IMPLEMENTATION OF TRIDENT: A DISCOVERY-CLASS MISSION TO TRITON.

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Overview: Trident is an exciting mission concept to investigate Neptune's large moon Triton, an exotic candidate ocean world at 30 AU (Prockter *et al.*, this meeting). The concept is responsive to recommendations of the recent NASA Roadmap to Ocean Worlds study (Hendrix et al., 2019), and to the 2013 Planetary Decadal Survey's habitability and workings themes (Squyres et al., 2011). A rare, low Δ*v* trajectory (Fig. 1) enables an MMRTG-powered spacecraft fitting under the Discovery cost cap. The spacecraft has a robust design and uses high heritage instruments (table 1) with minimal development costs.

New Horizons has effectively demonstrated the scientific value of fast flybys in the outer solar system. Trident's encounter with Triton will be similarly rapid, using remote sensing instruments with large apertures and high angular resolution sensors that operate millions to tens of thousands of kilometers before closest approach. Data is collected over several days around the encounter (Fig. 2), and returned over the course of one year.

An active-redundant operational sequence ensures unique observations during an eclipse of Triton – and another of Neptune itself – and includes redundant data collection throughout the flyby (Fig. 2, left panel). High-resolution imaging and broad-spectrum IR imaging spectroscopy, together with high-capacity onboard storage, allow near-full-body mapping over the course of one Triton orbit (Fig. 2, right panel). Trident passes through Triton's thin atmosphere, within 500 km of the surface, sampling its ionosphere with a plasma spectrometer and performing magnetic induction measurements to verify the existence of an extant ocean. Trident's passage through a total eclipse allows observations through two atmospheric radio occultations for mapping electron and neutral atmospheric density, Neptune-shine illuminated eclipse imaging for change detection since the 1989 Voyager 2 flyby, and high-phase-angle atmospheric imaging for mapping haze layers and plumes.

Why Now?: By launching during 2026, Trident takes advantage of a rare, efficient gravity-assist alignment, to capitalize on a narrow – but closing – observational window that enables assessment of changes in Triton's plume activity and surface characteristics since Voyager 2's encounter one Neptune-Triton season ago.

Conclusion: This mission design allows Trident to accomplish a scientifically rich yet radically cost-effective investigation of an unusual icy world, dramatically expanding the horizons of NASA's Discovery Program.

References: [1] Prockter L. M. et al. (2019) *LPS L,* this issue. [2] Hendrix, A. R. et al. (2019) *Astrobiology* 19(1), doi:10.1089/ast.2018.1955. [3] Squyres, S. W. et al. (2011) *Vision and Voyagers for Planetary Science in the Decade 2013-2022*, National Academies Press.

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Table 1: Trident's suite of mature instruments will produce a diverse and valuable set of measurements for both targeted science and exploration.

Instrument	Functionality
Infra-red spectrometer	2-100 km, near-global compositional mapping to 5 µm.
Narrow angle camera	Anti-Neptune regional mapping and limb imaging (<=200 m).
Wide-angle camera	Sub-Neptune and haze imaging and change detection (<= 1500 m).
Triaxial magnetometer	Ocean detection.
Radio science	Atmospheric occultations for neutral and electron profiles, and gravity for C22.
Plasma spectrometer	Atmospheric charged particles. Energetic inputs to ionosphere.

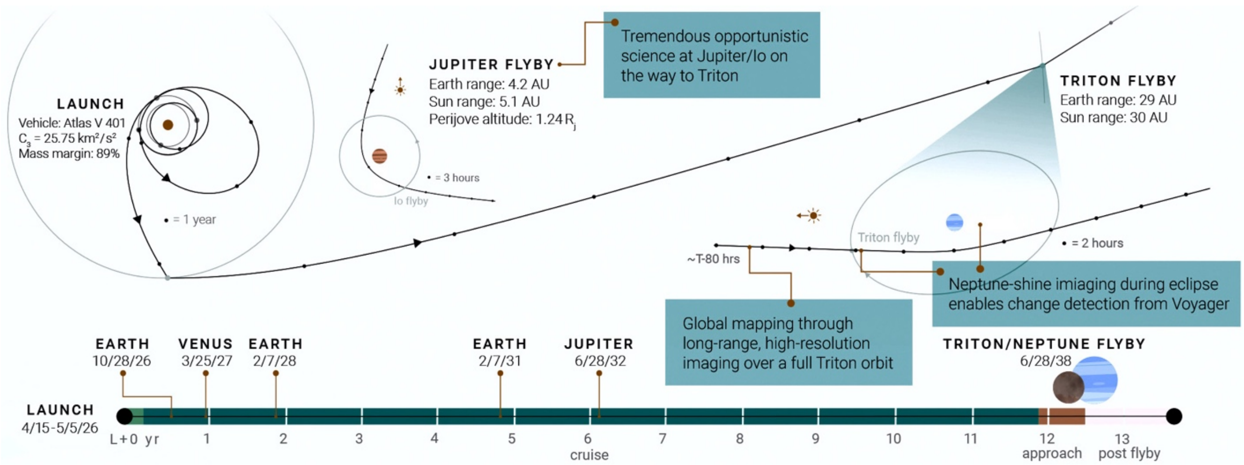

Fig. 1: Trident's efficient EVEEJN ballistic trajectory, incorporating a gravity assist at Jupiter, enables a minimal propulsion system and 12-year cruise to Trident, culminating in a fast flyby in 2038. The trajectory offers many bonus science opportunities.

