The Exploration of The Pluto System And The Kuiper Belt

Alan Stern, Principal Investigator
2007-2014: ACROSS THE DEEP

- **2007**
  - (9/07-11/07) Annual c/o #1
  - (9/08-12/08) Precess 05/29/08
- **2008**
  - (9/08-12/08) Precess 12/27/07
  - (7/09-9/09) Precess 12/15/08
- **2009**
  - (7/09-9/09) Precess 12/17/09
  - (5/10-7/10) Precess 11/17/09
- **2010**
  - (5/10-7/10) Precess 01/12/10
  - (5/11-7/11) Precess 01/12/11
  - TCM 11 (P-5y) Ltd Rehearsal 05/20/11
- **2011**
  - (5/11-7/11) Wake-up 01/03/12
  - Lunar Occ 01/21/12
  - Precess 01/24/12
  - Precess 11/12/11
  - TCM 11 (P-5y) Ltd Rehearsal 05/20/11
- **2012**
  - (5/12-7/12) Precess 1/26/13
  - Flt S/W Load
- **2013**
  - (5/13-8/13) Precess 1/14/14
  - Lunar Occ 01/21/12
  - Precess 01/24/12
  - Flt S/W Load
- **2014**
  - (6/14-8/14) Precess 12/07/14
  - Annual c/o #8
  - TCM 15
  - OpNav Campaign 1

**Weekly Beacon, monthly TM. contact in PS-H.**

- 2-3x8h/wk for Annual C/O
- 7x 8h/d for Precess
- TCMs in 3A-TCM or AS-TCM

**OpNavs last annual c/o:** 1 every 12hrs for 7 days
**NASA-DEFINED MEASUREMENT OBJECTIVES**

<table>
<thead>
<tr>
<th><strong>Group 1 Objectives:</strong></th>
<th><strong>Required</strong></th>
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<tbody>
<tr>
<td>Characterize the global geology and morphology of Pluto and Charon</td>
<td></td>
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<tr>
<td>Map surface composition of Pluto and Charon</td>
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<tr>
<td>Characterize the neutral atmosphere of Pluto and its escape rate</td>
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<thead>
<tr>
<th><strong>Group 2 Objectives:</strong></th>
<th><strong>Important</strong></th>
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<tbody>
<tr>
<td>Characterize the time variability of Pluto's surface and atmosphere</td>
<td></td>
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<tr>
<td>Image Pluto and Charon in stereo</td>
<td></td>
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<tr>
<td>Map the terminators of Pluto and Charon with high resolution</td>
<td></td>
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<tr>
<td>Map the composition of selected areas of Pluto &amp; Charon at high resolution</td>
<td></td>
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<tr>
<td>Characterize Pluto's ionosphere and solar wind interaction</td>
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<tr>
<td>Search for neutral species including H, H₂, HCN, and CₓHᵧ, and other hydrocarbons and nitriles in Pluto's upper atmosphere</td>
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<tr>
<td>Search for an atmosphere around Charon</td>
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<tr>
<td>Determine bolometric Bond albedos for Pluto and Charon</td>
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<tr>
<td>Map the surface temperatures of Pluto and Charon</td>
<td></td>
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<tr>
<th><strong>Group 3 Objectives:</strong></th>
<th><strong>Desired</strong></th>
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<tbody>
<tr>
<td>Characterize the energetic particle environment of Pluto and Charon</td>
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<tr>
<td>Refine bulk parameters (radii, masses, densities) and orbits of Pluto &amp; Charon</td>
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<tr>
<td>Search for magnetic fields of Pluto and Charon</td>
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<tr>
<td>Search for additional satellites and rings</td>
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REX—Radio science & radiometry
RALPH—VIS/IR Pan/Color imaging & spectroscopy
ALICE—UV imaging spectroscopy
LORRI—High-resolution imager
SWAP—KeV plasma spectrometer
PEPSSI—MeV plasma spectrometer
SDC—Student Dust Counter
Mission Status

- **Spacecraft**: Healthy
- **Payload**: Healthy, Well Calibrated
- **Trajectory**: On Course
- **Fuel**: 1.3x Originally Expected for KBO EM
- **Final Active Checkout**: In Progress
- **Final Hibernation**: Late August—Early December
- **Encounter Begins**: 15 January
ACO-8 Highlights

✓ Spacecraft Checkout
✓ Payload Checkout and Selected Calibrations
✓ Encounter Final Autonomy/Fault Protection Load
✓ Trajectory Correction Completed 15 July 2014
✓ Neptune EPO Imaging Complete
✓ First Pluto OpNav Campaign (Derivative Science)

❌ Heliospheric Dust, Lya, and Plasma Measurements
Encounter Overview

- Encounter Runs January to July (Soon!)
- Downlink Lasts July ‘15 to October ‘16
- Better Than HST: ~1 May
- Intensive Pluto Science: June-July; C/A 14 July
- Hazard Imaging: May-July

Note: AP - Approach Phase, DP - Departure Phase, NEP - Near Encounter Phase
Overview of Approach Science

Approach Phase 1
Atm Escape: Ambient Plasma
OpNav/Orbits/Masses
Surface Albedo Variability
‘High’ Phase Photometry

