National Aeronautics and Space Administration

FY23 Strategic University Research Partnership (SURP)

Charting Trajectory Pathways in the Uranian and Neptunian Systems

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Objectives:

Design and characterize maneuver-enabled trajectories for primary spacecraft from interplanetary arrival conditions to visit various regions in the Neptunian and Uranian systems

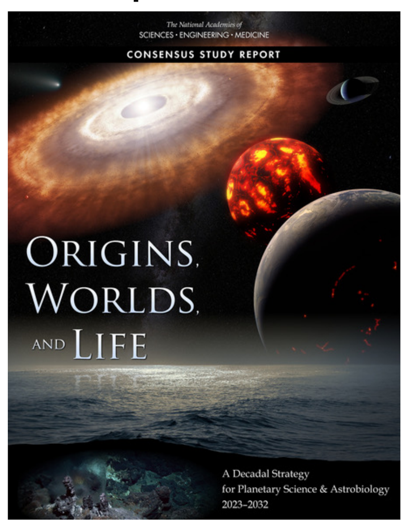
1-1. Define arrival conditions from interplanetary transfers and preliminary regions of scientific interest in each system
1-2. Analyze solution space in representative multi-body models of Neptunian and Uranian systems
1-3. Construct point solutions for the trajectory of a primary spacecraft in Neptunian and Uranian systems

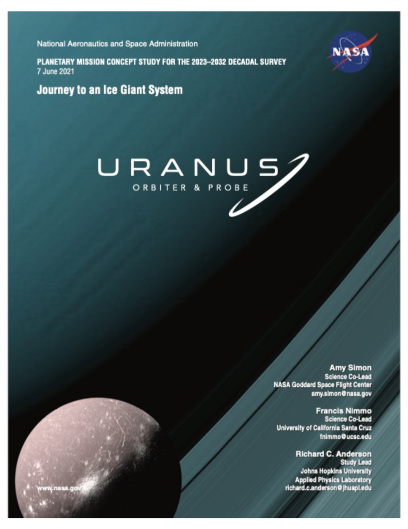
Background:

Ice giants Uranus & Neptune have not been visited since Voyager 2 "grand tour" flybys in 1986 & 1989

Mission objectives for a flagship mission to Ice Giants:

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





Significance/Benefits to JPL and NASA:

Automated, multi-body search capability to generate pathways for both primary and secondary spacecraft

Benefits to primary spacecraft (i.e., "flagship")

- Addition of multi-body trajectory options to traditional patched conic solutions
- Automated searches to explore trajectory design space while incorporating science return and operational constraints

Benefits of adding secondary spacecraft (i.e., "scouts")

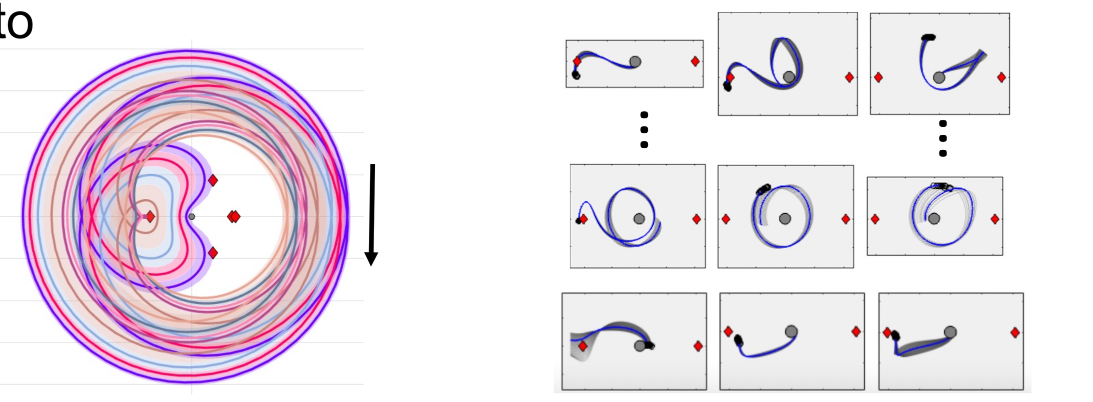
- Science multiplier: more observations, increased spatial & temporal coverage
- Design approach addresses limited capabilities of secondary platforms while still returning high-quality mission designs

