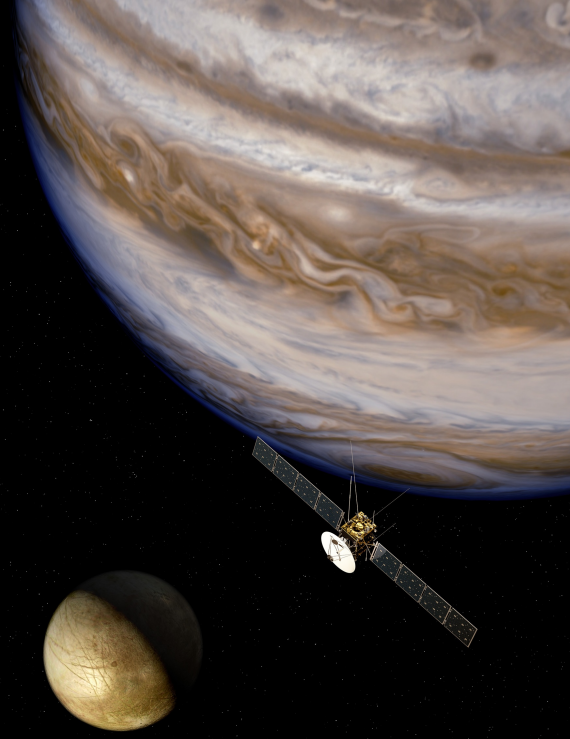
Heuristic Search for Transfer Design



Background:

- Multibody systems are highly nonlinear and chaotic due to balance of forces from planets and moons.

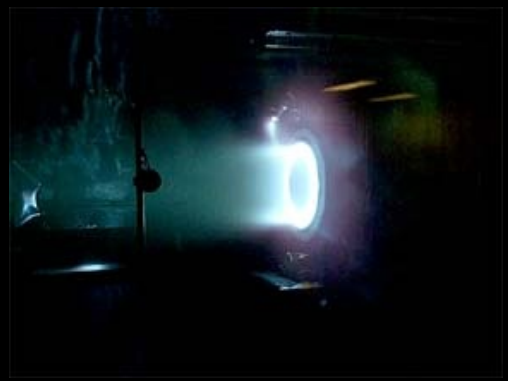
- For "low energy" missions to orbit moons and small bodies, traditional methods are unable to provide reliable initial guesses to optimizers.

Central Concept: *Approximate system with directed graph. Use to create a transfer skeleton.*

- Partition domain into small regions. 1 region = 1 node

- Ballistic dynamics: Add directed edge from node X to node Y if region X flows into node Y. Weight = nominal control cost

- Impulsive maneuvers: Add directed edge between nodes with *same position* but with different energy levels or headings. Weight is minimum fuel cost between these pairs.



Using A* Search in Itinerary Selection

Need for Heuristics:

- For minimum fuel problem, cost of large impulse 〉〉 nominal coasting cost.

- Most important scenario: Orbit insertion from approach or higher orbit. Requires large drop in energy.

- Result w/ uninformed search: Search explores too many coasting nodes before considering necessary impulsive maneuvers.

Simplified Energy Heuristic:

- Between any two energy levels with a given compact domain and moon radius there is a calculable most efficient maneuver cost.

〔This is a *tangential* maneuver at the highest velocity and/or lowest potential〕

- *Heuristic* ***as rule rela****xation:* it assumes this most efficient maneuver is possible everywhere in the domain.

- This makes h(n) a simple (consistent) function of energy(n′) and energy(goal).

- Heuristic steers search towards correct energy.

Applying the Search Results

Impact of the heuristic: Decrease in search times from ~2-3 minutes to ~1-10 seconds in simple test system.

Example in context: Search provides region and maneuver sequence. This allows for selection of arcs from a table which feed into a Sequential Convex Programming process to restore continuity and optimize.

〔Note: the actual partition is 4D and contains ~9,000 regions per energy〕