LORRI, SWAP, SDC, PEPSSI

Approach Phase 2
AP1 Plus:
Surface Color
Variability Studies
Satellite/Ring Search

RALPH, ALICE Too

Approach Phase 3 (AP3): P-21 to P-1
AP2 Plus:
Atm. Escape: Pickup Ions & Bow Shock
Surface Composition Variability
Airglow Variability
Clouds/Haze/Winds from Imaging
Pan, Color, and Composition Maps
All But REX

Charon Detection by New Horizons 2013.5
Latest Approach Imaging

2014 July 21 LORRI Imaging

Full Field

Zoom on Pluto-Charon
Encounter Highlights

- Approximately 6 months of encounter science at Pluto
- Exceed Hubble resolution for ~3 months
- Map entire sunlit areas of Pluto and Charon
- Make global composition maps of Pluto and Charon
- Map Pluto and Charon surface temperatures
- Explore Pluto’s atmosphere: Measure escape rate, pressure and temperature profile, composition; search for hazes
- Improve interior structure models; address if either Pluto or Charon is differentiated
- Obtain high resolution images of Nix and Hydra
- Make compositional measurements of Nix and Hydra
- Search for additional Pluto-system and rings

The most exciting discoveries will likely be the ones not anticipated
What Will We Find?
Predictions Are Risky
Predictions Are Risky
Surprises Surely Await
July 14, 2015 2:00 (P-10h) 

Highest Resolution 70m/px
Then on to KBOs 2017-2021
April 2014: Submitted 160-orbit regular proposal, including use of 40 orbits of Director’s Discretionary (DD) time offered by STScI

- Proposed to use the DD time for a pilot study to demonstrate feasibility by finding at least 2 cold classical KBOs in order to qualify for the rest of the search time
- Messages of support from OPAG, SBAG—Thank You!

June 13th 2014: Proposal accepted
- June 16th: Pilot observations start
- June 28th: 2 pilot program KBOs discovered

- June 30th: Full program approved
- July 7th: Full program started
- July 22nd: 100 orbits completed
Search Design

- 83 WFC3 total
- Track at the rate of a hypothetical reference KBO near the center of each field
- Two 1-orbit visits per field, usually separated by 3 hours
- Images processed with 1-2 days of receipt to reveal moving objects at the full range of possible rates for cold classical KBOs.

Section of single image

5 images star-subtracted, robustly stacked at KBO rate (same stretch)
As of July 18th
- 96% of search observations scheduled (through August 3rd), Limiting Mag R-27.5
- Several detections
- Expect ~20% of discoveries to be targetable by NH

First follow-up observations of detected KBOs scheduled August 2-3 to determine targetability.

Should complete both the survey and initial follow-up by September.
For More Information

- Visit [http://pluto.jhuapl.edu](http://pluto.jhuapl.edu)
- Read SSR 2008, V140, or Young & Stern 2010, IAU Symp. 263, 305.
- Ask me or any CoI.
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My other vehicle is on its way to Pluto
Backup Charts
### Summary of Best Resolution of Pluto and its 5 moons

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<tr>
<th></th>
<th>Panchromatic</th>
<th>Color</th>
<th>Infrared</th>
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<tbody>
<tr>
<td>Pluto</td>
<td>0.46 km/pixel hemispheric</td>
<td>0.64 km/pixel</td>
<td>6.0 km/pixel hemispheric</td>
</tr>
<tr>
<td></td>
<td>0.09 km/pixel regional</td>
<td></td>
<td>2.7 km/pixel local</td>
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<tr>
<td></td>
<td></td>
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<tr>
<td>Charon</td>
<td>0.61 km/pixel hemispheric</td>
<td>1.40 km/pixel</td>
<td>8.4 km/pixel hemispheric</td>
</tr>
<tr>
<td></td>
<td>0.15 km/pixel regional</td>
<td></td>
<td>4.7 km/pixel local</td>
</tr>
<tr>
<td>Nix</td>
<td>0.46 km/pixel</td>
<td>1.98 km/pixel</td>
<td>3.6 km/pixel</td>
</tr>
<tr>
<td></td>
<td>0.29 km/pixel possible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydra</td>
<td>1.14 km/pixel</td>
<td>4.6 km/pixel</td>
<td>14.6 km/pixel</td>
</tr>
<tr>
<td>P4</td>
<td>3.2 km/pix</td>
<td>(44 km/pix)</td>
<td>(24 km/pix)</td>
</tr>
<tr>
<td></td>
<td>2.0 km/pix possible</td>
<td>8 km/pix possible</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>3.2 km/pix</td>
<td>8 km/pix</td>
<td>(200 km/pix)</td>
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Resolutions in parentheses indicate unresolved targets.
Pluto at Approach

- Sunlit in southern hemisphere & dark in northern cap
- *New Horizons* approaches Pluto from southern hemisphere
- Solar phase angle at approach is 15°
- Pluto makes one rotation every 6.4 Earth days

- **Sub-solar position** (-49.4°, 30.7°)

- **Equator**
- **Prime Meridian**
- **To Spacecraft**
- **Sub-spacecraft position 10 days before C/A**
- **Sun’s Shadow**
- **North Pole**
- **Sun terminator**
- **X**
- **Y**
- **Z**
New Horizons Ground Track on Pluto

at Closest Approach

Sub-solar Position at C/A