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THE GALILEO ORBITAL TOUR FOR THE 1986 LAUNCH OPPORTUNITY

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Abstract

In September 1985 the orbital tour for the Galileo Project was selected for a May 1986 launch to Jupiter. After years of tour design effort and approximately 50 proposed orbital tours, a single tour emerged which satisfies all minimum science objectives in three general categories: Magnetospheric Science, Atmospheric Science and Satellite Science. This paper introduces the trajectory characteristics of the selected tour and discusses some of the final design considerations.

Because of the tragic Shuttle accident on January 28, 1986, the Galileo Orbital Tour for the 1986 launch opportunity cannot be realized. The purpose of this paper now becomes to document what has been achieved and to provide a benchmark for future tour designs.

Introduction

The Galileo spacecraft consists of an atmospheric probe and a Jupiter orbiter. Upon arrival at Jupiter the probe enters the Jovian atmosphere, while the orbiter is inserted into a Jovicentric orbit. The probe mission lasts slightly over an hour, while it samples the atmosphere and transmits data up to the orbiter. The orbiter mission lasts for 22 months, during which time it performs 10 orbits of Jupiter. On each orbit the spacecraft flies by one of the Galilean satellites at low altitude in order to modify the Jovicentric orbit so that another Galilean satellite can be encountered and in order to conduct scientific observations. The sequence of ten orbits is called the orbital tour. Very little propellant is used, since it is by design nearly a free fall trajectory.

The main purpose of the orbital mission is to study the Jovian atmosphere, the Jovian magnetosphere and the Galilean satellites. The purpose of this paper is to present the trajectory characteristics of the selected orbital tour for the May 1986 launch opportunity and to discuss the interplay between tour design and science requirements.

Orbital Tour Design Concepts

Most of the tour design concepts used in generating the final tour are described in Diehl[1] and Wolf[2]. Some fundamental concepts are discussed by Nock[3], Niehoff[4], Minovitch[5], Beckman[6], Uphoff[7] and Diehl[8]. The main result is that free fall trajectories can be designed about a planet (or the sun) in which satellites (or planets) are used for gravitational assists. Flybys can change orbital energy or inclination, or both. The Galileo orbital tour is nearly a free fall trajectory through the Galilean system which uses the gravitational assist of Europa, Ganymede and Callisto to shape the trajectory about Jupiter so that science objectives can be met. Unfortunately, Io is embedded so deeply in Jupiter's radiation field that, given the other scientific objectives, only one Io flyby is possible without exceeding the orbiter's maximum allowed radiation dose before ten orbits are completed. The single Io flyby takes place on the insertion orbit, and is designed to slow the spacecraft so that less propellant is needed to insert the spacecraft into an elliptic orbit about Jupiter, in addition to allowing scientific observations.

Orbit orientation (the angle measured clockwise at Jupiter from the sun direction to the apojove) is a very important science consideration for reasons to be discussed. Arrival conditions at Jupiter fix the initial orientation at about 120 deg. Due to the motion of Jupiter around the sun, the orbit drifts clockwise with time (at a rate of about 2.5 deg/month). Besides changing the energy and inclination of the spacecraft's orbit, targeted flybys are also used to control orbit orientation, adding to or counteracting the clockwise drift ("rotating" or "counter-rotating" the orbit).

Science Objectives

The tour is designed to satisfy many different science requirements, some of which conflict with each other. Tour design involves constantly striving to maintain a balance in science return, without shortchanging any individual requirement in the interest of the others. A complete, detailed list of the tour science requirements may be found in Diehl[1]. A short discussion of how some of the major requirements influence tour design follows.

Magnetospheric Science

The most important magnetospheric science objectives are to pass through the Jovian magnetotail at a distance of at least 150 R_J (Jupiter radii), and to pass through the wake and flux tube regions surrounding each satellite. The

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magnetotail lies in the direction opposite the sun from Jupiter. The arrival geometry and orbit orientation profile discussed previously make it appropriate to use the final orbit, often called the "tail petal" orbit, to achieve the magnetotail passage. The last satellite flyby must increase period to approximately 90 or more days in order to achieve a distance of 150 R_J at the tail petal apoapsis. "Wakes" streaming out in front of each satellite are created as charged particles, trapped in Jupiter's magnetic field and rotating at Jupiter's rotation rate (faster than the satellites), sweep by the satellites. "Flux tube" regions connect the satellites, rotating through Jupiter's magnetic field, with the Jovian ionosphere along magnetic field lines. Wake passes are achieved with flybys near the satellite's equator and in front of the satellite (decreasing orbital period) and flux tube passes are achieved with near-polar flybys.

Satellite Imaging

The SSI (Solid State Imaging) camera is capable of obtaining images with resolution in the range of tens of meters near closest approach during close satellite flybys. The goal of maximizing the number of images at resolutions of 80m or better for each satellite is given the highest priority. Resolutions this high are obtainable only at altitudes of 4000 km or less. The next highest priority is placed on images with resolutions better than 250m with low sun conditions. Low sun conditions are defined by two angles. First, the sun-viewed surface-zenith angle (or incidence angle) must be greater than 45 degrees in order to create shadows. Second, the sun-viewed surface-spacecraft angle (or phase angle) must be greater than 30 degrees to allow shadows to be seen. For low sun images at resolutions of better than 250 meters, the spacecraft must pass within 12500 km of the surface.

