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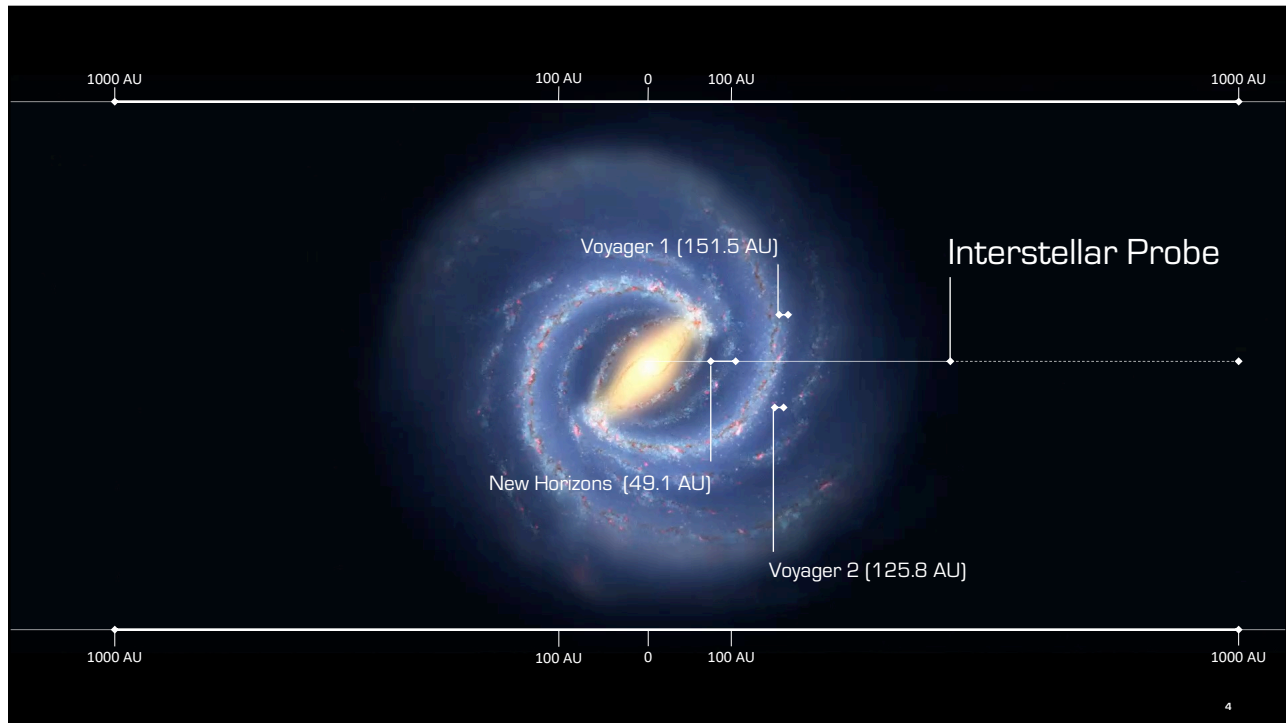
Mission Architecture

- Study Requirements (“Orthogonal” Requirements)
 - Nominal Design Lifetime: 50 years
 - Ability to operate at 1000 AU
 - Readiness by 1 January 2030
- Mass: 850-950 kg
- Power: Two Next Generation RTGs with $>300\text{ W}_e$ (total) after 50 years
- Payload
 - Mass: ~85 kg, trading lighter and heavier payloads
 - Two examples
- Telecommunication
 - X-band to achieve 500 bps downlink at 1000 AU
 - Large fixed dish (5m for X-band)
- Control
 - Spinning or three-axis depending on payload, thruster-only control
- Trajectory
 - 7.5-8.5 AU/year achieved by SLS Block 2 and Jupiter Gravity Assist
 - Near-nose direction baselined and five other directions documented

The illustration shows the Interstellar Probe spacecraft from a three-quarter perspective. It has a large, white, circular dish antenna mounted on a gold-colored cylindrical body. Several long, thin, gold-colored booms extend from the body, carrying various instruments. The background is a dark, starry space with a faint blue grid pattern.

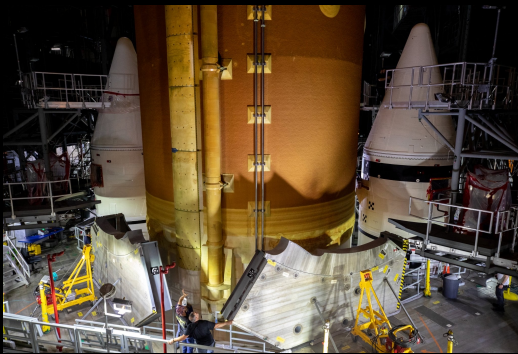
APL | 3

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First SLS Rocket Nearing Completion

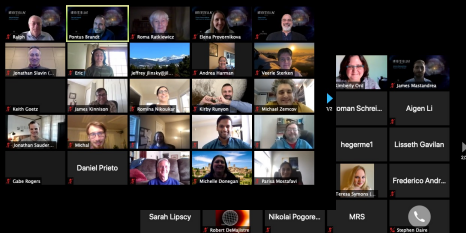


- SLS has published performance numbers
- Other Heavy Lift Vehicles (e.g., SpaceX Super Heavy/Starship) could be considered in the future, especially once their performance is publicized.

