New Horizons CAPS Briefing

Alan Stern/New Horizons Mission PI
Southwest Research Institute

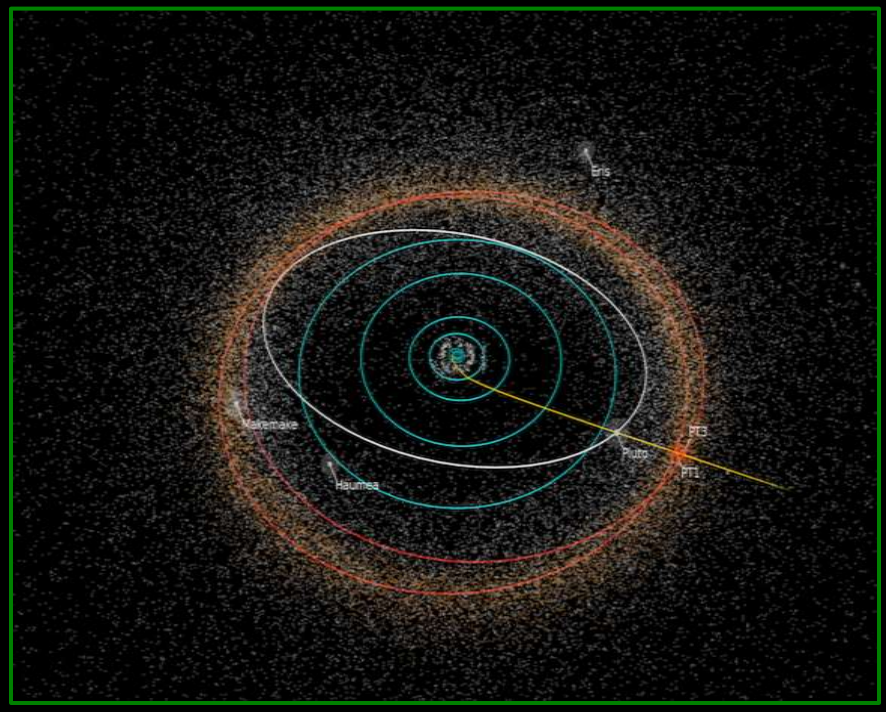
13 September 2017

Presentation Overview

- ❑ New Horizons is healthy and conducting a multi-pronged Kuiper Extended Mission (KEM) to study the Kuiper Belt to 50 AU: 2016-2021.

- ❑ Close flyby of the cold classical KBO 2014 MU69 on 1 Jan 2019. MU69 downlink thru ~ September 2020.

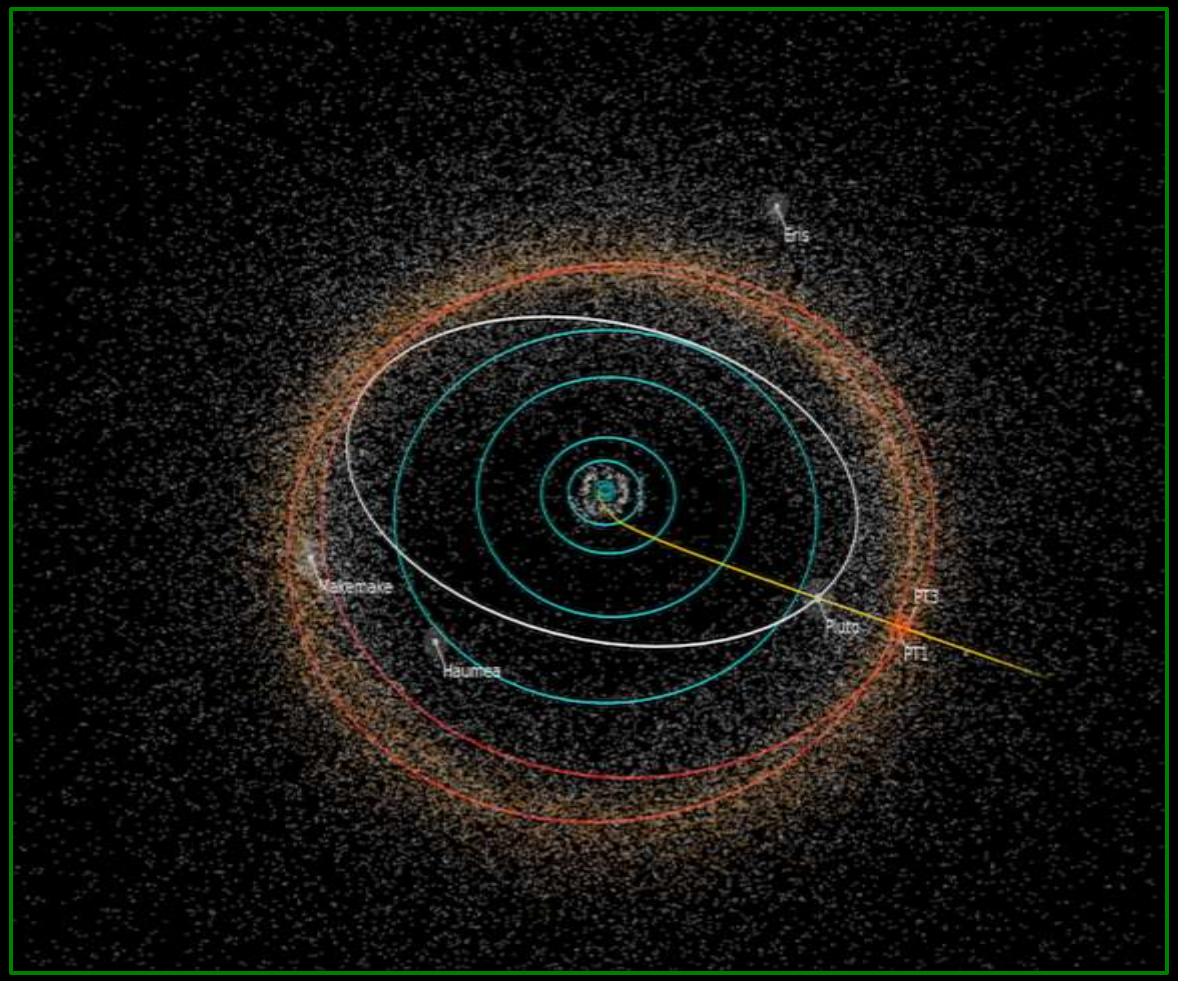
- ❑ Spacecraft ended hibernation 11 Sep to begin active science ops, instrument calibrations, and TCM thru December.



- ❑ Power and fuel to operate to ~2035.

- ❑ <u>Presentation Topics for Today</u>:
  - ✓ Brief Pluto Mission Update
  - ✓ Extended Mission Update
  - ✓ Discuss Pluto/KB Follow On Missions.

