National Aeronautics and Space Administration

FY24 Strategic University Research Partnership (SURP)

Charting Trajectory Pathways in the Uranian and Neptunian Systems

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Objectives:

Generate and examine the trajectory trade spaces that incorporate constraints and spacecraft parameters:

2-1. Identify and apply reasonable estimates for hardware and operational constraints and spacecraft parameters.

2-2. Update primitive-based trajectory design procedure to accommodate significant constraints and spacecraft parameters.

2-3. Generate a trade space of constrained trajectories via the updated primitive-based trajectory design process.

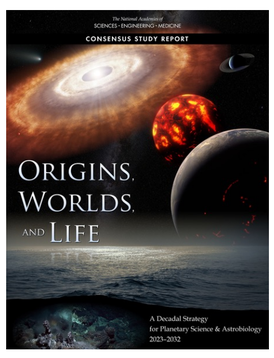
2-4. Characterize the trade space of constrained trajectories to extract meaningful heuristics and insight.

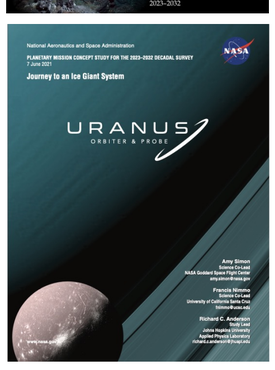
Background:

Ice giants Uranus & Neptune are targets of next high priority science missions.

Mission objectives for a flagship mission to ice giant planets:

- Perform remote and in situ measurement of a planet's atmosphere, interior, and magnetosphere
- Perform imaging of the rings and small satellites
- Flyby large satellites to study composition, gravity, surface features, and particle environment





Significance and Benefits to JPL and NASA:

Automated capability to generate trade space of pathways in a multi-body system

Benefits to trajectory design for ice giant missions:

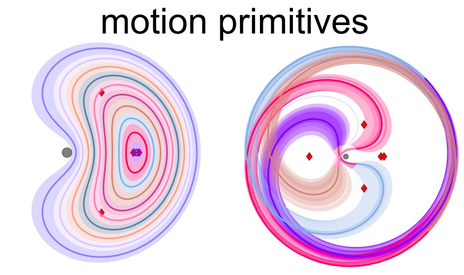
- Addition of multi-body trajectory options to patched conic solutions
- Automated solution space search incorporating science return and operational constraints
- Possible multi-spacecraft design for increased science return

Benefits to other mission concepts

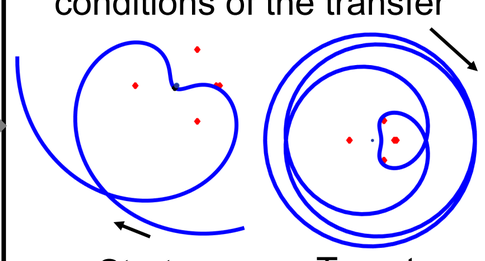
- Underlying algorithms readily adapted to other solar system destinations
- Supports concepts for planetary exploration, astrophysics, & heliophysics
- Suited for early concept formulation, enabling rapid iteration & maturation

Trajectory Design Approach:

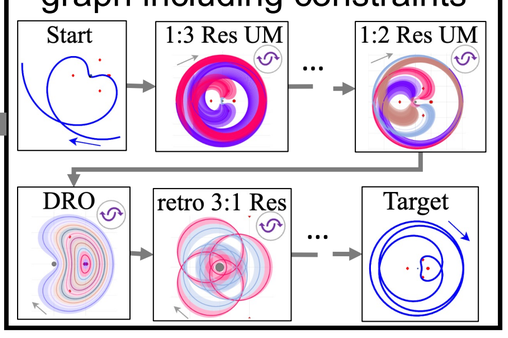
1. Use clustering to extract motion primitives



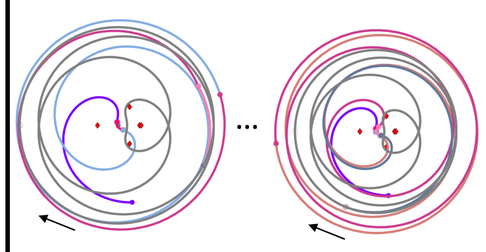
2. Select initial and final conditions of the transfer



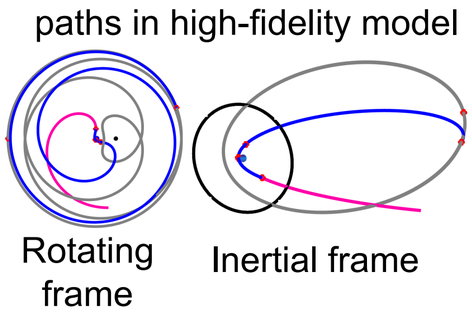
3. Construct motion primitive graph including constraints