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The Team Journey



For a 50-year Primary Mission, team dynamics and sociology are key concerns

And 438 members world-wide actively working in support for Interstellar Probe Exploration

Interstellar Probe Webinar : Season 2 : Episode 1

9 April 2021

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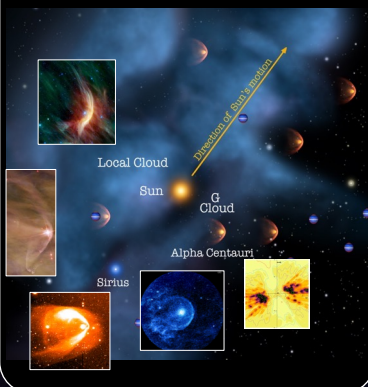
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Interstellar Probe

Humanity's Exploration of Interstellar Space Begins

Primary Goal

Our Habitable Astrosphere and its Home in the Galaxy



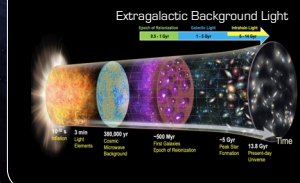
Planetary Supporting Goal

Evolution of Planetary Systems



Astrophysics Supporting Goal

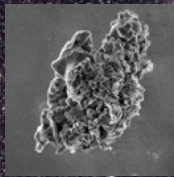
Formation of Early Galaxies and Stars



7

Supporting Goal: Understand Galaxy and Star Formation

Interstellar Dust: Galactic Messengers



Recent Nucleosynthesis:

In-situ isotopic ratios of D/H, $^3\text{He}/^4\text{He}$,

$^{13}\text{C}/^{12}\text{C}$, $^{18}\text{O}/^{16}\text{O}$, $^{22}\text{Ne}/^{20}\text{Ne}$,

$^{36}\text{Ar}/^{36}\text{Ar}$

Constraints on Cosmology:

^2H , ^3He , and ^4He abundances in the VLISM



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Supporting Goal: Understand The Origin and Evolution of Planetary Systems

MU69 "Arrokoth" (35 km)

New Horizons 1 Jan 2019



*Dwarf planets or a small body;
probably not both*

Pluto (2377 km)

New Horizons 14 July 2015



NASA/JHUAPL/SwRI/Roman Tischerko

Quaoar (1121 km)

HST 2006



Quaoar

Interstellar Probe $T_0 + 5.5$ years



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130+ Dwarf Planets Beyond Neptune!



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Big Picture: Comparative Planetology & Ocean Worlds

- What fraction are geologically active? Is there ongoing plume, cryovolcanic, and/or tectonic activity? How are some planets able to remain active billions of years after their formation, as is the case for Pluto?
- What can the variability of landforms and compositions tell us about the various formation processes and evolutions of KBO planets?
- What fraction likely have or once had liquid water? If they had water, how long did it remain liquid before freezing? Was there a widespread process that extended the life of subsurface oceans, such as antifreeze? How is this related to the planet's window for habitability?
- How do their atmospheres interact with the solar wind/interstellar medium, and how does that interaction change based on the planet's changing solar distance? Space weathering in and out of the heliosphere.
- Can dwarf planets be used as analogs to infer properties of dwarf exoplanets?

Comparative Planetology of Kuiper Belt Dwarf Planets Enabled by the Near-Term Interstellar Probe

White paper to the 2023 Planetary Science Decadal Survey

Kirby D. Runyon¹ (APL, 11100 Johns Hopkins Road, Laurel, MD, 240-228-5960, kirby.runyon@jhuapl.edu), Caitlin Ahrens², Chloe B. Beddingfield^{3,4}, Joshua T. S. Cahill⁵, Richard J. Carver⁶, Ian Cohen⁷, Bryan Holler⁸, Ted Stryk⁹, Peter Kolman¹⁰, Edwin S. Kite¹¹, James T. Keane¹², John F. Cooper¹³, Chester "Sonny" Harman¹⁴, Michele T. Bannister¹⁵, Kelsi N. Singer¹⁶, Alan Stern¹⁷, Abigail Rymen¹⁸, Noam Izenberg¹⁹, Andrew Annex²⁰

