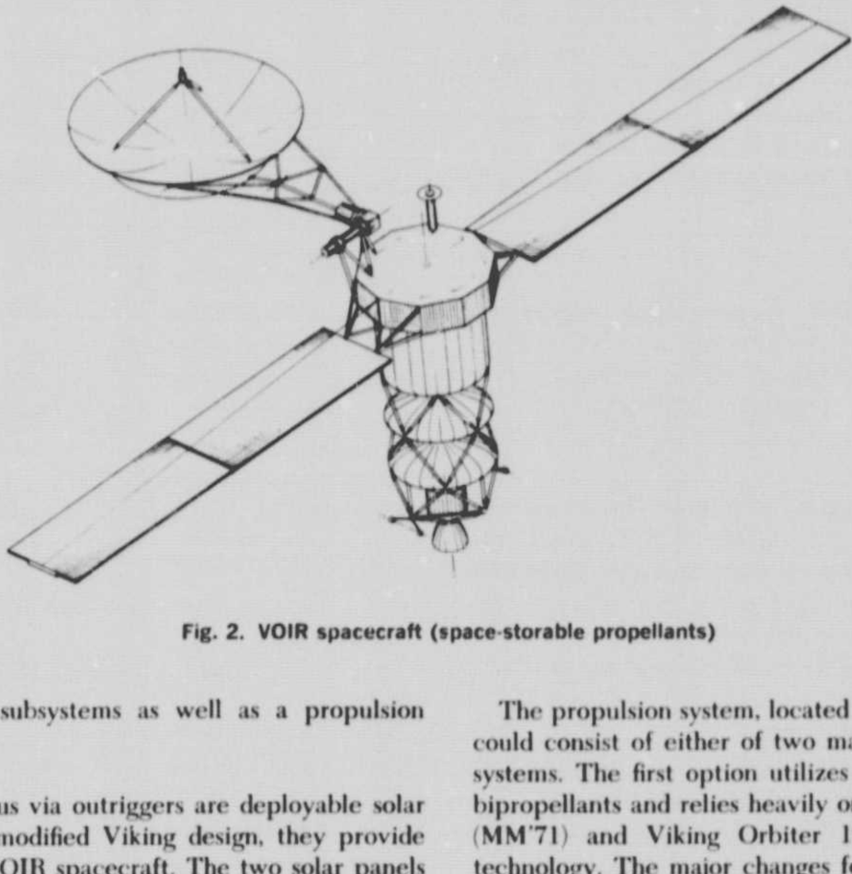


Fig. 2. VOIR spacecraft (space-storable propellants)

foundation for the subsystems as well as a propulsion support structure.

Attached to the bus via outriggers are deployable solar panels. Based on a modified Viking design, they provide the power for the VOIR spacecraft. The two solar panels have a combined area of about 14.8 m^2. Additional power can be achieved by the use of two Ni-Cd batteries, along with other electrical power equipment. The total power needed by the spacecraft at launch is about 304 watts.

The propulsion system, located at the aft end of the bus, could consist of either of two major classes of propulsion systems. The first option utilizes advanced Earth-storable bipropellants and relies heavily on the Mariner Mars 1971 (MM'71) and Viking Orbiter 1975 (VO'75) propulsion technology. The major changes for the VOIR mission are the use of hydrazine (N_2H_4) rather than monoethylhydrazine (MMH) as the fuel, and the use of a modified 4.0-kN thrust Shuttle reaction control engine instead of the 1.3-kN MM'71 and VO'75 engines. The use of N_2H_4 provides a 3% increase in specific impulse and increased thrust over conventional Earth-storable propellants. This allows insertion of the spacecraft into a 500-km circular orbit with one set of launch equipment and nominal IUS capability, but two burns of the insertion motor are required.

The second propulsion system option, space-storable propellants (fluorine/hydrazine), provides a significant improvement in specific impulse. Since the oxidizer in this case is a cryogenic, new spacecraft interface requirements result. The use of space-storable propellants permits capture of the baseline mission with a single burn, given nominal IUS capability. Multiple burns would allow the retro mass to be reduced significantly.

The telecommunications system is also based on MJS design. It consists of redundant X-band transmitters and S-band transmitters and receivers and the necessary supporting elements. The receivers obtain the uplink signal via the S-band low-gain antenna (LGA). The output of the X-band transmitters can be switched to the 3.1-m-diameter high-gain antenna (HGA) or to either of two X-band LGAs, a biconical (medium-gain) antenna, and a horn antenna. An L-band feed is added to the HGA for the radar.

