The Architecture of Nautilus: A Multi-Flyby Mission to Triton

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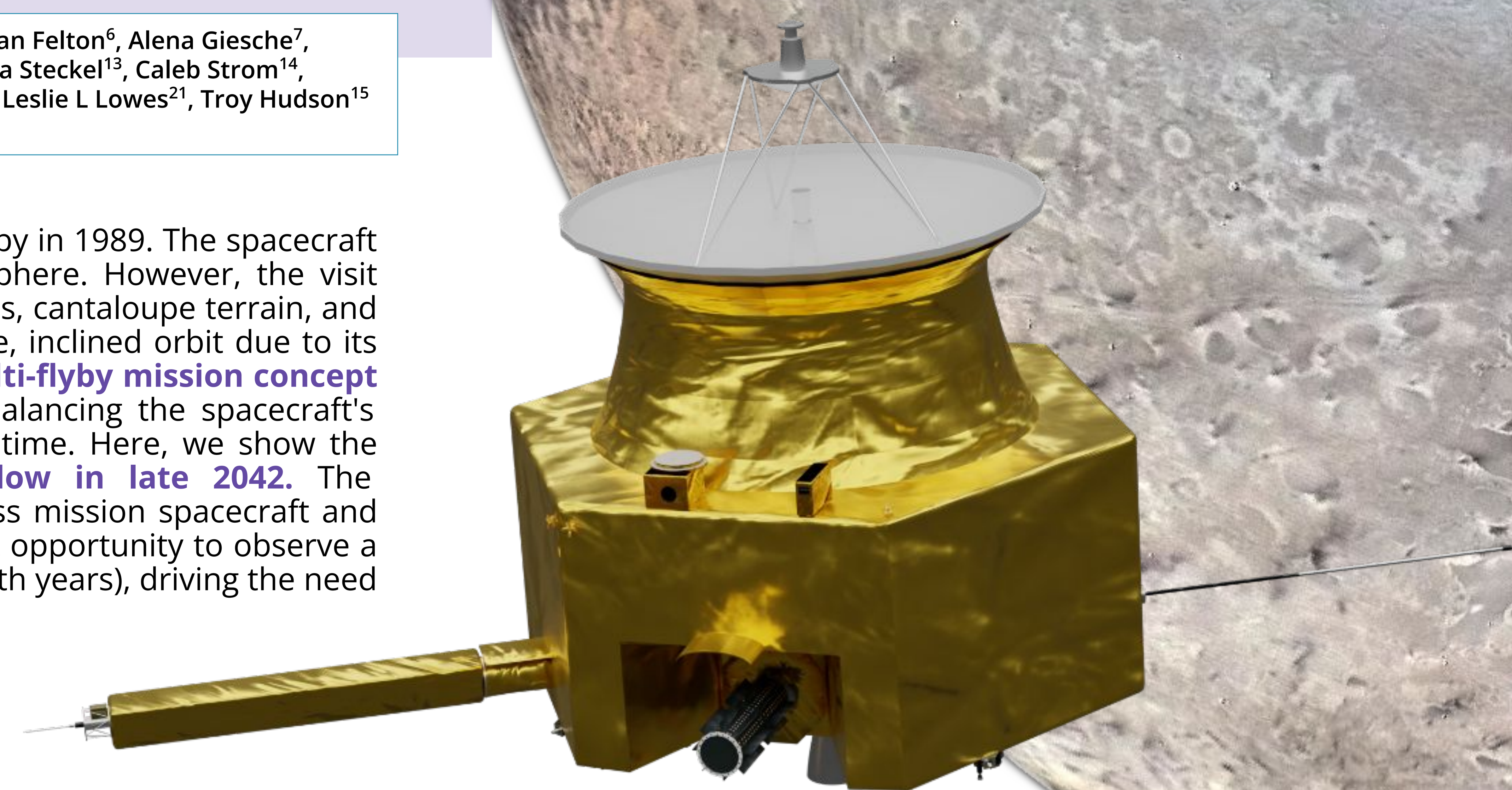
References