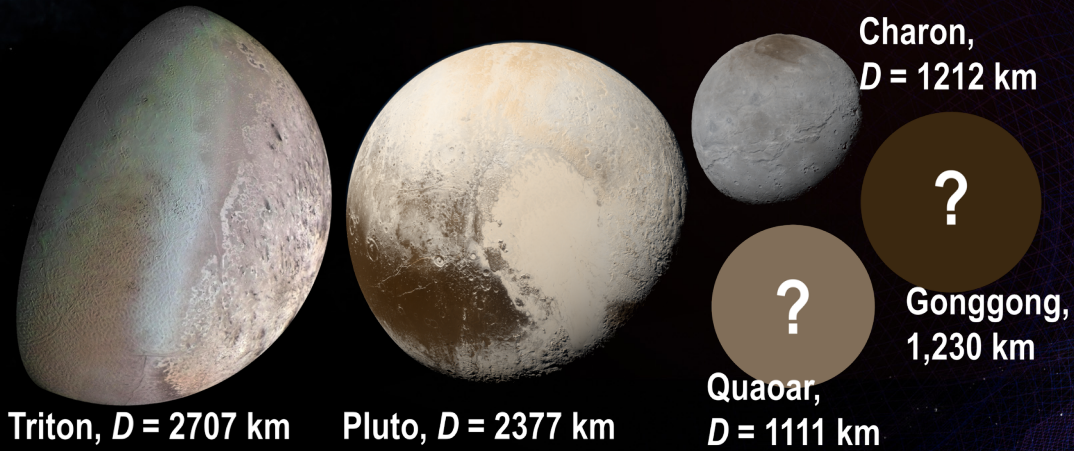
¹Johns Hopkins University Applied Physics Laboratory (APL), Laurel, MD; ²Arkansas Center for Space and Planetary Science; ³SETI Institute; ⁴NASA Ames Research Center; ⁵Space Telescope Science Institute; ⁶Roane State Community College; ⁷University of Chicago; ⁸California Institute of Technology; ⁹University of Canterbury, New Zealand; ¹⁰NASA Goddard Space Flight Center; ¹¹Southwest Research Institute; ¹²Johns Hopkins University



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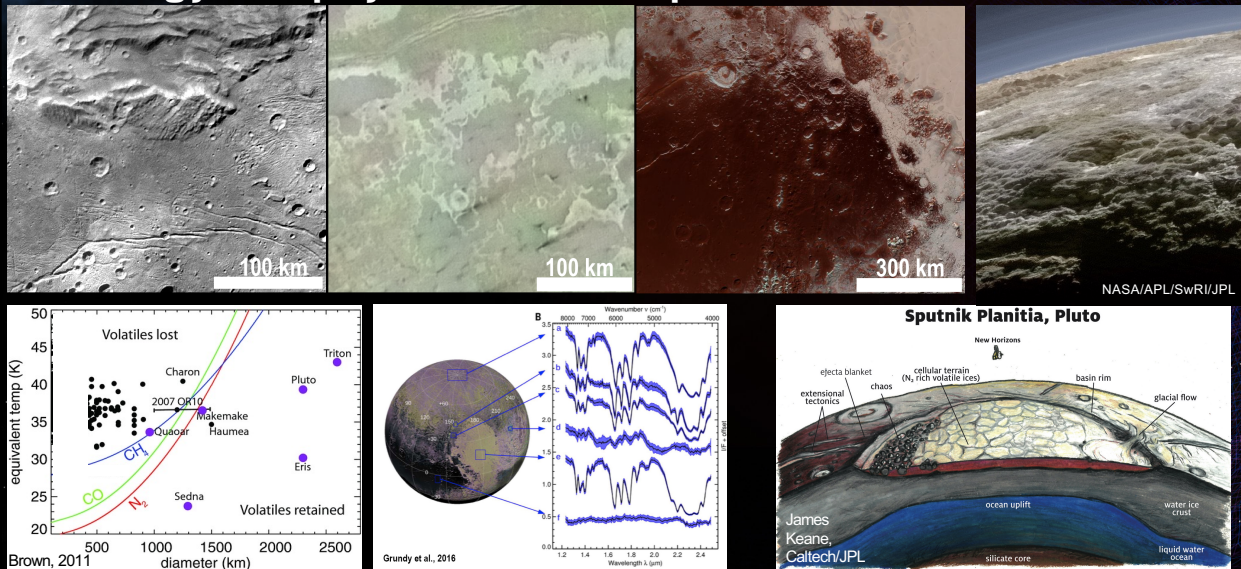
Triton, Pluto, and Charon were Just the Beginning!