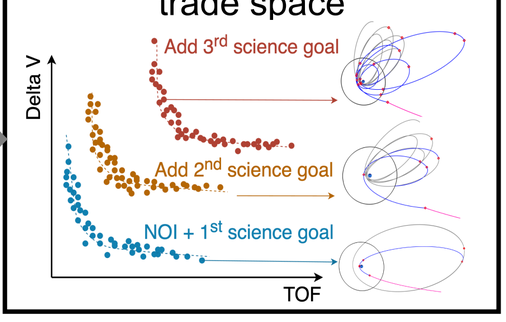
4. Search graph for initial guesses of distinct geometry



5. Generate constrained paths in high-fidelity model



6. Rapidly explore trajectory trade space

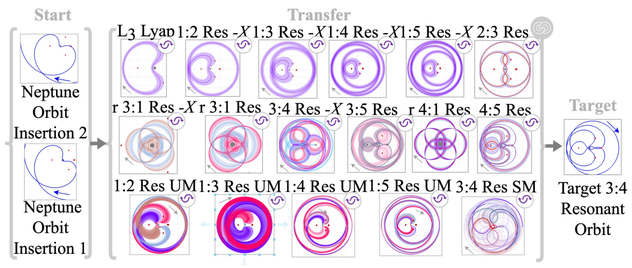


Transfers in the Neptunian System:

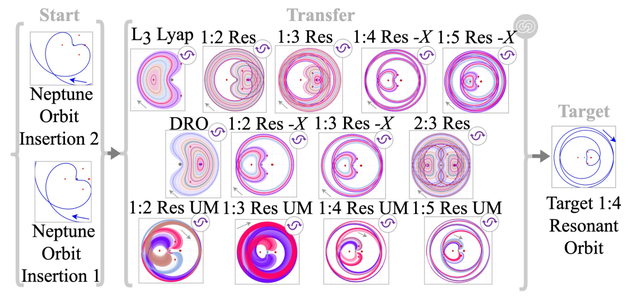
Initial conditions: (1) NOI with $v_\infty = 11.52$ km/s ; (2) NOI with $v_\infty = 8.83$ km/s

Target: 3:4 planar resonant orbit | 1:4 planar resonant orbit

Motion primitive graph with constraints

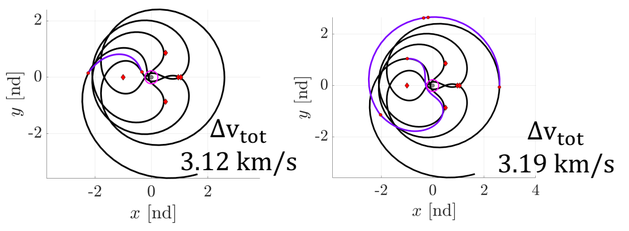


Constraint with margin: minimum distance from Neptune of 30,000 km

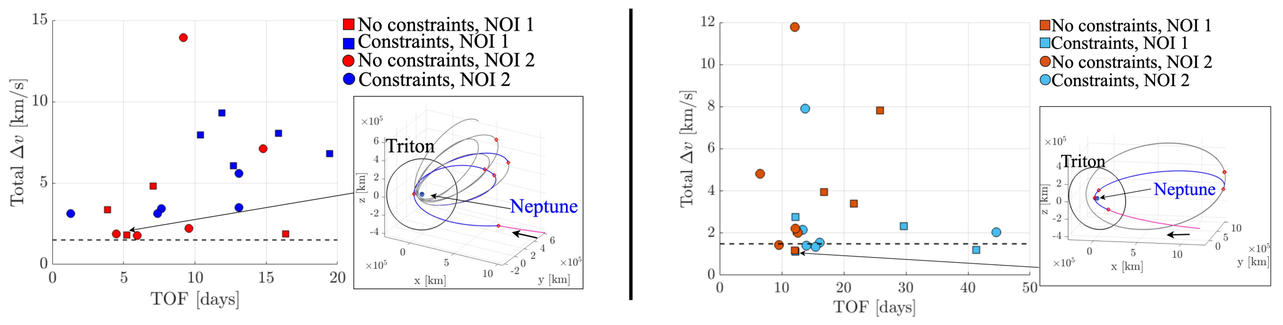


Constraint with margin: maximum single $\Delta v < 2$ km/s

Selected optimal transfers



Trajectory trade spaces



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Publications:

[1] Giuliana Miceli, Natasha Bosanac, Reza Karimi, "Generating the Trajectory Design Space for Neptunian System Exploration", *2024 AAS/AIAA Astrodynamics Specialist Conference*, Broomfield, CO, August 2024.

[2] Giuliana Miceli, Natasha Bosanac, Jeffrey Stuart, Farah Alibay, "Motion Primitive Approach to Spacecraft Trajectory Design in the Neptune-Triton System", *AIAA SciTech Forum and AAS/AIAA Space Flight Mechanics Meeting*, Orlando, FL, January 2024.

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