National Aeronautics and Space Administration

# Learning-Based Autonomous Guidance and Control for Fast Flyby to Interstellar Objects

**Principal Investigator: Benjamin Donitz (312); Co-Investigators: Hiroyasu Tsukamoto (Caltech), Declan Mages (392), Peter Dixon (348), Swati Mohan (343), Mitch Ingham (310), Damon Landau (312), Soon-Jo Chung (Caltech), Julie Castillo (322)**

Program: FY22 R&TD Topics

Strategic Focus Area: Networked Distributed Systems

**Objectives:**

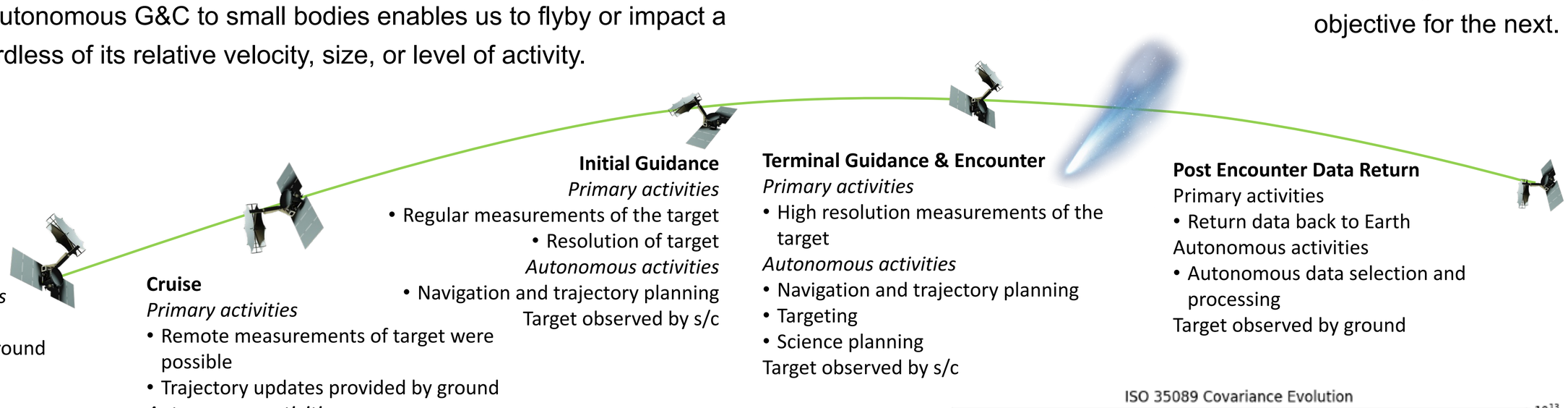
The objective of the fast-flyby R&TD was to develop and test learning-based algorithms to increase our ability to successfully perform a fast flyby to an interstellar object by developing learning-based guidance and control algorithms optimized for fast flybys to small bodies. This body of work represents an initial exploration and assessment of learning-based G&C algorithms for use in a fast flyby to a small body like an ISO.

**Significance/Benefits to JPL and NASA:**

This work brings JPL and NASA one step closer to enabling a dedicated mission to visit an interstellar object. This work is also related to other fast flybys of small bodies, including Kuiper Belt Objects, Long Period Comets, and Near Earth Objects. Autonomous G&C to small bodies enables us to flyby or impact a small body regardless of its relative velocity, size, or level of activity.

**Background:**

ISOs are a fascinating, yet underexplored class of small bodies. The Planetary Science and Astrobiology Decadal Survey marked the discovery of ISOs as some of the most impactful of the last decade and determined in-situ exploration of an ISO to be a strategic research objective for the next.



**Launch and Initial Acquisition**
*Primary activities*
- Launch
- Initial checkouts

*Autonomous activities*
- None

Target observed by ground

**Cruise**
*Primary activities*
- Remote measurements of target were possible
- Trajectory updates provided by ground

*Autonomous activities*
- None

Target observed by ground

**Initial Guidance**
*Primary activities*
- Regular measurements of the target
- Resolution of target

*Autonomous activities*
- Navigation and trajectory planning

Target observed by s/c

**Terminal Guidance & Encounter**
*Primary activities*
- High resolution measurements of the target

*Autonomous activities*
- Navigation and trajectory planning
- Targeting
- Science planning