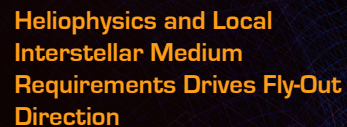
NASA/APL/SwRI/JPL

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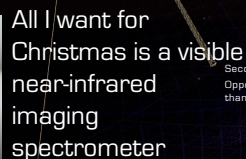
Geology, Geophysics, and Composition



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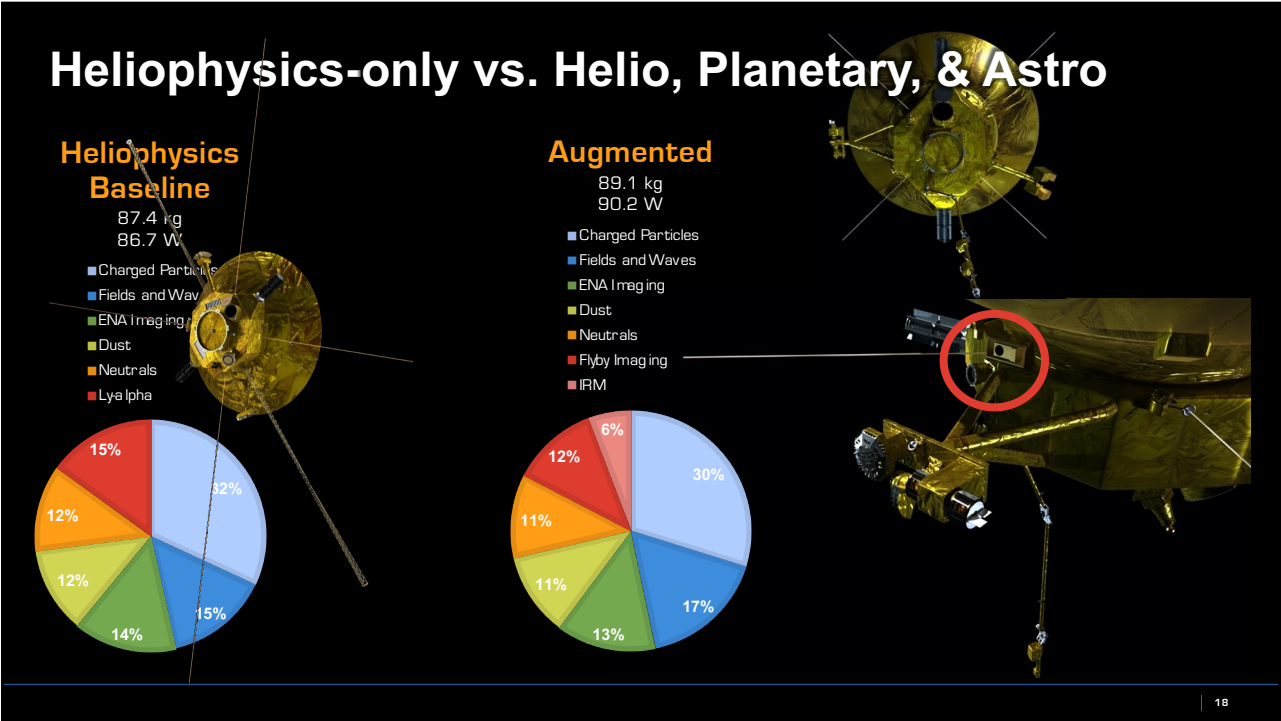


