

New Horizons Pluto/KBO Mission

Status Report for SBAG

Hal Weaver

NH Project Scientist

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New Horizons: To Pluto and Beyond

**The Initial Reconnaissance of The Solar System's
"Third Zone"**

**KBOs
2016-2020**

**Pluto-Charon
July 2015**

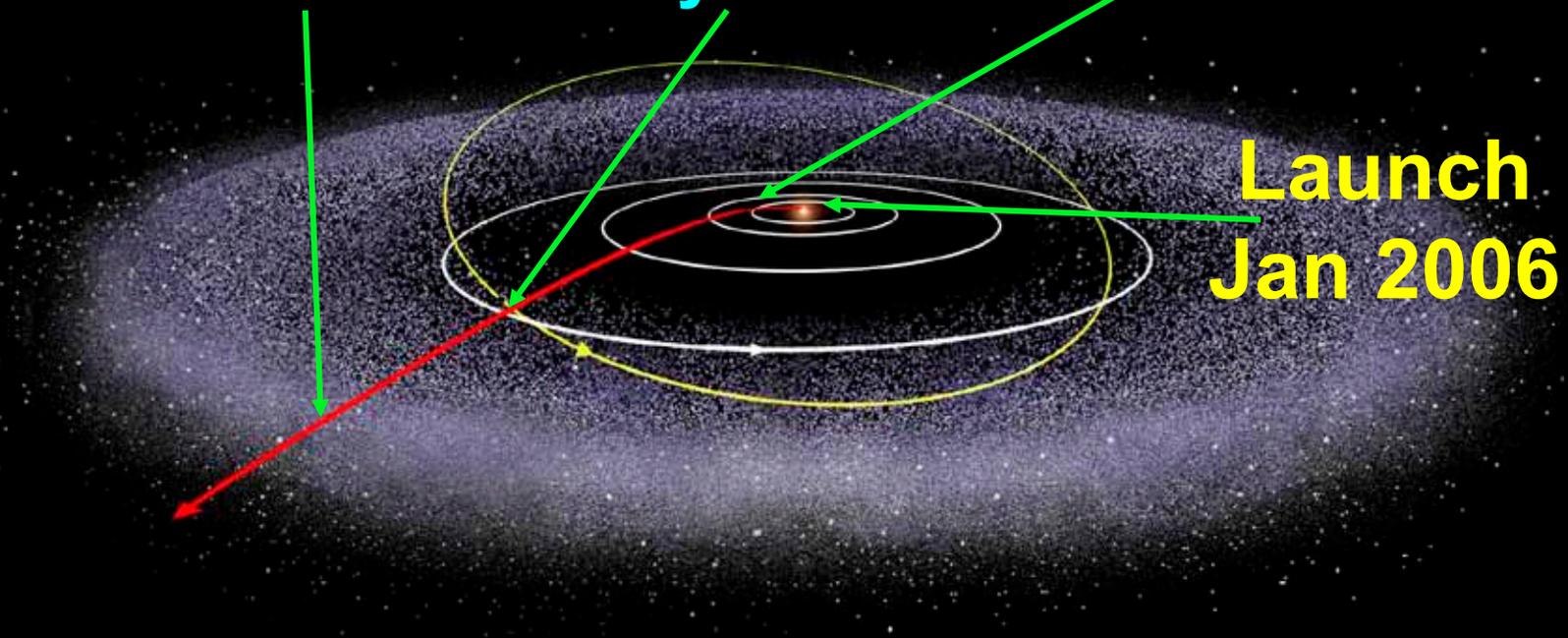
**Jupiter System
Feb-March 2007**

**Launch
Jan 2006**

PI: Alan Stern (SwRI)

PM: JHU Applied Physics Lab

New Horizons is NASA's first New Frontiers Mission



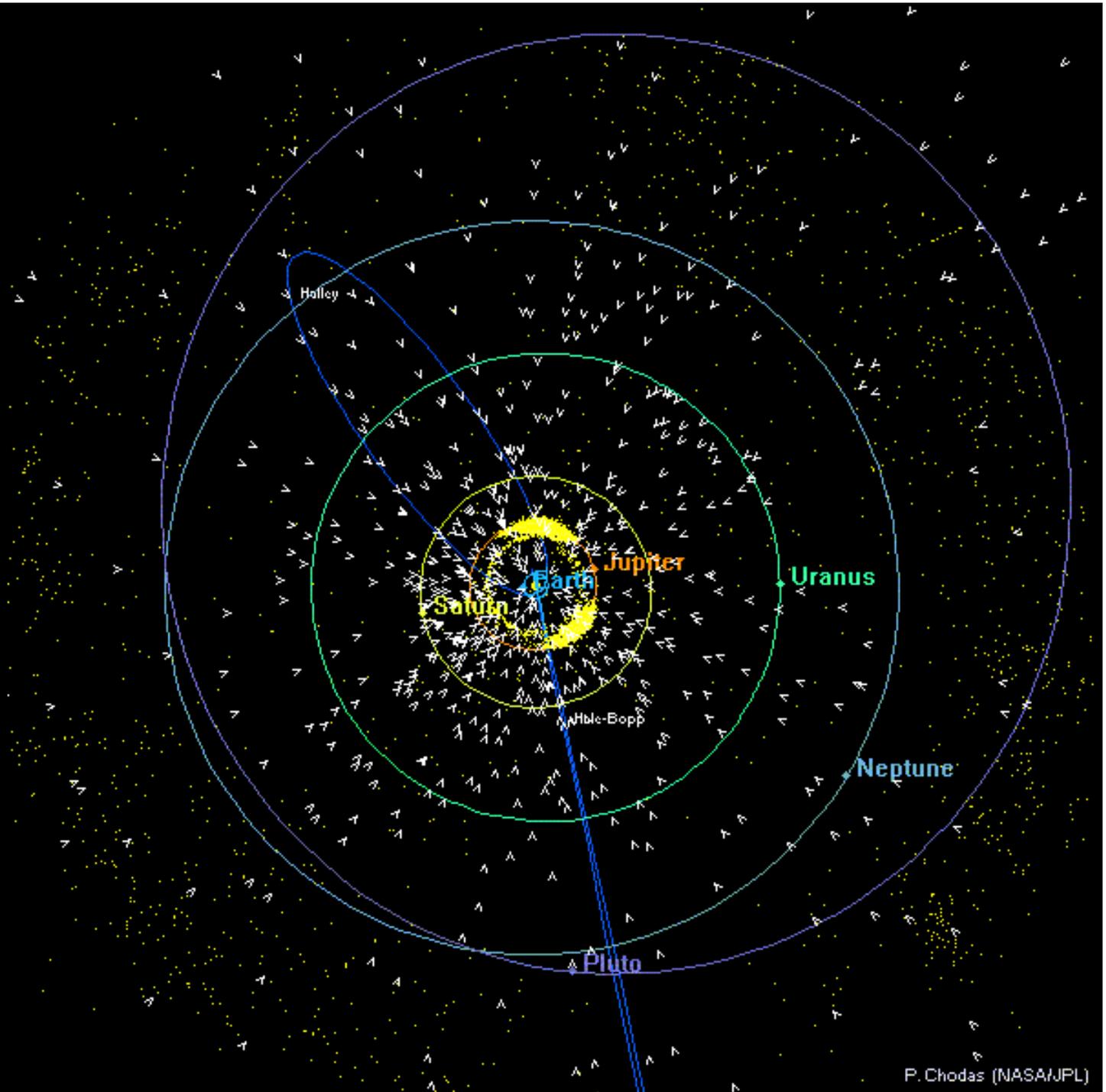
Frontier of Planetary Science

Explore a whole new region of the Solar System we didn't even know existed until the 1990s

Pluto is no longer an outlier!

