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Trident: Mission to an exotic active world

L. M. Prockter (1), K. L. Mitchell (2), C. J. A. Howett (3), D. A. Bearden (2), W. E. Frazier (2), and the Trident Team
(1) Lunar and Planetary Institute/USRA, Houston, TX, USA (prockter@lpi.usra.edu); (2) Jet Propulsion Laboratory, Pasadena, CA, USA; (3) Southwest Research Institute, Boulder, CO, USA

Abstract

One of the most unusual and surprising bodies in the solar system, Neptune's moon Triton has not been observed since the Voyager 2 flyby in 1989. The spacecraft captured a series of images, mostly of the southern, sub-Neptune hemisphere, establishing Triton as one of a rare class of solar system bodies with a substantial atmosphere and active geology. Although Triton is, like many other bodies, subject to the tidal, radiolytic, and collisional environment of an icy satellite, its starting point and initial composition is that of a Dwarf Planet originating in the KBO. It is this duality as both captured dwarf planet and large icy satellite that has undergone extreme collisional and tidal processing that makes Triton a unique target for understanding two of the Solar System's principal constituencies and the fundamental processes that govern their evolution. Thus, comparisons between Triton and other icy objects will facilitate re-interpretation of existing data and maximize the return from prior NASA missions, including *Voyager*, *New Horizons*, *Galileo, Cassini* and *Dawn*.

Trident is a mission concept that is submitted to NASA's <$500M Discovery program. Trident will address three overarching goals:

(1) *Explore evolutionary pathways towards habitable worlds:* Triton is an outlier among the compelling ocean world candidates: It originated from the Kuiper Belt, implying a higher abundance of carbon and nitrogen, key ingredients for habitability; its intense ionosphere, rather than the Sun, may drive the production of atmospherically derived organics; and powerful obliquity tides, rather than tidal heating, may sustain an ocean. The study of Triton will synthesize a new understanding of potential pathways toward habitability.

(2) *Explore what drives processes on active worlds:* Triton may be the most active icy world in the Solar System. Triton presents an ideal target for studying the long-term consequences of capture, including: persistent heating due to Neptune's gravitational influence, possibly leading to active geology via sustainment of an ocean; extreme seasonal variations from Triton's highly inclined orbit, effecting volatile migration across the surface and atmosphere and possibly leading to plume eruptions; and interactions of Neptune's magnetic field and particle environment, driving Triton's ionosphere and atmospheric chemistry.

(3) *Explore vast, unseen lands:* Triton, the largest captured moon in the Solar System, also has the most extensive unseen surface area of any solid body. Without near-global coverage, it is almost impossible to understand the geological history of a world. In the context of the incredible diversity of landforms and processes observed by Voyager, Triton offers rich opportunities for new discovery.

Contributions to these goals will be achieved in four objectives that address the following questions: (1) Is Triton an ocean world?; (2) What processes resurface Triton?; (3) What drives Triton's plumes?; and (4) Why is Triton's ionosphere so intense?

Exploration of Triton under Discovery is made possible by radioisotope power combined with a straightforward 13-year ballistic trajectory. Trident launches in 2025, exploiting a rare, extremely efficient Jupiter gravity-assist enabling a simple spacecraft design with large mass margin. A 2038 arrival at Triton capitalizes on a critical observational window – drawing to a close soon after and not to repeat for a century – to reveal changes in Triton's plume activity and surface characteristics one Triton season since the only previous spacecraft encounter by Voyager in 1989.

To address its goals and objectives, Trident carries a focused instrument suite consisting of: (1) a magnetometer, primarily for detection of the presence of an induced magnetic field which would indicate compellingly the presence of an ocean; (2) a high-resolution mapping and compositional infrared spectrometer with spectral range up to 5 µm, suitable for detection and characterization of surface materials at the scales of Triton's features; (3) a narrow-angle

camera, for imaging of the mostly unseen anti-Neptune hemisphere; (4) a wide-angle camera for repeat imaging of the sub-Neptune hemisphere to look primarily for signs of change; (5) a gravity and atmospheric occultation radio system; and (6) a plasma spectrometer to sample Triton's tenuous atmosphere.

To carry out these experiments, Trident executes a six-day encounter sequence that probes for an ocean, measures the ionosphere, and views nearly the whole of Triton as it traverses a single orbit around Neptune, mapping the >60% of the surface that is as yet unseen.

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