PKB-New Horizons Mission Background

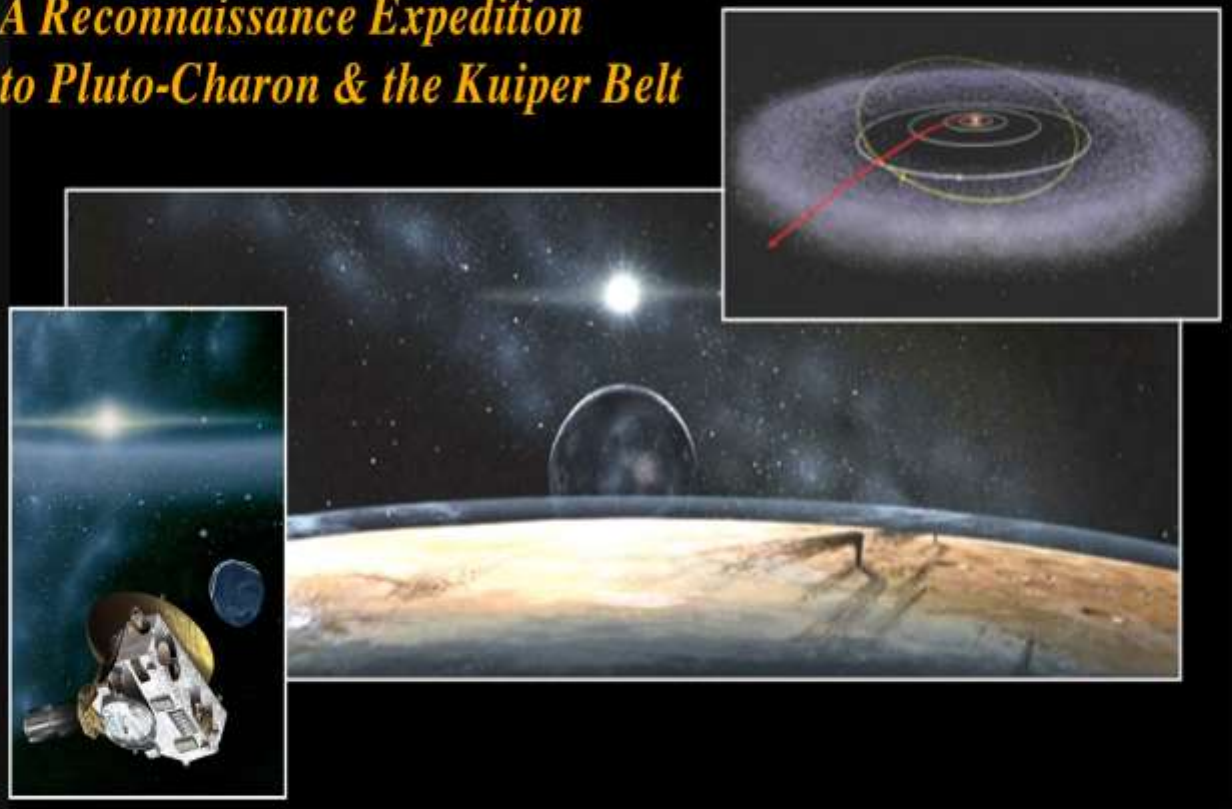


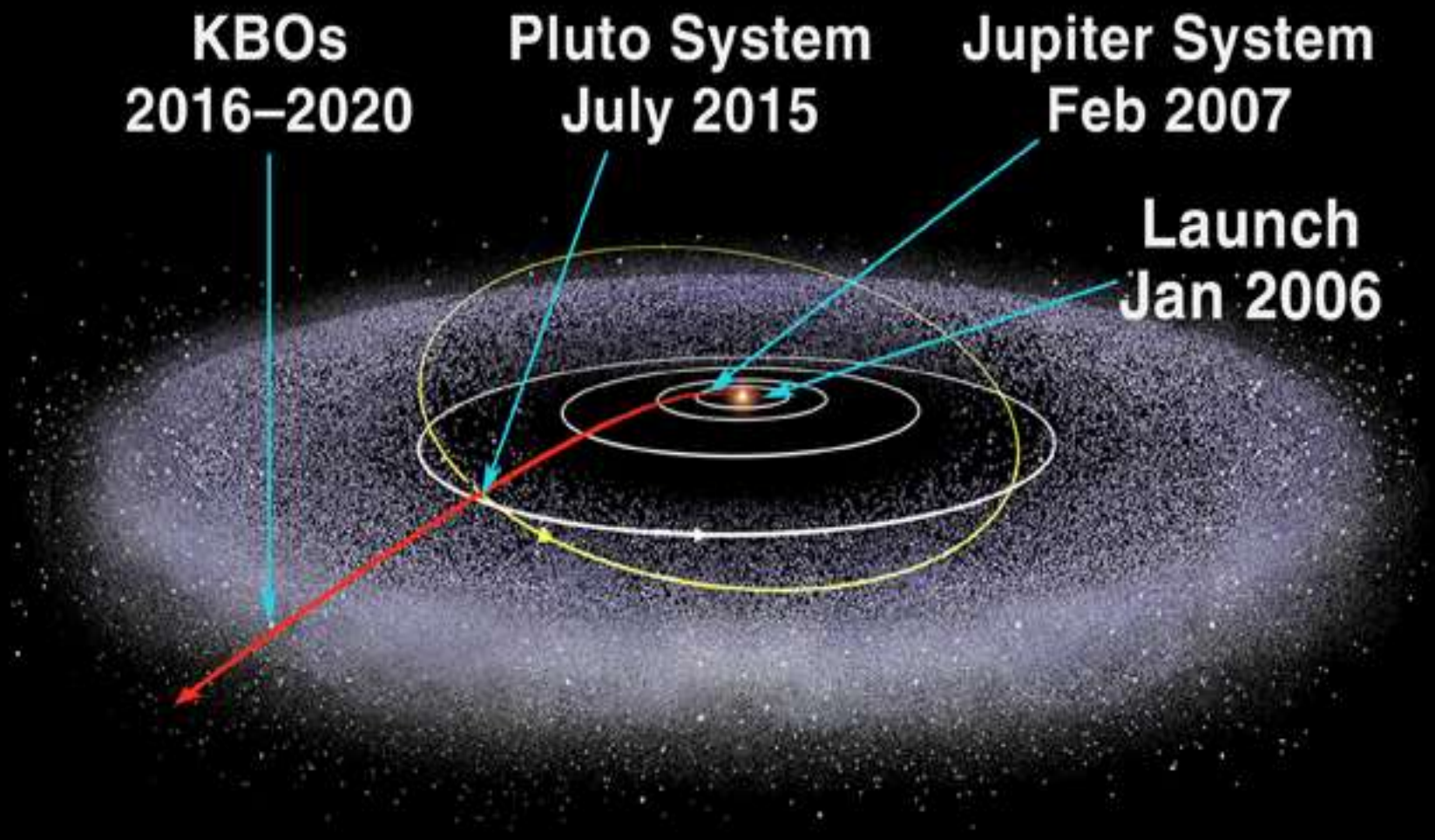
Mission Background:

- ✓ Long Series of PKB Mission New Start Attempts 1990-2000.
- ✓ Then PKB was the Highest Priority of 2003 DS for Medium Missions.
- ✓ New Horizons Selected Competitively via PKB AO.
- ✓ SwRI-APL Lead the Team.
- ✓ Launched in 2006.
- ✓ Total NASA RY Cost $807M thru EM1 Completion (FY21).

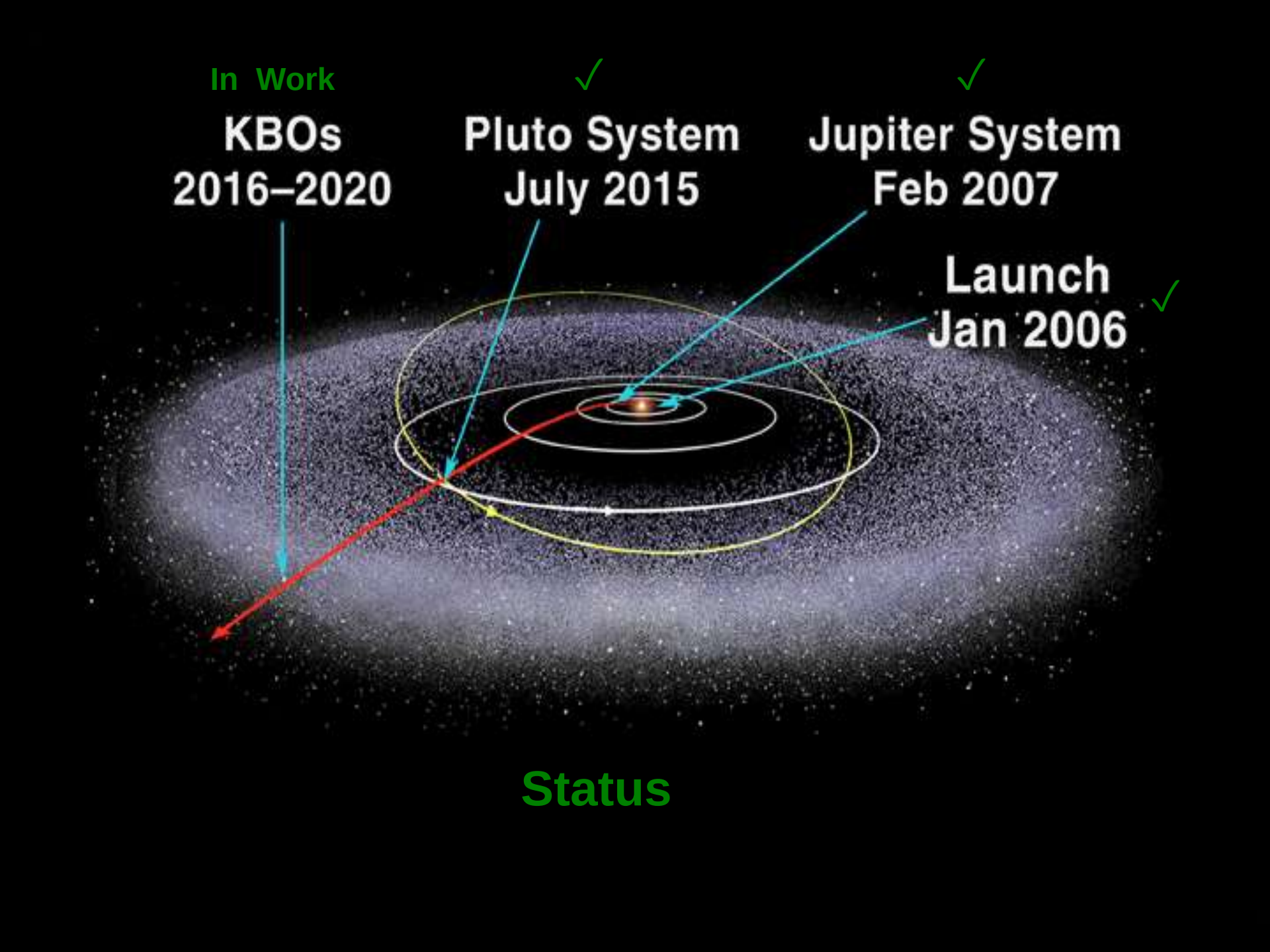
Highest Funding Priority Medium-Scale Mission
New Start of the 2003 Planetary Decadal Survey:

A Reconnaissance Expedition
to Pluto-Charon & the Kuiper Belt




KBOs
2016–2020
Pluto System
July 2015
Jupiter System
Feb 2007
Launch
Jan 2006

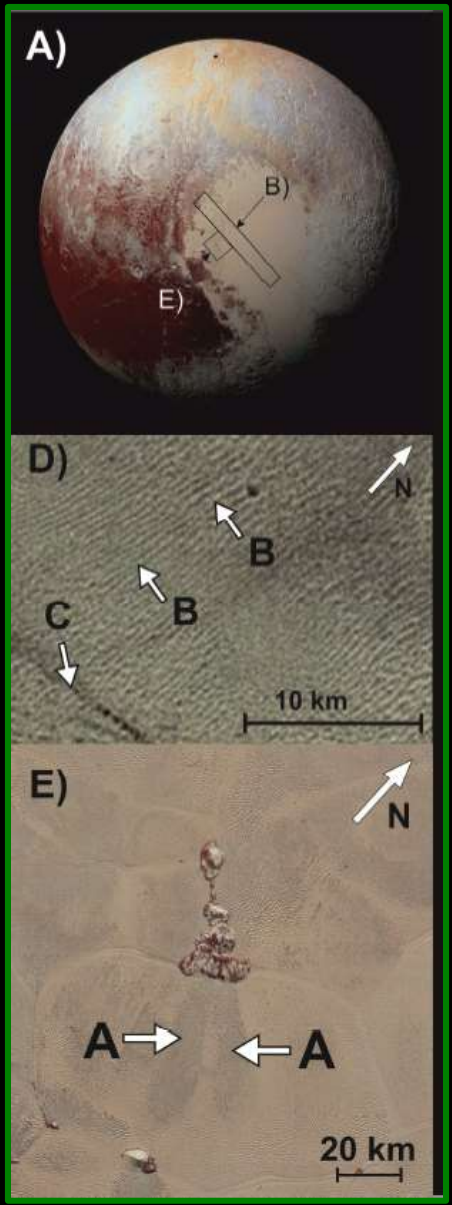
The Plan

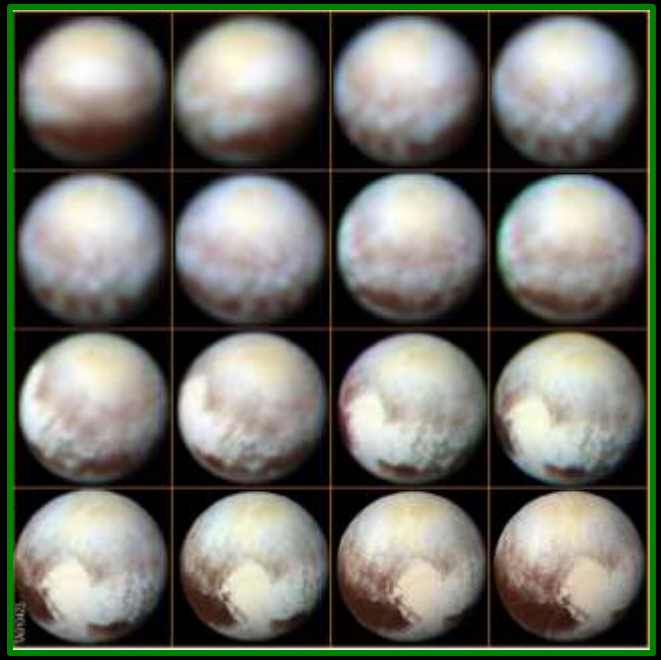

In Work
KBOs
2016–2020
✓
Pluto System
July 2015
✓
Jupiter System
Feb 2007
Launch
Jan 2006
✓
Status

