Planetary Mission Concept Study:
Pluto Orbiter and Kuiper Belt Exploration Mission

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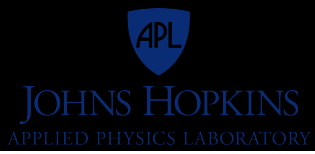


Mission Overview

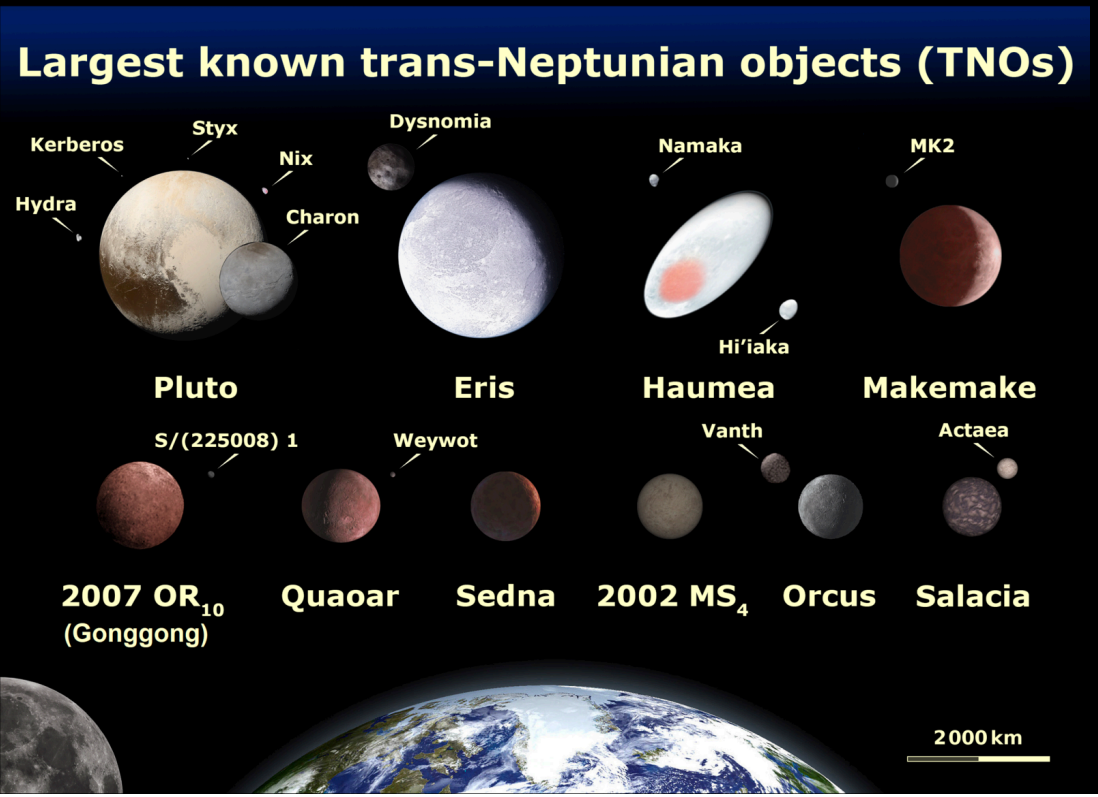
- Mission Level: Flagship
- Payload: Based on *New Horizons*, with additional instruments or some modifications based on current flight hardware.
- Trajectory: "Direct" to Pluto *system*, orbit barycenter (tour similar to *Cassini*), depart to other KBOs.
  - Direct to Pluto with Jupiter flyby.
  - Orbit through the Pluto-Charon system for ≈2 Earth years.
  - Primarily uses Charon as trajectory maneuvers (*very* similar to *Cassini* at Saturn).
  - Use Charon + burn to break orbit.
  - Trajectory to several different KBOs.
  - Possibility of orbiting another Dwarf Planet.
- Mission Timeline: Decades