The third priority goal is to obtain global coverage under both high and low sun conditions at resolutions of 1-2 km. High-sun coverage at resolutions of 1-2 km is best for the NIMS (Near-Infrared Mapping Spectrometer) instrument, which measures the spectrum of sunlight reflected from the surface in order to determine satellite composition. These resolutions are obtained at distances of 50,000 km - 100,000 km. These distances are attained on approach to and departure from targeted flybys. In addition, flybys with closest approach distances in the tens of thousands of km may be arranged in order to significantly enhance global coverage.[9,10] Distant flybys of this type are "nontargeted", that is, their flyby aimpoints (altitude, latitude, longitude of closest approach) need not be tightly controlled since their effect on the spacecraft's orbit is small. It is permissible from a navigation standpoint to arrange one targeted and one nontargeted flyby per orbit. The number of nontargeted flybys in the tour is maximized by carefully controlling orbit orientation and periapsis distance in order to take advantage of nontargeted flyby opportunities, which may be predicted[2]. Nontargeted flybys occurring on orbits oriented near the tail yield the best global coverage, since it is possible to view a nearly full moon from the closest approach point[9].

Observations of Jupiter's Atmosphere

Observations of cloud features and other dynamics in the Jovian atmosphere can only be made of sunlit portions of Jupiter and are best done at great distances in order to view the planet with the narrow angle camera. Unfortunately, the spacecraft spends a great deal of time on Jupiter's dark side. Figure 1 shows that the spacecraft spends less time over sunlit portions of Jupiter as the orbit is rotated toward the tail orientation. In order to maximize the amount of time available to observe lit portions of Jupiter, the orientation of the spacecraft's orbit must be kept close to the initial orientation for as long as possible, within the limits imposed by the requirement to achieve the tail petal orbit at the end of the tour. Consequently, targeted flybys near the beginning of the tour are designed to counteract the clockwise drift in orbit orientation discussed above. This means that nontargeted flybys on the early orbits occur at less favorable orientations for satellite coverage.

Other atmospheric phenomena of interest, such as lightning, are best examined as the spacecraft passes into Jupiter's shadow.

Radio Science

Radio science experiments support all three major science areas (magnetospheres, atmospheres and satellites).

When the spacecraft passes behind Jupiter as viewed from Earth, radio signals from the spacecraft are not cut off. Instead, they are refracted by the thick Jovian atmosphere on their way to Earth. Polarized radio signals are also influenced by the magnetic field of Jupiter, through a phenomenon called the Faraday effect. Because a great deal of information on the atmosphere and magnetic field may be gleaned by analysis of the refracted polarized signals, passes behind Jupiter (called occultations) are desired in the tour. In order to achieve occultations, the spacecraft's orbital plane, usually located near Jupiter's equator and the orbits of the satellites, must be tilted away from the equator. This may be done by using 360 deg. transfer orbits between targeted flybys[2]. Occultations of the spacecraft, as viewed from the Sun (shadow passages), are often achieved in conjunction with occultations of the spacecraft as viewed from Earth.

Occultations of the spacecraft by the Galilean satellites are also desired in the tour, in particular by Io, where the radio signal may be distorted due to outgassing from volcanic plumes. Since radiation considerations prohibit the spacecraft from approaching Io more than once, and no occultation occurs during that flyby (on the insertion orbit), any occultation of the spacecraft by Io must occur at a distance. The tours discussed in Diehl[1] and Wolf[2] contained no such distant satellite occultations. New developments in techniques of achieving these occultations resulted in the inclusion of seven distant satellite occultations in this tour (five by Io and one each by Europa and Callisto). A short discussion of methods of achieving them is included here.

Arranging a distant satellite occultation involves adjusting orbital inclination by using a 360 deg. transfer orbit, as described above for passes behind Jupiter. The inclination must be much more tightly controlled to be assured of passing behind a small satellite than is necessary to assure passage behind the relatively large figure of Jupiter.

The motion of the satellites about Jupiter also complicates the problem. Because during the tour the satellites' orbital planes are not viewed edge-on but appear tilted to an Earth-based viewer, the satellites appear to move across the sky not only in a left-right sense, but also in an up-down sense as they orbit Jupiter. (For this discussion, the north pole of Jupiter is assumed to be "up" to the Earth-based viewer.) Therefore, the inclination required to achieve a distant satellite occultation is not constant, but varies with the position of the satellite in its orbit. First, the time must be found at which the spacecraft passes nearest the satellite in the left-right sense, and then the spacecraft's inclination must be adjusted so that the spacecraft passes directly behind the satellite instead of above or below its image in the sky. Since Io passes behind Jupiter every rev as viewed from Earth, the spacecraft must pass behind Jupiter on any orbit containing a distant pass behind Io.

The Orbital Tour

Figure 1 displays the north trajectory pole view of the Galileo orbital tour selected for the May 1986 launch opportunity. The figure is shown in a sun oriented reference frame. The insertion orbit is defined as "Orbit 0" (see Figure 2). The Io flyby takes place on this orbit, followed by the probe relay phase of the mission and the Jupiter Orbit Insertion (JOI) burn. The orbit is still called Orbit 0 until the spacecraft reaches Apojove 1, where a perijove raise maneuver is performed to raise periapsis out of the harsher radiation environment near Jupiter. The orbital tour is considered to begin with Orbit 1. The science value of Orbit 0 is high because it includes a close Io encounter, occultations of the spacecraft as viewed from both Earth and Sun, and the distant nontargeted encounters displayed in Figure 2.