Target observed by s/c

**Post Encounter Data Return**
Primary activities
- Return data back to Earth

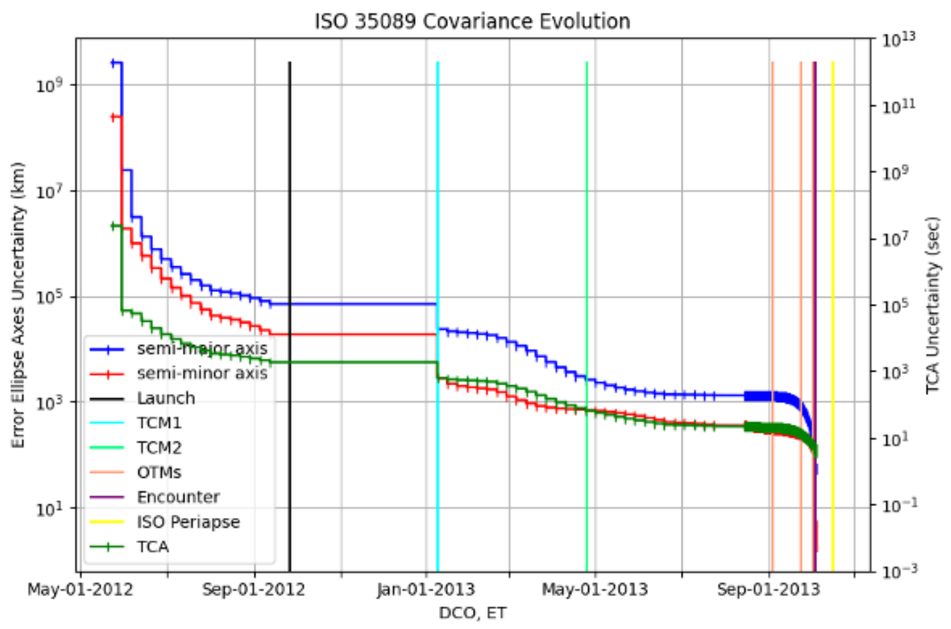
Autonomous activities
- Autonomous data selection and processing

