648

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ICARUS LANDER

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Icarus is one of the earth-crossing asteroids. It has a semi-major axis of 1.078 AU, giving it a period of 1.12 years, and an eccentricity of 0.827. The perihelion distance is thus 0.187 AU. The inclination of Icarus's orbit is 23°. Although it is a small body (radius ≈ 1km), it it still massive enough to be essentially immune to non-gravitational forces. These orbital and physical qualities make it an attractive target for testing General Relativity. The close passage to the sun means that it will be subject to a large relativistic perihelion precession; the high eccentricity makes the precession easy to measure; the high inclination allows the solar quadrupole moment (J_2) to be simultaneously determined via the nodal precession it predicts. The degeneracy between the relativistic effect and the effect of J_2 in the perihelion precession may thus be broken.

In this talk, I will present results from a preliminary study of a possible trajectory design for an Icarus lander and from a covariance study of the scientific return to be expected from such a mission.

The same properties of Icarus's orbit that make it so attractive for tests of General Relativity — its high inclination and high eccentricity — make it a difficult target to reach. Nevertheless a seven-year trajectory has been found[1] which has a $\Delta \upsilon$ requirement which is attainable. The mission events are as follows:

Depart Earth — 1/2/93 ($\Delta \upsilon$ = 0km/sec)

First Maneuver — 1/7/94 ($\Delta \upsilon$ = 1.51km/sec)

Gravity Assist/Earth — 2/28/95 ($\Delta \upsilon$ = 0.47km/sec)

Gravity Assist/Jupiter — 7/25/96 ($\Delta \upsilon$ = 0km/sec)

Second Maneuver — 10/25/99 ($\Delta \upsilon$ = 0.80km/sec)

Icarus Encounter — 10/13/00 ($\Delta \upsilon$ = 2.86km/sec)

The total $\Delta \upsilon$ is thus 5.64 km/sec. This is a difficult but a reasonable requirement.

A preliminary covariance study[2] to determine the scientific value of range data from an Icarus lander has been completed. In this study it was assumed that range data had an inherant accuracy of 10 cm. (It has been suggested that such an accuracy is attainable with the DSN. A feasability study of this would be a worthwhile task.) Two years of data were assumed with one data point per day. It was further assumed that the data from Icarus would be so accurate that they would overwhelm the information content of all other solar system data for the parameters of interest, an assumption which is almost certainly true at the assumed 10 cm accuracy, so all other solar system data were neglected. The parameters of interest were the orbital

1. The trajectory design was performed by A. Khatib.
2. The study used POSCOV, a program written by J.D. Anderson and E.L. Lau.

elements of Icarus and of the Earth, the GM of the sun, and PPN parameters β, γ, and the solar J_2. The *a priori* uncertainties for these parameters were 1% for β, 0.2% for γ, and 10^{-6} for J_2. The post-fit uncertainties are shown as functions of time in Figures 1-3.

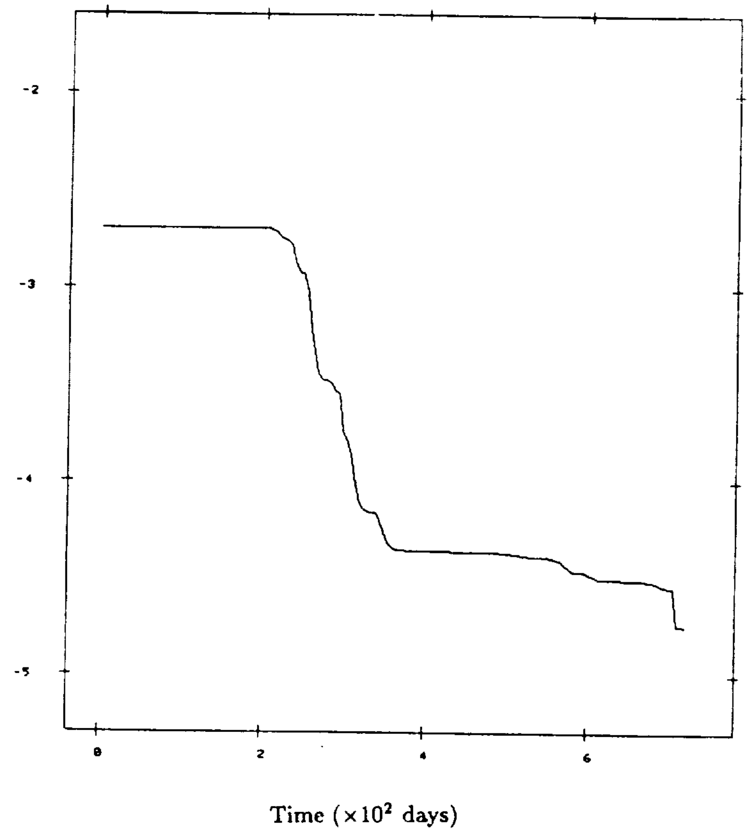


Figure 1. Log_{10} of the uncertainty in γ as a function of Icarus tracking time. There is no improvement until the first solar conjunction at t=300 days, which allows a measure of the gravitational time delay. Final formal uncertainty in γ is 1.8×10^{-5}

