Jupiter Orbiter Mother/Daughter Spacecraft Concept

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Theme

THE initial phase of the NASA Outer Planets Exploration Program is focusing on Jupiter. Pioneers 10 and 11 have recently obtained some limited imaging and environmental coverage of the planet indicating that the field strengths, particle fluxes, and their directions may be subject to large temporal variations. Unless these environmental conditions are measured in at least two locations simultaneously, the suspected temporal variations cannot be separated unambiguously from the spatial variations. This paper describes a Jupiter orbiter mother/daughter spacecraft concept that would employ two independent spacecraft to perform these simultaneous measurements and thus distinguish between the spatial and temporal variations of the field strengths and particle fluxes. In this concept, the mother spacecraft would, in addition, perform remote sensing of Jupiter and its natural satellites. The paper also provides a detailed description of the daughter spacecraft.

Contents

The Jupiter orbiter dual spacecraft concept would employ a three-axis stabilized Mariner spacecraft (mother) primarily dedicated to remote sensing of Jupiter and its natural satellites and a spin-stabilized daughter dedicated to in situ measurements of the planetary fields-and-particles environment. Together these spacecraft would perform the simultaneous measurements required to distinguish between the spatial and temporal variations of the field strengths and particle fluxes. The mother, designated Mariner Jupiter Orbiter (MJO), would be a close derivative of the MJS77 vehicle[1,2] and would contain a Viking-type bipropellant Earth-storable propulsion subsystem to provide the thrust needed to insert the mother/daughter pair into orbit about Jupiter. The daughter would be a relatively small system, launched piggyback on the mother, which takes advantage of the mother's transit and delivery capabilities. The daughter would be ejected from the mother after the pair have been inserted into orbit about Jupiter and have approached the first apoapsis point, as shown in Fig. 1.

Recent analysis has indicated that a 1981 launch of such a mother/daughter spacecraft pair would be feasible and that the spacecraft pair could achieve a broader spectrum of scientific objectives than other options studied, such as a Pioneer Jupiter Orbiter 1981 (PJO81)[3] or Mariner Jupiter Orbiter 1981 (MJO81)[4], for the same launch vehicle costs. In addition, the mother/daughter spacecraft pair has the potential for a cooperative international joint venture, since the daughter could be provided to NASA by a foreign space agency.

The Shuttle/Interim Upper Stage/MJS propulsion module launch vehicle would provide adequate energy to place a 675-kg MJO mother and a 150-kg daughter into orbit. The flight to Jupiter would take approximately 2.6 years. Using a Viking-type retropropulsion subsystem and an Io-powered insertion strategy, the mother/daughter pair could obtain a 6x169R_J orbit with an approximate period of 100 days. Once the daughter is ejected, it will operate independently of the mother, returning fields-and-particles data by a direct X-band telemetry link to Earth. Its single radioisotope thermoelectric generator (RTG) can provide power for an orbital lifetime exceeding 2.5 years. The primary interface between the mother and daughter would be a simple mechanical device consisting of a spin table, a release mechanism, and launch supports; a simple electrical interface is also envisioned.

Scientific and programmatic benefits obtainable from this mission would include the following: 1) a single launch vehicle may deliver two spacecraft to Jupiter for insertion into independent orbits. These orbits may be optimized in inclination and eccentricity to permit clear distinctions between temporal and spatial variations in the fields-and-particles data, since complementary instruments can be carried on both spacecraft to make simultaneous measurements from widely separated locations; and 2) after the daughter has been ejected, the mother's orbit may be pumped and cranked to achieve a low eccentricity and relatively high inclination, respectively, to maximize imaging and planetology coverage as well as close observation of the Galilean satellites. The daughter orbit would remain near the equatorial plane and be highly eccentric so as to maximize in situ coverage of Jupiter's magnetosphere.

Science considerations: candidate science instruments for a Jupiter orbiter mission would fall into two main categories: 1) instruments designed to perform in situ measurements of fields and particles, and 2) instruments designed for remote imaging and sensing of the planetary and satellite atmospheres and surfaces. A spinning spacecraft can provide the full-circle coverages needed for fields-and-particles measurements as well as for partial inflight instrument

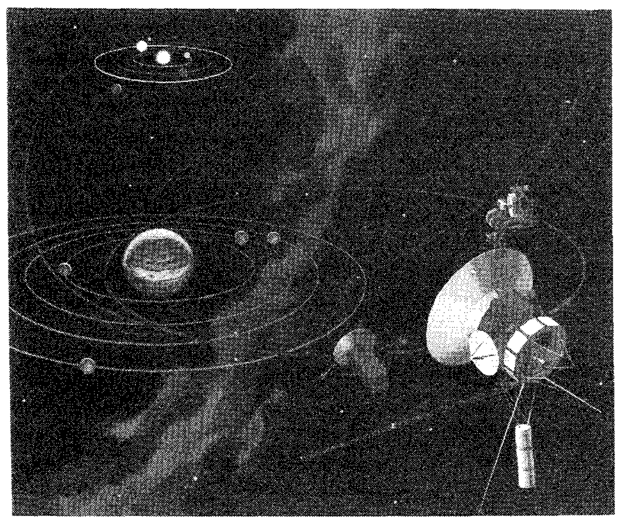

Fig. 1 Concept of Jupiter orbiter mother /daughter spacecraft pair, showing the daughter spacecraft before and after deployment.