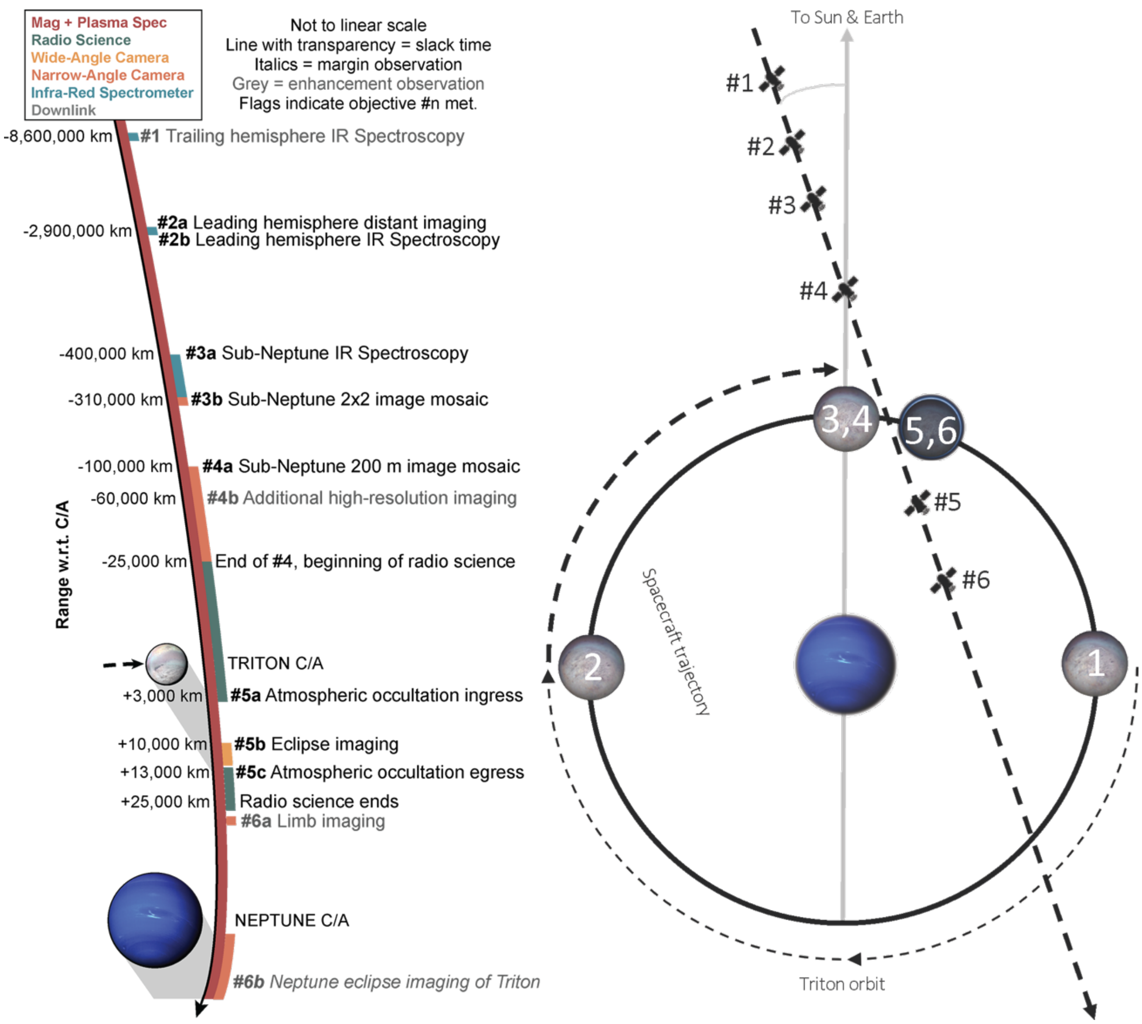

Fig. 2: (Left) The observation sequence starts before the magnetopause, and features: (i) distant remote sensing over a full Triton orbit of Neptune for near-global mapping, (ii) eclipse imaging under Neptune-shine illumination for Voyager repeat coverage, (iii) ingress and egress atmospheric radio occultations, and (iv) a 500-km range closest approach for ocean detection and sampling of Triton's ionosphere. To minimize single-point failure risk, Trident uses an active redundant operational sequence, with each observations either given sufficient time margin to repeat, or a backup observation (some using a different instrumental solution). (Right) Relative positions of spacecraft and Triton during six discrete sequence phases (not to scale).