Europa Orbiter Mission Design – Recent Developments

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The Europa Orbiter mission will place a spacecraft into orbit about Europa to determine the presence or absence of a liquid ocean on Europa. Previous work[i,ii] has described the baseline trajectory profile, which consists of a direct transfer from Earth to Jupiter, followed by a nearly ballistic Galileo-like tour to reduce perijove and period, and finally a series of nearly resonant encounters with Europa leading to orbit insertion. These Europa encounters, combined with perijove-raising maneuvers and third-body perturbations from Jupiter, reduce the orbital period and lead to an "elliptical approach" with respect to Europa (i.e., just prior to orbit insertion, the osculating spacecraft orbit with respect to Europa is a highly eccentric ellipse). In this paper, we update the baseline trajectory to reflect a January 2006 launch and discuss how constraints of solar conjunction and Earth range affect the launch/arrival space and ΔV performance, and how low-radiation, low-ΔV tours with the desired Europa orbit orientation are achievable through judicious tour design. Alternate interplanetary trajectory options for later launch years are also discussed.

The Europa Orbiter mission includes the following phases: interplanetary cruise, Jupiter arrival (which includes a Ganymede gravity-assist flyby prior to initial perijove passage, the orbit insertion burn, initial orbit and any perijove raise maneuver needed), a nearly ballistic satellite tour using Ganymede, Callisto and Europa flybys to reduce period, the "endgame" (consisting of nearly resonant Europa encounters, perijove-raising maneuvers at apojove to reduce the V_∞ at Europa encounter, and the Europa orbit insertion maneuver to place the spacecraft into orbit about Europa), and a 30-day Europa orbital phase.

Current plans call for the Europa Orbiter spacecraft to be launched in January 2006 on a direct trajectory to Jupiter. An Atlas V or a Delta IV launch vehicle with a Star 48V upper stage will inject the ~1600 kg spacecraft onto the interplanetary trajectory. A 21-day launch period is possible for a launch energy corresponding to a C_3 of 80 km^2/s^2.

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The endgame from a recently generated 2006 trajectory can be seen in Figure 1. The spacecraft has two Europa encounters in a shortened "endgame". The E17 encounter puts the spacecraft on a 4:3 resonance with respect to Europa (4 Europa orbits to 3 spacecraft orbits), while the E20 encounter puts the spacecraft on a 6:5 resonance, leading to Europa Orbit Insertion (EOI). The spacecraft performs two maneuvers at apojove and a final maneuver at Europa Orbit Insertion (EOI). Although this endgame is similar in make-up to tours previously evaluated, it has significantly lower EOI ΔV requirements (by 80 m/s). Factors affecting this improvement in ΔV cost will be discussed.