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Index categories: Lunar and Interplanetary Spacecraft Systems, Unmanned; Spacecraft Mission Studies and Economics.

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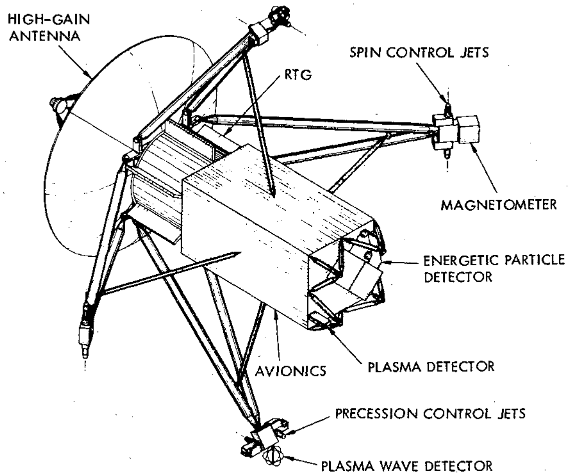

Fig. 2 Orbital flight configuration of the MJ081 daughter spacecraft.

calibrations. On the other hand, a three-axis stabilized spacecraft can achieve the precise pointing capability required by remote-sensing and imaging instruments.

The fields-and-particles instruments would have to be flown through the environmental regions they are expected to measure. Therefore, they would require highly elliptical orbits with low perijoves (1 to 6 R_J) and high apojoves (100 to 200 R_J). For complete mapping of the Jovian magnetosphere, both high-inclination (70 to 90°) and low-inclination (0 to 20°) orbits would be desirable. In contrast, instruments designed primarily for remote sensing would probably utilize a low-eccentricity orbit of high perijove, either in or near the plane of the Galilean satellite orbits, in order to avoid not only the high radiation hazards inside the orbit of Io (*J*1) but also the long time periods associated with apojoves greater than 100 R_J.

One attractive solution to this dichotomy is to have two separate spacecraft: one dedicated to fields and particles measurements and the other optimized for remote sensing. The remote-sensing spacecraft would also carry a complement of fields and particles instruments. The concept of a spin-stabilized daughter orbiter dedicated to fields and particles measurements was born from these considerations. It would be carried into orbit around Jupiter by the MJO mother spacecraft and deployed prior to or at the initial apojove. The mother spacecraft would then maneuver through a series of encounters with the Galilean satellites to use their gravity-assist capability to move into orbits more advantageous for the remote-sensing mission.[5]

The daughter's initial apojove would be positioned about 10-15° on the night side of Jupiter's dawn terminator, at which point the daughter is passing through the bowshock. In three years the daughter's apojove will rotate 90° with respect to Jupiter, because of Jupiter's orbital motion, and will traverse the planet's local midnight zone and magnetotail during the ninth orbit, about 2.5 years after orbit insertion. Both the Earth and Sun would be occulted at times dependent on the daughter's orbit. Neither Pioneers 10 and 11 nor Mariner Jupiter/Saturn 1977 will have explored this scientifically important Jovian magnetotail.

Daughter science objectives: consistent with the science and mission considerations described in the preceding paragraphs, the science objectives for the MJO daughter may be summarized as follows: 1) to investigate the shape, size, and dynamics of the Jovian magnetosphere; 2) to determine the interaction of the solar wind and magnetosphere with respect to low-energy (thermal) plasma particles, particle flows within the magnetosheath, and energetic particle fluxes; 3) to study the effects of Jupiter's satellites on the Jovian magnetic field and radiation belts as well as on plasma waves; and 4) to investigate the near fields of Jupiter.

Daughter payload: the following representative set of instruments will fulfill the science objectives: a magnetometer, an energetic particle detector, a plasma detector, and a plasma wave detector. The real-time data transmission rate for this payload would be about 270 bits/sec; the payload power and mass estimates are 19 W and 21 kg, respectively. Instrument descriptions are provided in Ref. 6.

Daughter description: the daughter spacecraft would be a new design (Fig. 2) but would take advantage of existing flight-proven technology for the various subsystems and elements of which it is comprised. It would consist of a 1.47-m-diam high-gain antenna with X-band (8.415 GHz) feed, a single high-performance (70-W, 7-Vdc output) RTG, the reference payload of four science instruments, four deployable booms that are symmetrically placed about the vehicle spin (longitudinal) axis, and a rectangular avionics compartment. A long, slender shape was selected in order to minimize the daughter impact on the MJO spacecraft. The four booms contain elements that are best remotely located from the electronics compartment, such as the attitude-control jets, plasma wave detector, and magnetometer. To assure stability about the spin axis, these booms also contain inert mass as necessary. The attitude-control jets utilize hydrazine as a monopropellant and have a propellant supply adequate for a three-year orbital life. An on-board computer uses a read-only memory for counting and sequencing, and shift registers are available for science data collection, buffering, and formatting for transmission. A complete description of the 140-kg daughter spacecraft is available in Ref. 6.

References

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