Pluto Flyby "Top 10" Findings

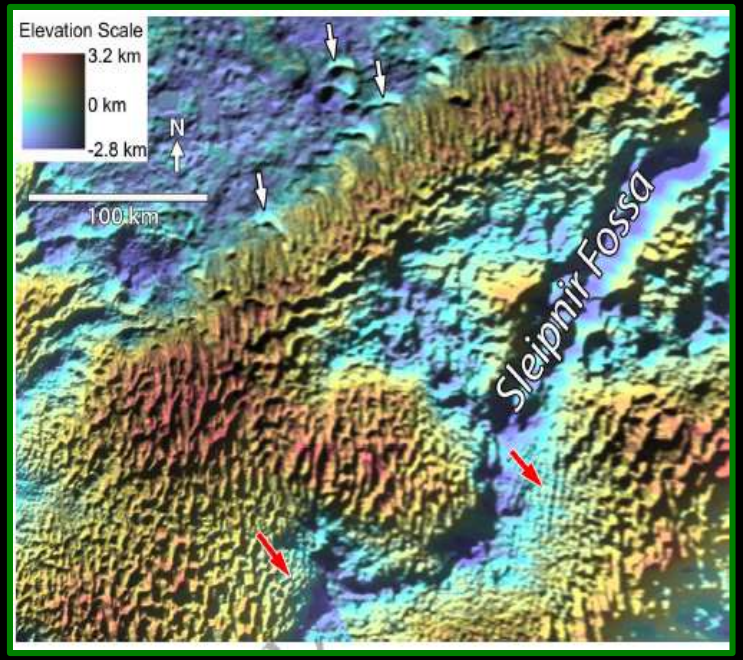
- The complexity of Pluto and its satellites.
- The degree of continuing and long term activity on Pluto's surface.
- The vast, 1000 kilometer-wide Sputnik Planitia N_2 glacier.
- Extensive, well organized atmospheric hazes.
- Dramatically reduced atmospheric escape rate vs. predictions.
- Evidence for strong changes in atmospheric pressure and the possible past presence of running or standing liquid volatiles on Pluto's surface.
- A possible liquid water interior ocean at Pluto.
- Charon's enormous equatorial extensional tectonic belt hints at the freezing of a former water ice inside Charon.
- Charon's dark, red polar cap.
- The lack of new satellites.

Some More Recent Results





Far Side Heterogeneity (Olkin et al., Icarus, submitted 2017)



Bladed Terrains (Moore et al., Icarus, submitted 2017)

Dunes and Wind Streaks (Telfer et al., Science, submitted 2017)

Pluto Prime Mission Update

- **All Pluto Data to Earth: October 2016**
- **All Pluto data delivered to PDS (April 2017); Pluto Mission Metadata to PDS: September 2017**
- **NH Science Team Continuing to Produce Papers at a Steady Clip:**
  - May 2017 Icarus special issue with 24 papers
  - >50 abstracts submitted for the 2017 DPS (October) and AGU (December)
  - Just published:
    - Kammer et al. on O_2 limits in Pluto's atmosphere (*Astron. J.*)
  - Recent Reviews:
    - Nature (Olkin et al 2017)
    - ARAA (Stern et al. 2018)
  - Recently accepted :
    - Dalle Ore et al. (Icarus) Charon's surface composition
    - Moore et al. (Icarus) Pluto's bladed terrain
    - Young et al. (Icarus) UV solar occultation
  - Recently submitted:
    - Bierson et al. (2017)
    - Cook et al. (Icarus) Composition of small satellites
    - Cook et al. (Icarus) Water ice distribution on Pluto
    - Grundy et al. (Icarus) Pluto haze as source of dark, red surface material
    - Hinson et al. (Icarus) Pluto's ionosphere
    - Lauer et al. (Icarus) Ring/debris constraints
    - Linscott et al. (Icarus) Pluto surface thermal measurements (REX)
    - Schenk et al. (Icarus) Pluto DEM
  - Numerous papers being circulated internally before submission; examples:
    - Olkin et al. Pluto surface colors
    - Schenk et al. Charon DEM
- **Next NH Science Team Meeting is 2018 Jan 17-19, at APL; Open to All.**

Extended Mission Background

16-PMSR16-0001
Alan Stern

Panel Summary Evaluation Form

Proposal No.:	16-PMSR16-0001
Organization:	Southwest Research Institute
PI Name:	Alan Stern
Proposal Title:	New Horizons Kuiper Belt Extended Mission
Solicitation Title:	PMSR16 – Solar System Exploration (SSE) – May 16-18, 2016
Solicitation Number:	PMSR16 Solar System Exploration
Science Merit Evaluation:	Excellent

Proposal Summary:

The proposed Kuiper Belt Extended Mission (KEM) would perform a close (3000 km) flyby of a ~30 km KBO, 2014 MU69, in 2019. During the flyby, the New Horizons spacecraft would collect images and spectroscopy of this object in an effort to provide a detailed study of its composition, volatile content and distribution, any satellites or ring structures, and evolution. In addition, remote observations of a sample of other KBOs would be made from 2016-2020 to collect lightcurves and phase curves, and to perform a search for evidence of rings or extended emission. The KEM also includes sampling of the local environment, including particle counts, dust, and plasma with significantly improved sensitivity compared to the Voyager missions.

2016:

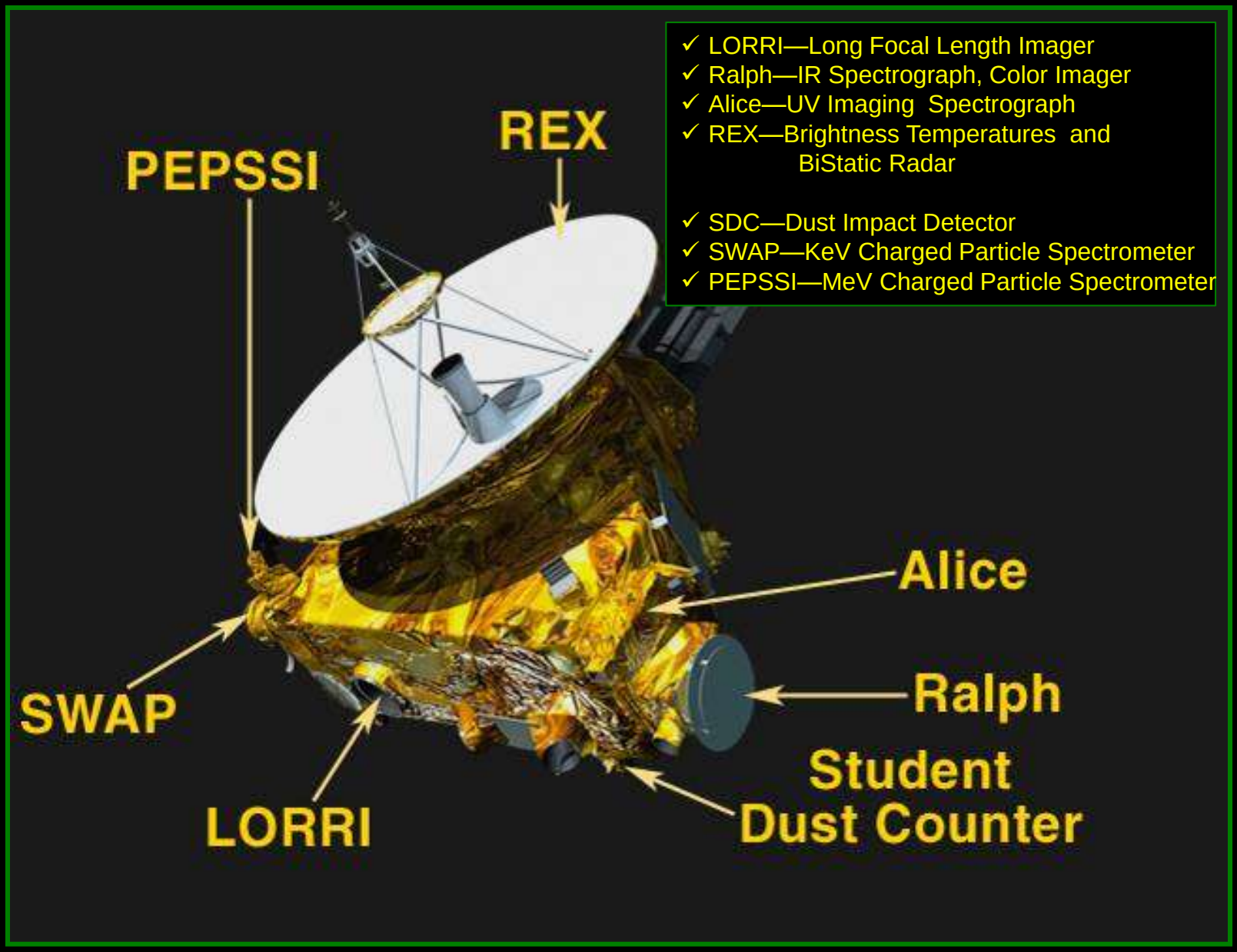
- ✓ NH 5-Year KEM PMSR Proposal 2016-2021.
- ✓ Senior Review Score: Excellent.
- ✓ Proposal Accepted, Fully Funded.
- ✓ KEM Start 01 Oct 2016.