[1] S. A. Stern et al., "ALICE: The Ultraviolet Imaging Spectrograph Aboard the New Horizons Pluto–Kuiper Belt Mission," Space Sci Rev, 2008 [2] D. C. Reuter et al., "Ralph: A Visible/Infrared Imager for the New Horizons Pluto/Kuiper Belt Mission," Space Sci Rev, 2008 [3] P. Wittmann, "The Jovian Plasma Dynamics and Composition Analyzer (JDC) for ESA's JUICE Mission". [4] L. Andersson et al., "The Langmuir Probe and Waves (LPW) Instrument for MAVEN," Space Sci Rev, 2015 [5] J. E. P. Connerney et al., "The MAVEN Magnetic Field Investigation," Space Sci Rev, 2015 [Titon Image] NASA / Jet Propulsion Lab / U.S. Geological Survey, Public domain, via Wikimedia Commons [Spacecraft Rendering] Jason Dekarske[3]



Background: Why Triton?

Neptune's moon, Triton, exposed beautiful, unique terrain to Voyager 2's flyby in 1989. The spacecraft imaged active features on human time scales, like plumes and an ionosphere. However, the visit developed more questions than it answered. What is the nature of its plumes, cantaloupe terrain, and subsurface ocean? Which unique features can we attribute to its retrograde, inclined orbit due to its origin as a captured Kuiper Belt object? **Nautilus, presented here, is a multi-flyby mission concept to Triton.** When considering such a mission, multiple challenges arise, balancing the spacecraft's scientific and operational capabilities, launch vehicle energy, and mission time. Here, we show the configuration of a proposed multi-flyby mission with a **launch window in late 2042.** The instrumentation package chosen relies on robust heritage from similar-class mission spacecraft and innovative subsystems that add flexibility to spacecraft operations. The next opportunity to observe a sunlit southern hemisphere will not occur for another Neptune year (165 Earth years), driving the need for such a mission to be considered and selected soon.

Science Objectives

1) Subsurface Ocean

Determine if Triton has a subsurface ocean and, if one exists, determine the mechanism sustaining it, focusing on the possibility of obliquity tides.

2) Atmosphere and Ionosphere

Determine whether ionization and escape processes in Triton's ionosphere are driven by precipitation of magnetospheric electrons or solar radiation.

3) Surface Geology

Determine if geologic features (e.g. cantaloupe terrain and walled plains) are formed or shaped by internal or external processes.

4) Metallic Core

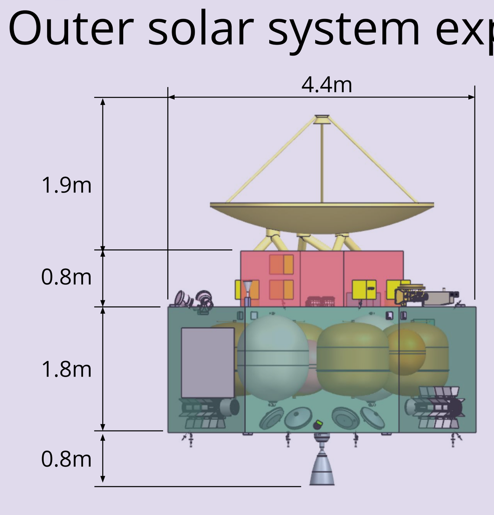
Determine whether Triton has a metallic core, which may be a consequence of capture.

