

# **New Horizons Pluto/KBO Mission**

## *Status Report for SBAG*

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The Johns Hopkins University Applied Physics Laboratory

# ***New Horizons: To Pluto and Beyond***

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

**KBOs  
2016-2020**

**Pluto-Charon  
July 2015**

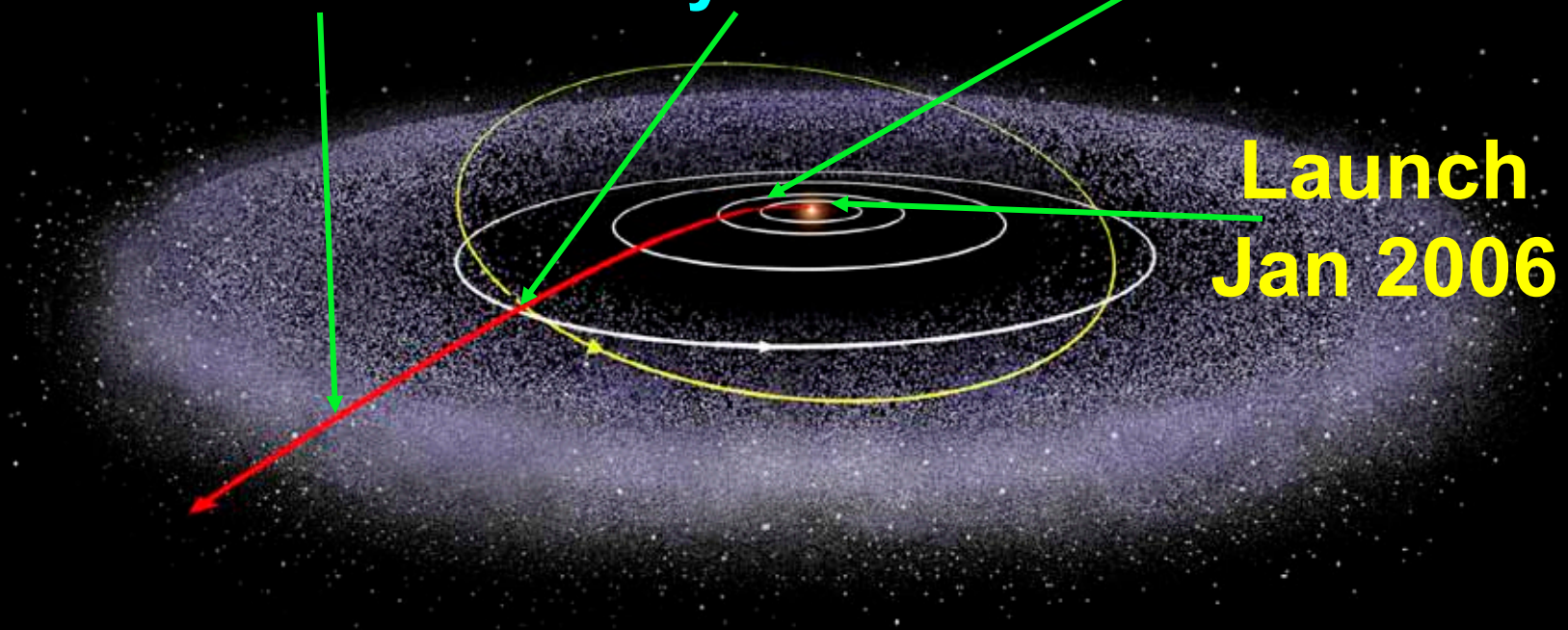