Pluto System is prototype of KBOs

New Horizons gives the first close-up view of these newly discovered worlds



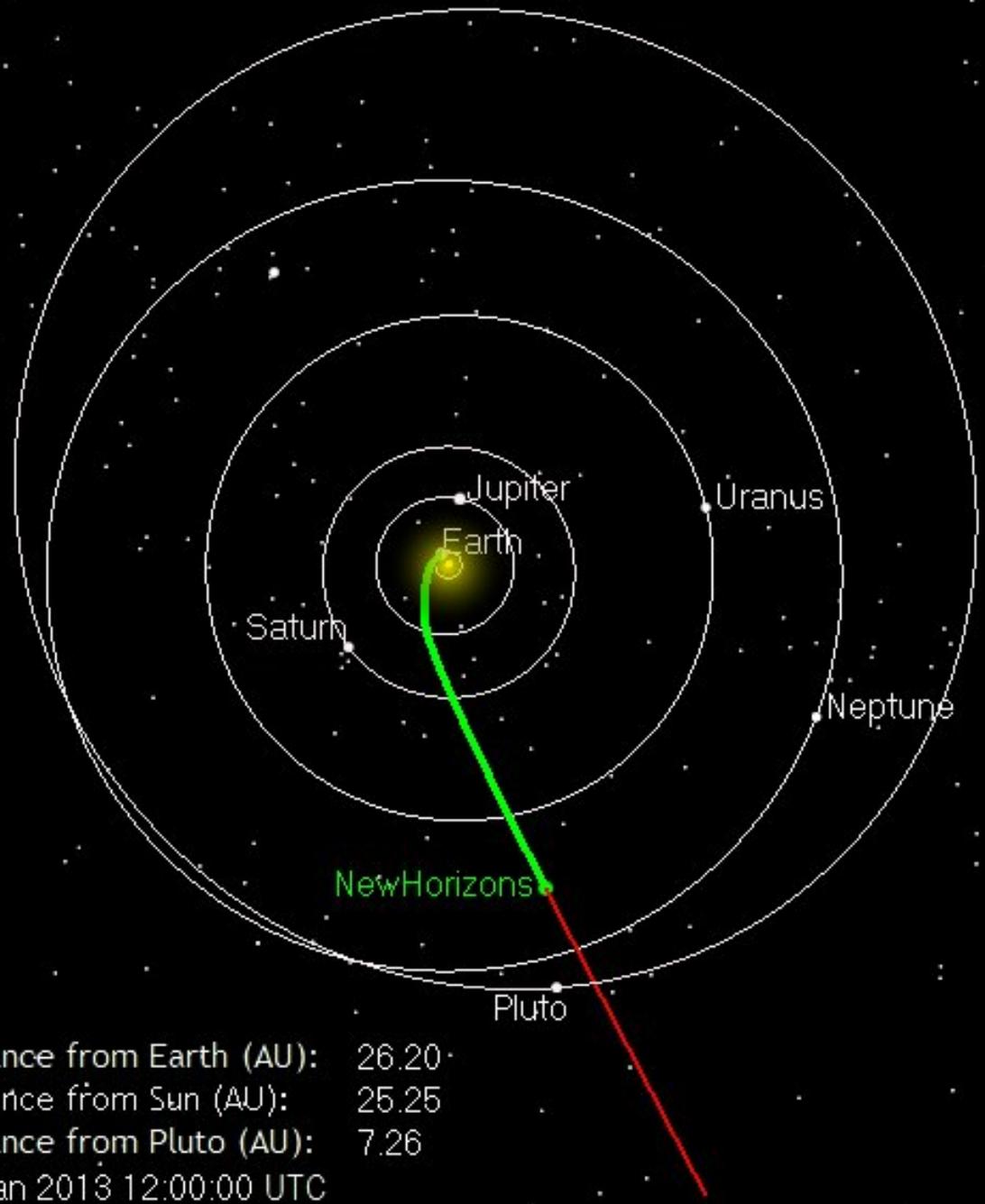
New Horizons Full Trajectory - Overhead View

New Horizons Now (overhead view)

**Passed Uranus orbit
2011-March-18**

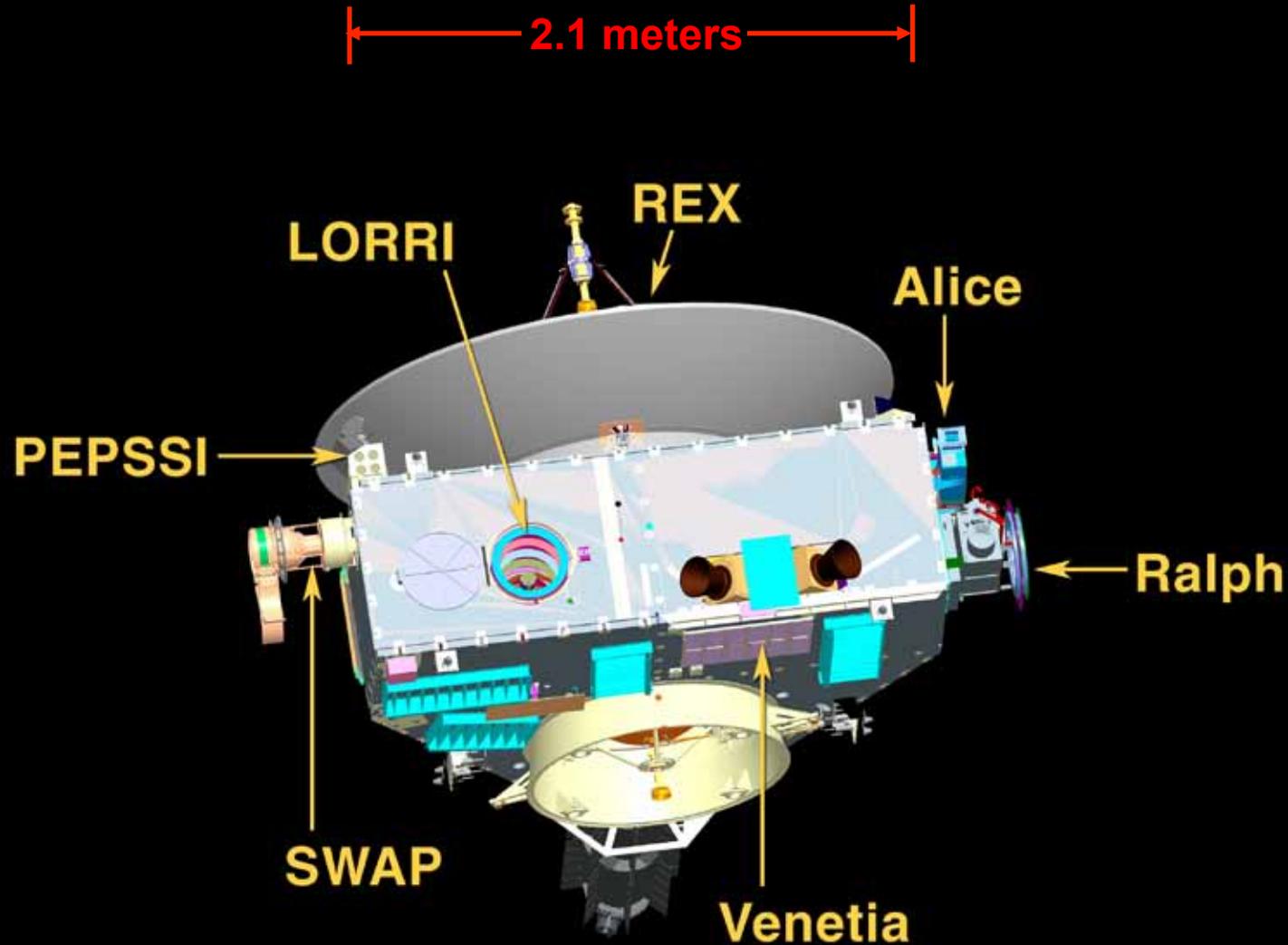
**Pass Neptune orbit
2014-August-25
(25 years after Voyager 2)**