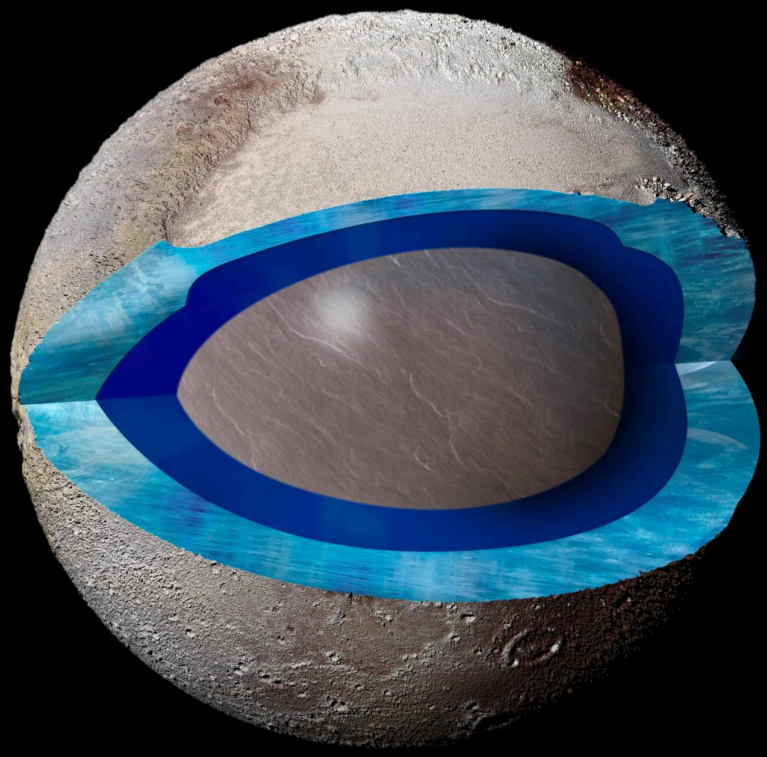
Motivation

- We learned a lot from *New Horizons* but key questions remain.
- *Numerous* community documents recommend this or something similar:
  - CAPS (2017): "a Pluto system orbiter and Centaur and/or Kuiper belt object flybys"
  - Mid-term Decadal Review (2018): Kuiper belt mission is important, specifically visiting a large and small KBO
  - Roadmap to Ocean Worlds (2019): "mission studies should be performed to address technology advances enhancing exploration of the Kuiper belt or a return to Pluto with an orbiter"

Primary Science Questions

- Is Pluto an ocean world?
- What is the history of the Pluto system?
- What is the diversity of the Kuiper Belt?





Sub-Questions, 1

"*Is Pluto an Ocean World?*"

- What is the evidence for a subsurface ocean on Pluto?
- Are Pluto (and Charon) fully differentiated?
- What is Pluto's internal heat budget?
- What is the extent and style of current, internally-derived surface activity (including the more coarsely imaged hemisphere and winter areas)?

The science team is revising these, given the benefit of 7 months' hindsight ...
but they remain similar, mainly just reordering/grouping/prioritizing.

Sub-Questions, 2

"*What is the history of the Pluto System?*"

- What are the relative ages and geologic processes acting on different terrains?
- What is the origin and evolution of Pluto's volatiles (surface and atmospheric)?
- What constraints do the small satellites place on the evolution of the system?

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Sub-Questions, 3

"*What is the diversity of the Kuiper Belt?*"

- How do the surface properties and compositions of KBOs vary, and how do they constrain the giant planet migration models?
- What is the cratering record on visited (to-be visited) KBOs, and how does it inform the Kuiper Belt's size-frequency distribution, and how does that constrain formation and evolution models of KBOs?
- What can the binary fraction, density, and shapes of KBOs tell us about their formation and the collisional environment in the primordial Kuiper Belt?
- [What is the intrinsic magnetic field strength and overall magnetic field configuration around KBOs?]

