Planetary Mission Concept Study

Pluto Orbiter and Kuiper Belt Exploration Mission

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Mission Overview

• Mission Level: Flagship

• Payload: Expanded from New Horizons

• Trajectory:
  • 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.
Motivation

- Building on the questions raised from the New Horizons encounter
- *Numerous* community documents recommend this or something similar:
  - CAPS suggested “a Pluto system orbiter and Centaur and/or Kuiper belt object flybys” are important follow-on missions in the next planetary science decadal survey (CAPS, 2017).
  - Roadmap to Ocean Worlds (ROW) recommends that “mission studies should be performed to address technology advances enhancing exploration of the Kuiper belt or a return to Pluto with an orbiter” (Hendrix et al., 2019).
Science Questions

• Is Pluto an ocean world?
• What is the history of the Pluto system?
• What is the diversity of the Kuiper Belt?
Science 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)?
Science 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?
Science 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?]
Nominal Trajectory

- Launch: 2027
- Cruise: 12 years direct to Pluto**
- Arrival in Pluto system: 2039
- Tour Pluto system: 2039-2041
- Break Pluto-system orbit: 2041
- Post-Pluto cruise to next (TBD) target:

<table>
<thead>
<tr>
<th>KBO</th>
<th>(\Delta v) (km/s)</th>
<th>Flyby Velocity (km/s)</th>
<th>Secondaries</th>
<th>D (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ixion *</td>
<td>3.06</td>
<td>3.76</td>
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<td>617</td>
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<tr>
<td>2017 OF(_{69})*</td>
<td>4.76</td>
<td>4.05</td>
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<td>Dziewanna</td>
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<td>Quaoar</td>
<td>5.69</td>
<td>5.35</td>
<td>3</td>
<td>1110</td>
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<td>2003 OP(_{32})</td>
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<td>6.94</td>
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<td>2002 MS(_{4})</td>
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<td>6.08</td>
<td>5</td>
<td>934</td>
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<tr>
<td>2007 JH(_{43})</td>
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<td>7.71</td>
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<tr>
<td>2010 OO(_{127})</td>
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<tr>
<td>2010 KZ(_{39})</td>
<td>7.59</td>
<td>7.65</td>
<td>0</td>
<td>666</td>
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<td>2004 PF(_{115})</td>
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<td>7.02</td>
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<td>406</td>
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<tr>
<td>2007 JJ(_{43})</td>
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<td>7.00</td>
<td>0</td>
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<tr>
<td>Varda</td>
<td>8.30</td>
<td>8.37</td>
<td>1</td>
<td>717</td>
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<tr>
<td>2005 RN(_{43})</td>
<td>8.37</td>
<td>7.95</td>
<td>0</td>
<td>679</td>
</tr>
</tbody>
</table>

14 possible post-Pluto targets (non-exhaustive list!)

* Indicates a target that could be orbited, assuming a maximum \(\Delta v\) of <10 km/s

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

- 59 Pluto encounters <100,000 km
- Multiple <3,000 km small satellite encounters
- Pluto sub-solar latitude is 56.8° to 55.2° N
  - NH sub-solar lat: 51.5° N
- 25 years after NH, Pluto would have gone through northern southern solstice (2029)
Nominal Pluto-System Tour

Pluto coverage:
- Complete equatorial coverage
- North and south polar coverage

Charon coverage: Global
<table>
<thead>
<tr>
<th>Instrument Capability</th>
<th>Predecessor Instrument</th>
<th>Instrument Heritage</th>
<th>Preliminary Instrument Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panchromatic High-Resolution Imager</td>
<td>LORRI</td>
<td>New Horizons, Lucy</td>
<td>( \lambda: 0.35 \text{ to } 0.85 \mu m ) ( \text{IFOV:} 5.0 \mu \text{rad sq.} )</td>
</tr>
<tr>
<td>Color Imaging and Near-Infrared Spectral Coverage</td>
<td>Ralph (MVIC and LEISA)</td>
<td>New Horizons, Lucy, O-Rex</td>
<td>LEISA: ( \lambda: 1.0 \text{ to } 5.0 \mu m ) (extended from NH LEISA) ( \text{IFOV:} 40\mu\text{rad sq} ) ( \text{MVIC:} \lambda: \text{Panchromatic (0.4 to 0.9 } \mu m) \text{ and five color channels spread between these wavelengths IFOV: 29 } \mu \text{rad sq.} )</td>
</tr>
<tr>
<td>UV spectral coverage</td>
<td>Alice</td>
<td>New Horizons, Rosetta, JUICE</td>
<td>( \lambda: 520-1870 \text{ Å} ) ( \text{FOV:} 0.1^\circ \times 4^\circ \text{airglow slit, } 2^\circ \text{sq. solar occultation channel} )</td>
</tr>
<tr>
<td>Thermal-IR coverage</td>
<td>TES</td>
<td>Lucy, MGS, and O-Rex</td>
<td>( \lambda: 6 – 100 \mu m ) ( \text{IFOV:} &lt;8 \text{mrad diameter} )</td>
</tr>
<tr>
<td>Radio Science</td>
<td>REX</td>
<td>New Horizons</td>
<td>Spacecraft telecom system</td>
</tr>
<tr>
<td>Ice Penetrating Radar</td>
<td>REASON</td>
<td>Europa Clipper</td>
<td>Dual frequency: ( \text{HF (9 MHz, sounding 1-30 km)} ) ( \text{VHF (60 MHz, sounding 300 m to 4.5 km)} )</td>
</tr>
<tr>
<td>Mass Spec</td>
<td>MASPEX</td>
<td>Europa Clipper</td>
<td>( &gt;1000 \text{amu} ) ( &lt;1 \text{ppt resolution} )</td>
</tr>
<tr>
<td>Laser Altimeter</td>
<td>LOLA</td>
<td>Messenger, LRO, MGS</td>
<td>( \lambda: 1064.3 \text{ nm} ) ( \text{FOV (of receiver) 400 } \mu \text{rad} ) ( \text{Timing Resolution 0.5 ns} )</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>MAG, MFI</td>
<td>IMAP, MAVEN</td>
<td>( 3 \text{nT to } 3000 \text{nT, sampling at } \sim \text{20 s, 1% accuracy} )</td>
</tr>
<tr>
<td>Plasma Ion Measurements</td>
<td>SWAP, CODICE</td>
<td>New Horizons, IMAP</td>
<td>( \sim \text{10eV/q to } 100 \text{ keV/q} ) ( \Delta \text{(m/q)/(m/q)} \leq 1 \text{ions} )</td>
</tr>
</tbody>
</table>

**Nominal Payload**

- Lots of New Horizons heritage
- But also some Europa Clipper, O-Rex, LRO and IMAP heritage too
Science Team Is Currently ...

- Revising science questions, to:
  - Prioritize observations based on those science questions
  - 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 further develop a Flagship mission to return to the Pluto-system and explore the Kuiper Belt.

• Specifically we will develop:
  • Mission trades within the team
  • The tour, payload and our full mission costing with NASA design labs.

• Final report to NASA by June 2020