**Pluto Closest Approach
2015-July-14**



Distance from Earth (AU): 26.20
Distance from Sun (AU): 25.25
Distance from Pluto (AU): 7.26
15 Jan 2013 12:00:00 UTC

NH Spacecraft & Instruments



Science Team:

PI: Alan Stern
Fran Bagenal
Rick Binzel
Bonnie Buratti
Andy Cheng
Dale Cruikshank
Randy Gladstone
Will Grundy
Dave Hinson
Mihaly Horanyi
Don Jennings
Ivan Linscott
Jeff Moore
Dave McComas
Bill McKinnon
Ralph McNutt
Scott Murchie
Cathy Olkin
Carolyn Porco
Harold Reitsema
Dennis Reuter
Dave Slater
John Spencer
Darrell Strobel
Mike Summers
Len Tyler
Hal Weaver
Leslie Young

Pluto System Science Goals Specified by NASA or Added by New Horizons

Group 1 Objectives: REQUIRED

Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the global geology and morphology of Pluto and Charon	None
Map surface composition of Pluto and Charon	
Characterize the neutral atmosphere of Pluto and its escape rate	

Group 2 Objectives: STRONGLY DESIRED

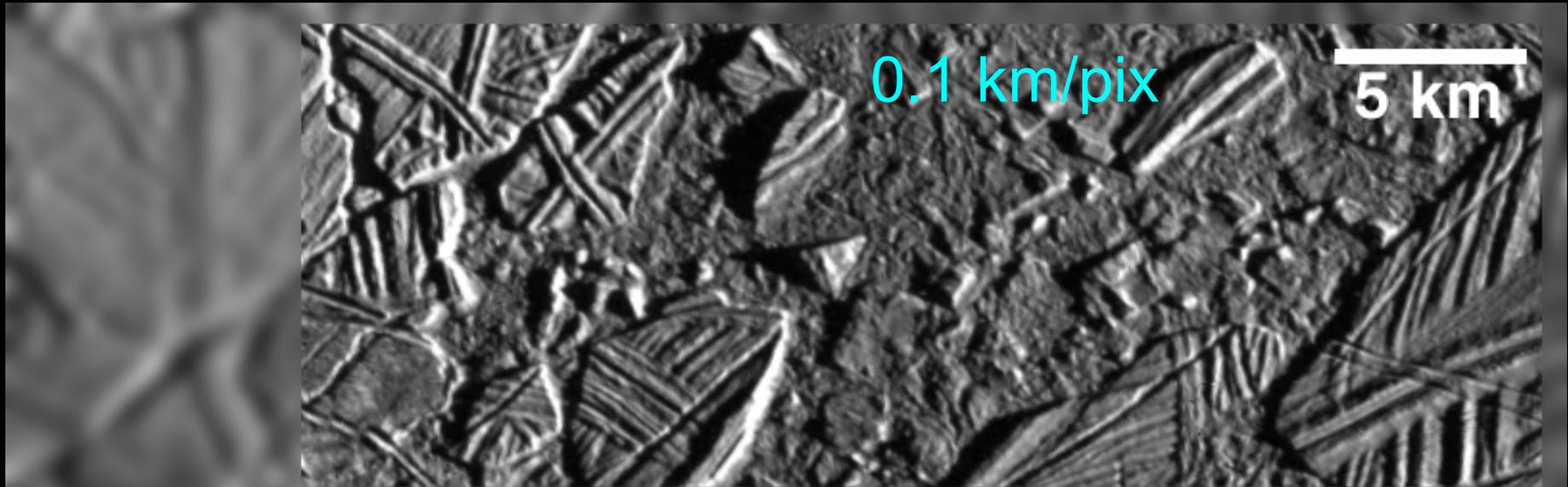
Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the time variability of Pluto's surface and atmosphere	Composition of dark surfaces on Pluto
Image Pluto and Charon in Stereo	"Far-side" imaging of Pluto and Charon
Map the terminators of Pluto and Charon with high resolution	"Far-side" color and composition of Pluto and Charon
Characterize Pluto's ionosphere and solar wind interaction	High resolution imaging of Nix and Hydra
Search for neutral species including H, H ₂ , HCN, and C _x H _y , and other hydrocarbons and nitriles in Pluto's upper atmosphere	Composition of Nix and Hydra
Search for an atmosphere around Charon	Shapes of Nix and Hydra
Determine bolometric Bond albedos for Pluto and Charon	
Map the surface temperatures of Pluto and Charon	

Group 3 Objectives: DESIRED

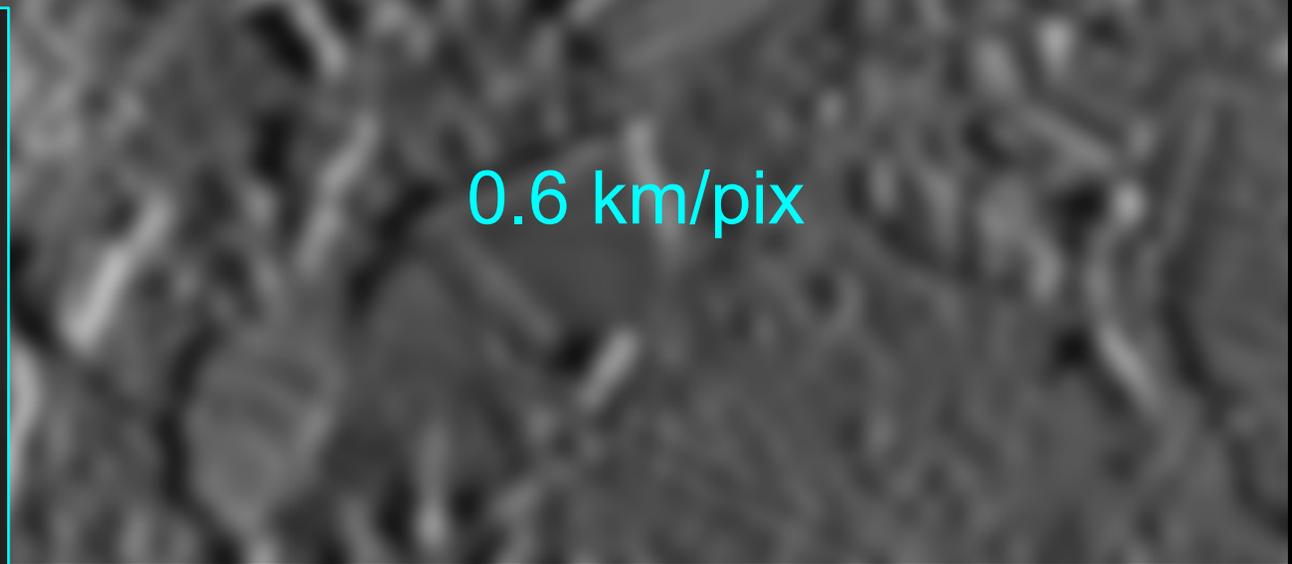
Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the energetic particle environment of Pluto and Charon	Surface microphysics of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon	Measure the surface temperatures of Nix and Hydra
Search for magnetic fields of Pluto and Charon	Measure the phase curve of Nix and Hydra
Search for additional satellites and rings	Image Nix and Hydra in stereo
	Education/Public Outreach