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Nominal Trajectory

- Launch: 2027
- Cruise**: 12 years
- Arrival**: 2039
- Tour**: 2039–2041
- Leave** Pluto-Charon System: 2041
- ≥14 possible post-Pluto targets

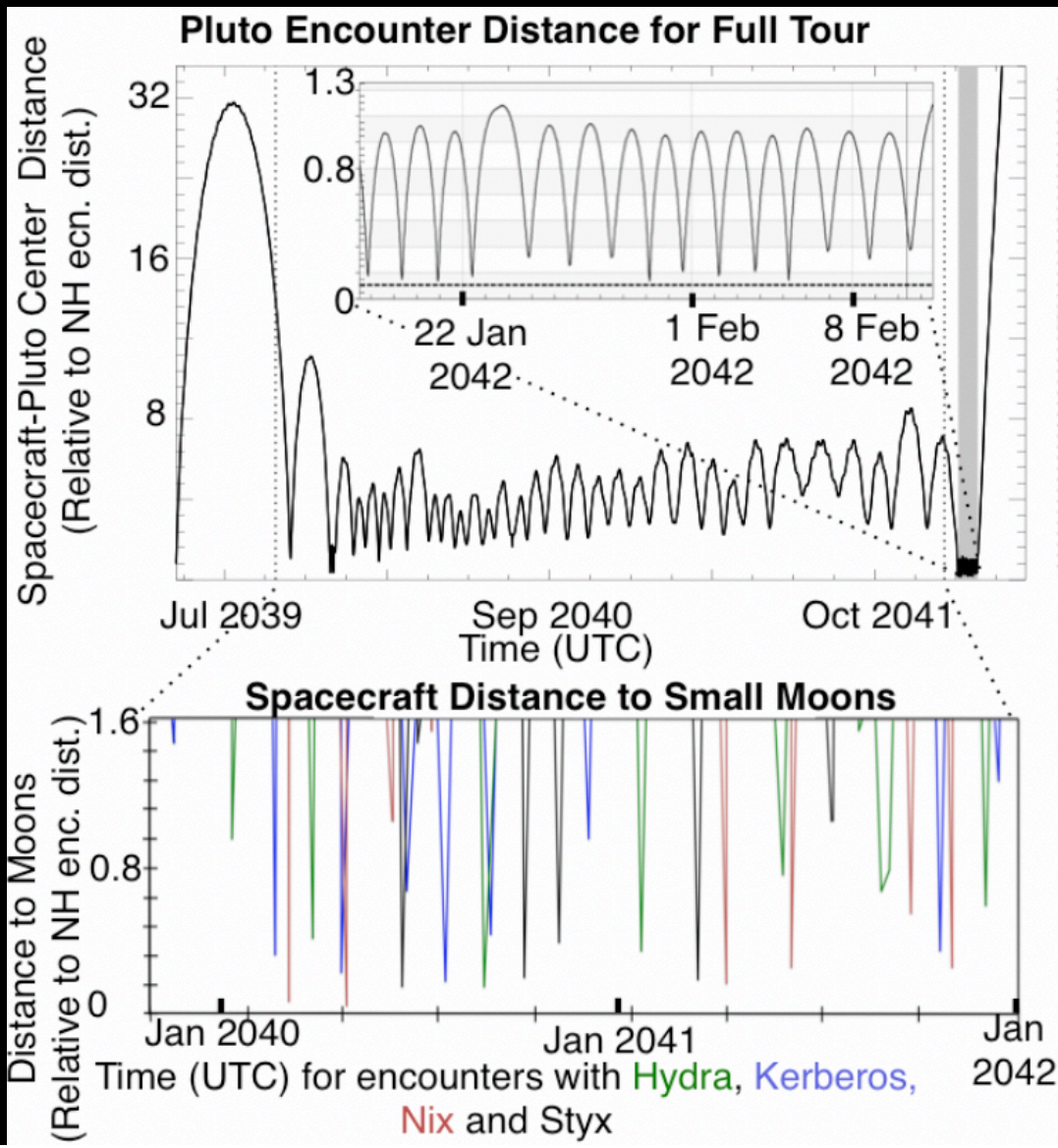
- **When proposed, this assumed we had all the propulsion we need. Accounting for existing propulsion, this proposed timeline might be greatly compressed.