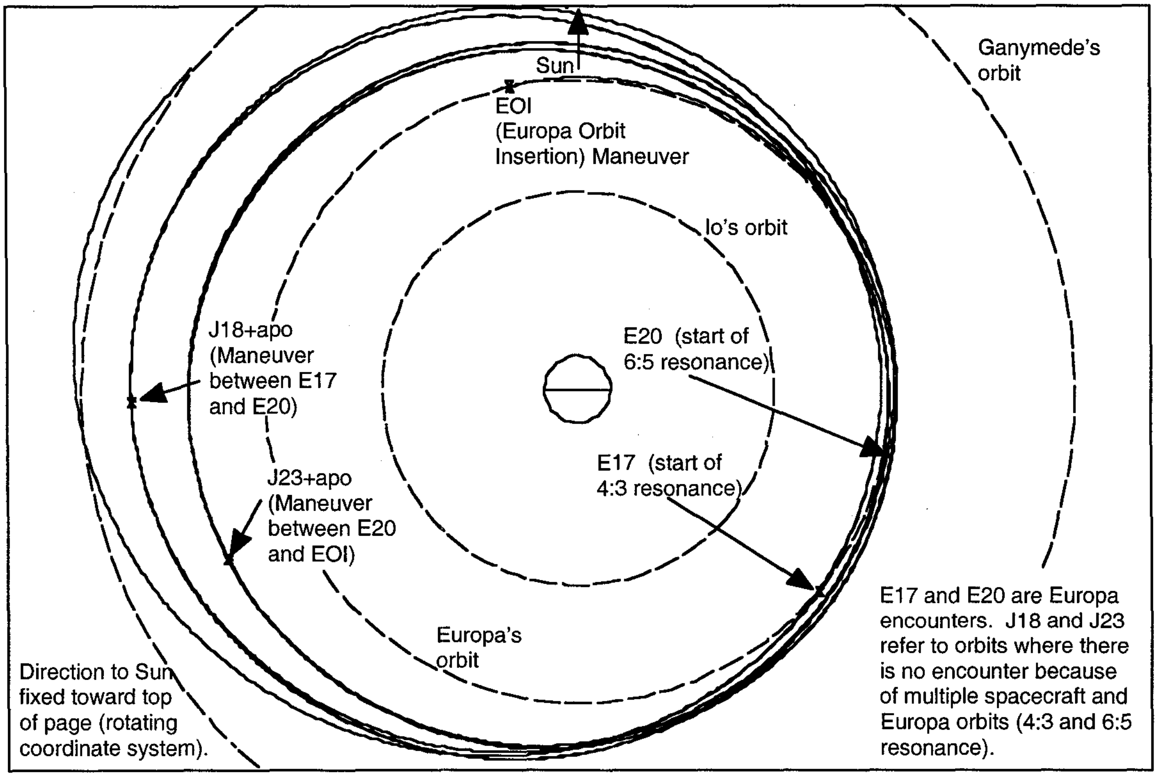

Figure 1. Closeup of Endgame for Tour 00-15

The Science Definition Team for Europa Orbiter has identified a strawman set of instruments that meet the primary objectives of the mission. These instruments include a spacecraft transponder for gravity field mapping, a laser altimeter, ice penetrating radar sounder and imaging instruments. The selection of the science team and instruments should be made shortly, perhaps in the fall of 2000. An initial assessment of the implications of that selection on the mission design will be discussed.

The current radiation design requirement is that the Europa Orbiter spacecraft must be able to withstand a 4 Mrad dose (as evaluated behind 100 mils of aluminum). Several trajectories selected for detailed evaluation of radiation dosage meet the <4 Mrad dosage requirement. As expected, reducing the number of perijove passages and maintaining higher perijove ranges are the key factors in lowering overall radiation dosage. Tours designed specifically for low radiation dosage have been evaluated.

In addition to radiation dosage, another primary consideration in the trajectory design is minimizing the ΔV expenditure to accomplish the mission objectives. Through the use of additional Ganymede flybys in the ballistic satellite tour phase, the orbital period can be reduced without the need for as many perijove-raising maneuvers in the endgame phase. The current mission ΔV allocation is 2300 m/s, which breaks down into approximately 1000 m/s for the combination of broken plane, Jupiter orbit insertion and initial perijove raise maneuvers, 750 m/s for the combination of tour, endgame and Europa orbit insertion maneuvers, about 250 m/s for navigation and statistical ΔV, and about 300 m/s for various liens. The most significant liens are related to potentially providing a telecom link at the Europa Orbit Insertion maneuver, performing altitude changes for science purposes, modifying the orbit at end of mission to increase the orbit lifetime, and orbit orientation issues pertaining to lighting conditions during the 30 day Europa orbital phase. These issues will be discussed in the paper.

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[i] J. M. Ludwinski, M. D. Guman, J. R. Johannesen, R. T. Mitchell, and R. L. Staehle, "The Europa Orbiter Mission Design," IAF 98-Q.2.02, 49th International Astronautical Congress, Sept. 28-Oct. 2, 1998, Melbourne, Australia.
[ii] J. R. Johannesen and L. A. D'Amario, "Europa Orbiter Mission Trajectory Design," AAS 99-360, AAS/AIAA Astrodynamics Specialist Conference, Aug. 16-19, 1999, Girdwood, Alaska.