Benefits to other mission concepts

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

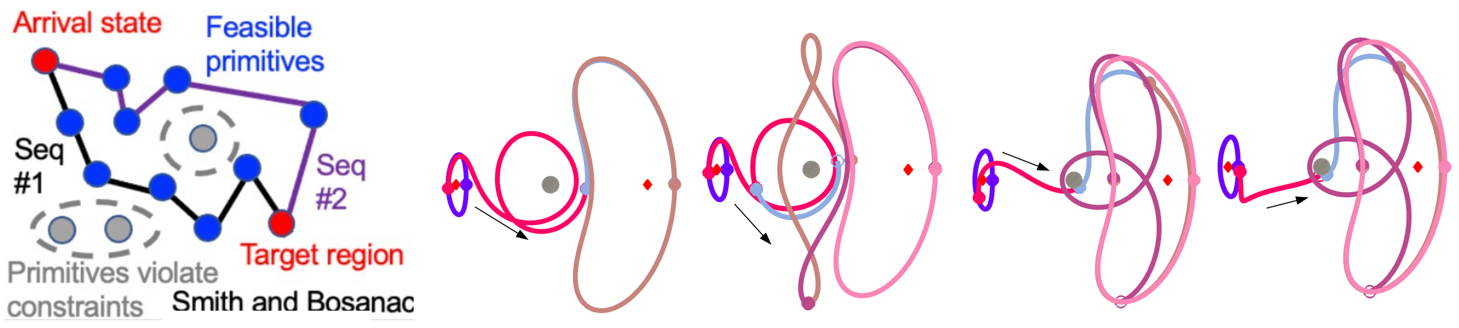
Trajectory Design Approach:

Use clustering to extract motion primitives summarizing fundamental solutions in approximate model

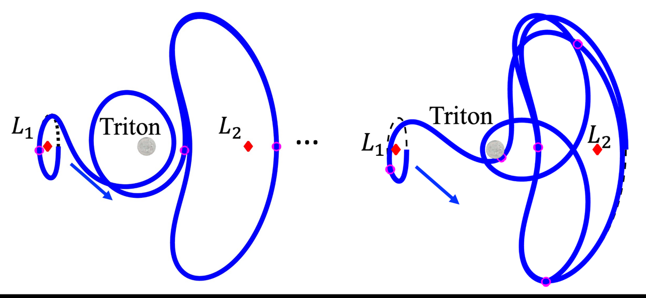


1:2 resonant orbits L_1 Lyapunov unstable manifold

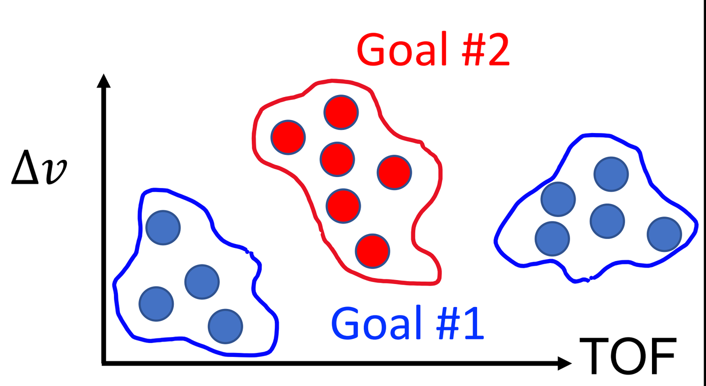
Construct motion primitive graph and search to produce motion primitive sequences forming initial guesses of distinct geometry