New Horizons Resolution on Pluto

(Simulations of MVIC context imaging vs LORRI high-resolution "noodles")



The Best We Can Do Now



HST/ACS-PC: 540 km/pix

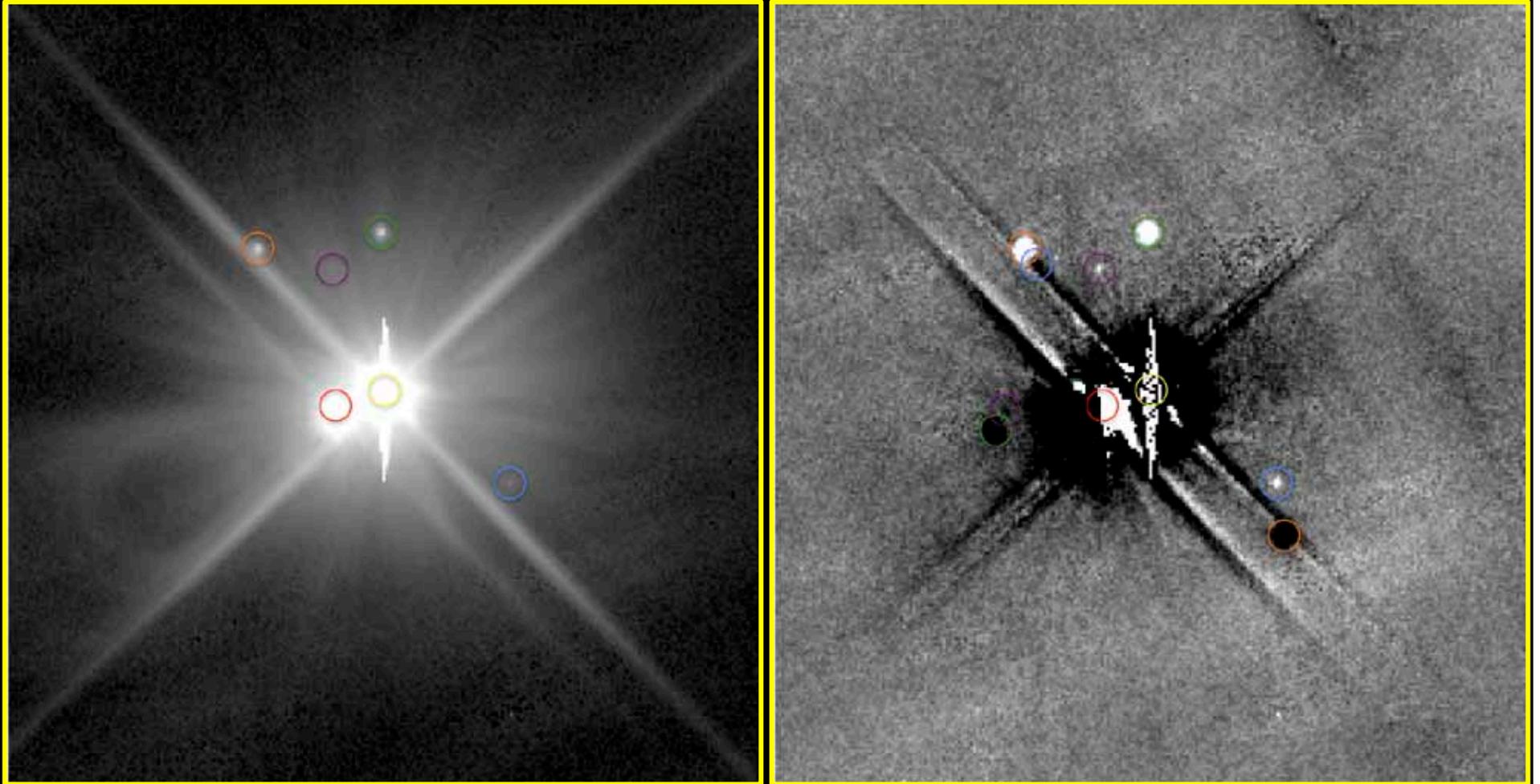
New Horizons Science Status

- New Horizons is on track to deliver the goods
 - The science objectives specified by NASA and the Planetary Community should be achieved, or *exceeded*
 - Nix, Hydra, P4, and P5 added (new discoveries)
 - More data collected than originally anticipated (~7x larger)
 - Only exception is direct measurement of Pluto's magnetic field, which was a Group 3 objective
 - Robust timeline with built-in redundancy to ensure success
- Rehearsal of most intense 22 hr flyby segment successfully conducted in May 2012 (“stress test”)
- Rehearsal of larger portion of P-7 to P+2 “Core Load” in 2013
- Conducting intensive search for KBOs that are targetable by New Horizons during an Extended Mission phase
 - Using large ground based telescopes with Hubble follow-up

**All systems are GO. Potential Impact Hazard is main concern at this time.*

Discovery of Pluto's Fifth Moon ("P5")

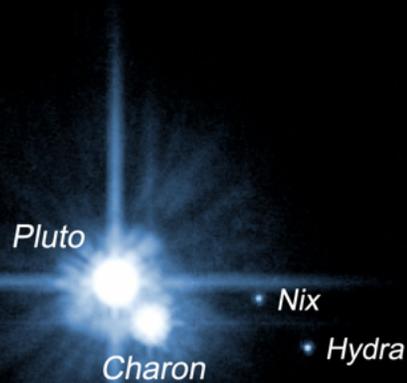
M. Showalter¹, H. Weaver², A. Stern³, A. Steffl³, M. Buie³, W. Merline³, M. Mutchler⁴, R. Soummer⁴, H. Throop⁵, ¹SETI Institute, ²JHU/APL, ³SwRI, ⁴STScI, ⁵PSI/NASA HQ



In support of NASA's New Horizons Pluto/KBO mission, Hubble performed the deepest search yet for satellites in the Pluto system. The figure to the left is a composite WFC3 image (102 min total exposure time) showing the discovery of a new satellite, provisionally named "P5", which is ~150,000 times fainter than Pluto. The figure to the right shows the *difference* between two such Hubble composite images, which more clearly shows the smaller satellites (both positive and negative) by suppressing the bright glare from Pluto and Charon. In each figure, Pluto, Charon, Nix, Hydra, P4, and P5 are labeled by ○, ○, ○, ○, ○, and ○, respectively. P5's orbit is inside Nix's and is near a 1:3 mean motion resonance with Charon.