**Jupiter System  
Feb-March 2007**

**Launch  
Jan 2006**

***PI: Alan Stern (SwRI)***

***PM: JHU Applied Physics Lab***

***New Horizons is NASA's first New Frontiers Mission***



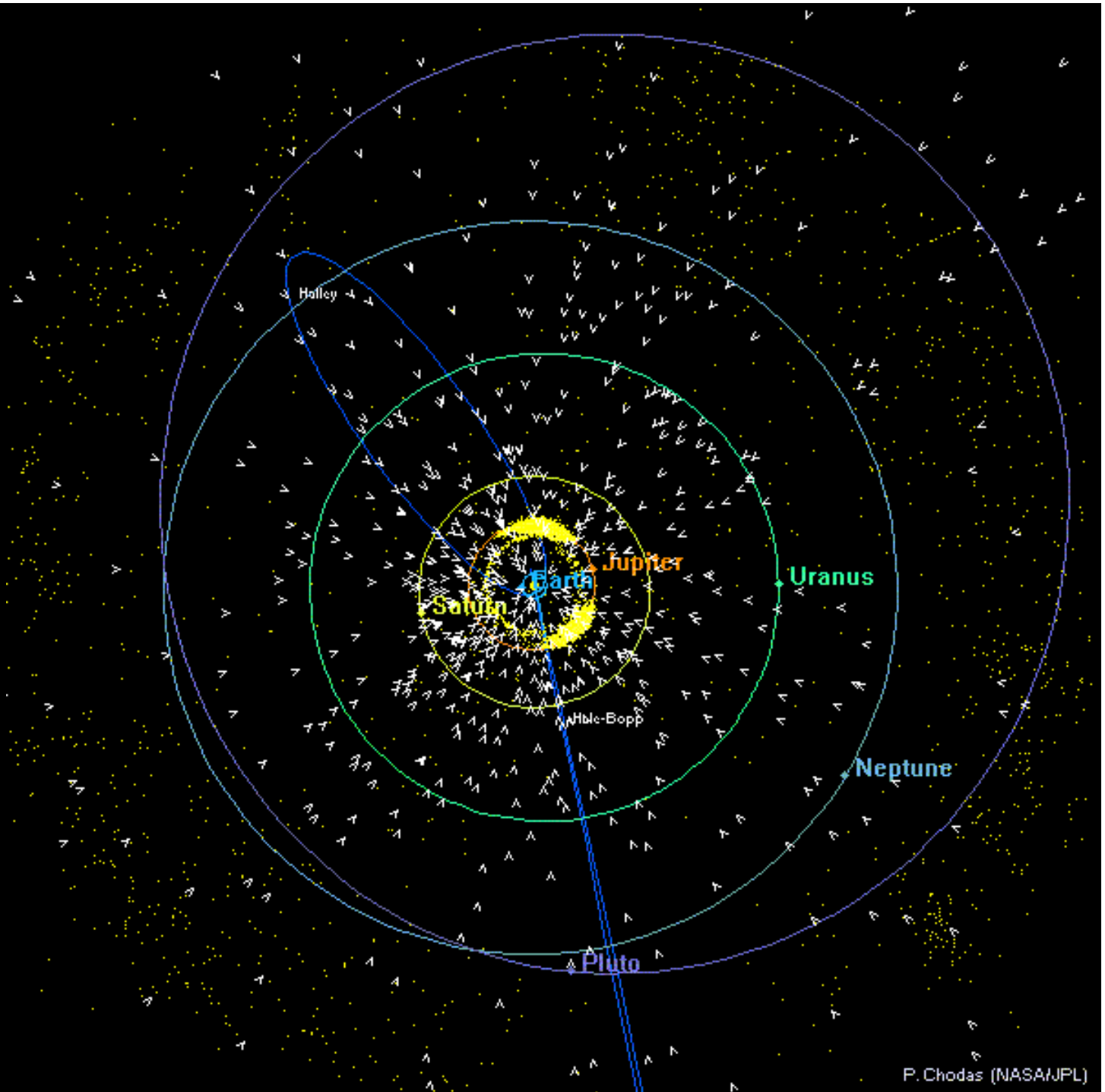
# Frontier of Planetary Science

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



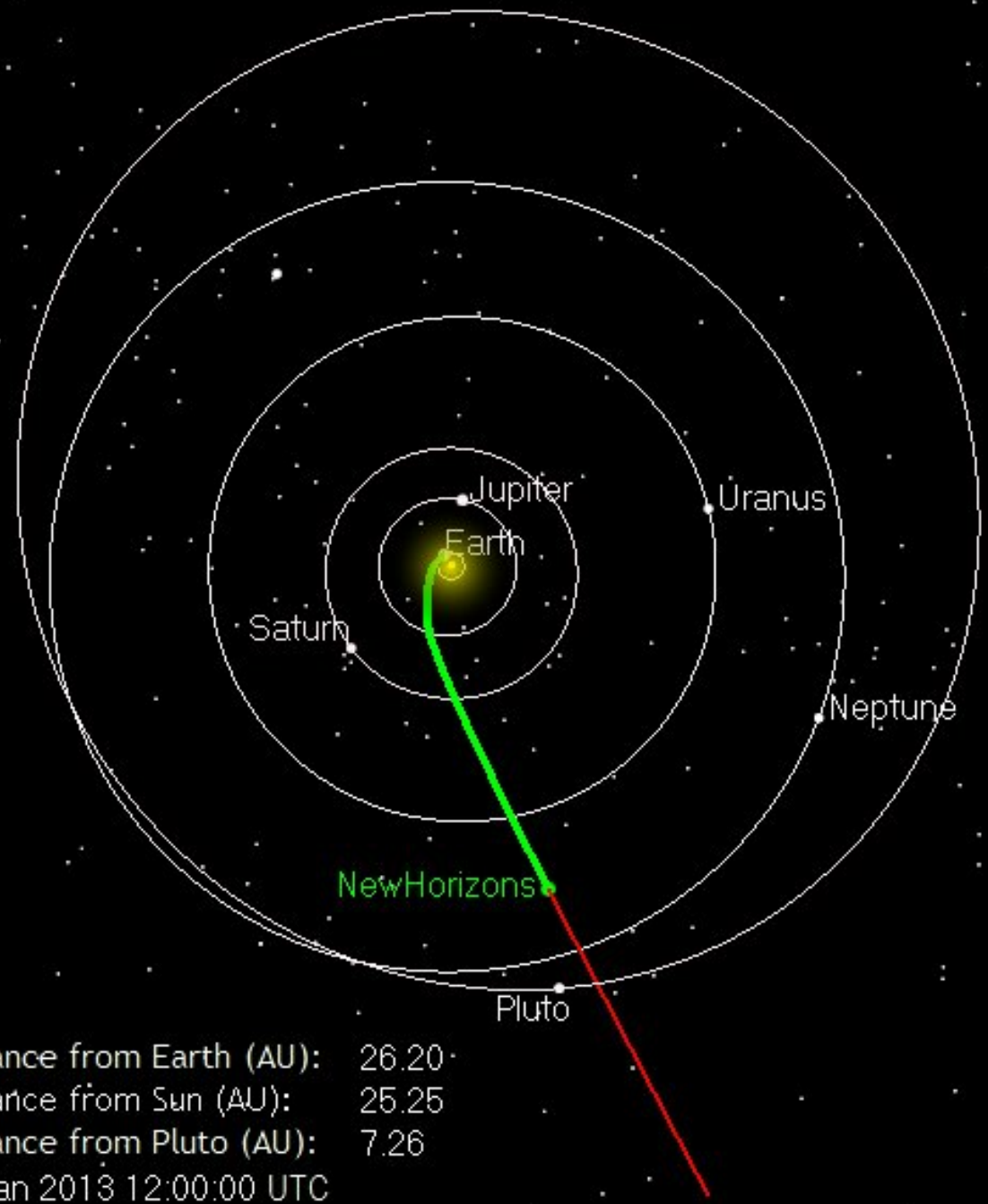
# New Horizons Now (overhead view)