Correct initial guesses to recover paths with maneuvers

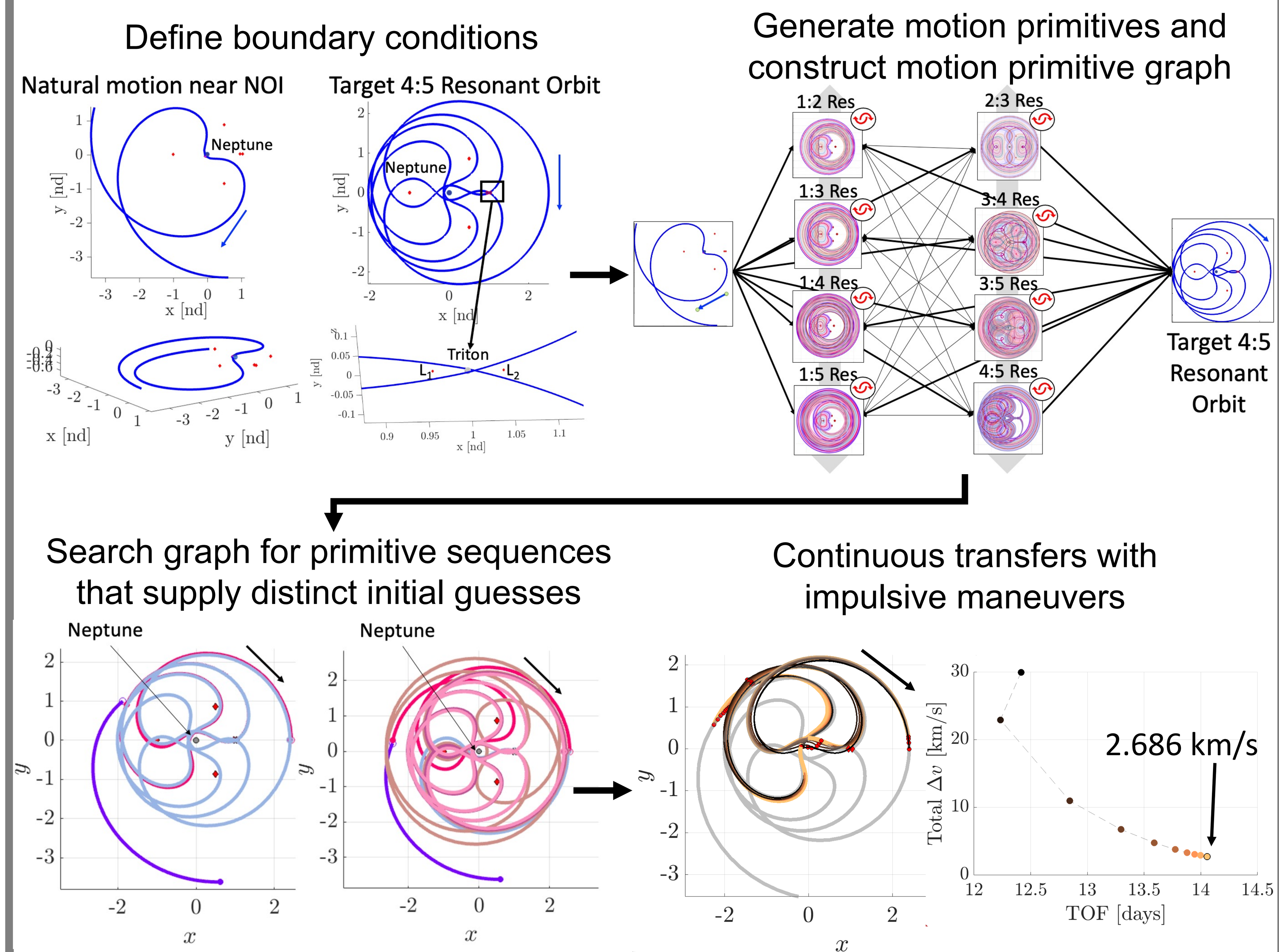


Explore trajectory trade space



Results:

Transfer scenario: NOI to 4:5 resonant orbit in Neptune-Triton system



Note: The total Δv depends on the initial guess geometry and other solutions might yield viable options; the transfer design space exploration is an avenue of ongoing work.

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Publications:

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

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