NEAR EARTH ASTEROID RENDEZVOUS (NEAR) REVISED EROS ORBIT PHASE TRAJECTORY DESIGN

C. E. Helfrich, J. K. Miller, P. G. Antreasian, E. Carranza, and B. G. Williams

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive, MS 301-150
Pasadena, CA 91109

D. W. Dunham, R. W. Farquhar, and J. V. McAdams

Applied Physics Laboratory
Johns Hopkins University
11100 Johns Hopkins Road
Laurel, MD 20723

Trajectory design of the orbit phase of the NEAR mission involves a new process that departs significantly from those procedures used in previous missions. In most cases, a precise spacecraft ephemeris is designed well in advance of arrival at the target body. For NEAR, the uncertainty in the dynamic environment around Eros does not allow the luxury of a precise spacecraft trajectory to be defined in advance. The principal cause of this uncertainty is the limited knowledge of the gravity field and rotational state of Eros. As a result, the concept for the NEAR trajectory design is to define a number of rules for satisfying spacecraft, mission, and science constraints, and then apply these rules to various assumptions for the model of Eros. Nominal, high, and low Eros mass models are used for testing the trajectory design strategy and to bracket the ranges of parameter variations that are expected upon arrival at the asteroid. The final design is completed after arrival at Eros and determination of the actual gravity field and rotational state.

As a result of the unplanned termination of the deep space rendezvous maneuver on December 20, 1998, the NEAR spacecraft passed within 3830 km of Eros on December 23, 1998. This flyby provided a brief glimpse of Eros, and allowed for a more accurate model of the rotational parameters and gravity field uncertainty [1]. Furthermore, after the termination of the deep space rendezvous burn, contact with the spacecraft was lost and the NEAR spacecraft lost attitude control. During the subsequent gyrations of the spacecraft, hydrazine thruster firings were used to regain attitude control. This unplanned thruster activity used much of the fuel margin allocated for the orbit phase. Consequently, minimizing fuel consumption is now even more important.

The deep space burn was finally executed on January 3, 1999, but this maneuver put NEAR on a trajectory that does not arrive at Eros until February 2000. Thus, the arrival conditions and orbital geometry are quite different from the previous orbit phase trajectory design [2]. As a result of these unforeseen events, the orbit phase trajectory design must now be revised to minimize fuel consumption and also to accommodate the different geometric conditions that the NEAR spacecraft will encounter at Eros in 2000. This paper discusses the revised orbit phase design process and results.

Before defining a targeting strategy, it is necessary to define spacecraft and mission constraints that the spacecraft trajectory must satisfy. These constraints are then transformed to trajectory design parameters and quantified. The final step in the design process is to target a trajectory that satisfies the numerical values assigned to these target parameters.

The spacecraft constraints that apply to the Eros orbit phase design include limiting fuel consumption and maintaining solar panel illumination. Other constraints relate to the flexibility and speed that mission operations can be performed and achieving the science requirements.

Probably the most important spacecraft constraint is to fly the prime mission within the remaining propellant budget. This is an even greater priority due to the unplanned events that occurred in December.

The most challenging constraint to satisfy concerns solar panel illumination. To satisfy spacecraft power requirements, the solar panels cannot be turned more than about 30 degrees off the sun line [3]. Since the science instruments are fixed with respect to the spacecraft body, it is necessary to turn the spacecraft to point these instruments at Eros. If the angle between the line to nadir and the plane perpendicular to the sun line is greater than 30 degrees, the nadir point cannot be imaged without violating the solar panel illumination constraint.

Another important constraint relates to the time to conduct mission operations. In order to conduct the mission smoothly without resorting to around-the-clock operations, the minimum time between spacecraft propulsive maneuvers is limited to one week. The major problem is turning around accurate orbit determination solutions in time to perform the propulsive maneuvers that are required to keep the spacecraft on course. The velocity change resulting from maneuver execution errors corrupts the orbit solution. A rapid redetermination of the orbit places a large amount of pressure on the Mission Operations team to deliver accurate solutions for the spacecraft orbit. As a result, a goal of allowing a minimum of one week between maneuvers was introduced in an attempt to minimize this pressure. This provides an increase in both data quantity and quality for the orbit solution.

Science constraints on the trajectory design result from the desire to obtain a particular orbital geometry and are generally not easily quantified. The requirement of the gamma ray spectrometer to obtain low orbits drives the trajectory design through a series of orbits which decrease in radius, and hopefully satisfy all the science requirements on orbit geometry. The general plan is to spend a specified amount of time in a series of circular orbits of predetermined radius before transferring to a lower radius. This satisfies imaging and navigation requirements, keeps the mission on schedule, and requires that only a single general imaging or mapping plan need be developed for any Eros gravity field that may be encountered.

The targeting strategy is simply an algorithm for translating the above spacecraft, mission, and science constraints into a trajectory that can be navigated. The general approach is to develop a broad set of objectives and compute a series of propulsive maneuvers that will steer the spacecraft in a manner that satisfies these objectives. This differs substantially from the traditional approach of defining a number of constraints and searching for the trajectory that globally minimizes some performance criteria. The NEAR approach is to compute a maneuver that satisfies a local set of constraints and performance criteria and then propagate the trajectory to see where it goes. At the appropriate time, at a minimum of one week in the future, the constraints are reevaluated and another maneuver is targeted. This step-by-step manner continues until all of the science objectives are achieved.

The application of the NEAR orbit phase trajectory design to the current best estimate of the Eros physical parameters is described in this paper. The resulting orbit is the prototype for the actual trajectory design to be carried out upon arrival at Eros in February of 2000. The trajectory is described and illustrated, and some of the problems encountered in the design and their resolution are discussed.

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Corresponding Author:

Cliff Helfrich
Jet Propulsion Laboratory
4800 Oak Grove Dr., MS 301-150
Pasadena, CA 91109
Tel: (818)354-1446 Fax: (818)393-6388
email: cliff@mojohand.jpl.nasa.gov