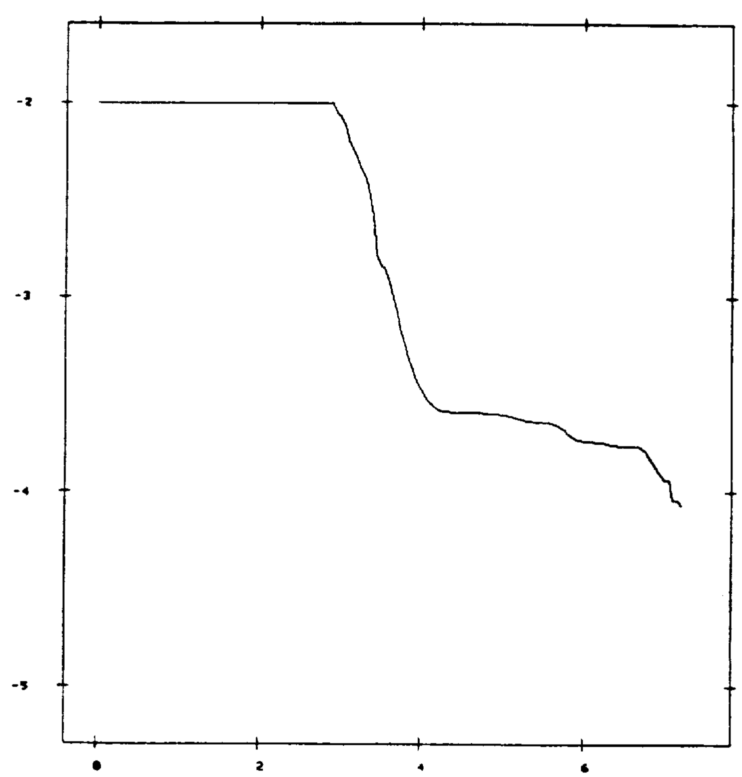
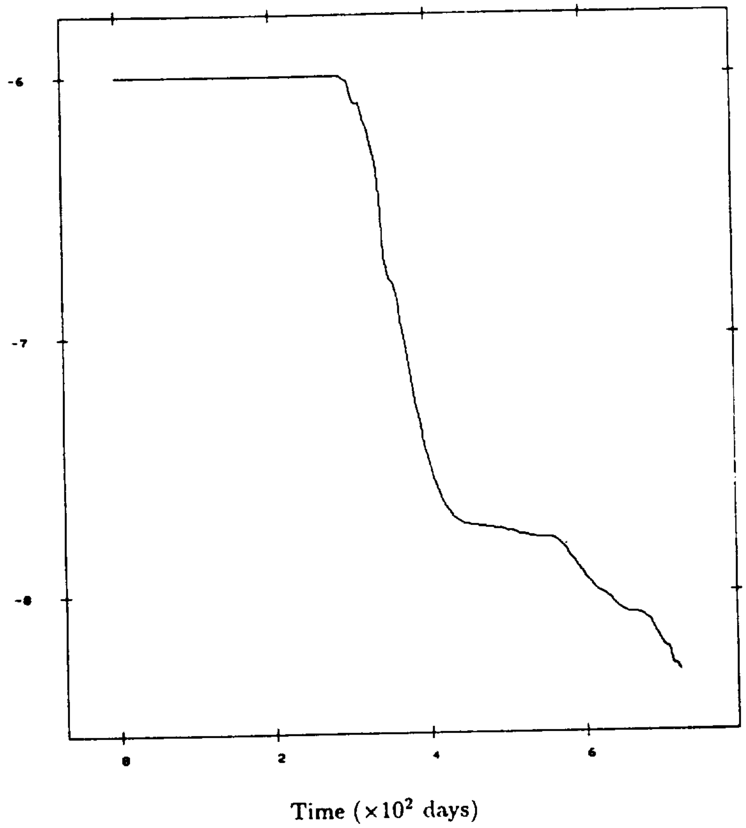


Figure 2. Log_{10} of the uncertainty in β as a function of Icarus tracking time. The strong correlation between β and γ in perihelion precession prevents improvement until the solar conjunction separates the two parameters. Final formal uncertainty in β is 9×10^{-5}.

Figure 3. Log_{10} of the uncertainty in $J_{2\odot}$ as a function of Icarus tracking time. The strong correlation between $J_{2\odot}$ and γ in perihelion precession prevents improvement until the solar conjunction separates the two parameters. The separation between $J_{2\odot}$ and β comes as a result of the determination of node precession. Final formal uncertainty in $J_{2\odot}$ is 5.3×10^{-8}.



DISCUSSION

Questions and answers at the end of Bender's paper (p. 147)