## New Horizons Full Trajectory - Overhead View

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

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

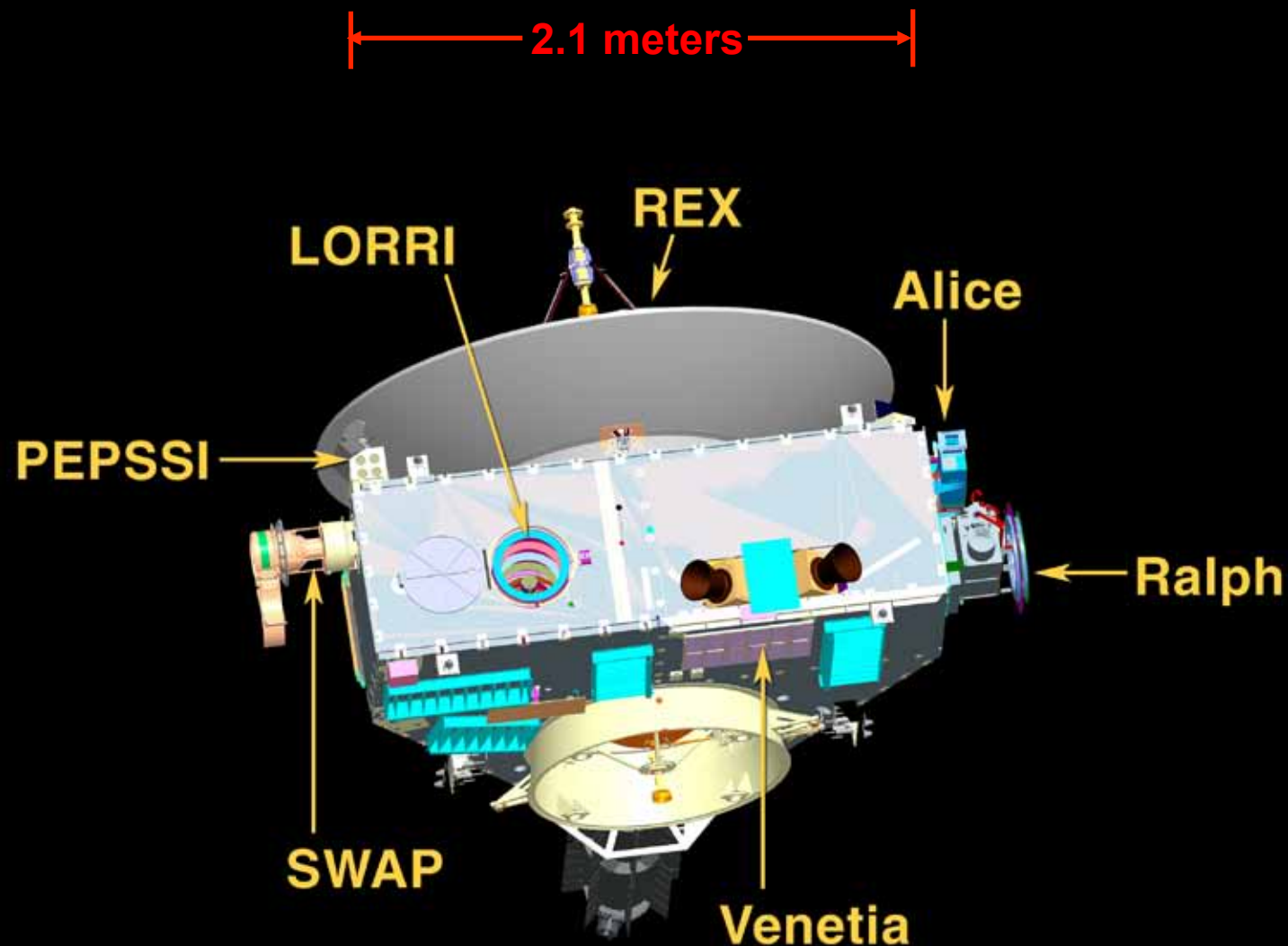
**Pluto Closest Approach  
2015-July-14**



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

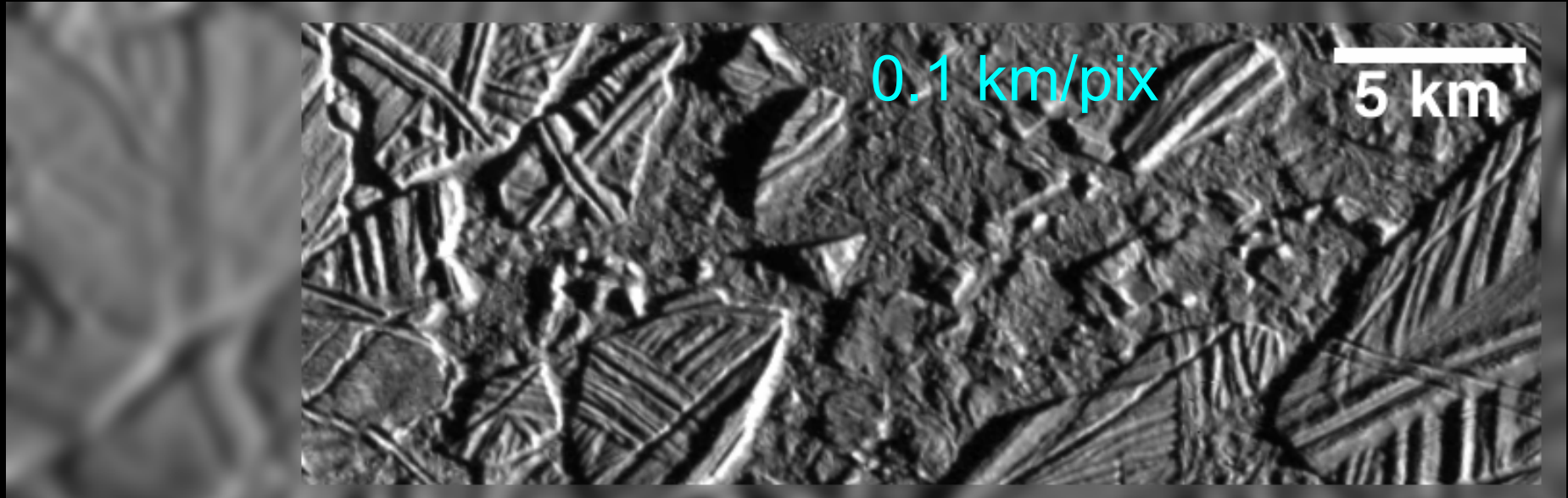
Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the time variability of Pluto's surface and atmosphere	Composition of dark surfaces on Pluto
Image Pluto and Charon in Stereo	"Far-side" imaging of Pluto and Charon
Map the terminators of Pluto and Charon with high resolution	"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 <sub>2</sub> , HCN, and C <sub>x</sub> H <sub>y</sub> , 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

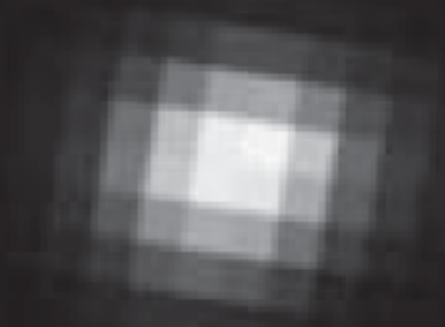
Specified by NASA	Added and ranked by New Horizons Science Team
Characterize the energetic particle environment of Pluto and Charon	Surface microphysics of Pluto and Charon
Refine bulk parameters (radii, masses, densities) and orbits of Pluto & Charon	Measure the surface temperatures of Nix and Hydra
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*

0.6 km/pix

This image shows a simulation of Pluto's surface features at a resolution of 0.6 km per pixel. The image is a grayscale simulation showing detailed surface textures and patterns.