Table 1 provides a summary of the selected orbital tour. The ten targeted encounters with Europa, Ganymede and Callisto are listed sequentially with date of closest approach, whether the encounter occurs on the inbound leg to perijove or on the outbound leg from perijove, the altitude and latitude at closest approach and a terse description of the objective (elaborated below). Asterisks mark all nontargeted encounters which are within 200,000 km. A brief description of each encounter follows with an elaboration of the scientific and trajectory design objectives.

Ganymede 1 Encounter (July 3, 1989)

The first encounter of the satellite tour is with Ganymede (see Figure 3). This flyby reduces the orbital period of the spacecraft from 206 days to 64 days. This period reduction results in a close wake pass. Since this is a period-reducing flyby on an inbound trajectory (encounter before perijove), the spacecraft's orbit is counter-rotated (rotated away from the anti-Sun direction) which is favorable for Jupiter atmospheric observations. Two consequences of this counter-rotating encounter are that the flyby is on the light side of the satellite and that the satellite is not occulted. The first consequence allows high-resolution, high-Sun imaging of Ganymede. The second permits unobstructed tracking of the spacecraft. The tracking data obtained from this nearly equatorial pass, together with tracking data from a high latitude pass, is used to construct a model of Ganymede's gravitational field. The first Ganymede encounter is also favorable for the NIMS (Near Infrared Mapping Spectrometer) experiment because the near-dawn orientation of the spacecraft's orbit (together with the inbound encounter) provides high-Sun conditions on approach. At closest approach, bright limb observations are possible, enabling the ultraviolet spectrometer (UVS) experiment to be performed.

Ganymede 2 Encounter (September 5, 1989)

A second encounter with Ganymede (Figure 4) is necessary to reduce the inclination of the spacecraft's orbit so that the other Galilean satellites, which are nearly in the Jovian equatorial plane, can be encountered. The initial inclination is a consequence of the interplanetary trajectory. This encounter must be a close, polar flyby, providing the opportunity to complete the Ganymede gravity-modeling experiment described above, as well as a passage through Ganymede's flux tube. The close polar view allows high-resolution, low-Sun imaging, a high-priority science objective. Because this encounter's approach conditions are similar to those of the Ganymede 1 flyby, there will be little benefit for global NIMS and SSI imaging.

Callisto 3 Encounter (October 29, 1989)

Callisto (Figure 5) is used to further reduce the orbital period from 56 days to 40 days, resulting in a wake pass. Since the encounter is also inbound, the spacecraft's orbit is counter-rotated which provides more time on Jupiter's lit side for atmospheric observations. The light-side pass permits high-resolution, high-Sun imaging of Callisto. On approach, the high-Sun conditions are favorable for NIMS. At closest approach, the bright limb is observable by UVS. Conditions at Callisto result in a subsequent nontargeted encounter with Europa.

Europa 3A Nontargeted Encounter (October 31, 1989)

This nontargeted encounter with Europa is too distant to provide 2-km-resolution imaging, but close enough to provide some 3-km-resolution coverage. The low-Sun conditions are favorable only for SSI global coverage.

Europa 4 Encounter (December 9, 1989)

Europa (Figure 6) is used to reduce the spacecraft's orbital period still further from 39 days to 27 days, resulting in a close wake pass. Since the encounter is also inbound, the spacecraft's orbit is counter-rotated, which is favorable for viewing Jupiter's atmosphere. The close light-side pass permits high-resolution, high-Sun imaging. The approach trajectory permits

NIMS global observations under high-Sun conditions. The Europa 4 encounter puts the spacecraft on a transfer orbit to Ganymede 5 in such a way that a nontargeted encounter with Ganymede occurs shortly after Europa 4 and a nontargeted encounter with Europa occurs shortly before Ganymede 5. Fortuitously, this transfer orbit provides an opportunity to perform a Faraday experiment (Figure 7).

Ganymede 4A Nontargeted Encounter (Dec. 11, 1989)

This close nontargeted encounter with Ganymede (Figure 8) provides global imaging opportunities for both SSI and NIMS, at better than 1-km resolution.

Europa 5A Nontargeted Encounter (January 7, 1990)

This nontargeted encounter with Europa is just close enough to provide global imaging at 1-km resolution for both SSI and NIMS.

Ganymede 5 Encounter (January 8, 1990)

This somewhat distant encounter with Ganymede increases the spacecraft orbital period from 29 days to 36 days. Since the encounter is outbound and the period is increased, the spacecraft orbit is counter-rotated, but only slightly, due to the distance of the encounter. The resulting orbit orientation is favorable for Jovian atmospheric observations. Also, imaging of Ganymede's light side is possible during closest approach at resolutions better than 150 m. The approach is favorable for NIMS because of the high-Sun conditions. An occultation of the spacecraft as viewed from Earth occurs after the encounter.