Example Accommodation

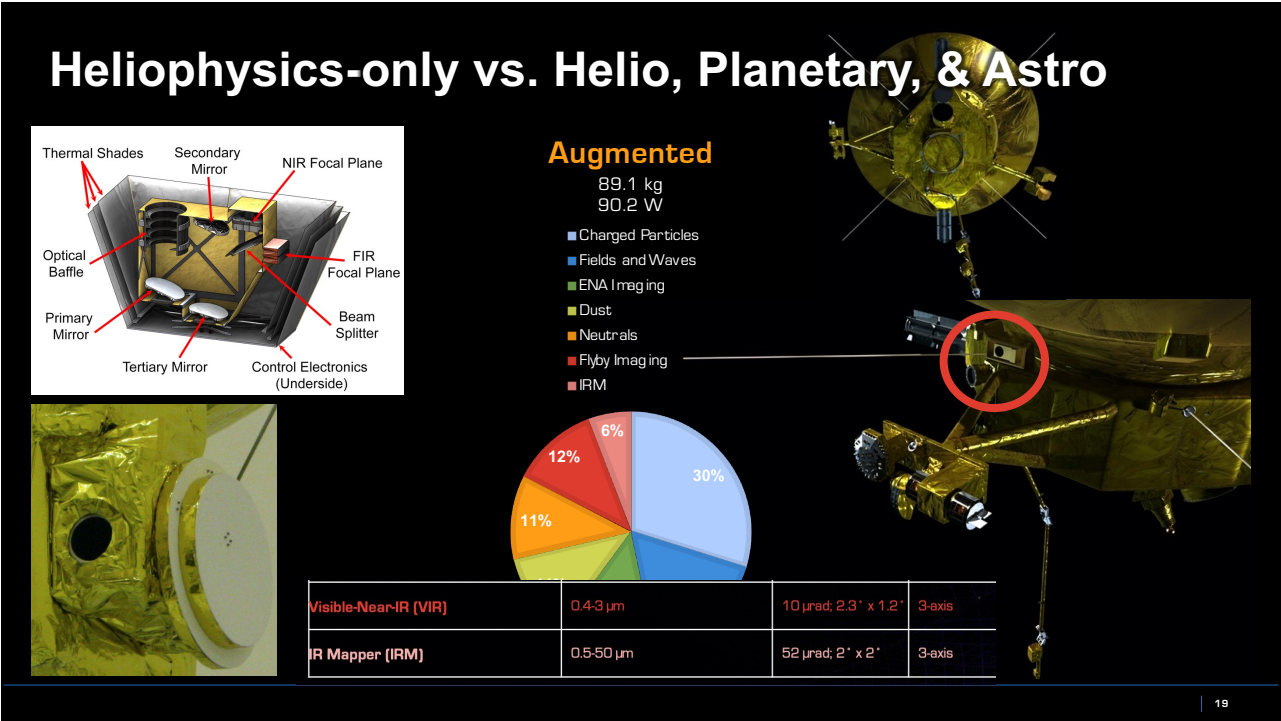


Second boom to balance MAG
Opportunity for instrumentation other than a second pair of MAGs?

-



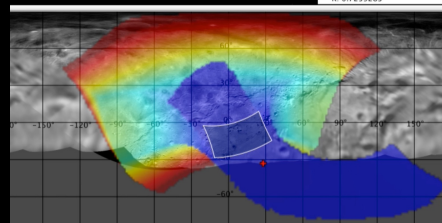
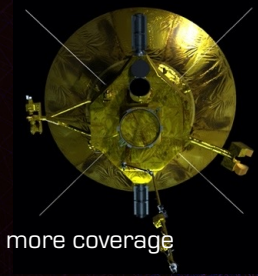
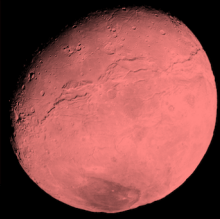
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Dwarf Planet Flyby

- Transition from spin-stabilized to 3-axis control
- OpNav on approach
- Flyby Distance: 5,000-40,000 km
- Speed: >7 au/year
- Most dwarf planets have faster spin than Pluto: 10s hours vs. 6.39 days = more coverage



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Quaoar: Example Target Dwarf Planet

- 1,111 km diameter
- 43 au in 2030
- Hot classical KBO
- ~Densest KBO? (1.99 g/cm³)
- Methane and ethane detected on surface
- Has a moon Weywot (170 km)
- Possible Launch February 7, 2030
- JGA Nov. 16, 2030
- Arrive April 14, 2036



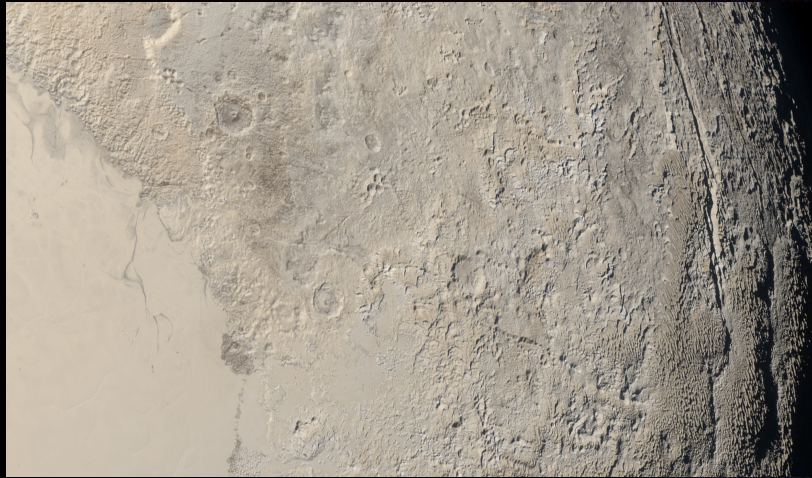
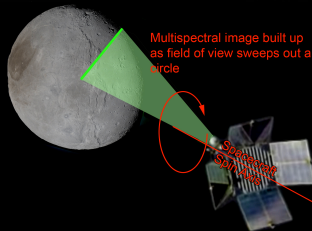
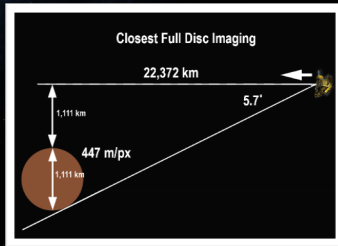
Lately, Orcus (satellite Vanth) has arisen as dynamically more favorable to reach