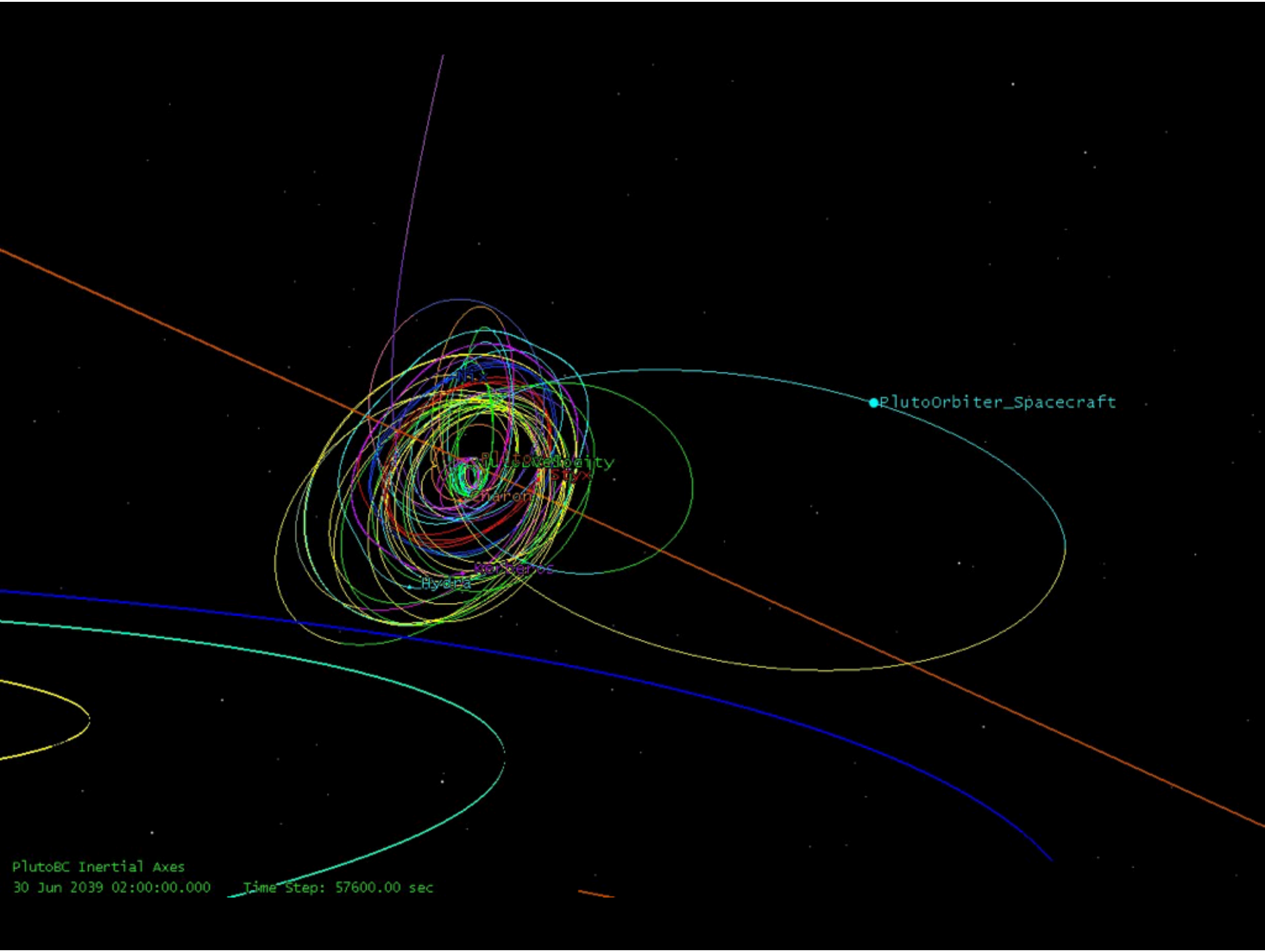
KBO	Δv (km/s)	Flyby Velocity (km/s)	Secondaries	D (km)
Ixion *	3.06	3.76	1	617
2017 OF_{69}*	4.76	4.05	2	533
Dziewanna	5.00	7.10	0	470
Quaoar	5.69	5.35	3	1110
2003 OP_{32}	6.31	6.94	1	230
2010 RF_{43}	6.47	7.95	1	636
2002 MS_4	6.57	6.08	5	934
2007 JH_{43}	7.52	7.71	1	505
2010 OO_{127}	7.54	7.94	0	501
2010 KZ_{39}	7.59	7.65	0	666
2004 PF_{115}	7.6	7.02	2	406
2007 JJ_{43}	7.66	7.00	0	610
Varda	8.30	8.37	1	717
2005 RN_{43}	8.37	7.95	0	679

** Target could be orbited, assuming maximum Δv of <10 km/s*

Nominal Pluto-Charon System Tour, part 1

- 59 Pluto encounters ≤100 Mm.
- Multiple <3 Mm small satellite encounters.
- +25 years from *New Horizons*, Pluto would have gone through northern summer solstice.