Europa 6 Encounter (February 12, 1990)

The Europa 6 encounter (Figure 9) sets up a 360-degree transfer to the Europa 7 encounter so that the spacecraft's orbit can be inclined to provide an occultation of the spacecraft by Jupiter and a distant occultation of the spacecraft by Io as viewed from Earth (Figures 10 and 11). On this orbit, the spacecraft moves across the sky (as seen from Earth) fast enough so that it is near Io's orbit during only one Io rev, affording only one opportunity for a distant Io occultation. An occultation of the spacecraft by Jupiter as viewed from the Sun also occurs during this transfer orbit (Figure 12). A close polar flyby is required to accomplish the inclination change, so that high-resolution, low-Sun imaging can also be done. The flyby results in a slight counter-rotation which is outweighed by the free rotation of the orbit towards the tail petal due to Jupiter's revolution about the Sun. The orbital orientation is still beneficial for Jupiter atmospheric observations. Approach conditions permit some global NIMS imaging.

Europa 7 Encounter (March 19, 1990)

The Europa 7 encounter is used to remove the inclination put into the spacecraft's orbit by Europa 6, so that the spacecraft is returned to the equatorial plane of Jupiter, where the other Galilean satellites can be encountered. This necessitates a polar flyby which results in a flux tube pass. The close polar flyby provides an opportunity for high-resolution, low-Sun imaging. The combined effects of free rotation towards the tail petal and the rotation induced by the encounter result in a reduced but still significant amount of time available for Jovian atmospheric observations. Some NIMS global coverage is possible on approach, but conditions are redundant with the Europa 6 encounter. After the Europa 7 encounter, the spacecraft is occulted by Jupiter as viewed from both Earth and Sun.

Ganymede 8 Encounter (April 22, 1990)

This inbound, period increasing encounter rotates the spacecraft's orbit towards the tail petal. The orbital period is increased from 35 days to 67 days. Closest approach occurs over the dark side of Ganymede; nevertheless, some high resolution, low-Sun imaging of lit terrain is possible. Occultations of the spacecraft by Ganymede as viewed from both Earth and Sun occur shortly after closest approach. Still later, the spacecraft passes behind Jupiter as viewed from both Earth and Sun.

Callisto 8A Nontargeted Encounter (April 25, 1990)

This close nontargeted encounter with Callisto provides the opportunity to obtain global coverage at 1-km resolution for both NIMS and SSI.

Callisto 9 Encounter (July 1, 1990)

This outbound encounter decreases the spacecraft's orbital period from 67 days to 48 days so that the orbit is rotated further towards the tail petal. The period reduction results in a wake pass. The close dark-side pass allows some high-resolution, low-Sun imaging. Satellite occultations occur shortly after encounter as viewed from both Earth and Sun.

Ganymede 10 Encounter (August 14, 1990)

This is the final targeted encounter of the tour. This inbound flyby increases the period from 48 days to 114 days, rotating the spacecraft's orbit to the tail petal orientation and increasing the apoapsis to 180 R_J. The spacecraft's distance behind Jupiter on the anti-Sun line is approximately 150 R_J, which will permit magnetotail observations. The close dark-side pass of Ganymede permits some high-resolution, low-Sun imaging. Occultations of the spacecraft by Ganymede as viewed from both Earth and Sun occur after closest approach. The encounter is designed to initiate 360-degree transfer orbit back to Ganymede (for a potential post-tour 11th encounter) so that the orbital inclination can be controlled to provide an occultation of Jupiter and several distant satellite occultations as viewed from Earth.

During the tenth orbit, the spacecraft is moving mostly away from Earth. Consequently, its motion from right to left across the sky is much slower than on orbit 6, allowing opportunities for distant Io occultations on more than one Io rev. In fact, an inclination was found for which distant Io occultations occur on three separate Io revs, with two occurring on a single rev (four occultations in all). On this rev, the two occultations occur near the right ansa of Io's orbit, as the image of Io first passes the spacecraft from left to right, then from right to left (Figures 13 and 14).

Near the end of the tour, the position of Jupiter in relation to the ecliptic is such that the tilt of the satellites' orbital planes apparent to an Earth-based viewer is very small. Therefore, to an Earth-based viewer the satellites hardly appear to be moving in the up-down sense in the plane of the sky (where "up" is in the direction of Jupiter's north pole) as they orbit Jupiter. Therefore, the range of inclinations needed to achieve a distant occultation by any of the Galilean satellites is reduced. Because of this, the same inclination used to achieve the four distant Io occultations also yields distant occultations of both Europa and Callisto on the tenth orbit. The spacecraft's distance behind Jupiter during these occultations is greater than 10,000,000 km (see Figure 1).

The spacecraft is also occulted by Jupiter as viewed from the Sun. This distant solar occultation offers the best opportunity to observe lightning on the dark side of Jupiter.

Europa 10A Nontargeted Encounter (August 15, 1990)

This close nontargeted encounter provides an opportunity for global coverage at better than 1-km resolution for both SSI and NIMS.

Science Value Versus Science Requirements

The orbital tour presented above was selected based on the satisfaction of science requirements in the areas of atmospheric science, magnetospheric science, satellite science and radio science experiments (which support the other three areas). A large number of scientific criteria were involved in the evaluation process. In this section only the highlights of the major areas will be reviewed in regard to the achievement of the scientific objectives.