New Satellites: *Good and Bad*

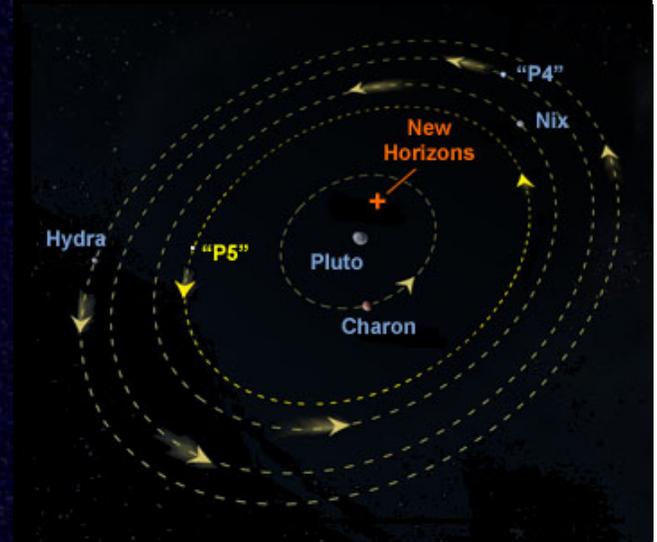
Hubble: May 2005



Hubble: July 2012



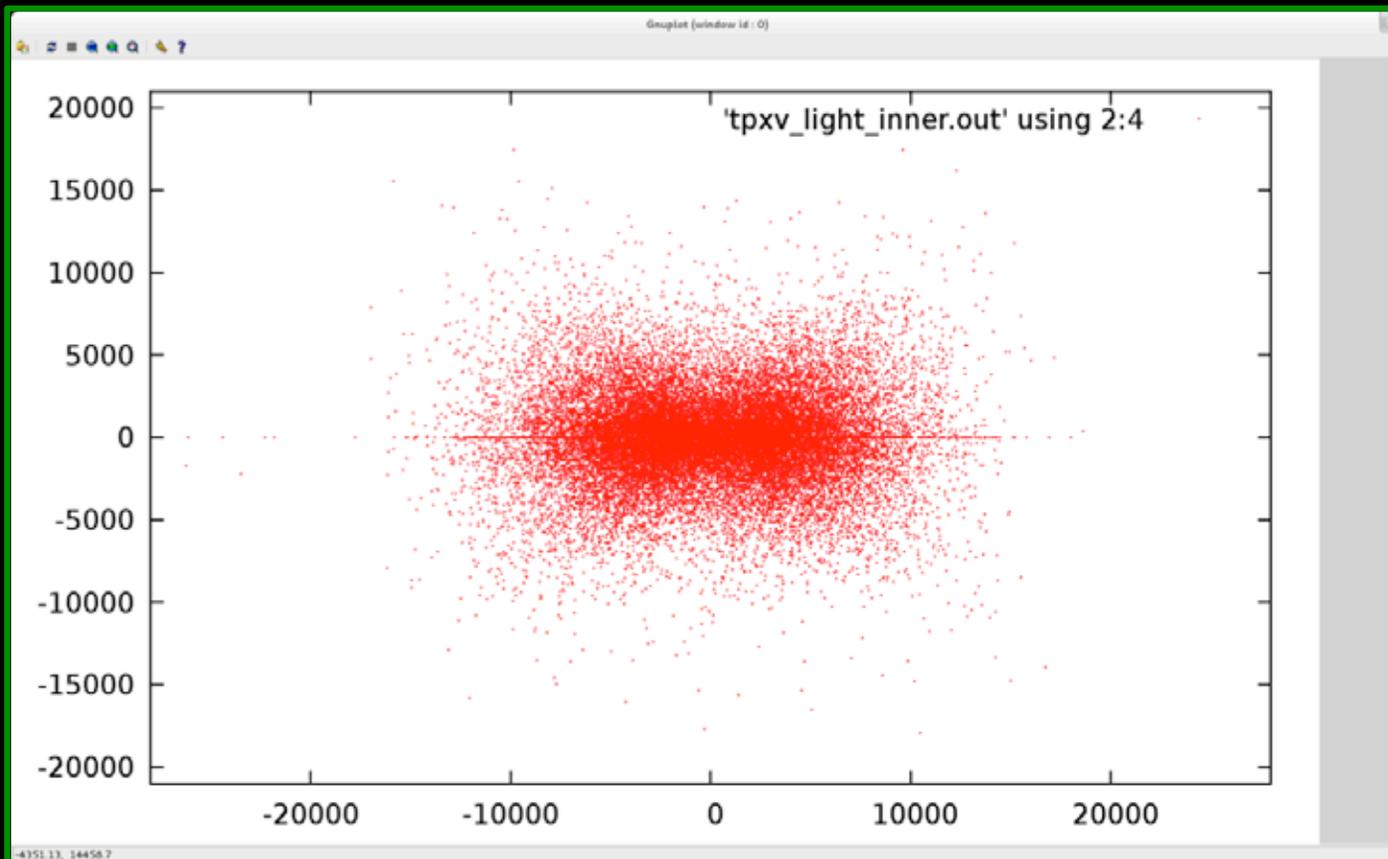
Pluto + 5 Moons



*Six for the price of one, but with strings attached. Where there are small satellites, there will be debris. A collision between mm-sized particles and the NH spacecraft moving at ~14 km/s could result in a **loss of mission**.*

Potential Hazard for New Horizons

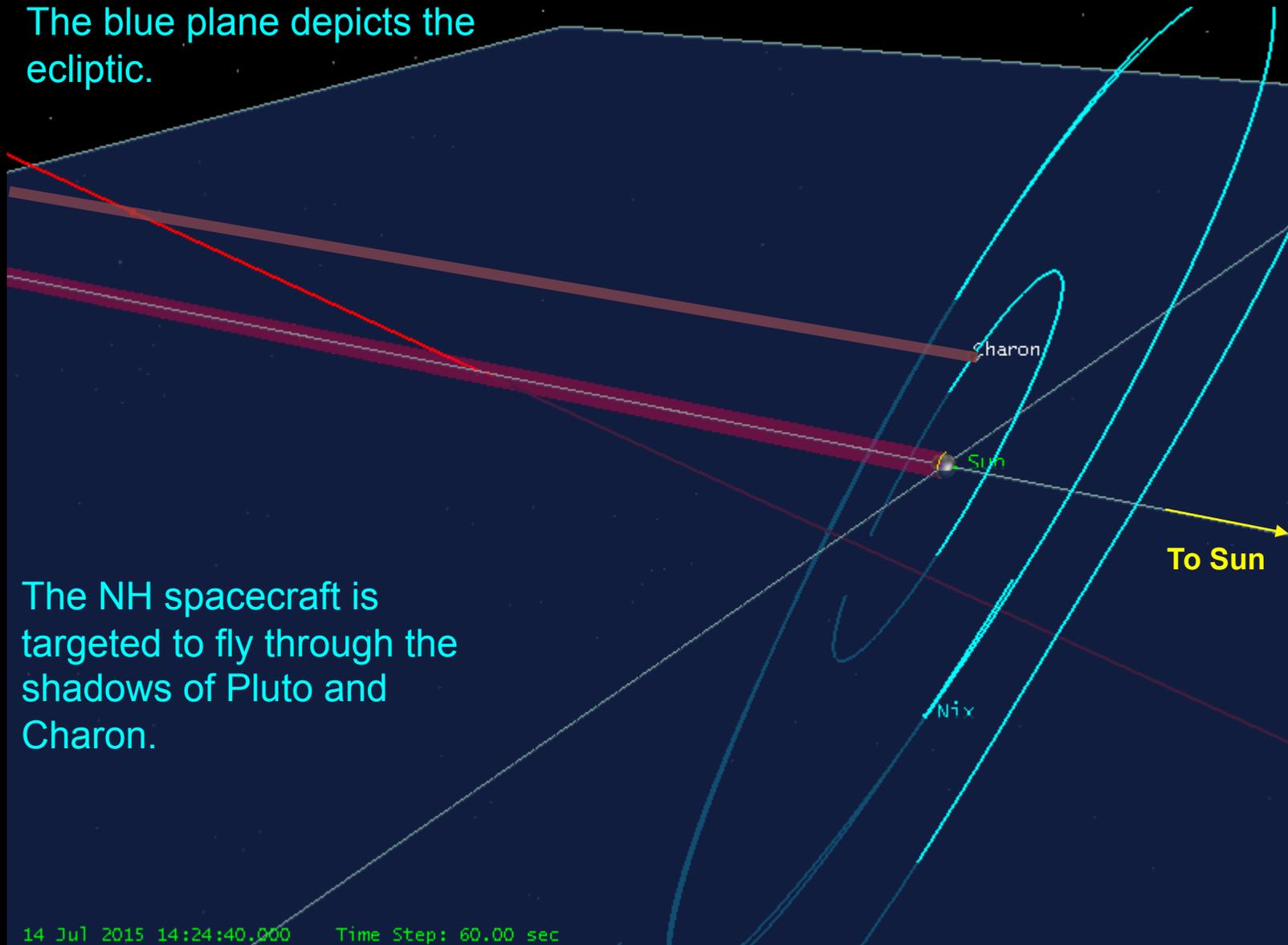
- The discovery of multiple satellites in the system raises the concern that *debris* associated with those satellites might pose a risk to the New Horizons spacecraft as it passes through the Pluto system.