Extended Mission Overview

SMD Senior Review process approved a 5-year, 2016-2021 KB exploration mission, including:

- ✓ **Distant observations of 24-30 other KBOs and numerous Centaurs (2016-2020).**
- ✓ **KB heliospheric plasma/dust/neutral gas transect to 50 AU (2016-2021).**
- ✓ **The 2018-2019 close flyby of KBO 2014 MU_{69}.**
- ✓ **Target of opportunity KBO mutual events, stellar occultations, etc., as they present themselves.**

New Horizons Scientific Payload



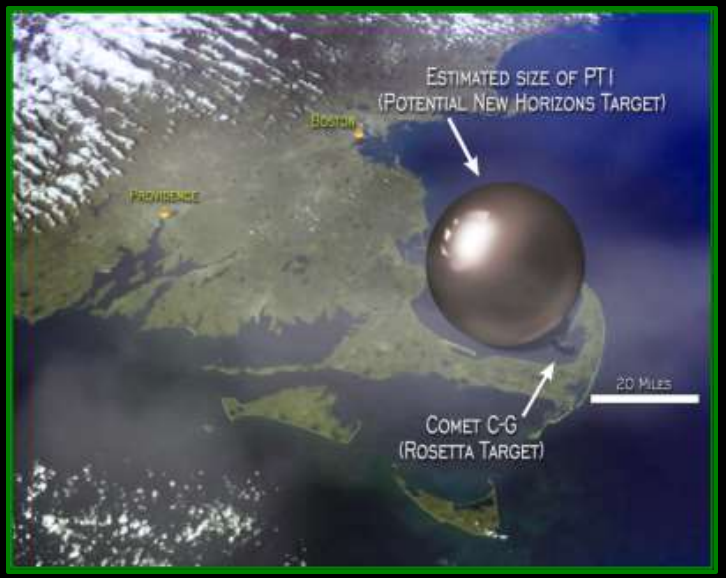
Extended Mission Science Objectives

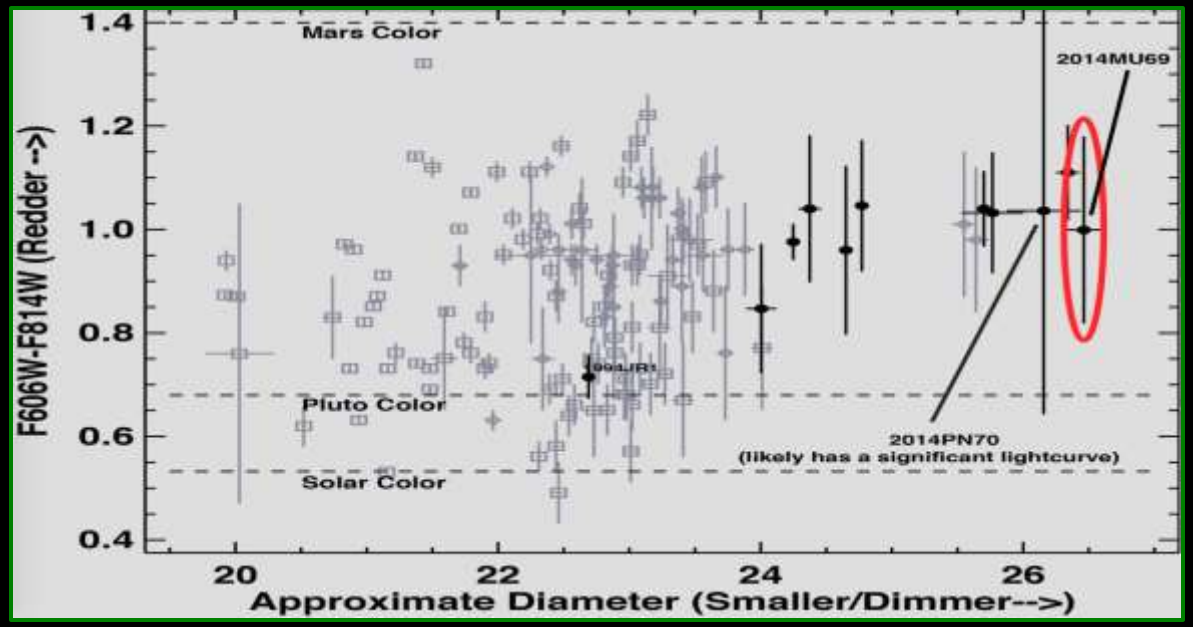
Science Objectives		
Group	**Science Objective**	**Entire Payload Employed**
1	Characterize the global geology, morphology, and rotational characteristics of MU69	✓ Imaging, Stereo
1	Map surface composition of MU69	✓ IR Spectroscopy
1	Search for any satellites and rings of MU69	✓ Imaging
2	Characterize composition and magnitude of any volatile or dust escape from MU69	✓ Imaging, UV Spectroscopy
2	Physical properties of MU69 surface	✓ Imaging, IR Spectroscopy
2	Determine MU69 crater size/frequency distributions	✓ Imaging
2	Properties of any MU69 satellites and rings, to the extent possible	✓ Imaging
2	Properties of distant KBOs	✓ Imaging, IR Spectroscopy
3	Constrain MU69 solar wind, charged particle interaction	✓ Imaging
3	Characterize plasma and dust environment (near 42 - 46 AU) as it pertains to understanding MU69 and other CCKBOs	✓ Charged Particle Spectra
3	Characterize plasma, neutral gas, and dust environment across the Kuiper Belt (35 - 50 AU)	✓ Charged Particle Spectra, Dust Counter, Radio, Imaging
3	Constrain bulk parameters (mass, density) of MU69	✓ Dust Counter, Charged Particle Spectra, UV Spectroscopy
3	Characterization of scattering properties of any satellites and rings of MU69	✓ Imaging, Radio
	Supplementary compositional studies of MU69	✓ Imaging
3	Microwave scattering properties of MU69	✓ IR and UV Spectroscopy
3	Time Variability of MU69	✓ BiStatic Radar
		✓ Various

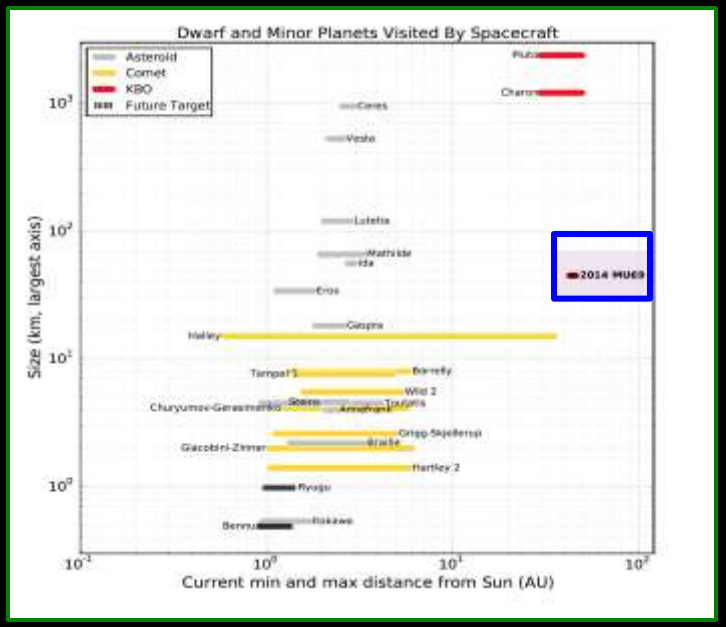
2014 MU69 Flyby

2014 MU_{69} Overview

V Mag	~27.5
Diameter (p~0.11)	~30 km
Color (vs. Pluto)	~0.3 mag
Semi-major Axis	44.2 AU
Eccentricity	0.036
Inclination	1.9 deg
Cold Classical	Primordial