Jupiter Atmospheric Measurements

Imaging of the Jovian atmosphere is evaluated by a number of parameters, but the most distinguishing is the amount of time available for imaging at a distance greater than 15 Jovian radii with a phase angle of less than 90 degrees (more than half of Jupiter's disk sunlit). During the orbital tour, 38 days of atmospheric observation time is obtainable, which is the largest value obtained for all tours considered for the December 1988 arrival date.

Magnetospheric Science

Magnetospheric science requirements include:

1) Close wake passes with Europa, Ganymede and Callisto

2) Flux tube passes with Europa and Ganymede

3) Passes through the magnetotail of Jupiter at greater than 150 Jovian radii and within 15 degrees of the anti-sun direction

All these requirements were achieved, with an additional Callisto wake pass.

Satellite Imaging

The original science requirement calls for greater than 50% coverage at 1 km resolution of the Galilean satellites. No orbital tour has ever achieved this goal. However, at 2 km resolution more than 50% coverage is obtained in the selected tour. The global coverage results are displayed in Table 2. In the tour design effort it was discovered that greater global coverage is possible, but only at the expense of other science requirements. The results for high resolution imaging were satisfactory providing a reasonable distribution between Europa, Ganymede and Callisto. NIMS global coverage was considered to be very satisfactory. The overall value of satellite science is equivalent to the orbital tour presented in Diehl[1].

Radio Science

Radio science requirements include:

1. At least three occultations of the spacecraft by Jupiter. Polar, mid-latitude and equatorial occultations are desired.

2. A Faraday experiment, which can be performed during a near grazing occultation.

3. An occultation by each satellite.

All the above requirements were achieved, with the Io and Europa occultations occurring in the tenth orbit.

Conclusions

The Galileo orbital tour selected for the 1986 launch opportunity met or exceeded all the minimum science requirements. Although this particular tour cannot be flown, it at least provides a benchmark by which future tour designs can be measured.

Acknowledgments

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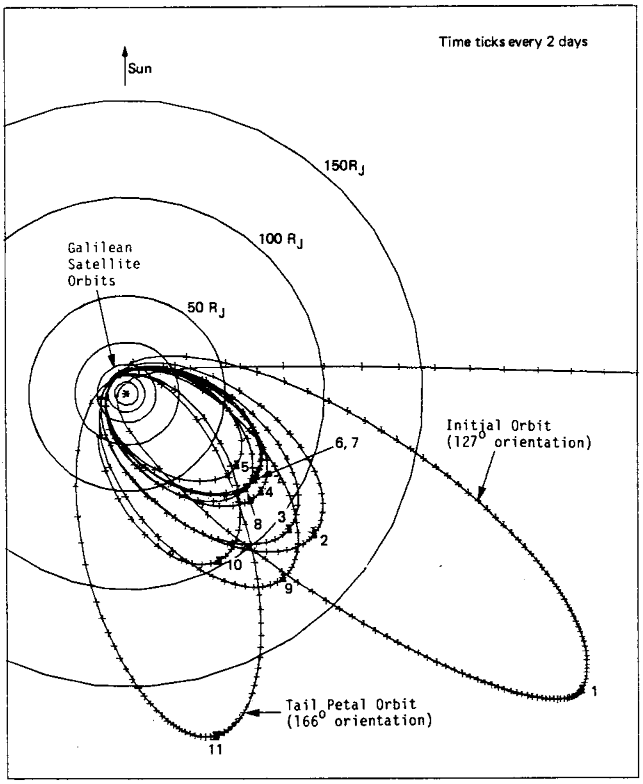
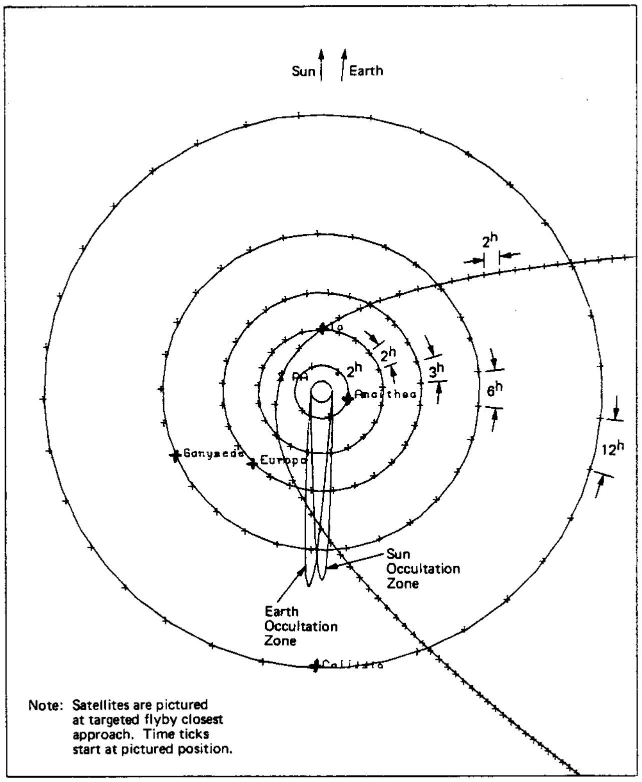


Fig. 1 Satellite tour petal plot.