PlutoOrbiter_Spacecraft
Nix
Charon
Hydra
PlutoBC Inertial Axes
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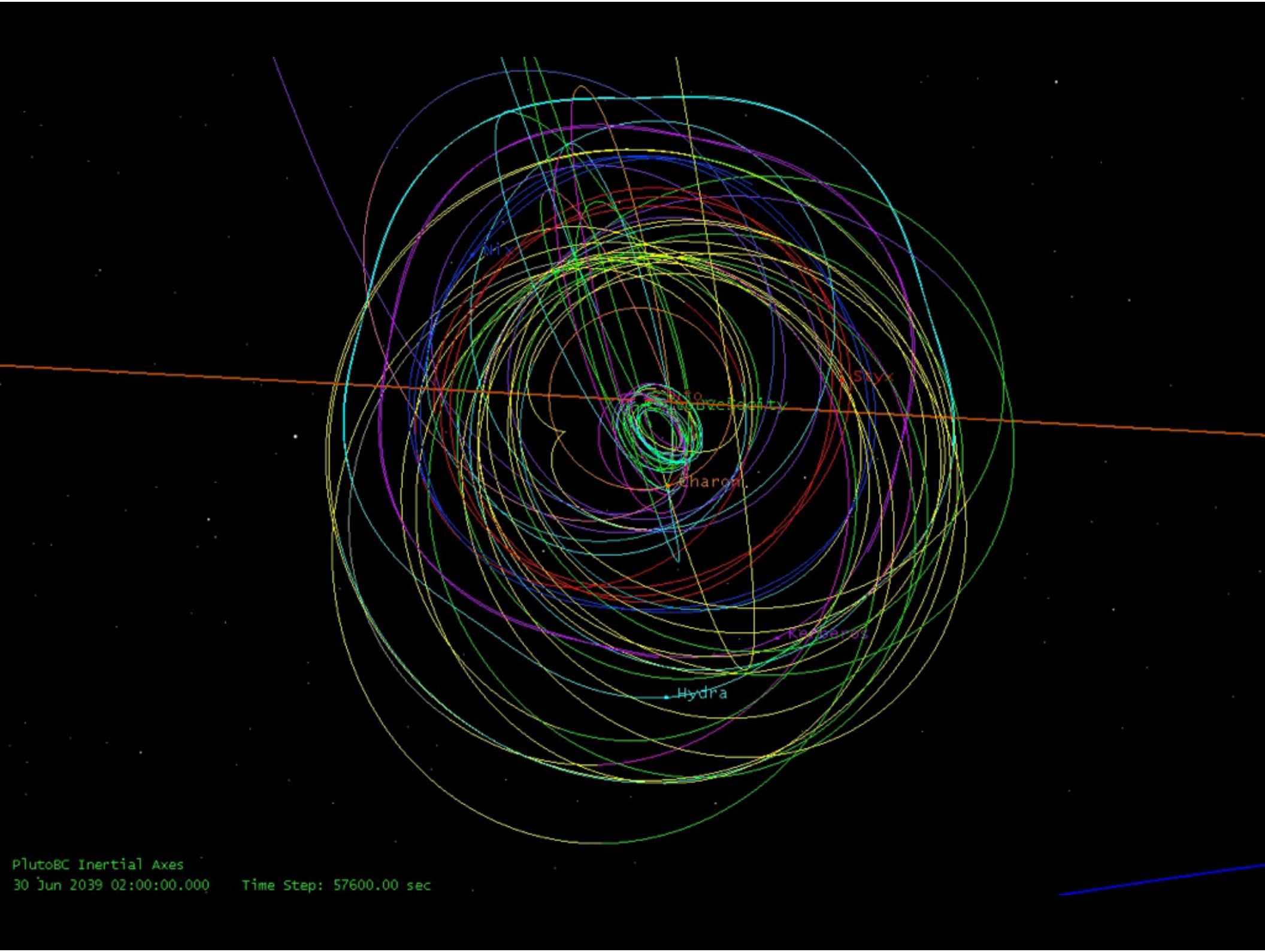
Nix