The high-gain antenna requires three degrees of freedom for radar mapping of the surface of Venus and radar altimetric determination of surface features, as well as for high-bit-rate communications with Earth.

Radar mapping relies upon the ability of the antenna to be pointed continuously at a surface point 10 deg to the side of the subspacecraft point (surface intersection point of the radial line from the planet's center to the spacecraft). Radar altimetry requires that the antenna be aimed at the subspacecraft point on nonmapping orbits.

Antenna pointing requirements necessitate that high spacecraft attitude stability be maintained throughout the orbital portion of the VOIR mission. Antenna pointing is accomplished by three actuators which operate the three-degree-of-freedom antenna pointing mechanisms. The spacecraft is stabilized by an attitude control system based on the MJS'77 design. The Sun and Canopus are used as celestial references for attitude control.

Data handling and command functions are handled separately. Data compression techniques may be used separately or incorporated within the radar.

Data storage is provided by two (redundant) NASA standard 10^9-bit tape recorders, capable of recording and playback rates up to 5.88 Mb/s.

The VOIR requirements for data management are summarized in Tables 1 and 2.

Other subsystems used in the spacecraft, such as thermal control, cabling, and mechanical devices, are also based on MJS'77 design. Table 3 presents the VOIR spacecraft mass summary, including a breakdown of the two propulsion system options that could be used in this mission.

Table 1. Data requirements

Number of data streams	2
Science data rate	500 (uncoded)/250 kb/s (coded)
Engineering data rate	50/25 bits/s
Total number of engineering measurements	256
Engineering data frame size	128 measurements
Number of engineering formats	4
Engineering measurement length	8 bits
Science data format	Block of 2048 6-bit words
Bit error rate	$< 5 \times 10^{-6}$
Data storage requirement	1.2×10^9 bits
Data record rates	0.5 and 5.8 Mb/s

Table 2. Control requirements

Number of coded command interfaces	8
Number of bits/coded command	14
Number of discrete command interfaces	90
Command bit rate	4 bits/s
Number of bits/command	42

Table 3. VOIR spacecraft mass summary

Subsystem	Mass kg	Remarks
Structure	220.2	Includes solar panel structure and outriggers, and propulsion support structure.
Radio frequency	40.0	
Modulation/demodulation	9.2	
Power	132.0	
Computer command	15.3	
Flight data	15.9	
Attitude and articulation control	118.9	Includes entire attitude-propulsion system with thrusters, valves, associated hardware, hydrazine and helium (pressurant), 24.4 kg of usable hydrazine, and tankage; also all actuators.
Pyrotechnics	8.8	With VO'75-based propulsion actuation unit
Cabling	41.8	Includes radar, solar panel, propulsion, and actuator cabling.
Temperature control	22.7	Includes blanket for propulsion subsystem.
Mechanical devices	21.0	Includes solar panel-related devices.
Data storage	25.4	
S/X/L band antennas	6.9	Includes radar L-band feed for high-gain antenna.
Radar	57.0	Transmitter/receiver/power converter 30.0 kg, based on processor assembly 22.0 kg, data compressor 5.0 kg.
Total	735.1	(Net mass in orbit.)

	Earth-storable	Space-storable
Propulsion inerts	455.0	572.5
Total (dry spacecraft with APS fuel)	1190.1	1307.6
Usable propellants	3000.0	3027.0
(ΔV, m/s)	(3700)	(4350)
Total (separated mass)	4190.1	4334.6
Spacecraft adapter (Same as for baseline VOIR plus 3 kg for increased structural support required for heavier spacecraft.)	89.4	89.4
Total (launch mass, no contingency)	4279.5	4424.0

IV. Mission Options

Launch opportunities for VOIR are also available in November 1981 and December 1984. The former is somewhat inferior to the 1983 opportunity, while the latter is approximately equal to it. Both permit mission accomplishment with no increased performance difficulties.

A possible strategy to be considered is the addition of nonradar science instruments to the VOIR payload. These could include a mass spectrometer and a dayglow experiment, which would provide a greater understanding of the composition of the Venus atmosphere. A UV imaging instrument is another possibility. This equipment could take advantage of the spacecraft stability necessary for remote sensing by the radar.

Another possible option is the combination of a VOIR spacecraft with a high-attitude buoyant station. This station would float in the atmosphere of Venus and study atmospheric circulation and properties. The VOIR spacecraft could be the support and relay vehicle for the buoyant station.

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