Pluto Encounter Geometry

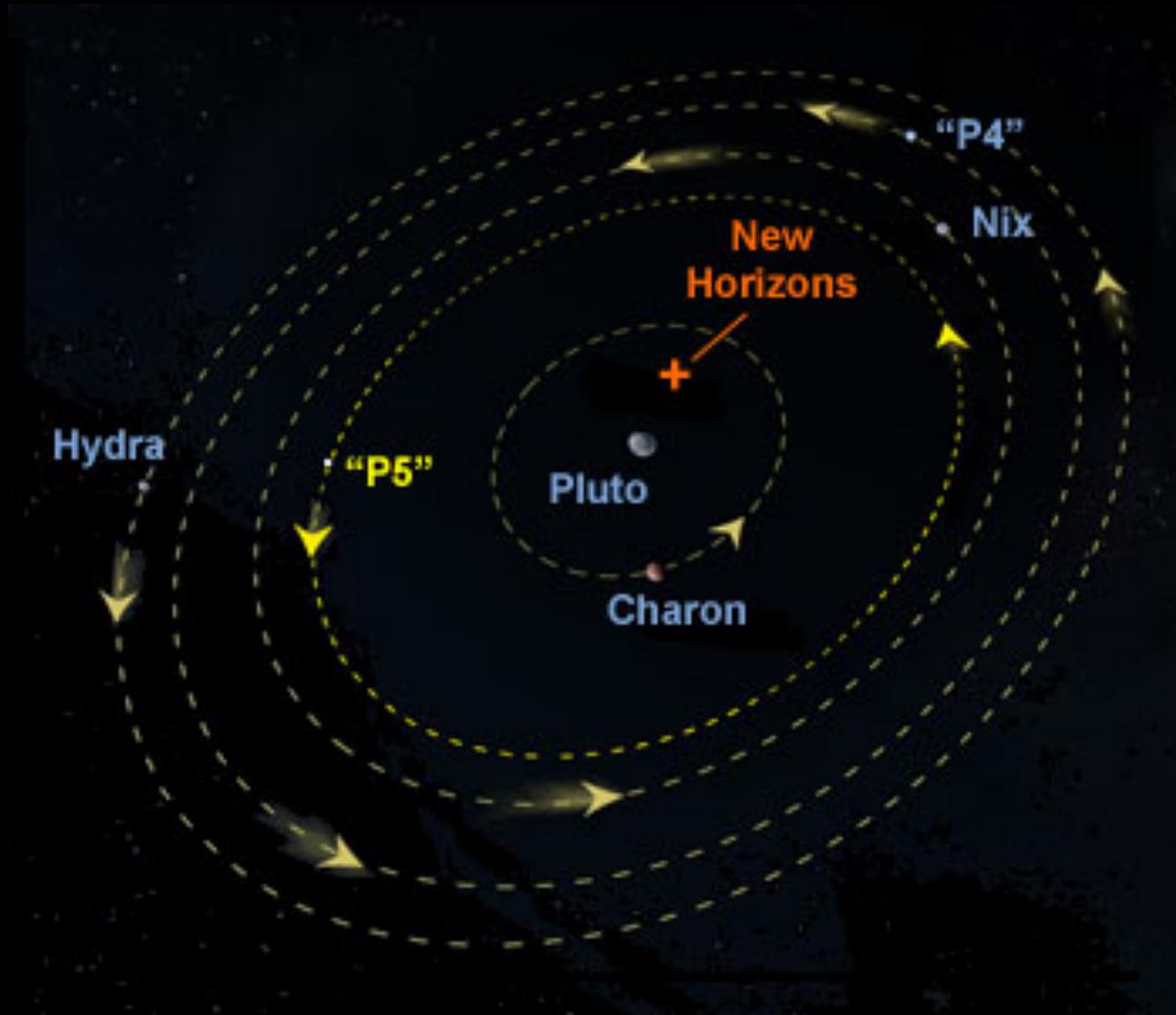
The blue plane depicts the ecliptic.

The NH spacecraft is targeted to fly through the shadows of Pluto and Charon.