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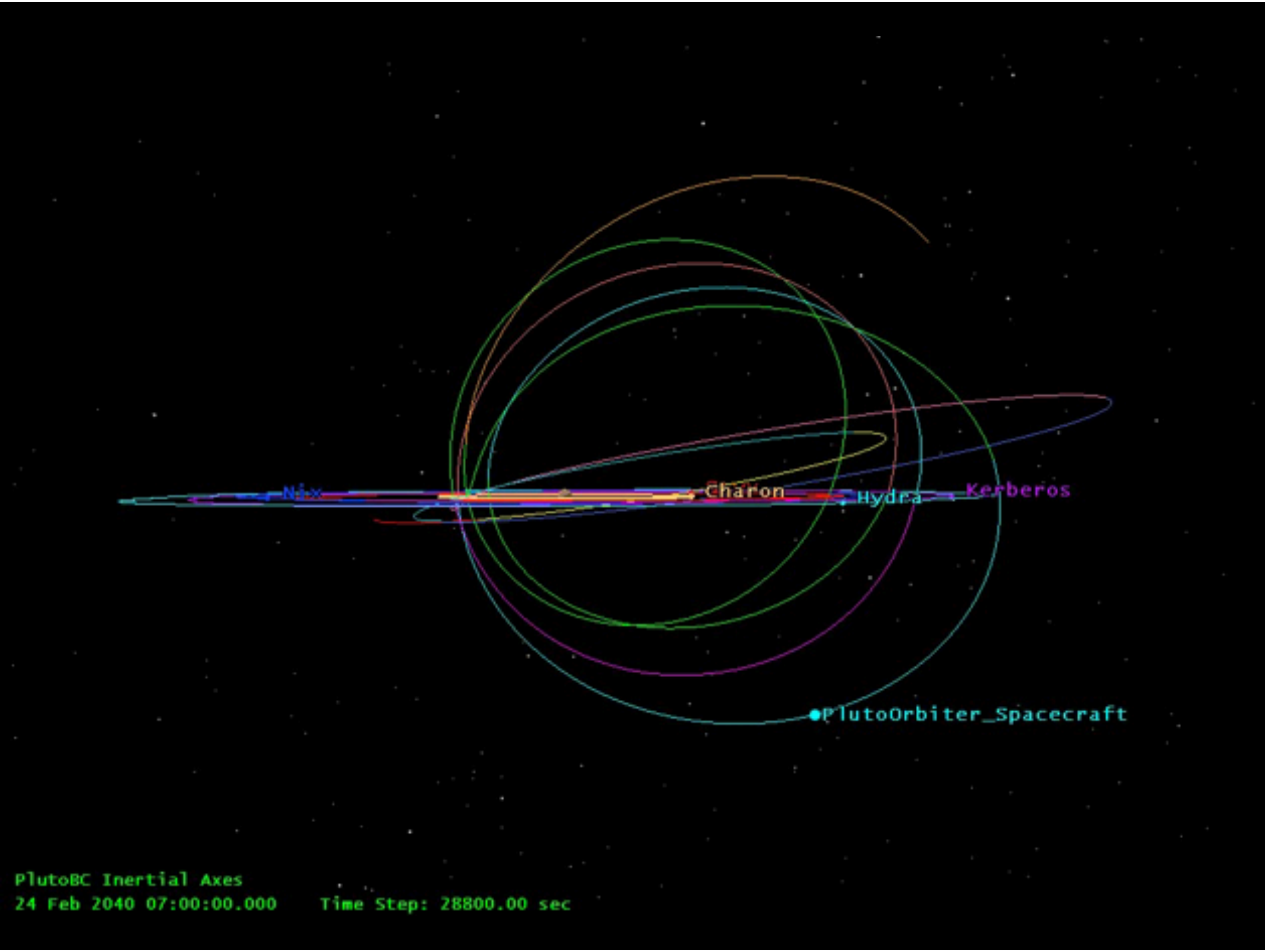
Nix
Charon
Hydra
Kerberos
PlutoOrbiter_Spacecraft
PlutoBC Inertial Axes
