Galileo mission tour performance

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The Galileo mission is an ambitious attempt to explore the Jovian system by spacecraft. This voyage of exploration is a logical successor to the reconnaissance voyages of Pioneers 10 and 11, Voyagers 1 and 2, and Ulysses. These spacecraft merely flew past Jupiter, spending relatively little time in its system. Galileo differs from these earlier spacecraft in that it will remain within the Jovian system, studying the planet and its four major satellites for a period of two years.

Insertion into orbit around Jupiter will occur on December 7, 1995. The portion of the mission encompassing observations of Jupiter and the major and minor satellites, and magnetospheric mapping, has become known as the Jovian tour. During this period Galileo will encounter each of Europa, Ganymede, and Callisto at least three times on trajectories that will bring it to altitudes from 200 to 3200 kilometers. The availability of precision navigation permits flight controllers to exploit gravity-assists throughout the tour. This reduces propellant expenditure and enables a ten encounter tour within a period of 16 months. Furthermore, the ten encounters occur on eleven highly eccentric orbits - orbits with extended major axes which will elucidate Jupiter's magnetosphere. Figure 1 illustrates the tour trajectory plot, and a summary of tour characteristics is provided in Table 1. So-called non-targeted encounters are also listed in Table 1. These are designated by adding an "A" to the encounter number. Non-targeted encounters have higher altitude flybys, as shown in the Table.

The Jovian satellite tour was designed for a fully functional spacecraft. Unfortunately, on route to Jupiter, Galileo's deployable high gain antenna (HGA) failed to open, leaving a single low gain antenna (LGA) as the spacecraft's sole telecommunication link.

This paper will assess orbit determination capabilities of the LGA mission. The tour in Table 1, while optimized for an HGA mission, will nevertheless remain for the LGA mission. Moreover, it will be shown that despite significantly degraded tracking data and a reduced picture budget, this tour will still be successfully navigated.

Propellant margin (P.M.), the quantity of fuel and oxidizer remaining after ten encounters, is a concern to flight controllers. Positive P.M. indicates a 90% probability of tour completion, whereas negative P.M. implies a probability of less than 90%. Delivery accuracies to each target satellite must be met in order to maintain a positive P.M. balance. Therefore to ensure a ten encounter tour, propellant usage must be guided by accurate orbit determination.

The HGA mission had a data rate capability of 115,000 bits per second (X-band) - ample bandwidth to return science, navigation, and engineering data in near real-time. The LGA mission is expected to return only 40 bits per second over S-band frequencies. Due to the paucity of this LGA data and the priority of science data, severe limitations have been placed on acquisition of radiometric tracking data. Only a single track (eight hours) of two-way S-band Doppler data per week will be acquired.

Jovian distances preclude acquisition of standard S-band ranging data. Spurred on by Galileo's plight, a refined ranging formulation has recently been developed at JPL to overcome this limitation. This formulation, called pseudo-noise ranging, excels under adverse signal-to-noise conditions and shall be applied to the LGA Galileo tour.

Optical navigation images (opnavs) i.e. satellite images against a star background, were important for the HGA mission; they are critical in the LGA tour. The success of the LGA tour hinges on these opnavs. By employing newly developed image compression and editing techniques, up to thirty-five opnavs per orbit can be returned.