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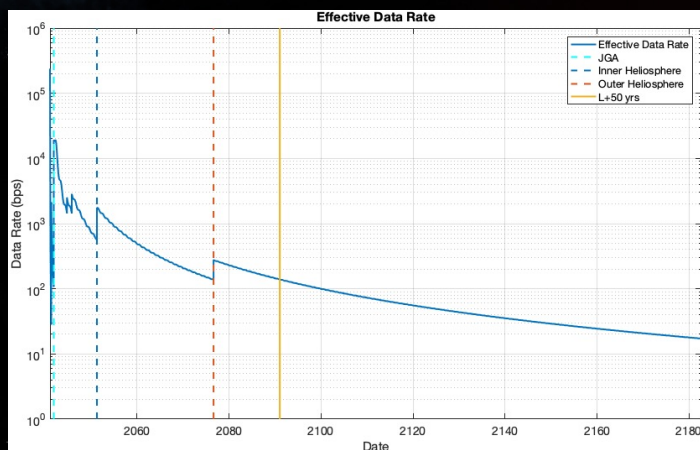
NoseCam: "Helio+" Baseline



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Communications



Comparable to or better than New Horizons at Pluto



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Breaking News

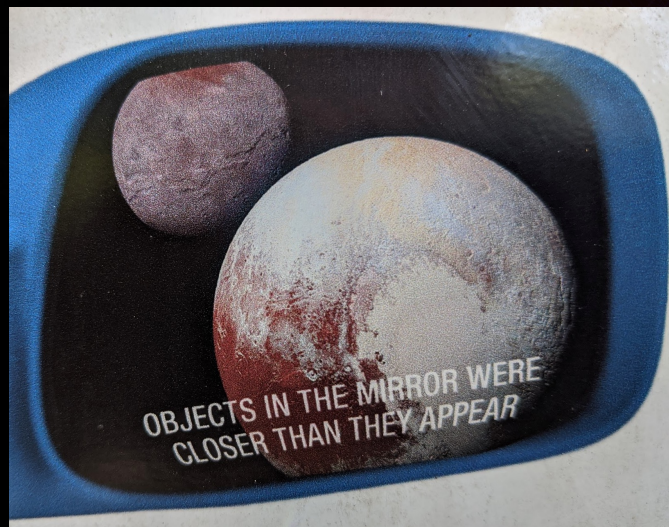
- Finalized the STM
- Final Mission Concept Report to National Academies Heliophysics Decadal Survey Panel
 - Appendix A, Planetary Science (Orcus! Quaoar! Gonggong! Eris!)
- Fourth Interstellar Probe Workshop, Sept. 27-Oct. 1:
<http://InterstellarProbe.jhuapl.edu/Resources/Meetings/agenda.php?id=146>



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Let's Get More Dwarf Planets in our Rearview Mirror!