Note: Satellites are pictured at targeted flyby closest approach. Time ticks start at pictured position.

Fig. 2 Trajectory pole view of Orbit 0 near perijove.

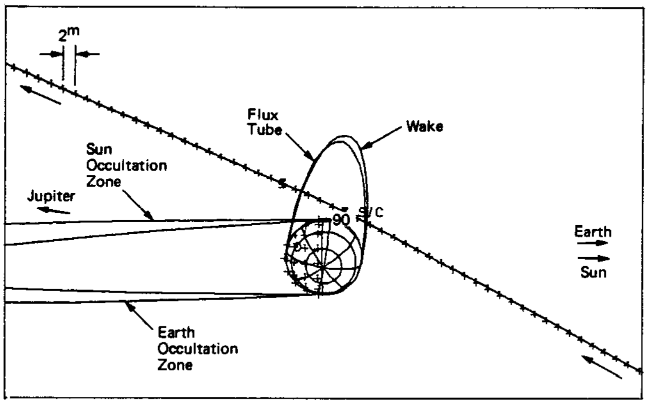


Fig. 3 Trajectory pole view of Ganymede 1 encounter.

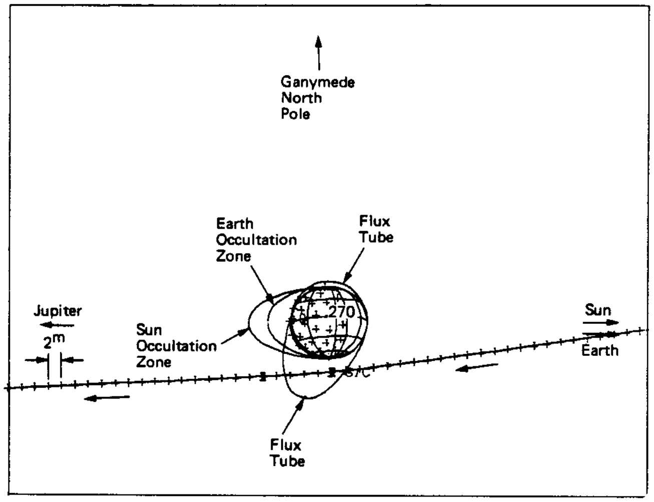


Fig. 4 Trajectory pole view of Ganymede 2 encounter.

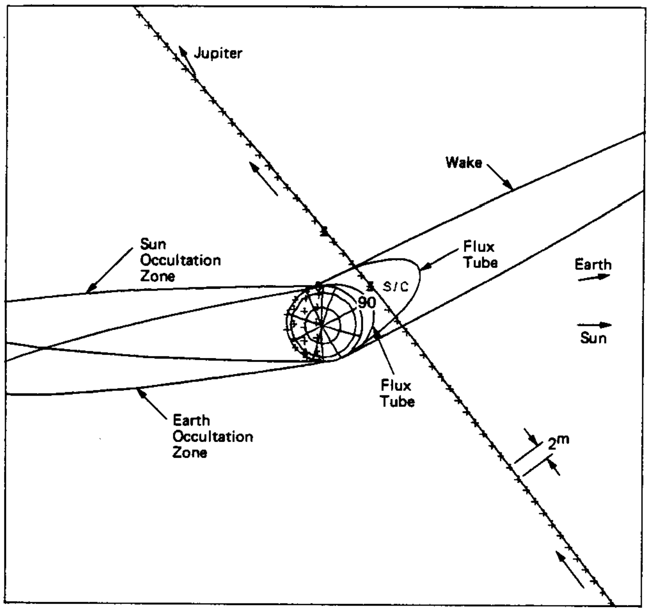


Fig. 5 Trajectory pole view of Callisto 3 encounter.

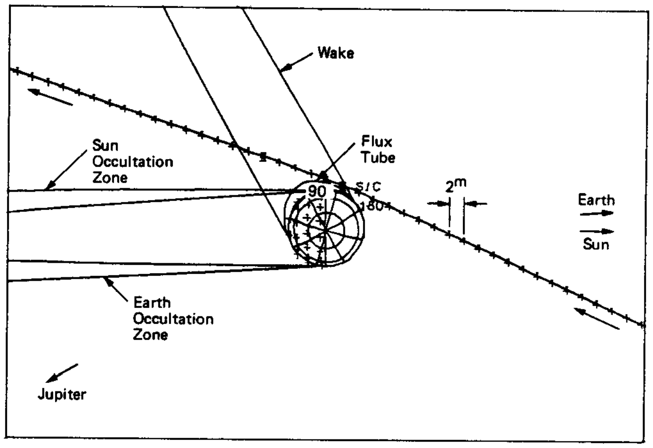


Fig. 6 Trajectory pole view of Europa 4 encounter.

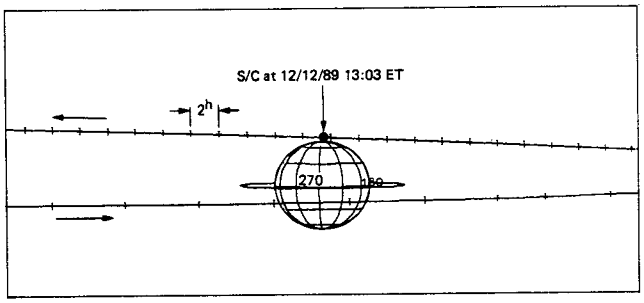


Fig. 7 Earth view of Jupiter near Perijove 4: Faraday experiment.