# New Horizons Science Status

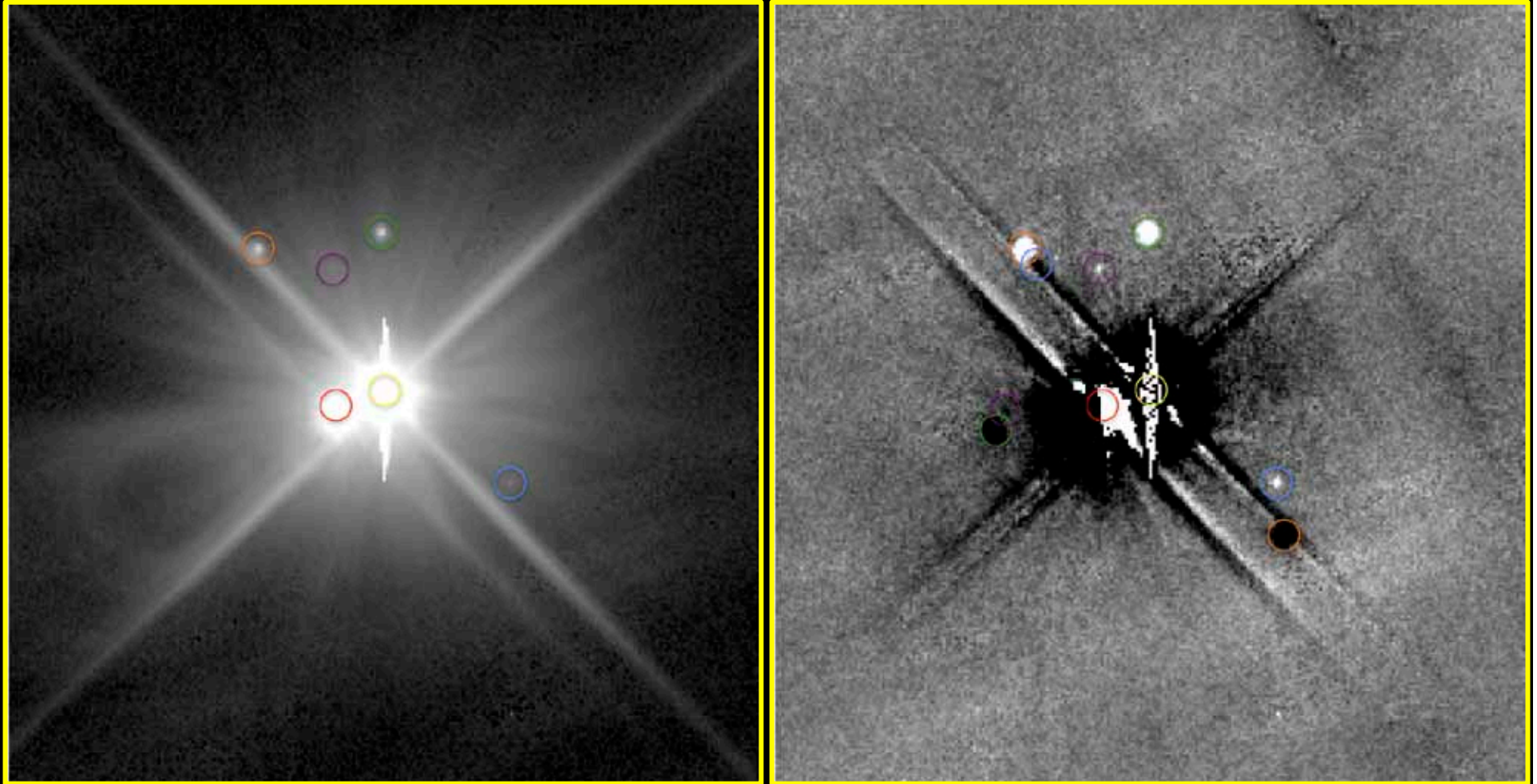
- New Horizons is on track to deliver the goods
  - The science objectives specified by NASA and the Planetary Community should be achieved, or *exceeded*
    - Nix, Hydra, P4, and P5 added (new discoveries)
    - More data collected than originally anticipated (~7x larger)
    - Only exception is direct 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")

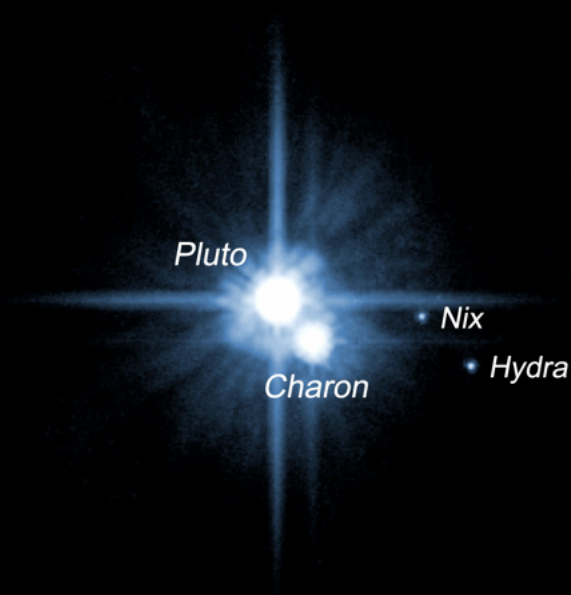
M. Showalter<sup>1</sup>, H. Weaver<sup>2</sup>, A. Stern<sup>3</sup>, A. Steffl<sup>3</sup>, M. Buie<sup>3</sup>, W. Merline<sup>3</sup>, M. Mutchler<sup>4</sup>, R. Soummer<sup>4</sup>, H. Throop<sup>5</sup>, <sup>1</sup>SETI Institute, <sup>2</sup>JHU/APL, <sup>3</sup>SwRI, <sup>4</sup>STScI, <sup>5</sup>PSI/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*