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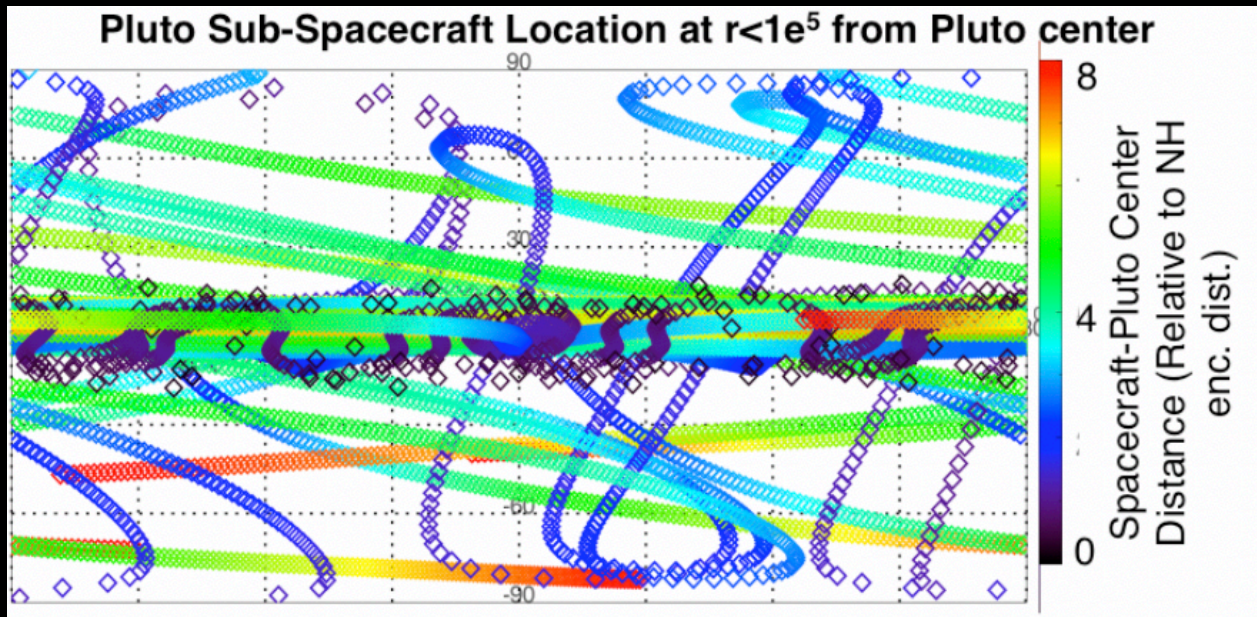
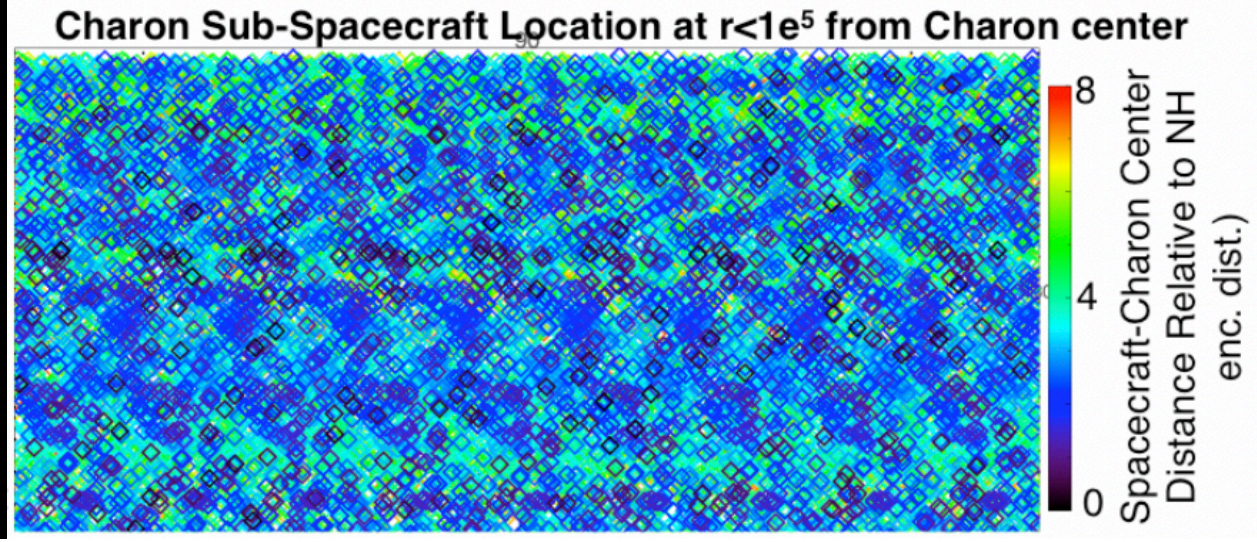
Nominal Pluto-Charon System Tour, part 2