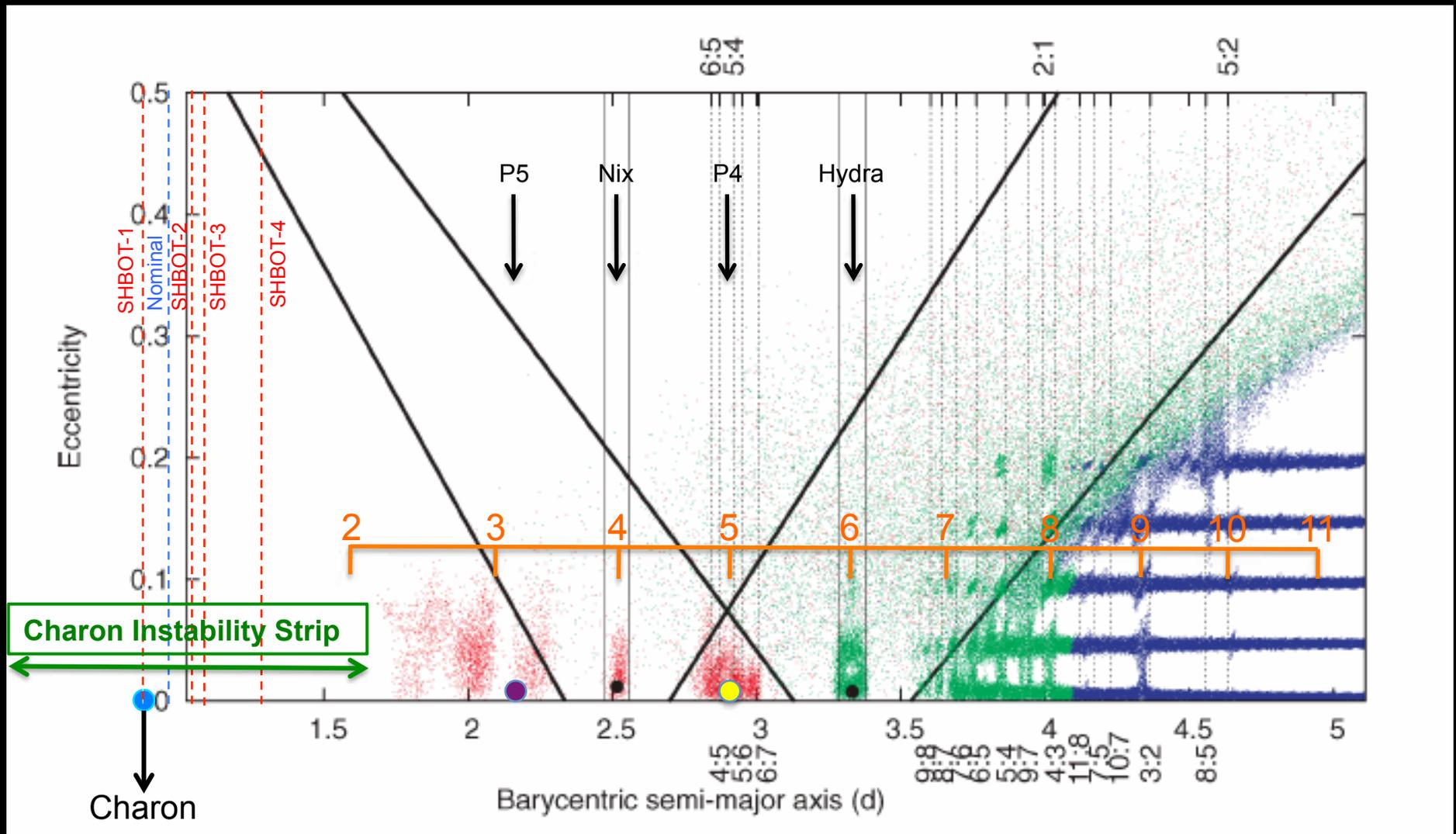


14 Jul 2015 14:24:40.000 Time Step: 60.00 sec

Where is it safe?



Region between P5 & Hydra is *Unsafe*, but *Charon Instability Strip* provides debris clearing for NH nominal trajectory and inner SHBOTs



X-axis is in units of Pluto-Charon distance (19,573 km) Adapted from Pires dos Santos et al. 2011
 Orange labels show locations of Mean Motion Resonances (MMRs) with Charon

Hazard Mitigation (1)

- NH spacecraft is in flight, so can't improve shielding
 - *But we are carefully investigating susceptibility of different regions of the spacecraft to particle impacts*
 - Both modeling and lab testing indicate the s/c is better protected than originally assumed, and flying *antenna to ram (ATR)* affords excellent protection for particle radii of several millimeters
- Insert two extra data downlinks, one at P-1 day and another at P-2 days
 - Substitute high quality science for Health & Safety engineering data to avoid complete loss
- Insert new LORRI mosaics at P-64, P-44, P-35, P-28, P-21, and P-18
 - Deepest search for satellites and debris before last TCMs

Hazard Mitigation (2)

- If the nominal trajectory is deemed unsafe, the only viable hazard mitigation is to *change* the trajectory:
 - *Safe Haven By Other Trajectory (SHBOT)*
- SHBOT for New Horizons:
 - NH is building SHBOT plans, including aim point designs and encounter sequencing
 - Two choices: Generic Inner SHBOT (GIS) or Outer SHBOT
 - *GIS will be Antenna To Ram for maximum protection*
 - SHBOT can be executed as late as P-10 days (~10 million km away), if approach or Earth-based observations warrant
 - But earlier is better to preserve fuel for extended mission
 - SHBOT encounter sequences will require a year to plan and must be completed by early 2014
 - SHBOT is not quite as good scientifically as the Nominal plan, but results will still revolutionize our understanding of the Pluto system & the Kuiper Belt
 - GIS is especially good and includes even better imaging of Nix