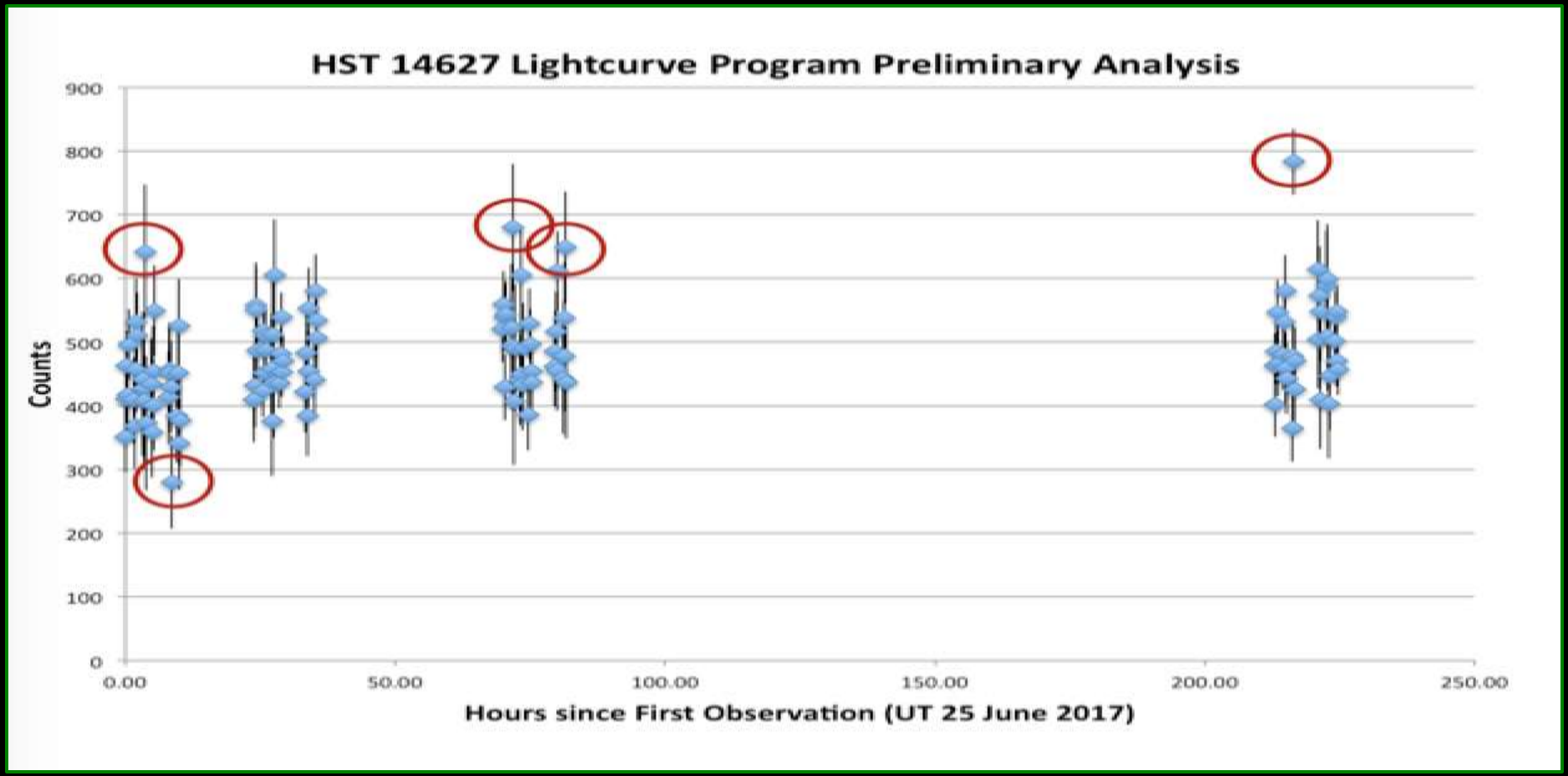




New MU69 Results 1: HST

2017 HST Lightcurve Program (Benecchi et al. 2017, in prep.):

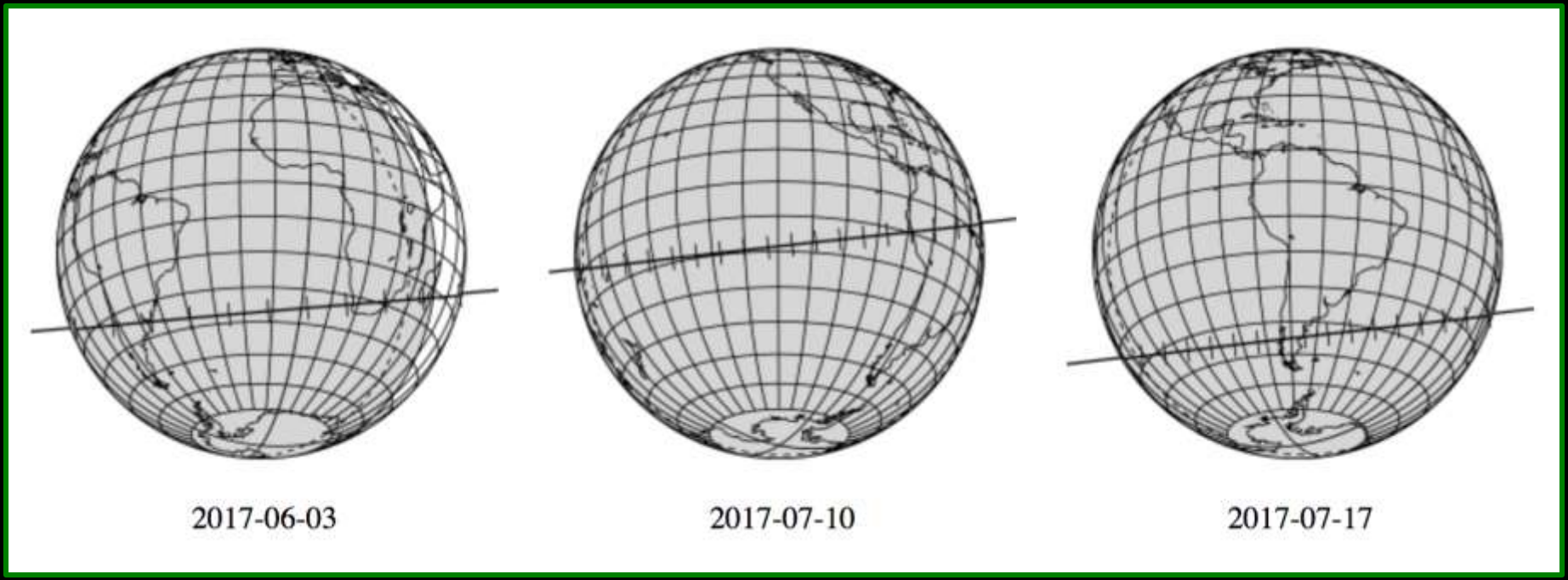
- **Low Lightcurve Amplitude (<20%)**
- **24 New Astrometric Data Points**



Occultation Opportunities

Three 2017 2014 MU_{69} Stellar Occultation Opportunities:

- **Sky Velocity: 20-24 km/s, hence 1-2 second events.**
- **Requires milliarcsec positional precision using HST & Gaia.**
- **Objectives: Size, albedo, binarity, dust hazard, astrometry.**



Portable Telescopes

- SwRI: 22 16-inch Portable Dobsonian Telescopes
- UVA: 3 Additional Portables, Including 24-inch Dobsonian

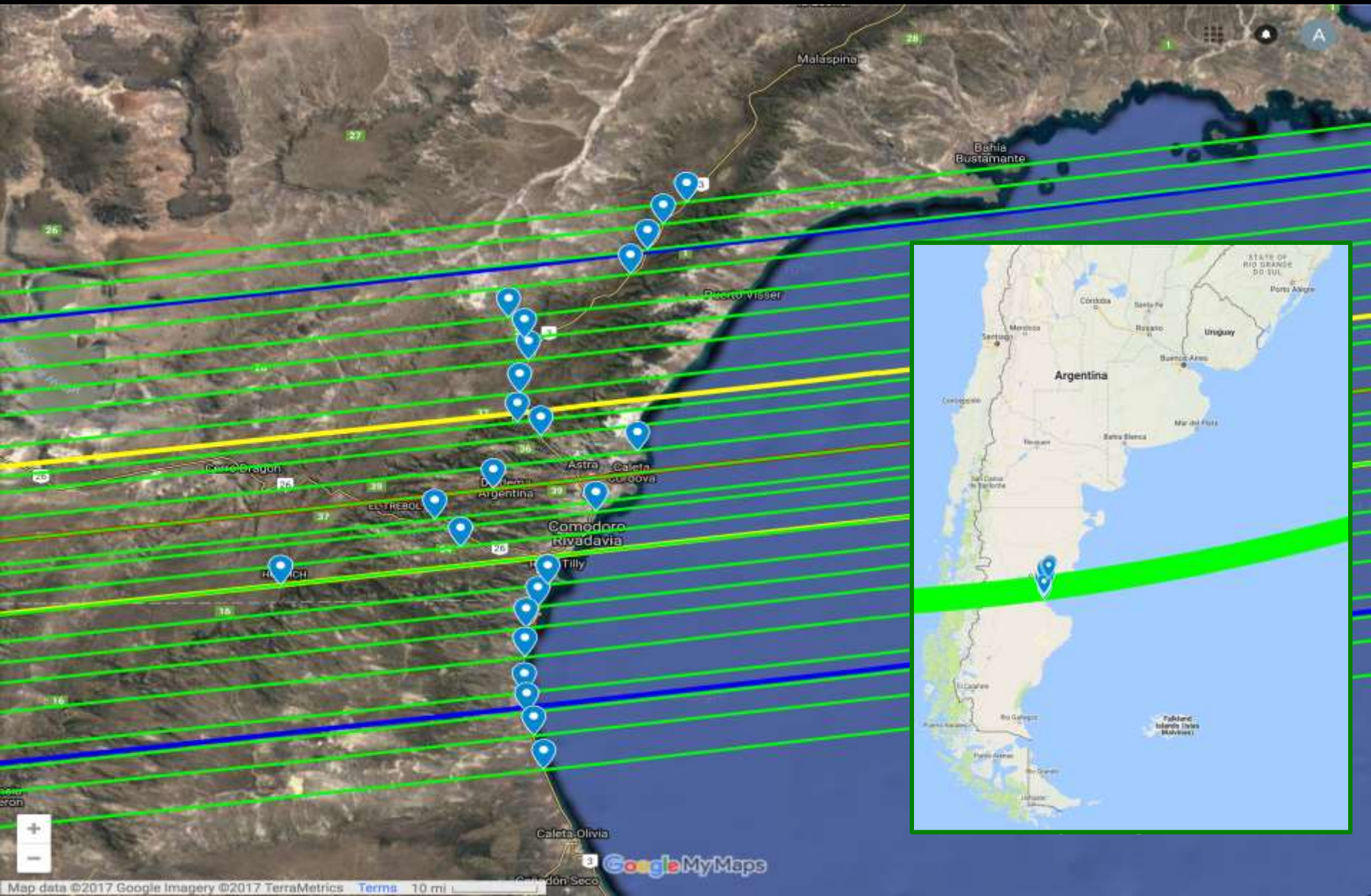
03 June South Africa

Credit: Henry Throop, Planetary Science Institute

Credit: Henry Throop, Planetary Science Institute

10 July Event: SOFIA

17 July Patagonia



17 July Patagonia

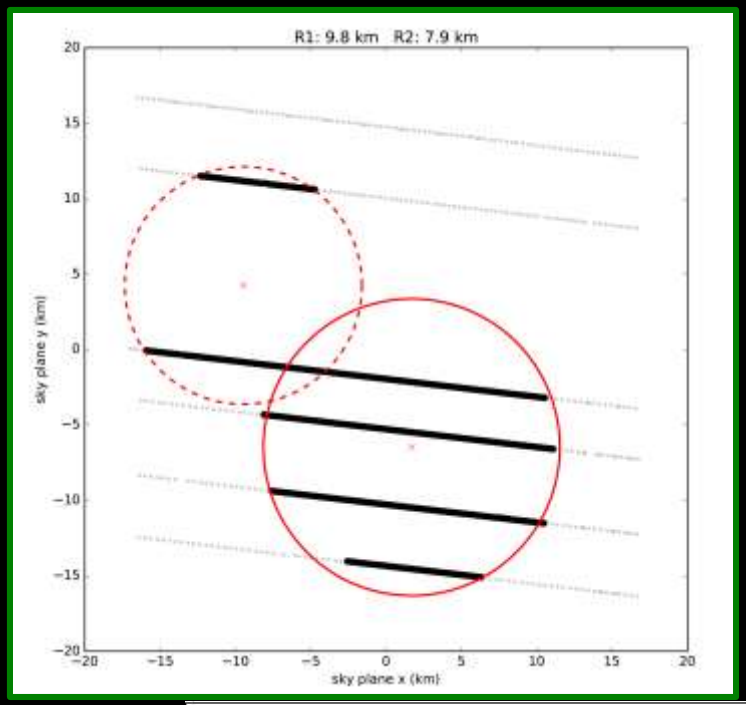
Comodoro Rivadavia, Patagonia, Argentina in Winter
“Capital of the Winds”

Wind Mitigation

Success!

