INTEGRATION OF MISSION DESIGN AND NAVIGATION FOR A EUROPA GEODESY ORBITER

Dylan Boone[(1)] **and Daniel J. Scheeres**[(2)]
[(1)] *University of Colorado at Boulder, 429 UCB Boulder CO 80309, 303-492-6417, dylan.boone@colorado.edu*
[(2)] *University of Colorado at Boulder, 429 UCB Boulder CO 80309, 303-492-6417, scheeres@colorado.edu*

Keywords: *Europa, phase space, covariance analysis , periodic orbit, orbit determination*

ABSTRACT

Orbits about planetary satellites are known to be unstable due to the perturbing gravity of the third body [3]. This effect is dependent on the inclination of the orbit and the strength of the third body's gravity. The goal of the Jupiter Europa Orbiter mission is to measure the Love numbers, geophysical coefficients which give insight into whether there is liquid water on the body. Missions like JEO require near-polar, mapping type orbits which are greatly affected by this gravitational instability. General low altitude, high inclination orbits impact on the surface of the planetary satellite after a time span on the order of weeks. Periodic orbits computed in the Restricted Three Body Problem have the potential to extend this lifetime to the order of months [1].

In this work, we investigate the properties of phase space in the vicinity of a periodic orbit and examine the effect of these properties on orbit lifetime and the measurement update for orbit determination. Low altitude, near-polar periodic orbits are found in the three-body system at Europa and an initial covariance matrix is created by processing range-rate and altimetry measurement types over 7 days. This processed covariance is used to draw randomly dispersed initial conditions around the periodic orbit from a multivariate normal distribution in a Monte Carlo analysis. This Monte Carlo simulation shows that there is a preferred nonzero eccentricity for these orbits which can extend the nominal orbit lifetime to around 200 days without control maneuvers.

We employ the concept of dynamic coordinates to understand what component of the orbit initial conditions are along the stable, unstable, and center manifolds associated with the periodic orbit, respectively [2]. We show that the randomly drawn orbits in the vicinity of the periodic orbit exhibit longer lifetimes than the computed periodic orbit. This is shown to be an effect of the stable and center manifolds of the periodic orbit. The figures below show the dynamic coordinate decomposition of the orbit initial conditions dispersed via the computed covariance matrix in a 10000 iteration Monte Carlo run. The eigenvectors of the State Transition Matrix evaluated at the system period time correspond to six-dimensional directions associated with the linear manifolds of the periodic orbit. The coordinate system representation is chosen so that the x-axis bisects the acute angle of intersection of the left stable and unstable manifolds. The coordinates of each orbit are color coded by lifetime; blue for greater than 50 days, cyan for greater than 70 days, magenta for greater than 100 days, and yellow for greater than 150 days. Due to the properties of left and right eigenvectors which represent the manifold directions, we can infer that the yellow line traced by the longest lifetime orbits follows the right stable manifold. An orbit which is exactly periodic would pick up some component along the unstable manifold upon dispersion and depart from the

fixed point [4]. However, certain orbits with small but nonzero components along the unstable manifold may follow the stable manifold in toward the periodic orbit and then depart along the unstable manifold, potentially doubling the lifetime of the orbit.

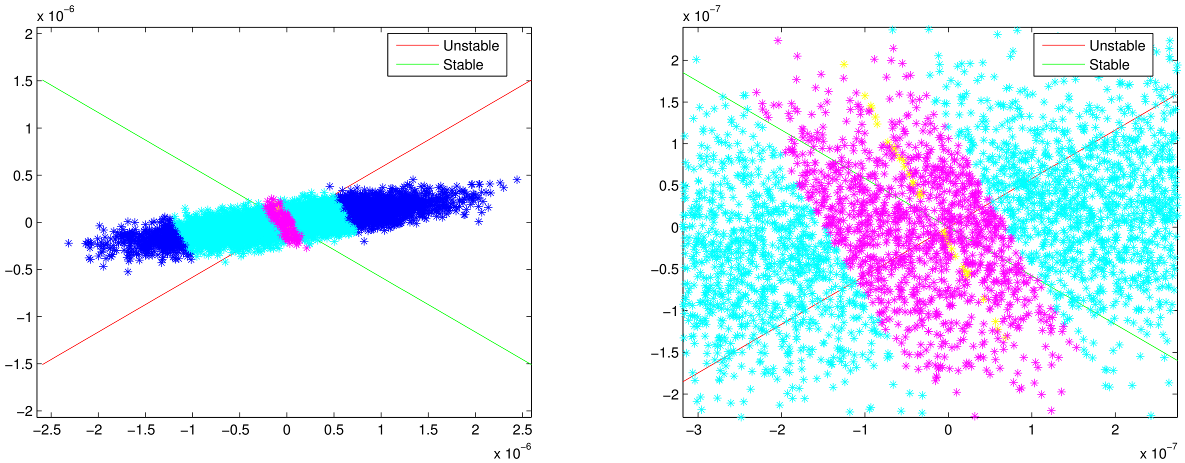

Figure 1. Dispersed orbit dynamic coordinate projection distribution (left) and zoom (right)

The extended orbit lifetime generated by the covariance matrix is an unforeseen benefit of conducting geodesy science in an unstable orbit environment. With this knowledge of manifold properties, we discuss a method to choose a long lifetime orbit. These same manifolds are shown to affect the processing of information in the orbit determination process. The State Transition Matrix can be decomposed into matrices containing it's left and right eigenvectors and eigenvalues. We show how the information content of measurements along the stable and unstable manifolds is increased or decreased when mapped in time due to the local characteristics of phase space. This work integrates the orbit design and orbit determination processes for a more complete characterization of the orbit environment and mission design. While these results are computed for the Jupiter-Europa system, any three-body system will exhibit these characteristics to some degree since the mathematical formulation of the problem is the same.

1. References

[1] Boone and Scheeres. "Evaluation of Periodic Orbits for the JEO Mission at Europa in Terms of Lifetime and Stability." AAS Astrodynamics Specialist Conference. Girdwood, AK, August 2011.

[2] Gustafson and Scheeres. "Dynamically Relevant Local Coordinates for Halo Orbits." AAS Astrodynamics Specialist Conference. Hawaii, August 2008.

[3] Scheeres et al. "Stability Analysis of Planetary Satellite Orbiters: Application to the Europa Orbiter. JGCD 24(4): 778-787, 2001.

[4] Scheeres, Han, and Hou. "Influence of Unstable Manifolds on Orbit Uncertainty." JGCD 24(3): 573-585, 2001.