JOURNAL OF SPACECRAFT AND ROCKETS
Vol. 39, No. 1, January–February 2002

Interplanetary Mission Design Using Gravity Assists

CLOSE planetary flybys provide a nonpropulsive means for altering the orbital characteristics (most notably orbital energy) of an interplanetary trajectory, thereby saving precious propellant mass. Gravity-assist trajectories have made several high-energy interplanetary missions possible, such as Voyager I and II, Galileo, and Cassini. To reach ambitious interplanetary targets of scientific interest, future mission designs will continue to employ gravity assists so that launch mass or flight time (or possibly both) are reduced.

This issue of the *Journal of Spacecraft and Rockets* contains five papers focused on recent advances in interplanetary mission design using gravity assists. The topics of the five papers include a new analysis tool for designing gravity-assist trajectories, combining aerodynamic maneuvers with the planetary gravity assist, and enabling new mission concepts through gravity-assist maneuvers.

The first paper, "Graphical Method for Gravity-Assist Trajectory Design," presents a new analytical technique for quick identification of all viable gravity-assist trajectories between specified planetary targets. Based on Tisserand's criterion, this method depicts interplanetary transfers as contours of constant hyperbolic excess speed (V_∞) with respect to a given planet. Potential gravity-assist trajectories between planets (and estimates for their flight time) are obtained by the intersections of these V_∞ contours. This graphical technique gives mission designers a powerful tool for finding economical gravity-assist trajectories to desired targets in the solar system.

The second paper, "Automated Design of the Europa Orbiter Tour," applies the graphical method based on Tisserand's criterion ("Tisserand graphs") to a gravity-assisted tour of Jupiter's satellites. The Jovian tour will involve 10 or more flybys of the Galilean satellites before the spacecraft's orbital energy is sufficiently reduced for insertion into orbit about the satellite Europa. Using Tisserand graphs alleviates the enormous computational task of finding possible tour configurations and substantially reduces hyperbolic arrival speed at Europa and total radiation dosage.

The third paper, "Design of Aerogravity-Assist Trajectories," investigates the combination of atmospheric flight with the gravity-assist maneuver. The authors demonstrate that aerogravity-assist maneuvers can potentially yield much larger changes in orbital energy than pure gravity-assist trajectories. Tisserand graphs are again used to identify viable aerogravity-assist trajectories. Subsequent analysis shows that Venus and Mars provide more effective aerogravity assists when compared to aerogravity-assist maneuvers with Earth.

The fourth paper, "Mars Free Returns via Gravity Assist from Venus," presents a nonpropulsive abort trajectory for returning a crewed spacecraft bound for Mars back to Earth (similar to the Apollo 13 abort scenario). Through Tisserand graph analysis, the authors discover that a free return (made possible by a Venus gravity assist) satisfies the energy and flight-time constraints of NASA's Design Reference Mission for human exploration of Mars.

The last paper, "To the Far Side of the Sun Using Venus Gravity Assist," explores a new mission concept for placing a satellite in the vicinity of Earth's orbit on the opposite side of the sun (i.e., 180 deg ahead of Earth). Therefore, a satellite in this orbit will drift about the "far side" of the sun for enhanced observation of solar phenomena. The author shows that two Venus gravity assists can position a satellite in this far-side orbit without propulsive maneuvers.

These papers represent significant advances in interplanetary mission design using gravity-assist trajectories, including the exploration of new mission concepts that are feasible only through the use of gravity assists. The new analysis method presented in this special section, the Tisserand graph, may become a standard tool for interplanetary mission designers and eventually lead to the development of exciting future deep-space missions.

C. A. Kluever
Associate Editor