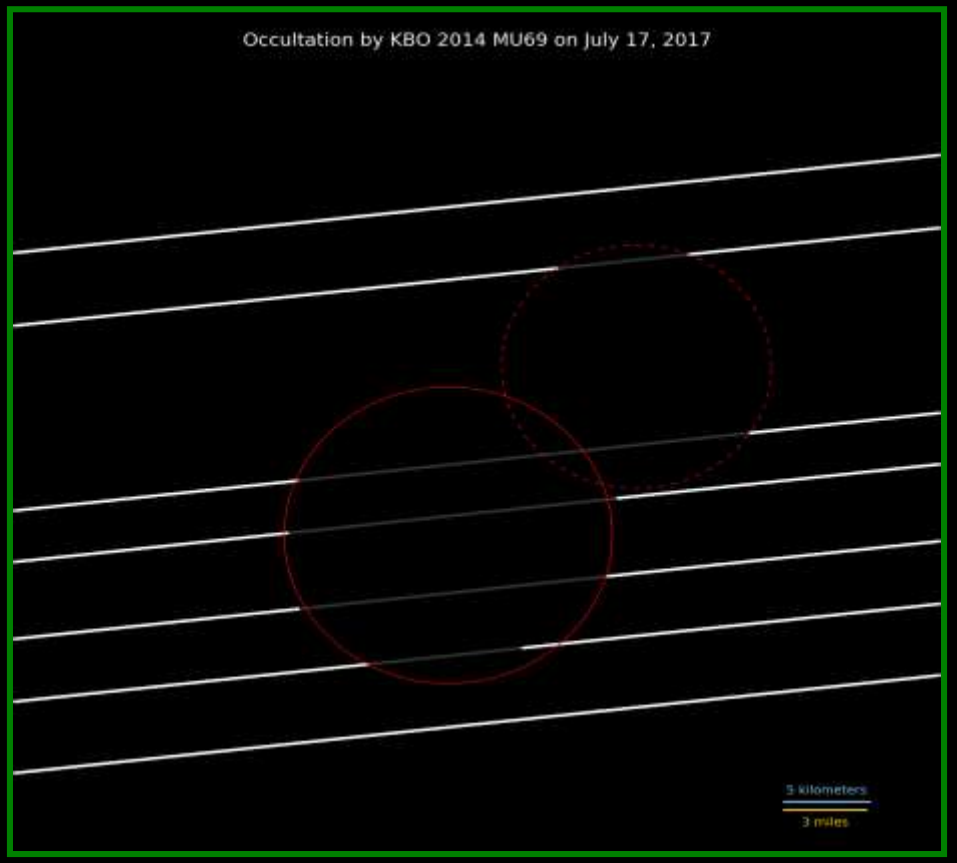
Success!

- The most complex occultation campaign in history.
- Yielded size, albedo, orbit, binarity, dust hazard data.



New MU60 Results 2: Occultation

Measured size, albedo, likely binarity, established significant debris constraints, obtained new super-accurate astrometry location (Buie et al. 2017, in prep).




01 JAN 2019

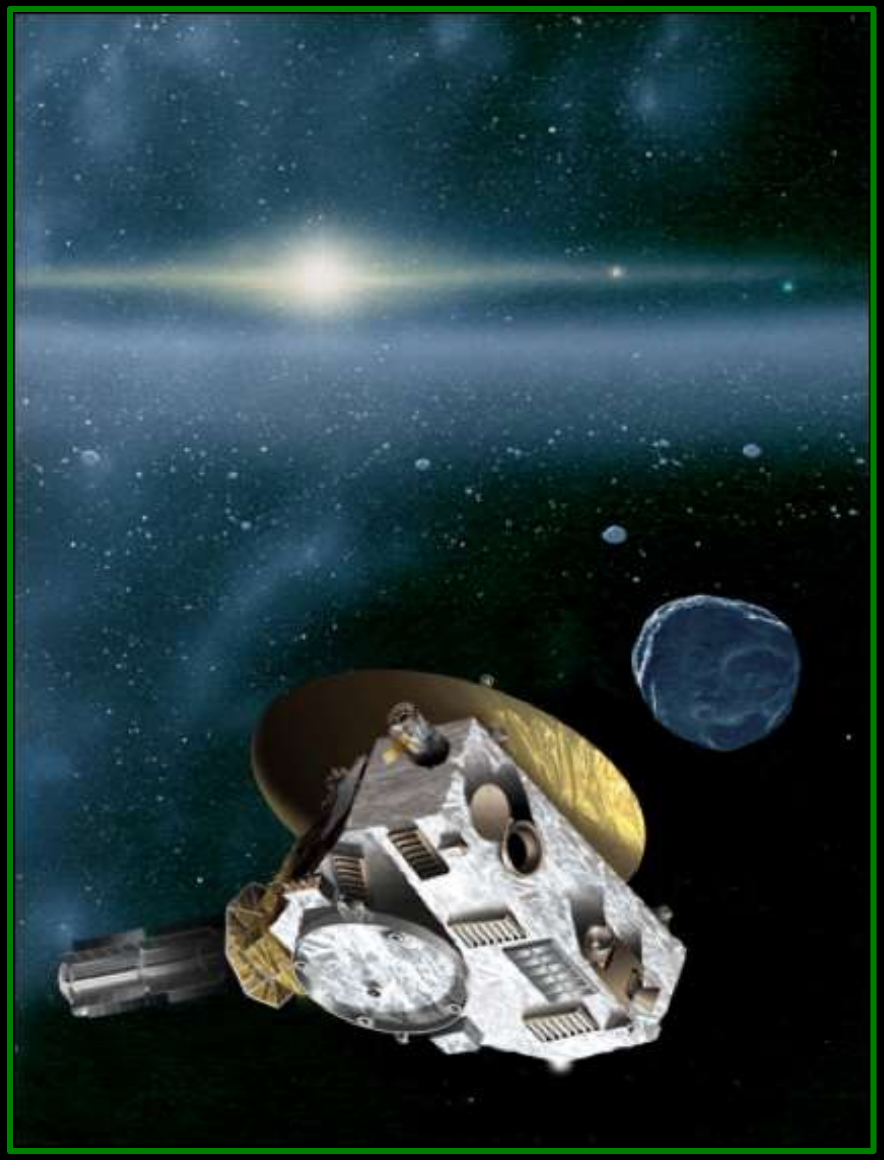
News: MU69 Flyby Distances

- Prime and Alternate Trajectories Planned.
- Flyby distances: 3500 km (Prime), 10,000 km (Alternate).
- Compare to Pluto at 12,500 km.

Best Observations of MU69

	Prime (nominal)	Alternate (nominal)	Pluto (actuals)
LORRI pan Imaging (lower SNR)	35 m/pix	65 m/pix	80 m/pix
MVIC pan Imaging (higher SNR)	141 m/pix	262 m/pix	320 m/pix
MVIC color imaging	270 m/pix	506 m/pix	700 m/pix
Stereo imaging	66 m/pix	126 m/pix	470 m/pix
LEISA NIR spectroscopy	1.5 km/pix	2.8 km/pix	2.8 km/pix
Gravity	Maybe	No	Yes
Daytime radiometry	Probably	No	Yes
Nighttime radiometry	Yes	Yes	Yes

New Horizons:
An Observatory in the Kuiper Belt



New Horizons:
An Observatory in the Kuiper Belt

- Observing Dozens of Distant Large and Small KBOs and Centaurs.

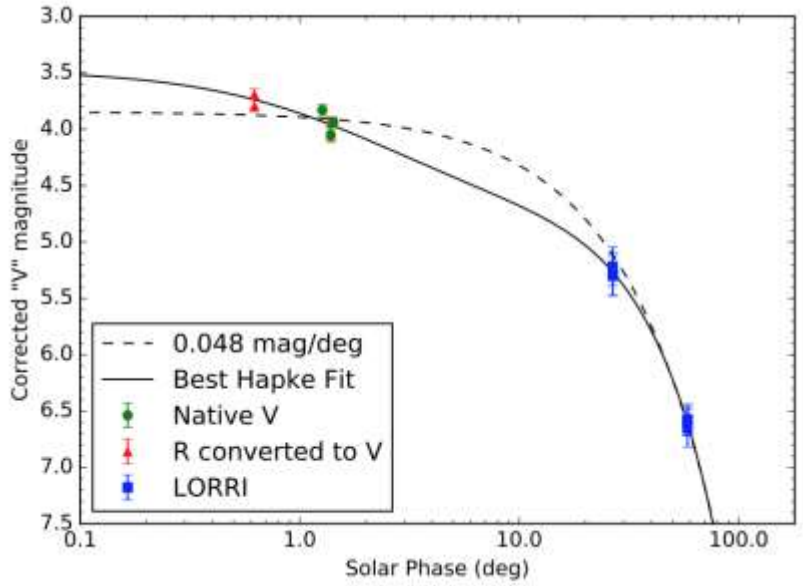
- In Unique Ways That Only New Horizons Can.