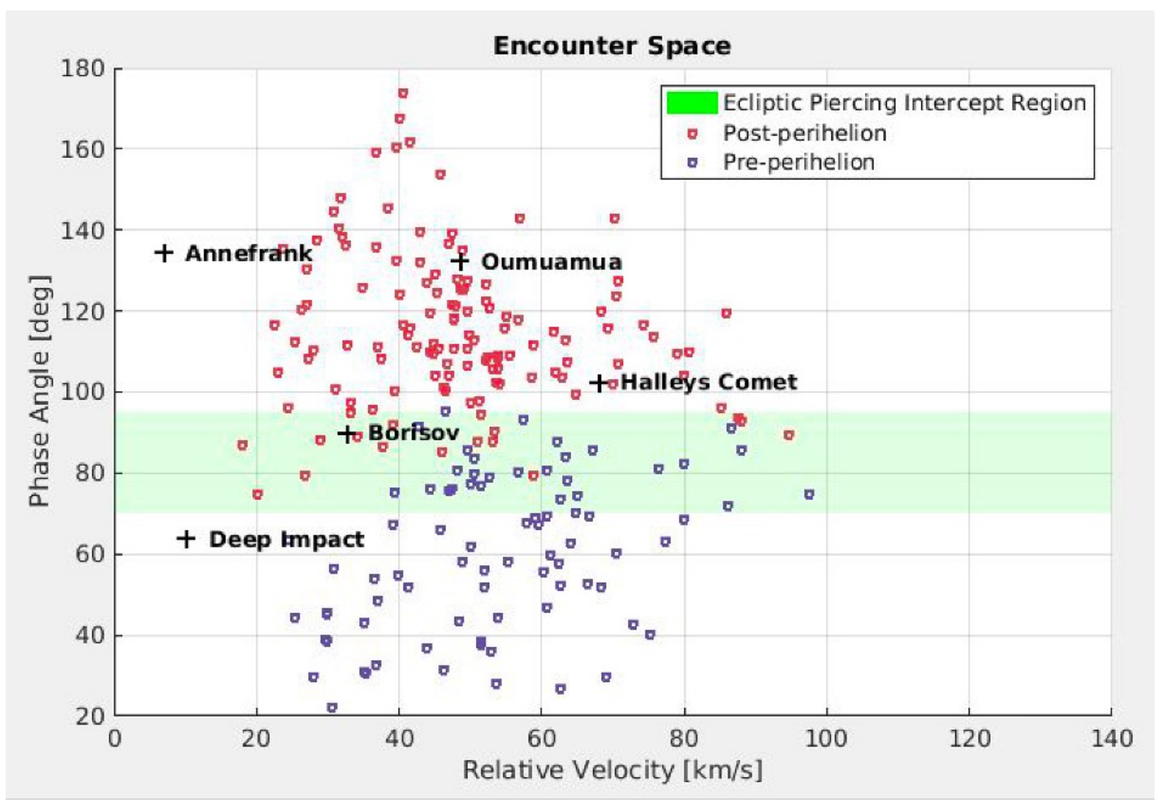
Target observed by ground

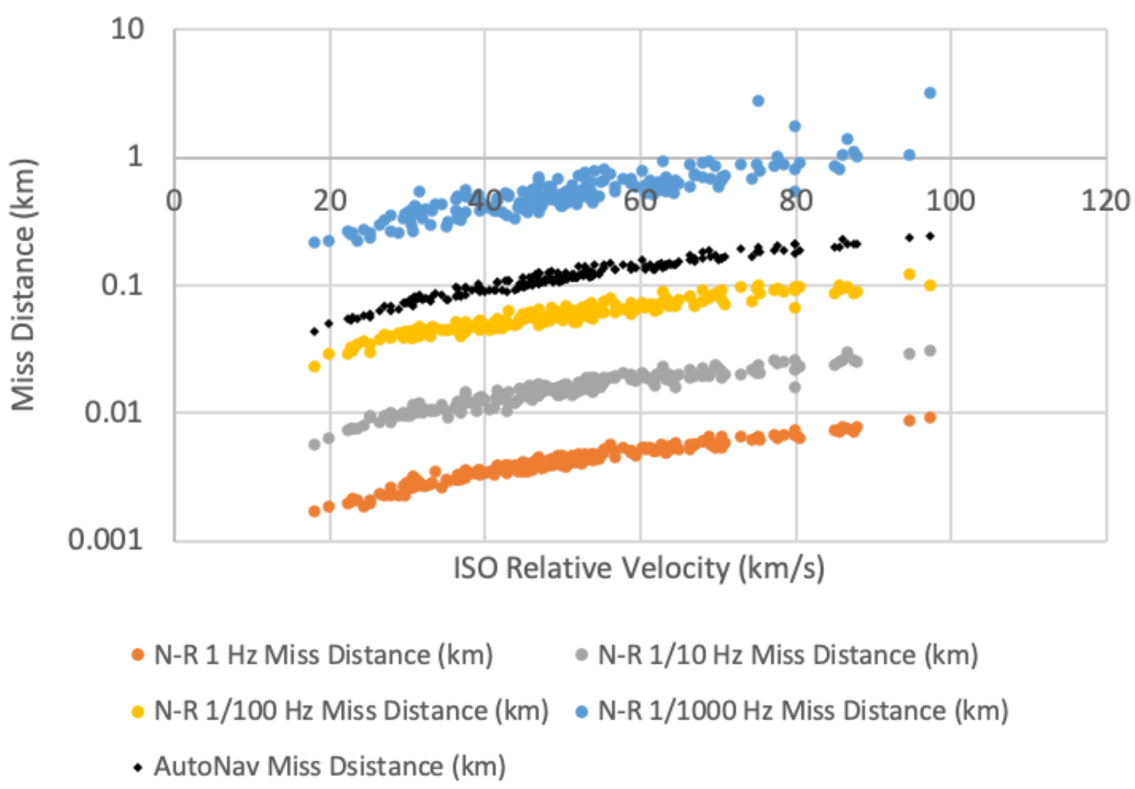
Transition from cruse to initial guidance is when spacecraft opnav error is < error from ground

**Approach and Results:**

Researchers at JPL generate trajectories to feasible synthetic interstellar objects based on a population of anticipated observable targets, and performed simulated ground observation campaigns to determine the evolution of the ISO's state knowledge overtime. Meanwhile, researchers at Caltech developed the Neural-Rendezvous (N-R) G&C algorithms which is specifically optimized for highly reliable fast flybys of small bodies. We test the novel G&C approach on each of the trajectories generated and compare the performance and resource (i.e. delta-V) consumption against the state of practice AutoNav.




**National Aeronautics and Space Administration**

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

**www.nasa.gov**

Clearance Number: CL#
Poster Number: RPC#R21131


**Selected Publications:**

Declan Mages, "Navigation evaluation for fast interstellar object flybys," published in *Acta Astronautica, Volume 191, Pages 359-373*, 2022. https://www.sciencedirect.com/science/article/pii/S0094576521006081

Hiroyasu Tsukamoto, "Neural-Rendezvous: Learning-based Robust Guidance and Control to Encounter Interstellar Objects," submitted to *AIAA Journal of Guidance, Control, and Dynamics* (under review). https://arxiv.org/pdf/2208.04883.pdf

**PI/Task Mgr. Contact Information:**

Email: Benjamin.P.Donitz@jpl.nasa.gov