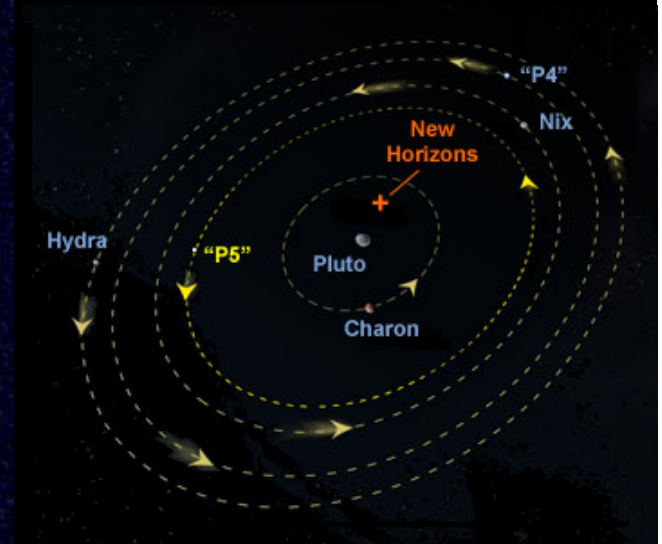
Hubble: May 2005



Hubble: July 2012



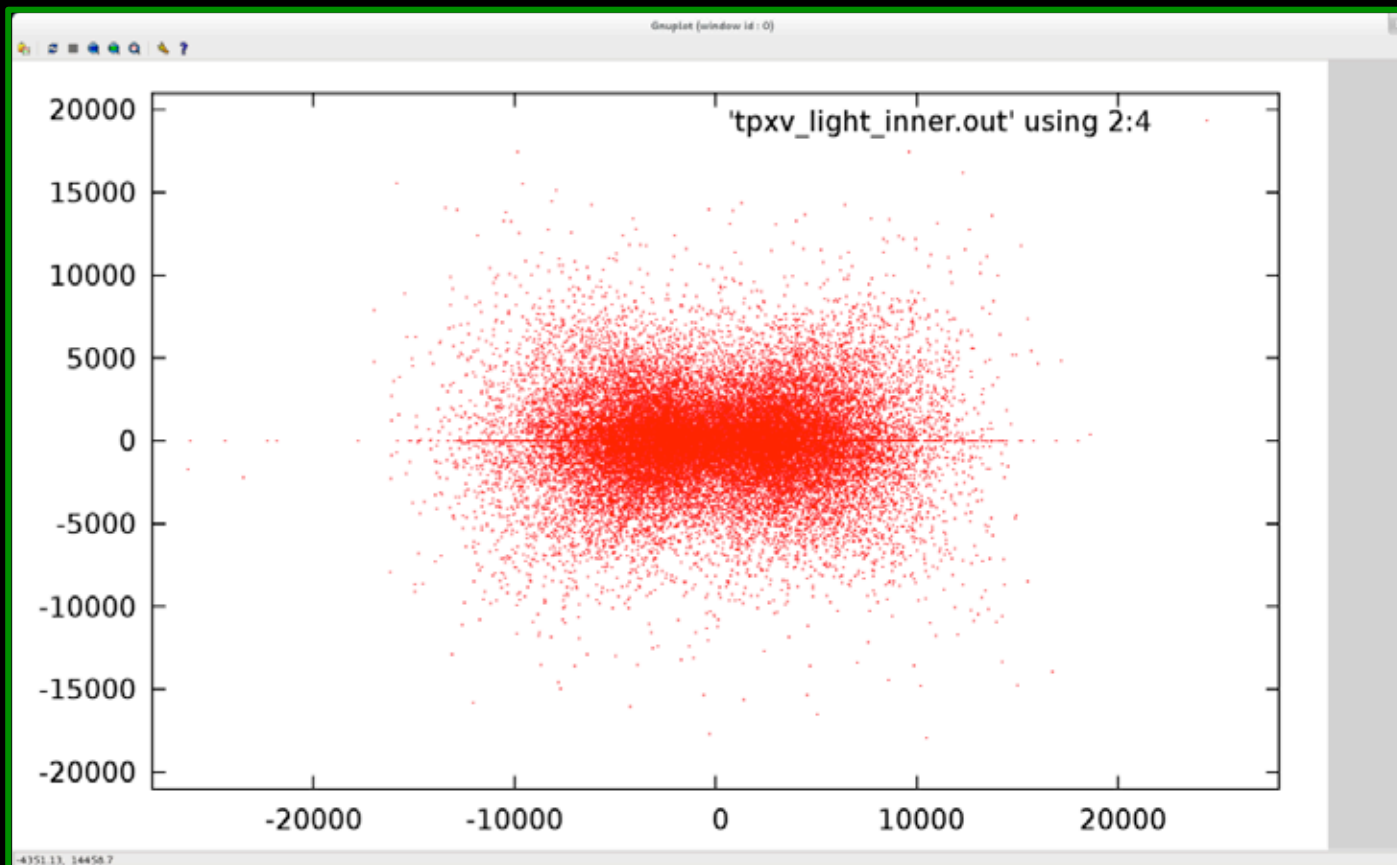
Pluto + 5 Moons



*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

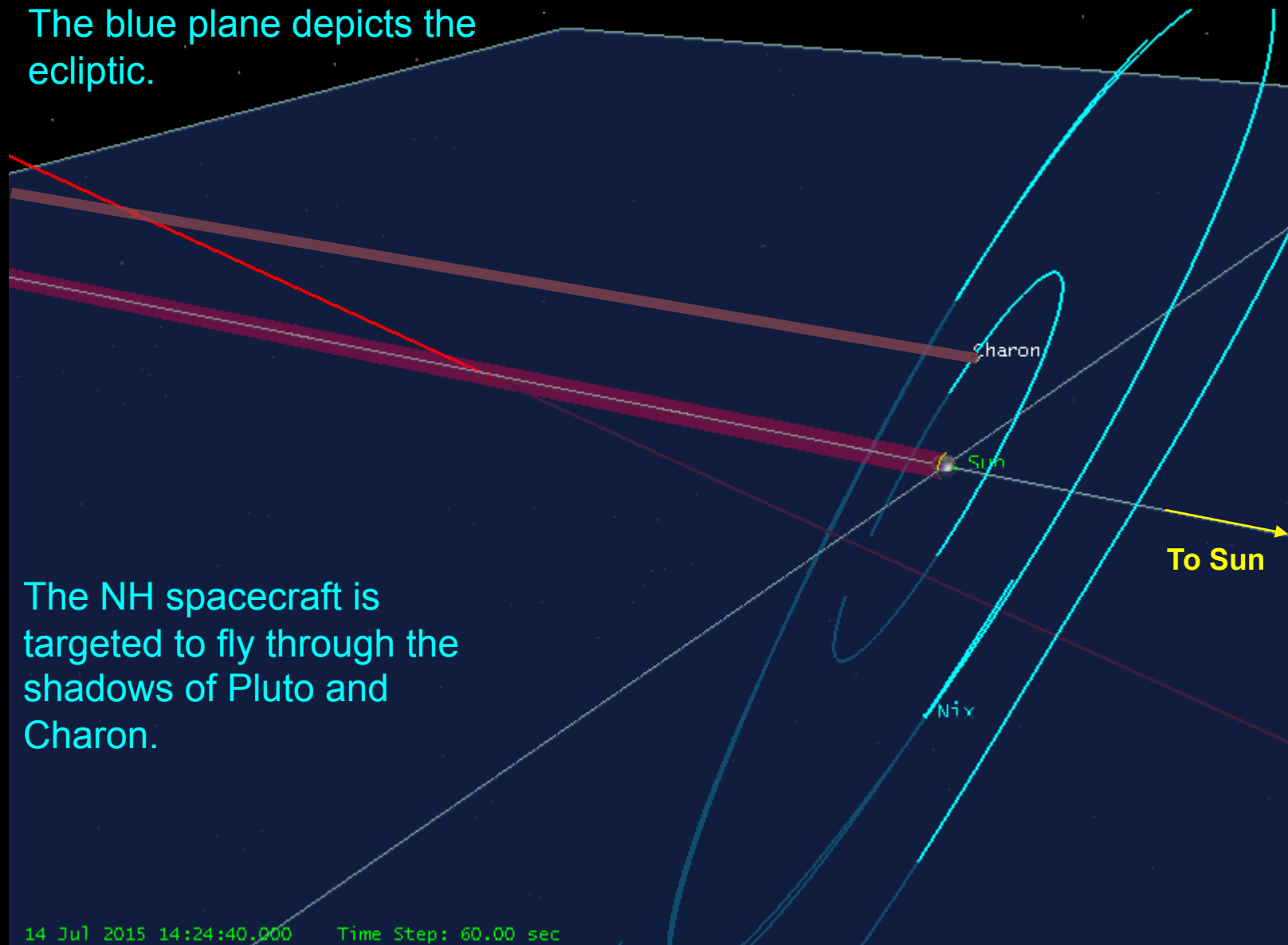