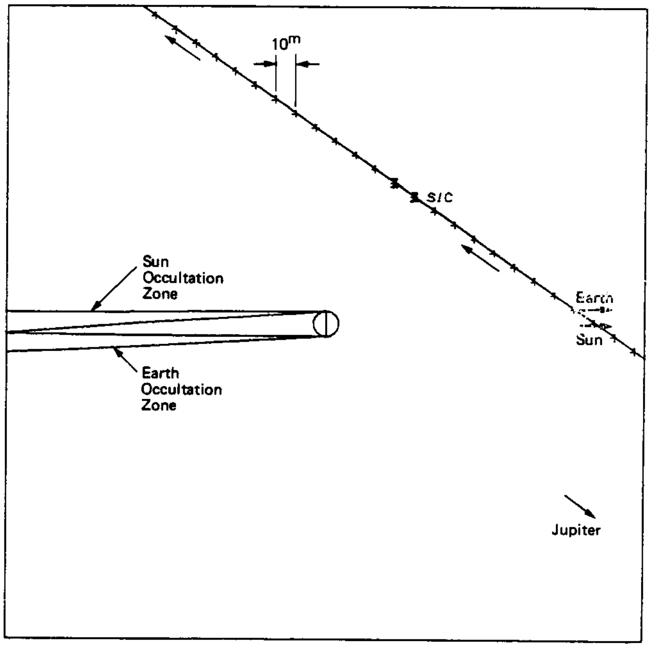


Fig. 8 Trajectory pole view of Ganymede 4A nontargeted encounter.

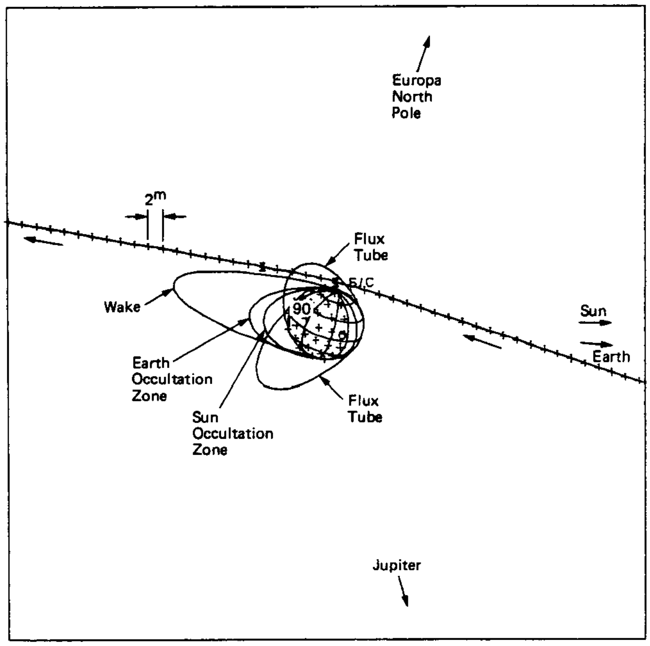
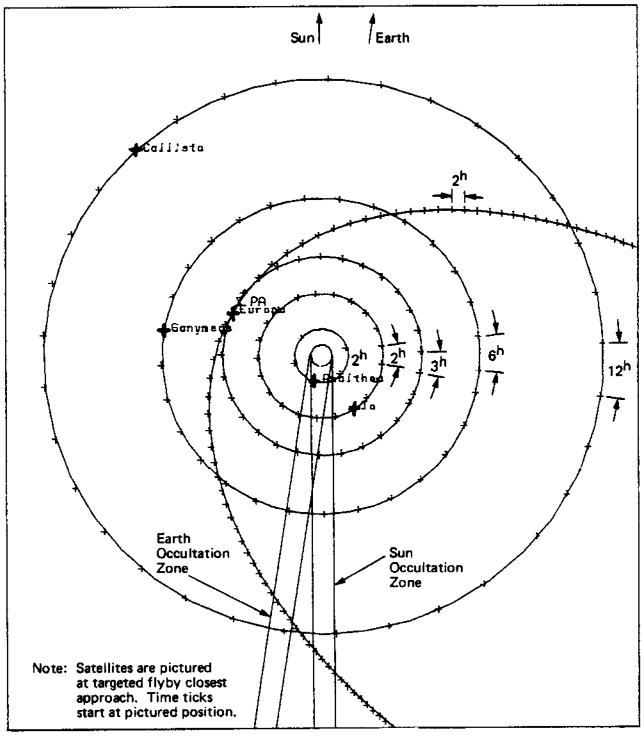


Fig. 9 Trajectory pole view of Europa 6 encounter.



Note: Satellites are pictured at targeted flyby closest approach. Time ticks start at pictured position.

Fig. 12 Trajectory pole view of Orbit 6 near perijove.