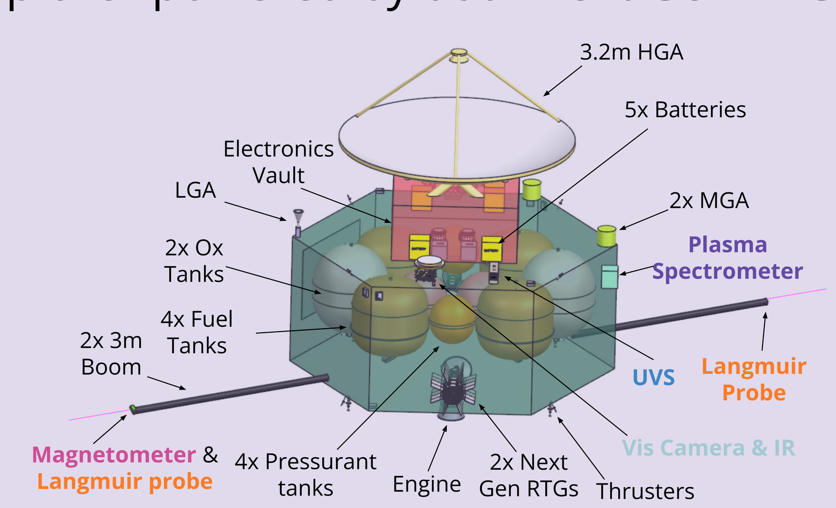
5) Plumes

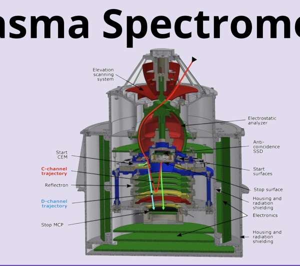
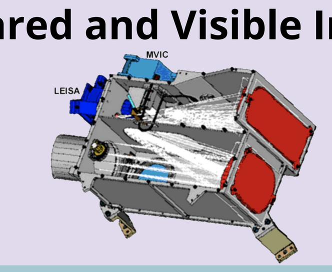
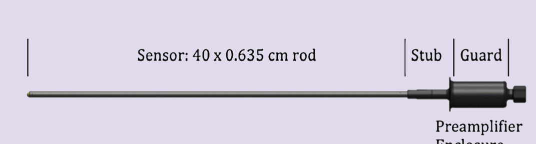
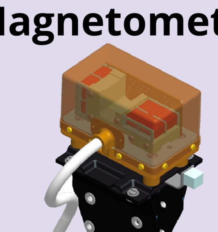
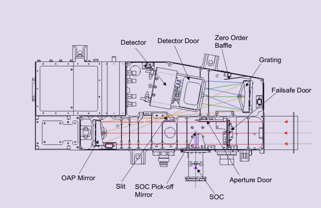
Determine whether Triton's plumes are the result of solar irradiation, melting volatiles caused by internal heat, or cryovolcanism.