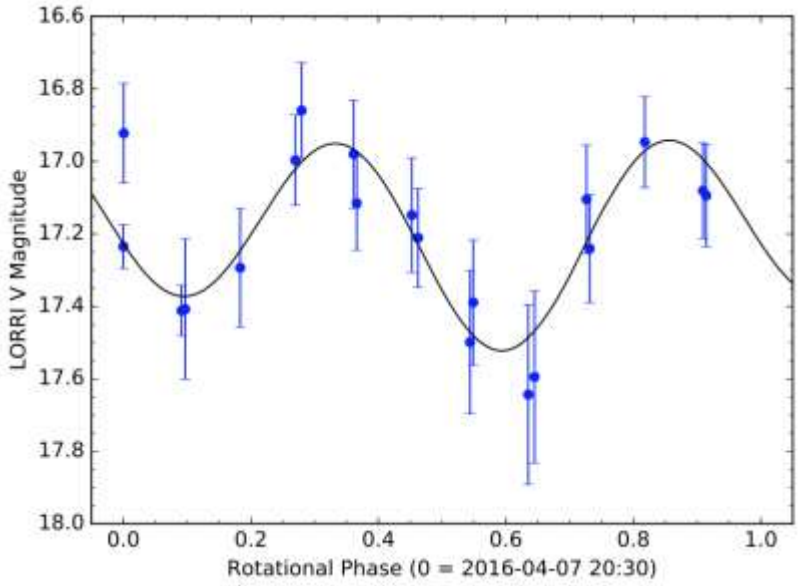
- Studies During 2016-2020 Include:
  - Close Satellite Searches
  - Extended Phase Curves
  - Dust/Ring Searches
  - Orbits and Astrometry
  - Lightcurves, Shapes
  - Helio Plasma, Dust, and Gas

	LORRI-082a	K3LR_NGC3532_082a_L1L4_2017261__cal	2017-261T11:00:00	18 Sep 2017 11:00:00	Calibration Check
	LORRI-117a	K3LR_HZ84_117a_L2_2017261__DKBO	2017-261T13:00:00	18 Sep 2017 13:00:00	Distant KBO observation - HZ84
	LORRI-117b	K3LR_HZ84_117b_L2_2017261__DKBO	2017-261T14:00:00	18 Sep 2017 14:00:00	Distant KBO observation - HZ84
	LORRI-117c	K3LR_HZ84_117c_L2_2017261__DKBO	2017-261T15:00:00	18 Sep 2017 15:00:00	Distant KBO observation - HZ84
	LORRI-105e	K3LR_Quaoar_105e_L2_2017261__DKBO	2017-261T18:00:00	18 Sep 2017 18:00:00	Distant KBO observation - Quaoar
	LORRI-105f	K3LR_Quaoar_105f_L2_2017261__DKBO	2017-261T20:08:24	18 Sep 2017 20:08:24	Distant KBO observation - Quaoar
	LORRI-116a	K3LR_QE394_116a_L2_2017262__DKBO	2017-262T00:00:00	19 Sep 2017 00:00:00	Distant KBO observation - QE394
	LORRI-105g	K3LR_Quaoar_105g_L2_2017261__DKBO	2017-262T16:08:24	19 Sep 2017 16:08:24	Distant KBO observation - Quaoar
	LORRI-105h	K3LR_Quaoar_105h_L2_2017261__DKBO	2017-262T18:16:48	19 Sep 2017 18:16:48	Distant KBO observation - Quaoar
	LORRI-116b	K3LR_OE394_116b_L2_2017263__DKBO	2017-263T00:00:00	20 Sep 2017 00:00:00	Distant KBO observation - OE394
	LORRI-118a	K3LR_HJ103_118a_L2_2017263__DKBO	2017-263T11:00:00	20 Sep 2017 11:00:00	Distant KBO observation - 2011-HJ103
	LORRI-116c	K3LR_OE394_116c_L2_2017264__DKBO	2017-264T00:00:00	21 Sep 2017 00:00:00	Distant KBO observation - OE394
	LORRI-115c-g	K3LR_MU69ApprField_115c_L2_2017264 K3LR_MU69ApprField_115d_L2_2017264 K3LR_MU69ApprField_115e_L2_2017264 K3LR_MU69ApprField_115f_L1_2017264 K3LR_MU69ApprField_115g_L1_2017264	2017-264T14:00:00	21 Sep 2017 14:00:00	Opnav MU69 approach star field. 5 visits back-to-back.
	LORRI-121a	K3LR_HE85_121a_L2_2017265__DKBO	2017-265T19:40:00	22 Sep 2017 19:40:00	Distant KBO observation - HE85

- Numerous results papers in early prep.

A KBO Observatory: 1994 JR1 Results

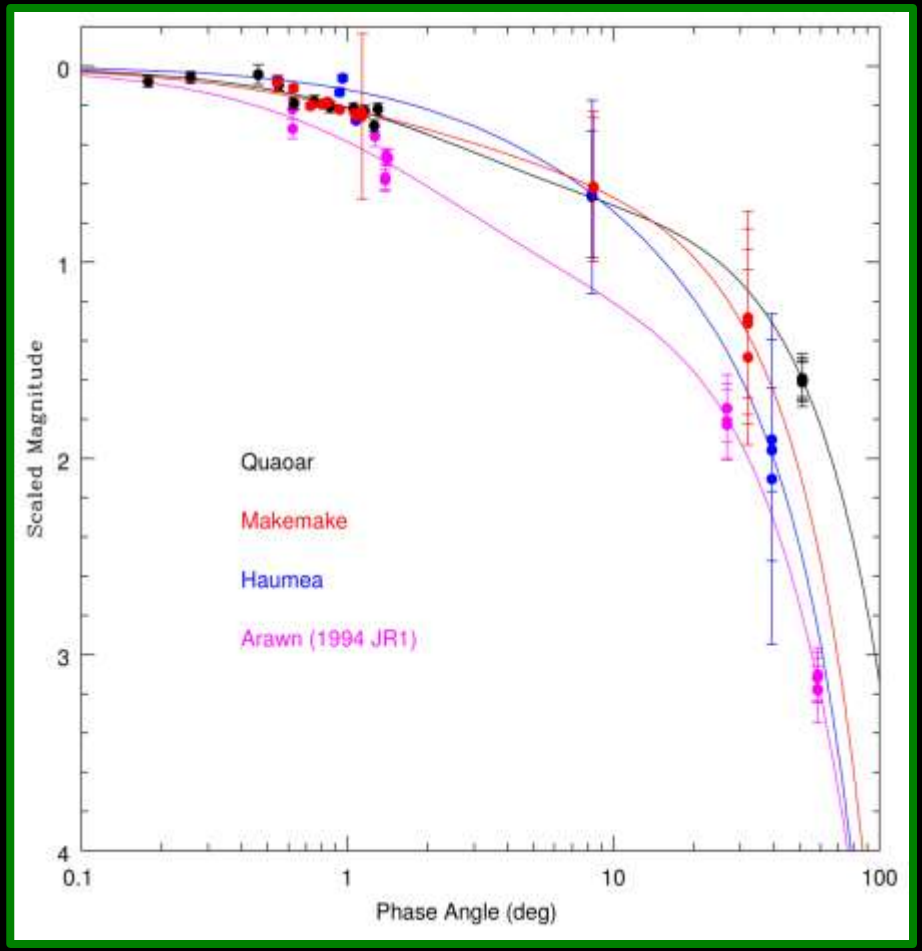




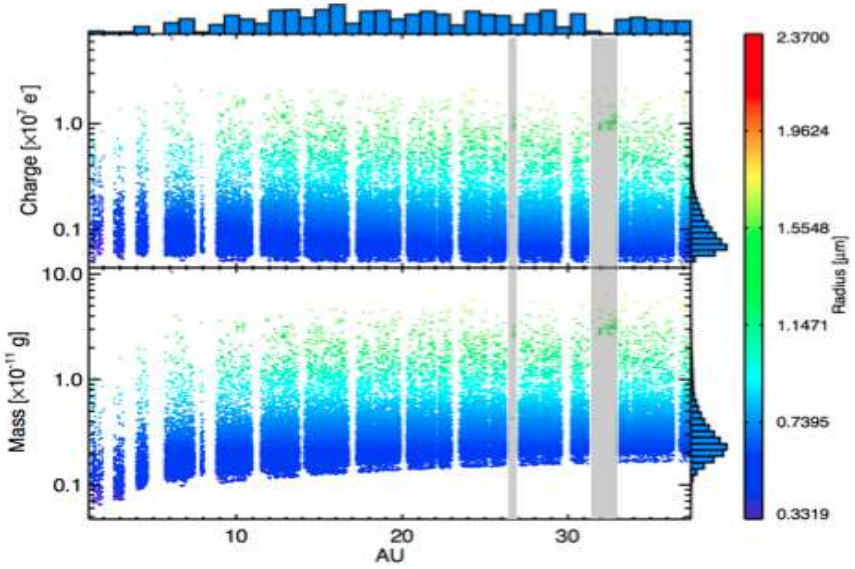
- Porter et al. (ApJ, 2016).
- First high phase observations of a KBO (up to 58 degrees!)
  - Phase curve fit indicates a rough surface.
- 1st measurement of rotation period: 5.5 hrs.
- Accurate new astrometry constrains orbital evolution.

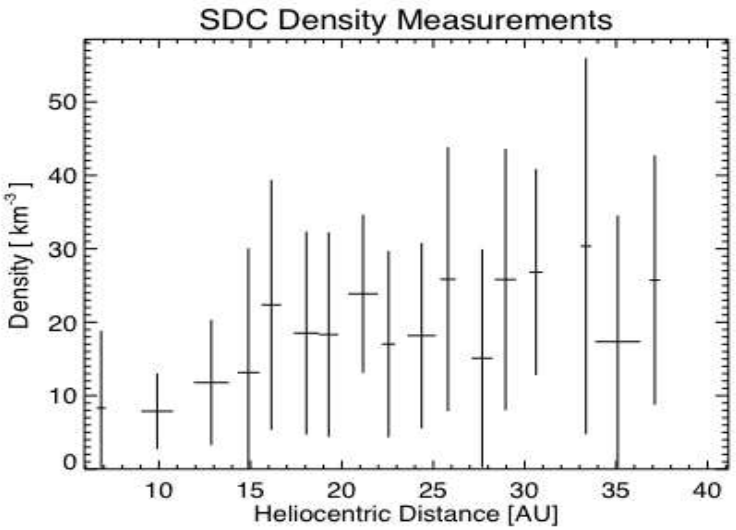
Additional High-Phase Dwarf Planet Observations

- Four dwarf planets already observed at high phase.
- Detected clearly heterogeneous phase curve behaviors.
- Numerous more high-phase observations planned.

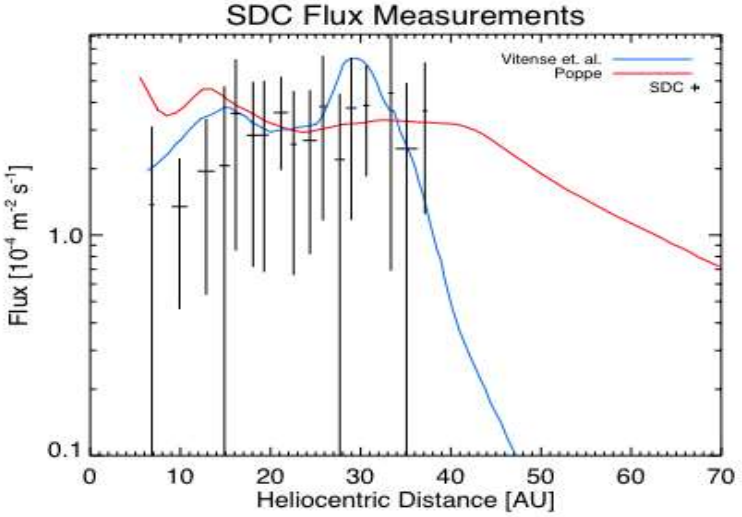


Kuiper Belt Dust Results





- All SDC recorded hits from launch to March 1st, 2017
- Gray bars indicate high threshold periods (encounter rehearsal and Pluto encounter)
- Up-tick in measured mass is due to the slowing down of New Horizons



Refs: C. Vitense et al., *The Astronomical Journal 147*, 154 , 2014
A. Poppe, *Icarus 264*, 369. 2016

Future Extended Mission Concept (Post 2021)

- Power and Fuel to Fly through mid-2030s.