- The discovery of multiple satellites in the system raises the concern that *debris* associated with those satellites might pose a risk to the New Horizons spacecraft as it passes through the Pluto system.



# Pluto Encounter Geometry

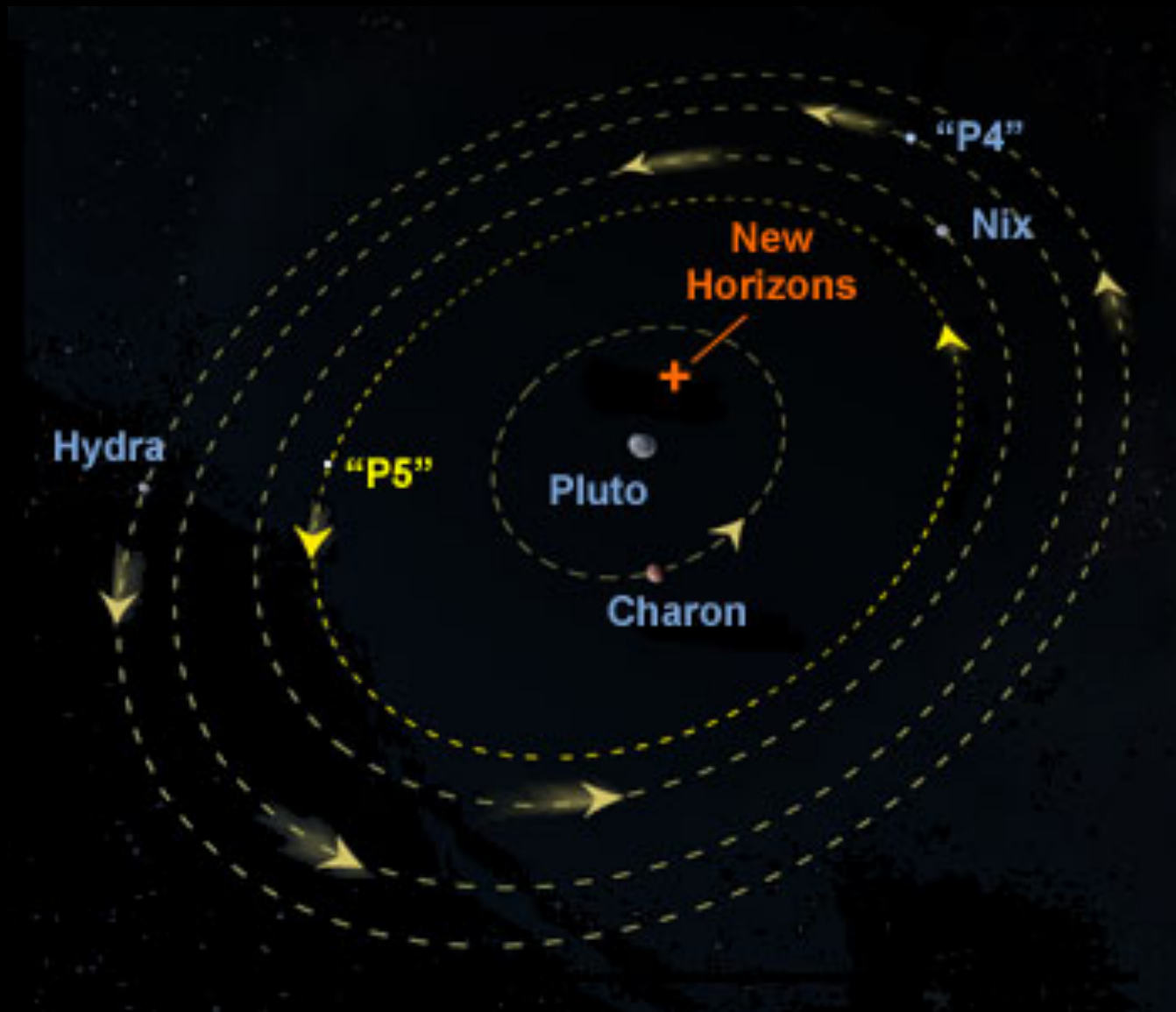
The blue plane depicts the ecliptic.