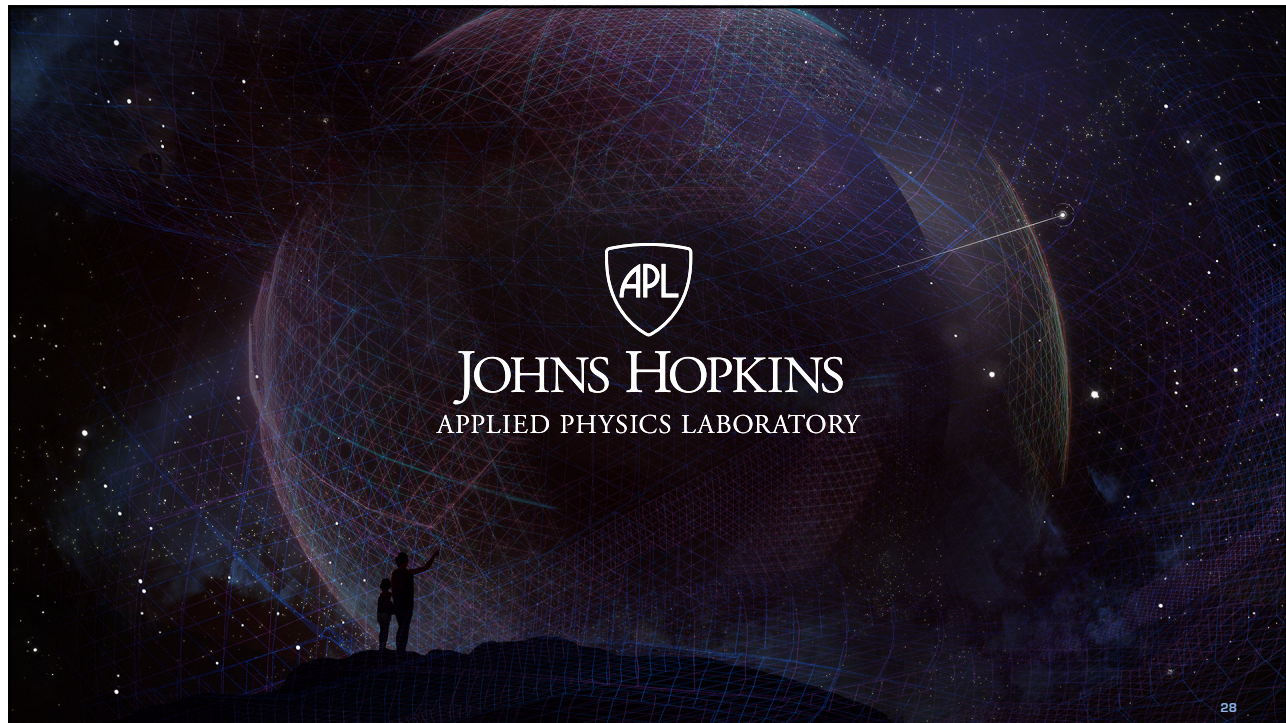


Presenter's Actual Bumper Sticker

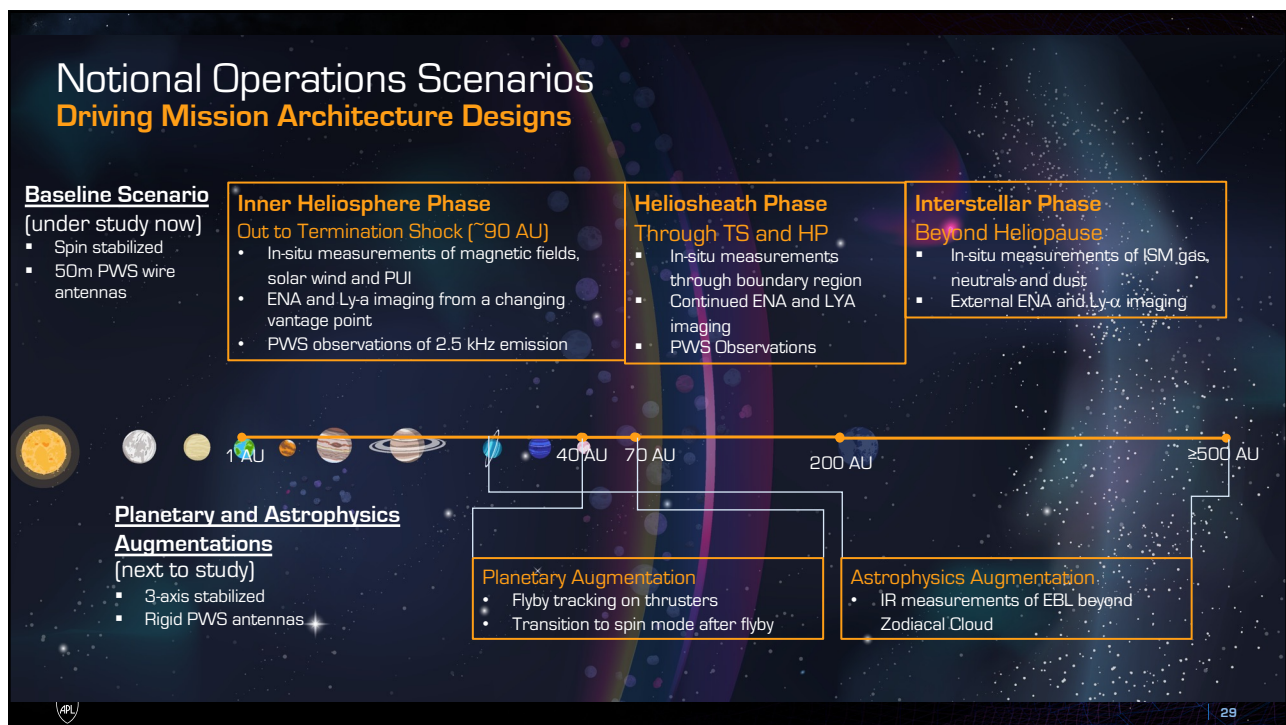


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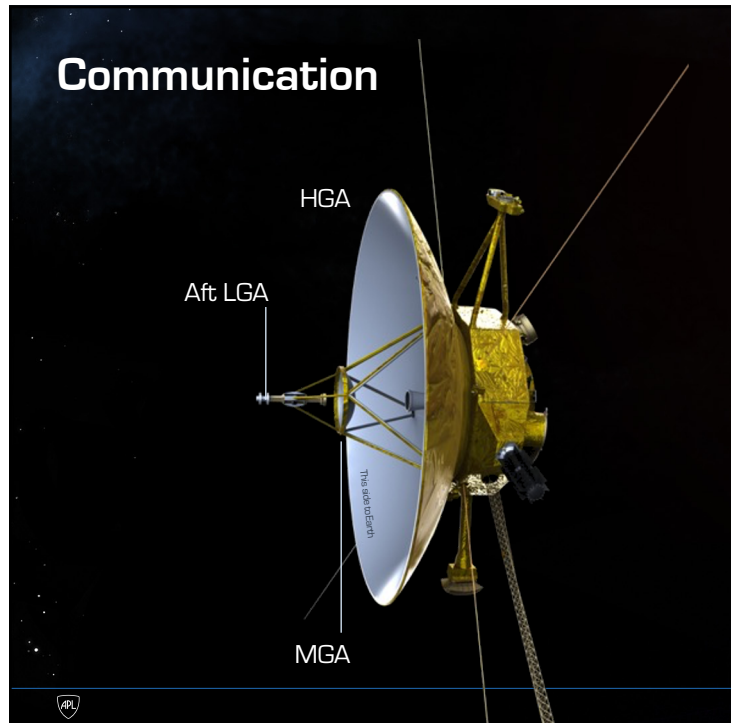