- Senior Review EM Proposal 2 for 2021-2024:
  - Additional KBO Flyby Search Now Under Way
  - Numerous KBO and Centaur Observations
  - New KBO & Centaur Targets Expected from LSST
  - Giant Planet Observations
  - Astrophysical Applications
  - Heliospheric Science
  - Pale Blue Dot “21”, etc. for EPO

- Add FSW Applications Codes to ~100x Enhance Productivity as an Observatory.

New Horizons KEM Concern

There is a threat to move New Horizons to SMD Helio Division, during or at the end of KEM. Implications:

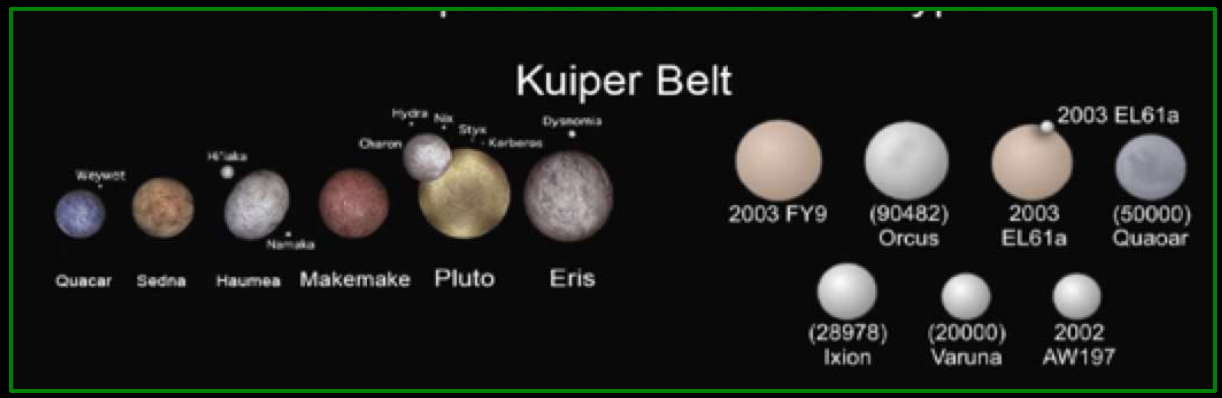
- **Potential Truncation of Post-MU69 Kuiper Belt/Other Planetary Science Observations.**

- **Precludes Future New Horizons Kuiper Belt Exploration Proposals.**

Pluto Follow On
and
Future Kuiper Belt/Centaur Exploration Missions

Expectations for KB Planet Exploration (Stern et al. 2018)

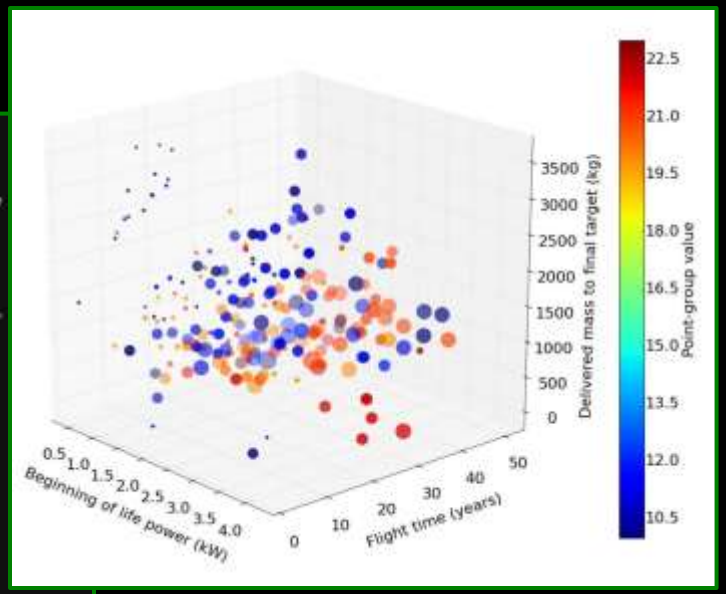
- Surprises
- Activity
- Complexity
- Object Diversity
- NH_3
- Sputnik Planitia Analogs?
- Climate Change and Atmospheric Variability
- Evidence of Surface Liquids
- Interior Oceans
- Complex Satellite & Accompanying Ring Systems



Pluto/KB Follow On Missions

- The complex nature of Pluto has spurred interest in PFO (Pluto Follow On) orbiter missions.

- Additional interest exists in flyby exploration of Centaurs and KBO planets to explore the diversity of this population.



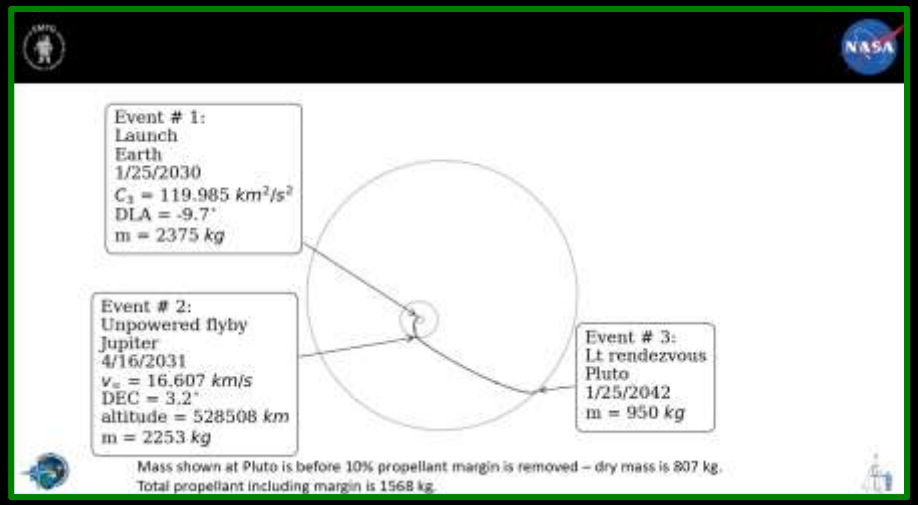
PFO/KB Studies & Interest Groups

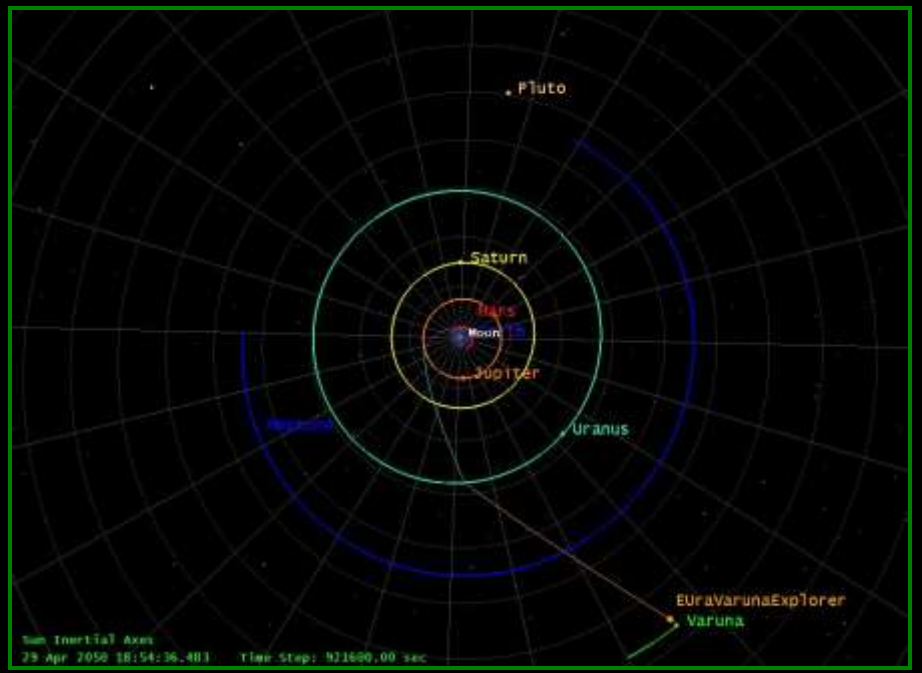
- ❑ Early Studies Occuring at:
  - ❑ SwRI
  - ❑ Ball
  - ❑ Lockheed-Martin
  - ❑ GSFC
  - ❑ NIAC

- ❑ PKB Follow On Community Interest Group: Already >100 Members. (Email to Join: ksinger@boulder.swri.edu)

- ❑ DPS-2017 PFO Workshop: October 15, 3:30-5:30 pm.

- ❑ Want NASA to Fund Pre-Decadal Studies.





Backup Slides

Naming MU69

- Plan nearly in place with SMD to informally name MU69 by early 2018.
- Public name nomination/ voting.
- Details to be announced.

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Astronomers Ask Public to Help Name Pluto's New Moons

Monday, February 11 2013 - 1:39 pm, PST

Mountain View, Calif. (SETI Institute) - The discoverers of Pluto's two tiniest moons are inviting the public to help select names for the new moons.

By tradition, the moons of Pluto have names associated with Hades and the underworld. Beginning today, people can vote by visiting:

http://plutorocks.seti.org

"The Greeks were great storytellers and they have given us a colorful cast of characters to work with," said Mark Showalter, Senior Research Scientist at the Carl Sagan Center of the SETI Institute in Mountain View, California. He and the teams of astronomers who made the discoveries will select two names based on the outcome of the voting.

Until now, these small moons have been referred to as, simply, "P4" and "P5". Like Pluto's three other moons, Charon, Nix and Hydra, they need to be assigned names derived from Greek or Roman mythology.