

# Designing Trajectories in a Planet-Moon Environment using the Controlled Keplerian Map

Piyush Grover and Shane Ross

Department of Engineering Science and Mechanics

Virginia Tech, Blacksburg, VA-24060

Designing fuel efficient trajectories which visit different moons is best handled by breaking up the problem into multiple three-body problems. This approach, called the patched three-body approach has received considerable attention in recent years, and has proved to lead to substantial fuel savings compared to the traditional patched-conic approach. We consider the problem of designing fuel-efficient multi-moon orbiter spacecraft trajectories in the Jupiter-Europa-Ganymede-spacecraft system with realistic transfer times. Fuel-optimal (i.e. near zero fuel) trajectories without using any control are first determined but turn out to be infeasible due to very long transfer times involved. We then describe a methodology which exploits the underlying structure of the dynamics of the two three-body problems, i.e. Jupiter-Europa-Spacecraft and Jupiter-Ganymede-Spacecraft, using the Hamiltonian structure-preserving Keplerian map approximations derived earlier and using small control inputs in the form of instantaneous  $\Delta V$ s to get trajectories with realistic time-of-flight. A typical trajectory constructed using the control algorithm can complete the mission in a small fraction of the time-of-flight of an uncontrolled trajectory.