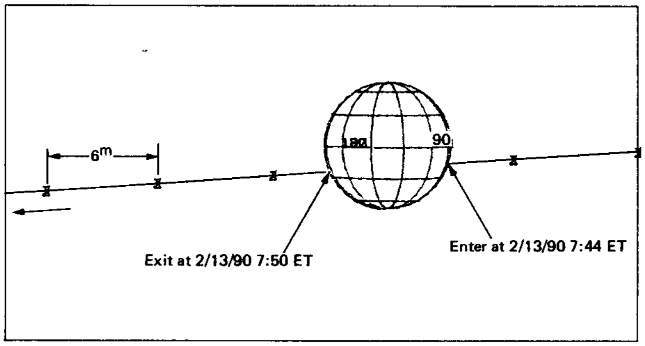


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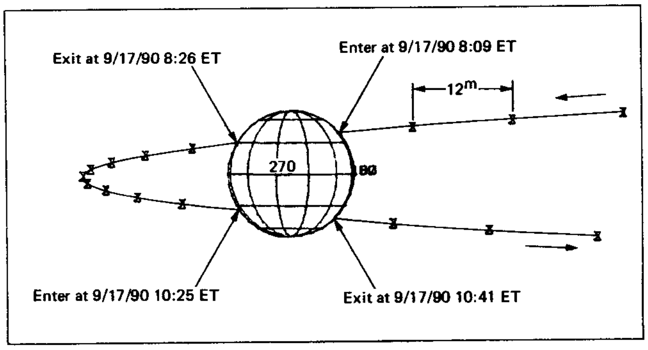
Fig. 10 Earth view of distant Io occultation on Orbit 6 (motion of S/C relative to Io).



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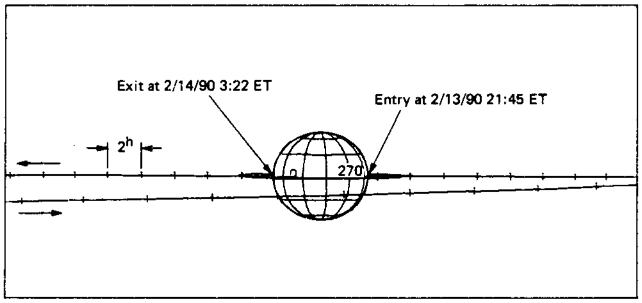
Exit at 9/17/90 10:41 ET

Fig. 13 Earth view of first distant Io occultation on Orbit 10 near quadrature (motion of S/C relative to Io).



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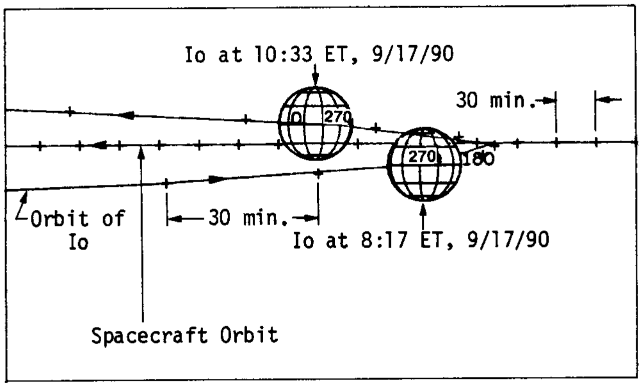
Entry at 2/13/90 21:45 ET

Fig. 11 Earth view of Jupiter near Perijove 6.



Io at 10:33 ET, 9/17/90

Io at 8:17 ET, 9/17/90

Fig. 14 Earth view of distant Io occultations on Orbit 10 (motion of Io and S/C relative to Jupiter).

Table 1 Summary of tour

Encounter	Satellite (inbound/outbound)	Altitude, km	Latitude, deg	Objective
1	3 Jul 89/Ganymede (in)	830	-15	Wake pass; UVS; equatorial gravity experiment; reduce period.
2	5 Sep 89/Ganymede (in)	792	-80	Flux tube; polar gravity exp.; reduce inclination.
3	29 Oct 89/Callisto (in)	1403	-4	Wake; UVS; counter-rotate orbit orientation.
3*	31 Oct 89/Europa (in)	123174	2	Satellite global coverage.
4	9 Dec 89/Europa (in)	317	-3	Wake; counter-rotate; Faraday exp.
4*	11 Dec 89/Ganymede (out)	29620	5	Satellite global coverage.
5*	7 Jan 90/Europa (out)	48013	-5	Satellite global coverage.
5	8 Jan 90/Europa (out)	6561	19	Coverage; Jupiter occultation; counter-rotate.
6	12 Feb 90/Europa (out)	200	68	Jupiter and distant Io occultations.
7	19 Mar 90/Europa (out)	200	-70	Flux tube; Jupiter occultation.
8	22 Apr 90/Ganymede (in)	947	-18	Satellite occultation; Jupiter occultation; rotation.
8*	25 Apr 90/Callisto (out)	25012	1	Satellite global coverage.
9	1 Jul 90/Callisto (out)	1634	-15	Wake; satellite occultation; rotation.
10	14 Aug 90/Ganymede (in)	592	-11	Satellite occultation; rotation; Jupiter and distant satellite occultations.
10*	15 Aug 90/Europa (in)	25076	18	Satellite global coverage.
Tail Petal Apojove	11 Oct 90			180 R_J; orbit orientation of 166 deg; end of nominal mission.

Table 2 SSI coverage

Satellite	Percent coverage	
	1-km resolution	2-km resolution
Europa	29	56
Ganymede	33	69
Callisto	26	64