Spacecraft Configuration

Outer solar system explorer powered by dual Next Gen RTGs

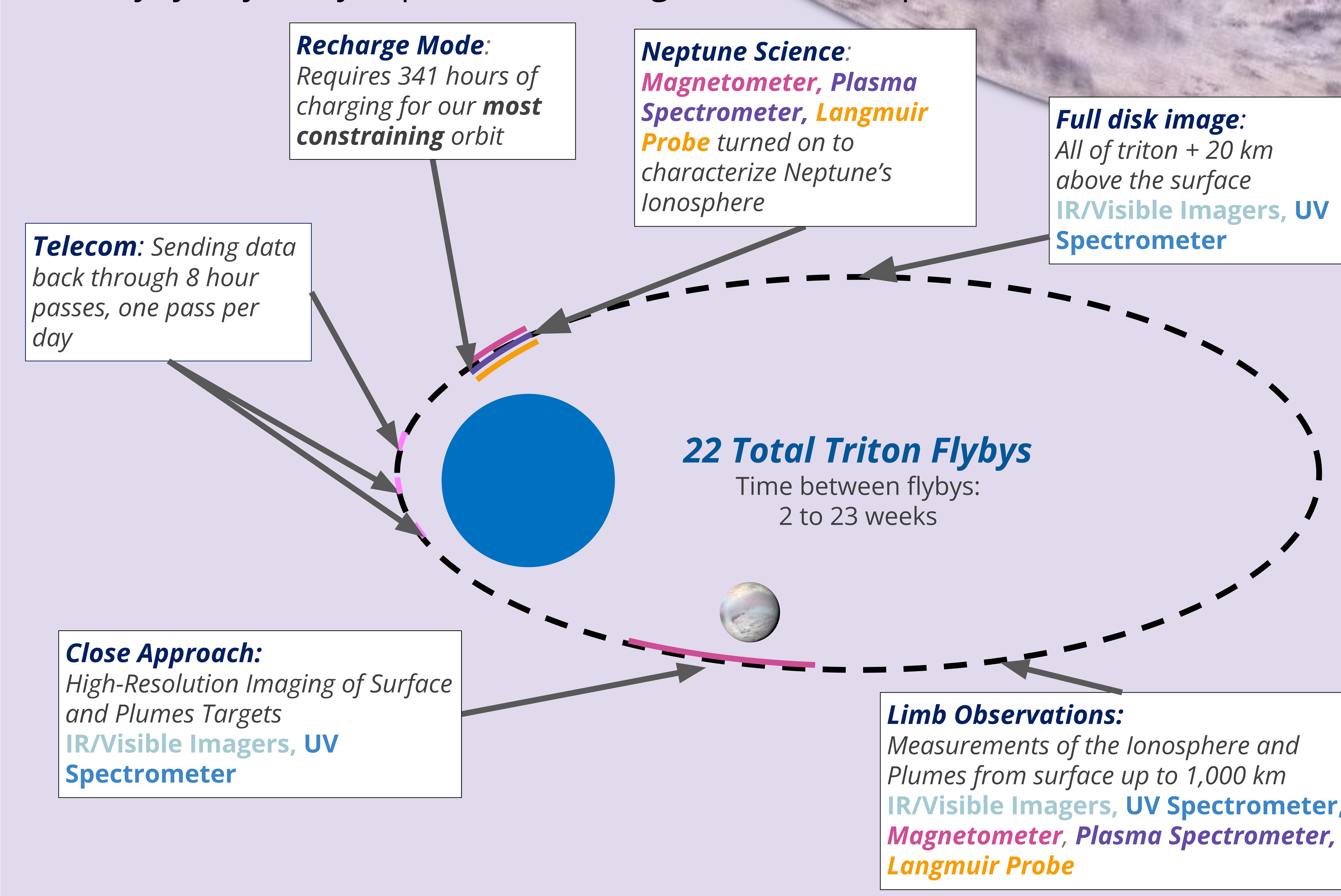




Plasma Spectrometer 	**Heritage: JUICE JDC[3]** Objectives: 2, 5 Range: 10-30,000 eV, 1-30 amu Resolution: 15% ΔE/E, 28 M/ΔM
Infrared and Visible Imager 	**Heritage: New Horizons Ralph[2]** Objectives: 1, 3, 5 Range: 350-850 nm (Vis) 1.25-2.5 μm (IR) Resolution: 20 m/px (Vis) 200 λ/Δλ, 54m/px (IR)
Langmuir Probe 	**Heritage: MAVEN LPW[4]** Objectives: 1, 2 Range: -5-5 V, 0-150 μA Resolution: 25 mV, 1nA
Magnetometer 	**Heritage: MAVEN MAG[5]** Objectives: 1, 2 Range: 0-10,000 nT Resolution: 0.5 nT
UV Spectrometer 	**Heritage: New Horizons Alice[1]** Objectives: 2, 5 Range: 60-200 nm Resolution: 1 nm/px, 400 m/px

Concept of Operations

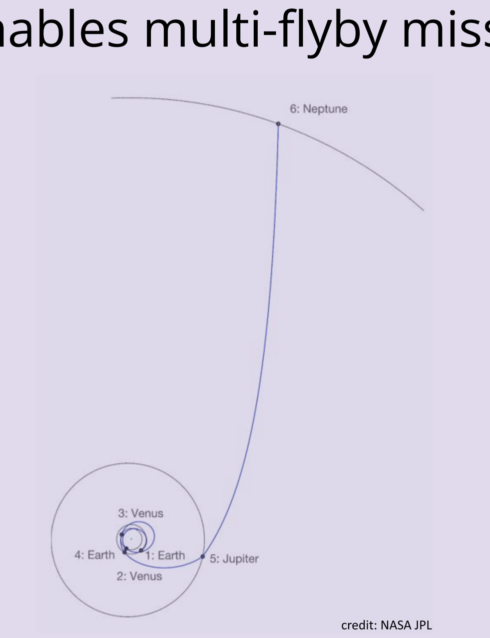
Multi-flyby trajectory explores wide range of scientific questions