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Communication



Interstellar Probe Communications Subsystems	
HGA	5m Solid Composite
MGA	0.37m Solid Composite
TWTA Power	52 W
Subsystem Mass (CBE)	72.9 kg HGA – 53.7 kg
Downlink Data Rate ¹	2592 bps (375 AU) 365 bps (1000 AU)
Uplink Data Rate ²	2000 bps (375 AU) 250 bps (1000 AU)

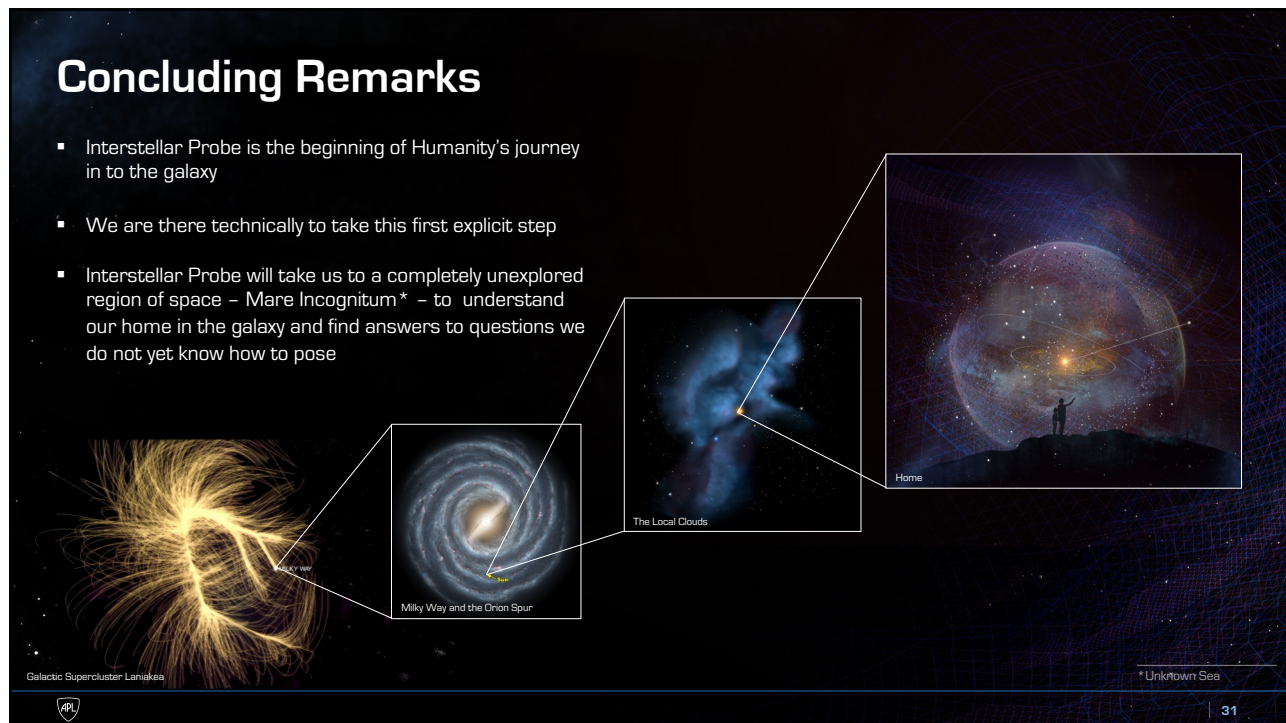
¹ – Turbo R1/6 encoding, ngVLA Ground Station
² – DSN 70m station w/ 80 kW Tx, LDPC encoding

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Concluding Remarks

- Interstellar Probe is the beginning of Humanity's journey in to the galaxy
- We are there technically to take this first explicit step
- Interstellar Probe will take us to a completely unexplored region of space – Mare Incognitum* – to understand our home in the galaxy and find answers to questions we do not yet know how to pose



Galactic Supercluster Laniakea

Milky Way and the Orion Spur

The Local Clouds

Home

* Unkintown Sea

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