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

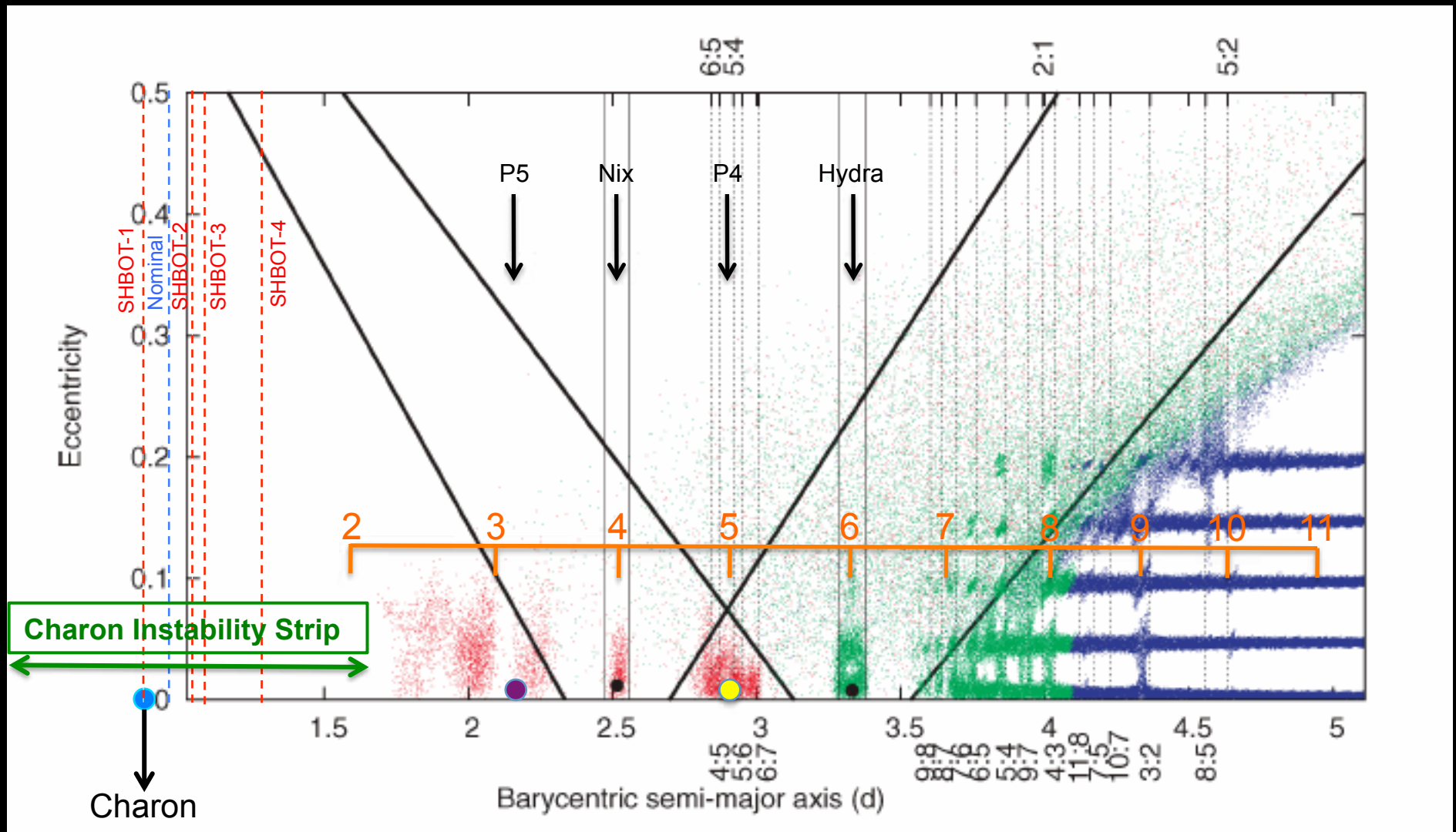




# Where is it safe?



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

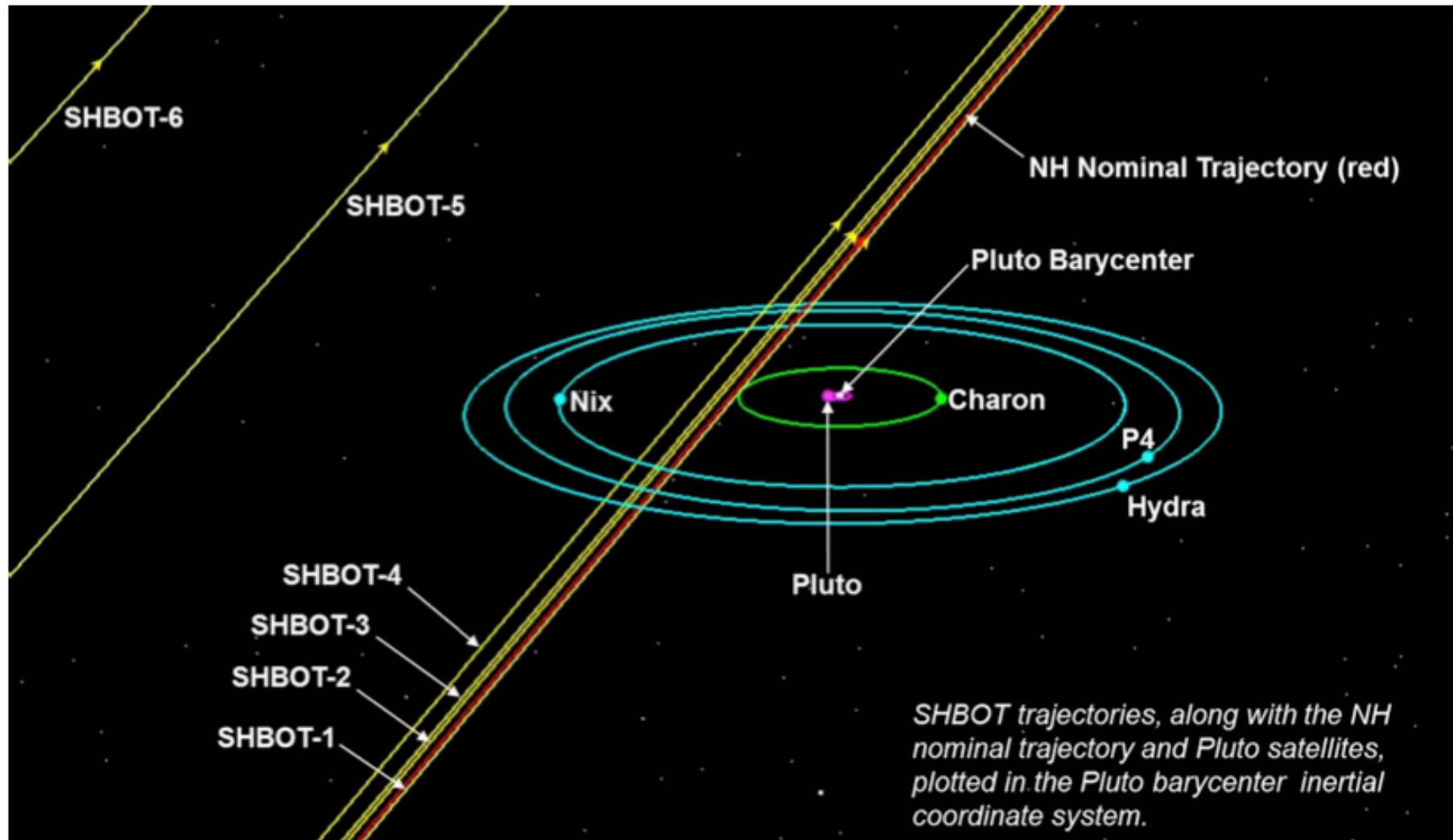
## Hazard Mitigation (2)