- Primary Pluto imaging is equatorial, but with off-nadir pointing can get global coverage.



- Since Charon is used for gravity assist to change trajectory, coverage of Charon is significant.



Nominal Payload

Instrument Capability	Science Objectives Addressed	Predecessor Instrument	Instrument Heritage	Preliminary Instrument Specs
Panchromatic High-Resolution Imager	Geology, Navigation, KBO searches and distant KBO light-curves (Q1.4, 2.1, 2.3, 3.1, 3.2, 3.3, 3.4, 3.5)	LORRI	New Horizons, Lucy	λ: 0.35 to 0.85 μm IFOV: 5.0 μrad sq.
Color Imaging and Near-Infrared Spectral Coverage	Surface composition and geology, atmospheric structure (Q1.2, 2.1, 3.1, 3.2)	Ralph (MVIC and LEISA)	New Horizons, Lucy, O-Rex	**LEISA**: λ: 1.0 to 5.0 μm (extended from NH LEISA) IFOV: 40μrad sq **MVIC:** λ: Panchromatic (0.4 to 0.9 μm) and five color channels spread between these wavelengths IFOV: 29 μrad sq.
UV spectral coverage	Atmospheric physical/chemical processing, structure, and evolution (Q2.2)	Alice	New Horizons, Rosetta, JUICE	λ: 520-1870 Å FOV: 0.1° x 4° airglow slit, 2° sq. solar occultation channel
Thermal-IR coverage	Surface heat flow and activity detection (Q1.4, Q2.3)	TES	Lucy, MGS, and O-Rex	λ: 6 – 100 μm IFOV: 8 mrad diameter
Radio Science	Gravity field, thermal structure of atmosphere (Q1.1, 1.3, 1.4, 1.5, 3.1)	REX	New Horizons	Spacecraft telecom system
Ice Penetrating Radar	Characterize ice shell structure (Q1.1, 1.2, 1.4)	REASON	Europa Clipper	Dual frequency: HF (9 MHz, sounding 1 to 30 km) VHF (60 MHz, sounding 300 m to 4.5 km)
Mass Spec	Composition and distribution of Pluto's ionosphere. Atmospheric physical/ chemical processing, structure, and evolution (Q2.2)	MASPEX	Europa Clipper	>1000 amu <1 ppt resolution
Laser Altimeter	Shape determination (Q1.1, Q1.4)	LOLA	Messenger, LRO, MGS	λ: 1064.3 nm FOV (of receiver) 400 μrad Timing Resolution 0.5 ns
Magnetometer	Planetary formation/differentiation, formation studies, solar wind-planetary interaction, magnetic field configuration (Q3.6)	MAG, MFI	IMAP, MAVEN	3 nT to 3000 nT, sampling at ~20 s, 1% accuracy

Science Team Is Currently ...

- Revising science questions, to
- prioritize observations based on those science questions, to
- prioritize instruments and features of a refined trajectory.

- Science team is divided into 7 different "theme teams" and each team is working their priorities, which the PI and DPI will combine.

Conclusions

- We will develop a Flagship-level mission to return to the Pluto-Charon system and explore the Kuiper Belt.
- Specifically, we will develop:
  - Mission trades within the science team.
  - Mission trades for the tour, payload, etc. at APL.
- Timeline:
  - Mid-October: Supposed to have started.
  - Mid-March (LPSC): Interim reports due.
  - June 2020: Final report due.