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Integration of Geodesy Mission Design and Navigation for Planetary Satellite Orbiters

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Planetary satellites have become the primary targets of proposed missions to the outer planets as the places in the Solar System most likely to harbor extraterrestrial life. Observations from the Galileo spacecraft suggest Europa has a subsurface salt-bearing ocean and water plumes have been observed at Enceladus's south pole. However, orbits about planetary satellites are known to be unstable due to the perturbing gravity of the primary body. This work investigates the properties of phase space in the vicinity of a periodic orbit and examines the effect of these properties on the orbit evolution and lifetime. Low altitude, near-polar periodic orbits are found in the Circular Restricted Three Body Problem and a covariance matrix is generated for each nominal periodic orbit by processing range-rate and altimetry measurement types in a Square-root Information Filter. Computed Love number estimation uncertainties yield similar or better performance than previous studies. 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. These simulation results show a bias toward longer lifetime orbits that is associated with the linear manifolds of an unstable periodic orbit. Lifetimes for both Europa and Enceladus orbiters are increased by an order of magnitude over the nominal lifetime and long lifetime orbits are not isolated in phase space. A mathematical development of information accumulation in the orbit determination process is given for the Europa L_2 equilibrium point using the eigenstructure decomposition of the State Transition Matrix. The covariance matrix for an equilibrium point orbit is shown to collapse along the left unstable manifold for epoch state estimation and collapse along the left stable manifold for current state estimation.