- 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

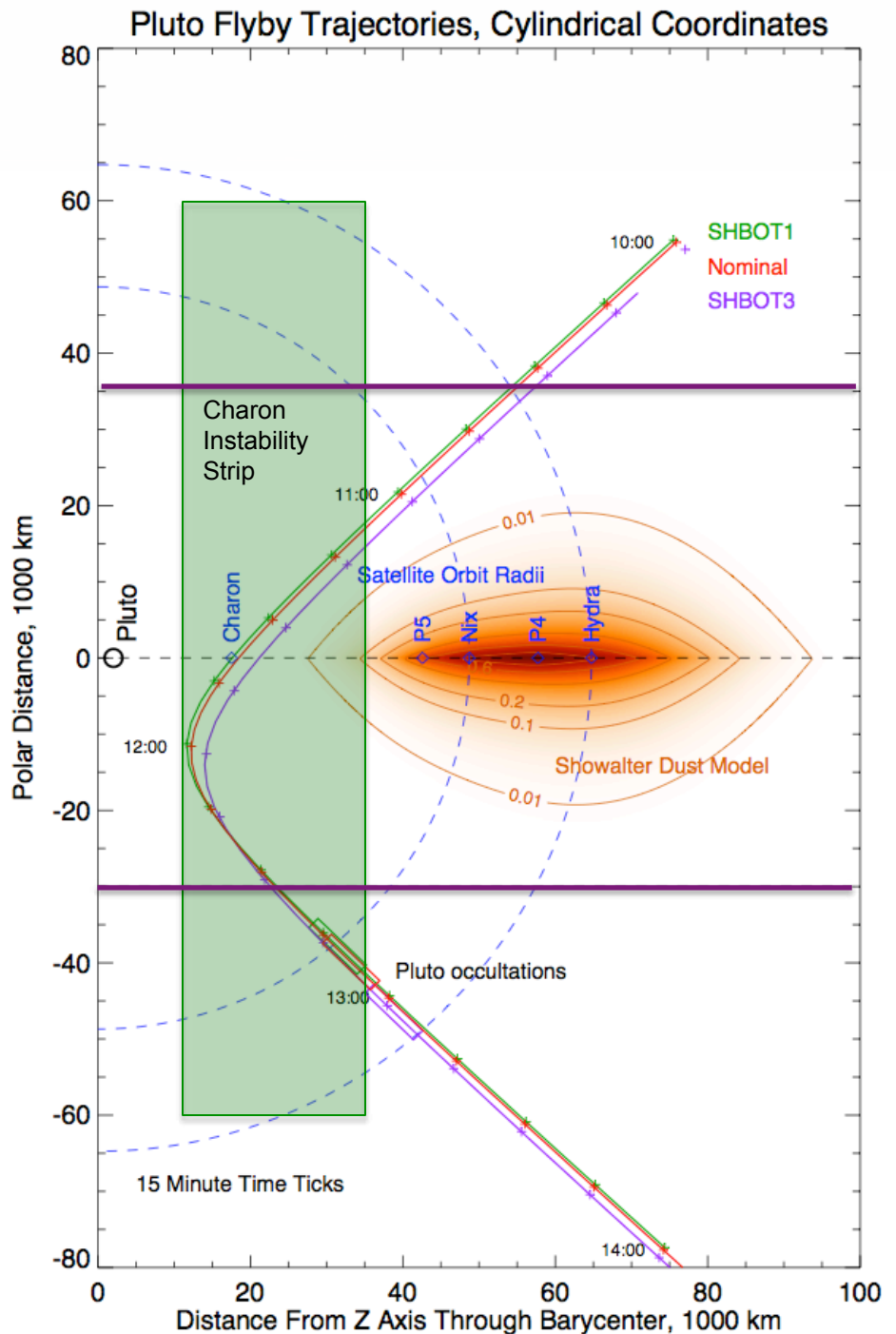


**Figure 1. SHBOT trajectories plotted with respect to Pluto barycenter. Positions of Pluto, Charon, and other satellite are at 11:49:58 UTC on July 14, 2015.**



# 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  $\sim 0.03$  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.

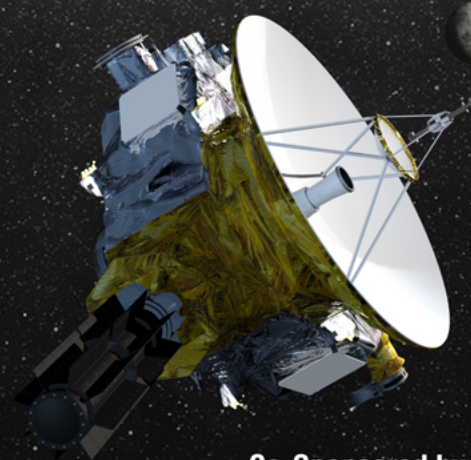
***Registration is now open!***  
***Abstract Deadline is April 15:***  
***<http://plutoscience.jhuapl.edu>***

# **NEW HORIZONS**

Shedding Light on Frontier Worlds

## **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