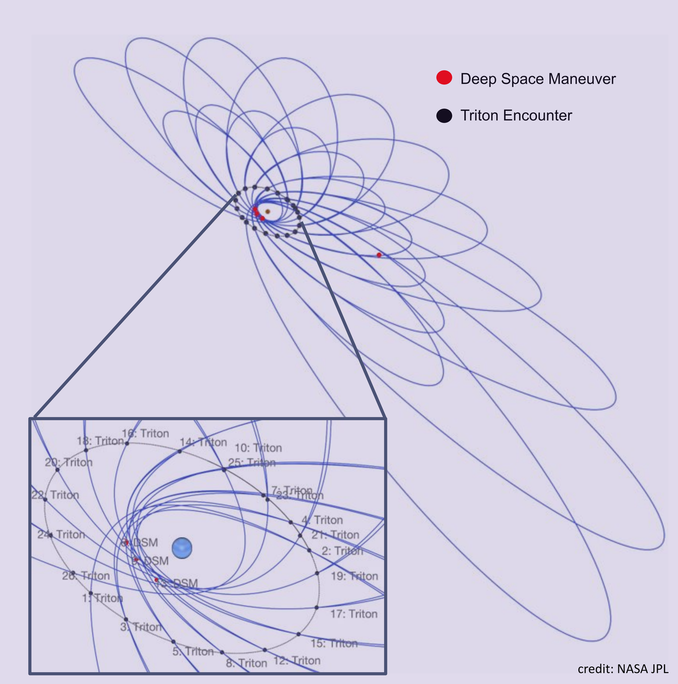
Trajectory

Unique trajectory design enables multi-flyby mission at Triton

Launch Details	
Launch date	August 3, 2042
C_3	39.1 km²/s²
Launch window flexibility	±10 days; up to +3 C_3
Mission duration	Cruise: 14.7 years Science: 3 years
Cruise trajectory	Earth-Venus-Venus-Earth-Jupiter-Neptune
Neptune Orbital Insertion Delta-V	2,018 m/s



Tour Details	
Science flybys	22
Max. velocity of Triton flybys	~4.6 km/s
Initial Time between Triton flybys	6 - 23 weeks
Time between flybys after all DSMs	2 - 6 weeks
Spacecraft end of life	Neptune entry disposal
Total DV	2,795 m/s
Tour DV	199 m/s
Disposal DV	100 m/s
Mission deterministic DV	2,475 m/s
Mission statistical DV	220 m/s (140+30+50)



Considerations/Future Tradespace

- The Jupiter flyby design requires a radiation hardened vault for sensitive electronic components. This vault significantly increases spacecraft mass. Increasing Jupiter flyby distance can decrease spacecraft mass while increasing cruise duration.
- Surface feature pushbroom imaging at closest approach, where relative velocity is highest, exceeds an achievable spacecraft slew rate. To reduce slew rate requirements, a scanning mirror could be added to the infrared and visible imager.
- A ~15 year cruise time presents significant risk for spacecraft performance and requires additional qualification and accelerated lifetime testing. Additionally, to retain personnel from launch to the science tour phase necessitates additional knowledge transfer procedures.
- The launch window in 2042 is essential to observe the southern hemispherical, periodical, sunlit portion of Triton. This coincides with a favorable configuration of Earth, Venus, and Jupiter for gravity assists.
- Significant advances in computation, propulsion, and power management over decades until launch can mean an improvement in spacecraft autonomy at the risk of flight hardware inexperience.