SHBOT Mission Design

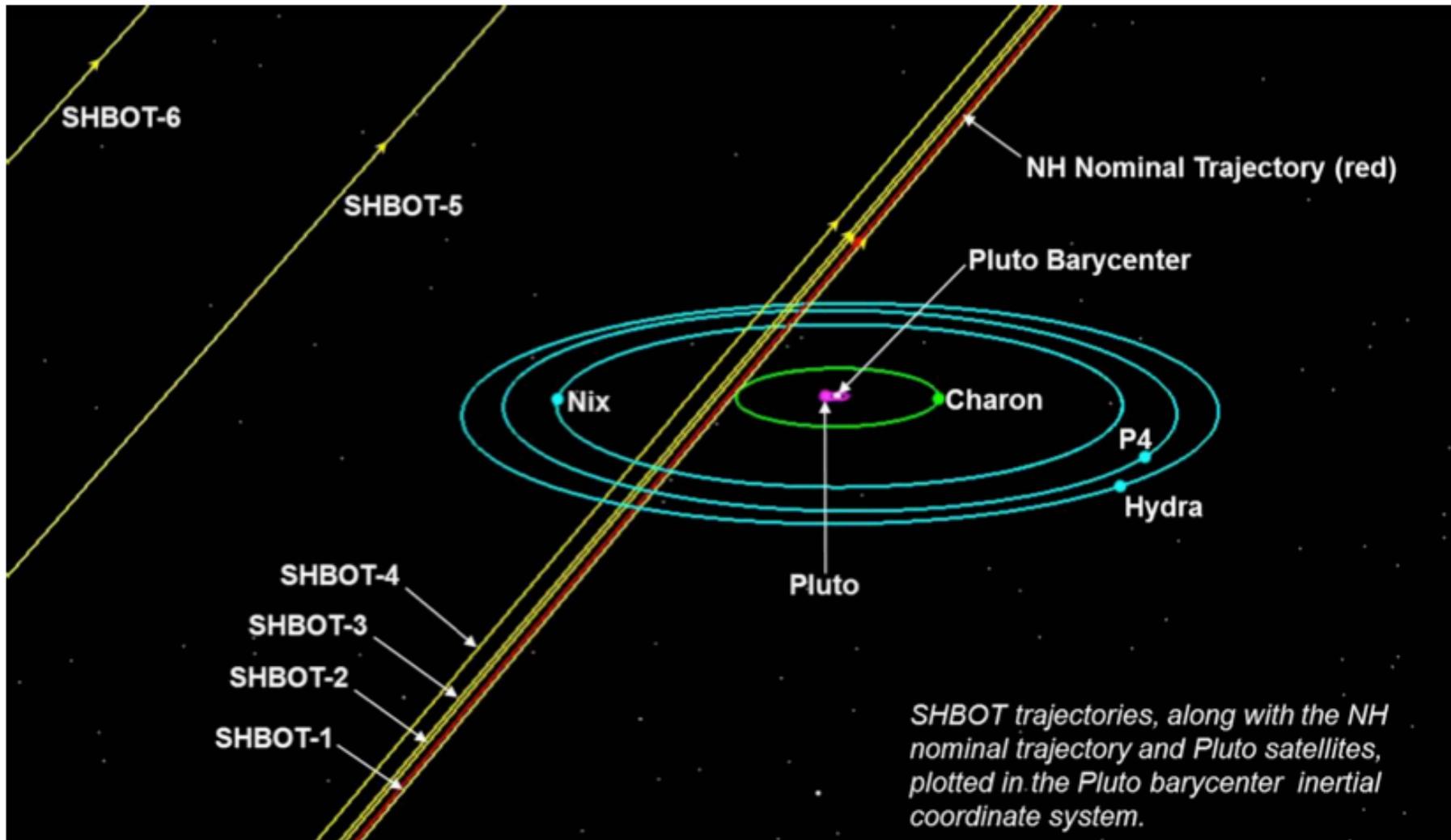
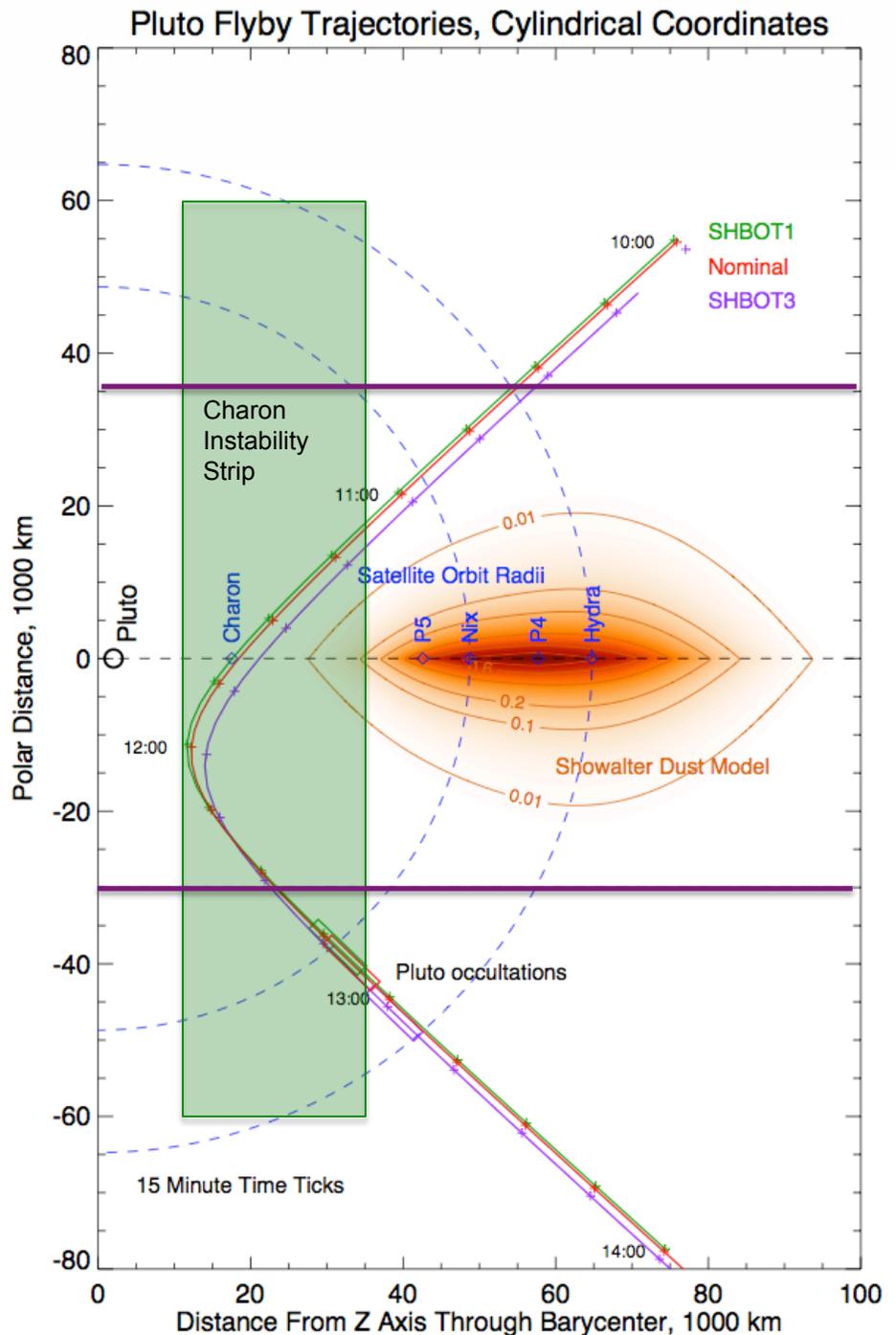


Figure 1. SHBOT trajectories plotted with respect to Pluto barycenter. Positions of Pluto, Charon, and other satellite are at 11:49:58 UTC on July 14, 2015.



Inner SHBOTs

- Nominal and SHBOT3 trajectories are shown in cylindrical coordinates, for ease of comparison to the Showalter dust model, with his assumed mean dust ejection speed of ~ 0.03 km/sec, consistent with the Youdin et al. mass upper limits
- Mutual collisions, not included in the Showalter model, will tend to flatten the dust distribution further
- The trajectories are outside the dust torus on approach to Pluto, and the nominal and SHBOT3 trajectory *occultations* are far removed from the dust torus, possibly enabling a Group 1 objective
- The nominal trajectory and inner SHBOTs penetrate the Pluto-Charon orbital plane when the spacecraft is inside the *Charon Instability Strip*, where Charon clears most debris from the system
- Current plan is to go Antenna To Ram (ATR) for the times between the horizontal purple lines



Hazard Mitigation (3)

- Theoretical investigations of stability of satellites and debris in the Pluto system
 - Held *Hazards Workshop* in Boulder on 2011 November 3-4
 - Assembled an international team of experts to investigate models of particle orbits in the Pluto system
 - Debris escaping from small satellites is *not* confined to the orbital plane of the known objects in the system (3-dimensional problem)
 - Region between Nix and Hydra is *not* a good choice for SHBOT
 - Family of stable orbits exists inside Charon's orbit, but unlikely to be populated
 - Charon clears region from its orbit out to $\sim 1.5x$ its orbit
 - Current baseline trajectory seems to be a *good* choice
 - Continue studying SHBOT cases to enable *optimal* selection during the coming year
- Astronomical Observations
 - Team has pushed satellite and debris searches to the limits of currently available capabilities
 - Hubble, Keck, ALMA, ...

In preparation for the flyby of the Pluto system culminating in July 2015, the New Horizons project team will hold a scientific conference at The Johns Hopkins Applied Physics Laboratory in Laurel, Maryland on 22-26 July 2013.

This conference will allow the mission science team and interested members of the planetary science community to:

--Integrate the broad range of existing datasets and perspectives about this system and its context in the Kuiper Belt.

--Discuss and begin to prepare ground-based and other observing proposals to provide additional context alongside the New Horizons encounter.

--And introduce potential new mission collaborators and those interested in participating in Pluto system data analysis programs to the details of the scientific investigations planned during the 6-month long New Horizons encounter.

Registration is now open!
Abstract Deadline is April 15:
<http://plutoscience.jhuapl.edu>

NEW Shedding Light on Frontier Worlds **HORIZONS**

**The Pluto System on the Eve of
Exploration by New Horizons:
Perspectives and Predictions**

**A Scientific Conference
July 22–26, 2013**



Co-Sponsored by:

**The Johns Hopkins University Applied Physics Laboratory
and
The Southwest Research Institute**

To be held at the Applied Physics Laboratory, Laurel, MD

Local Organizing Chair: Hal Weaver, New Horizons Project Scientist
Program Committee Chair: Alan Stern, New Horizons Principal Investigator