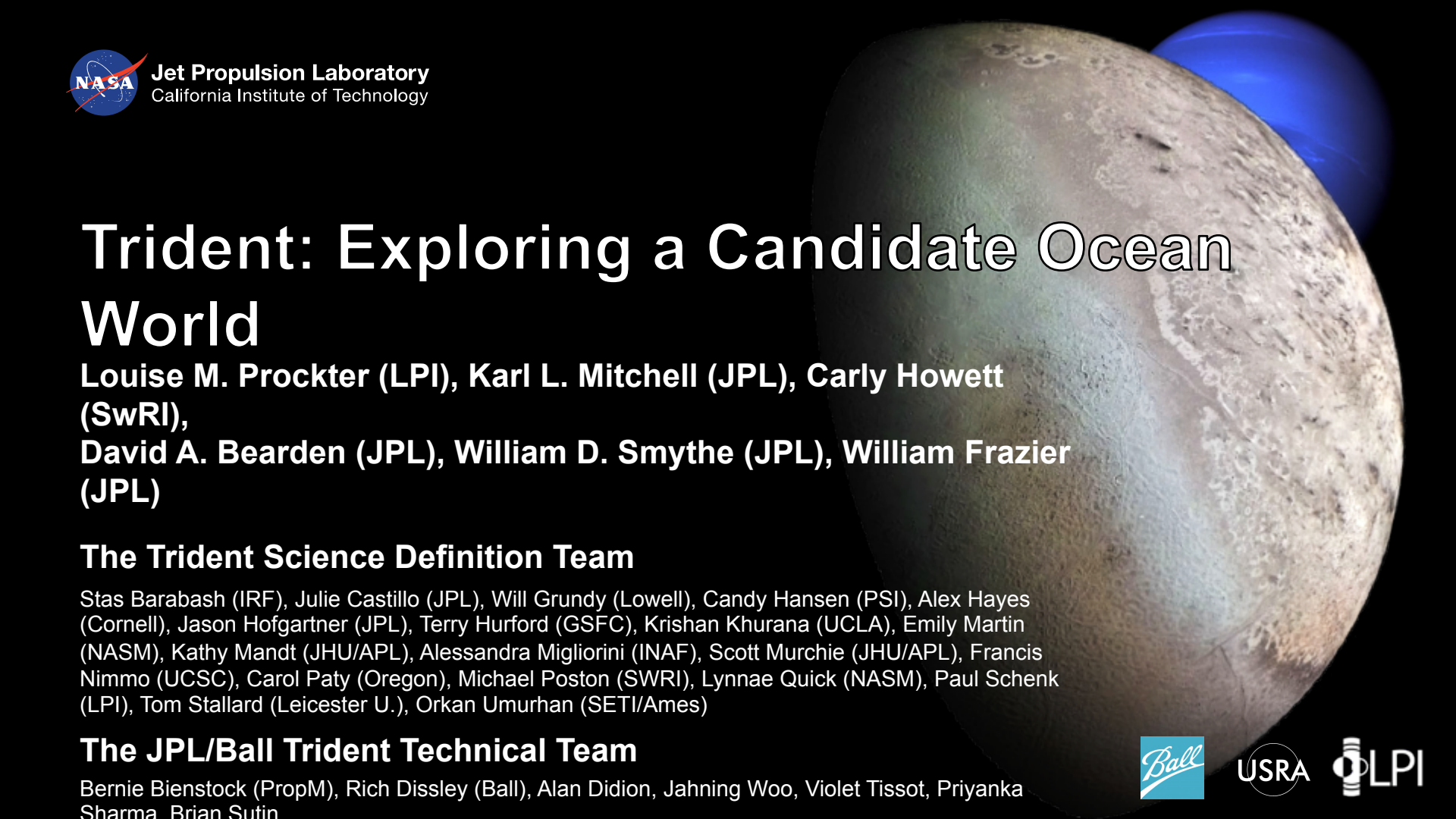

Jet Propulsion Laboratory
California Institute of Technology

Trident: Exploring a Candidate Ocean World

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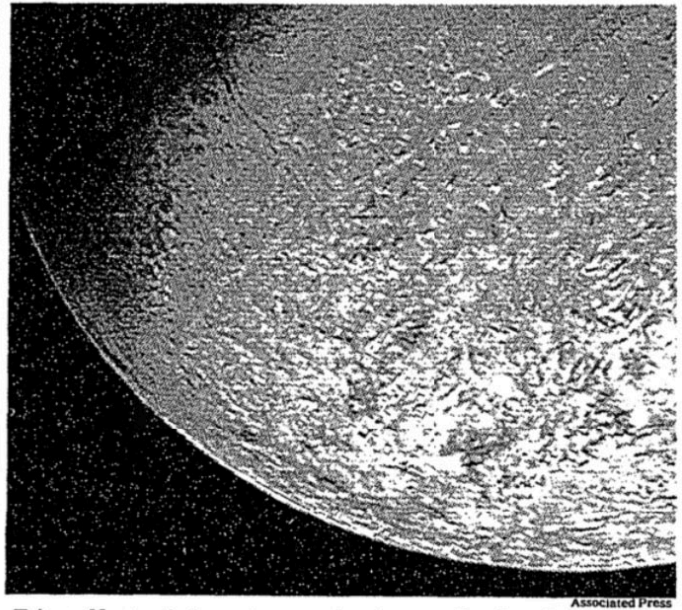


Associated Press

Triton, Neptune's largest moon, in photograph taken from 330,000 miles away and transmitted by use of a nuclear generator that relies on a "battery" of natural radioactive decay to produce power.

Pictures of Triton, Neptune's Moon, Show Signs of a Never-Seen Icy Volcanism

By JOHN NOBLE WILFORD

Special to The New York Times

PASADENA, Calif., Aug. 25 — Speeding away from its fourth and last planetary encounter, Voyager 2 today left jubilant scientists agog as they viewed new photographs showing in dazzling clarity Neptune and especially its largest moon, Triton, where frozen lakes and ridges bespeak a past of slow-flowing icy volcanism never before seen in the solar system.

The pictures of Triton showed a mottled terrain of grayish pink, with smooth icy expanses only rarely marred by an apparent meteorite crater, and with long double ridge lines running out of rugged regions and sometimes transecting each other. A light haze hung high over polar regions that appeared covered with bright, thick frost.

Astonished and puzzled, scientists were reduced to unscientific expressions like "bizarre" and "wow!" as the Voyager left the solar system.

Champagne and Pizza

Some of the scientists drank champagne when confirmation arrived by radio, 4 hours and 6 minutes after the fact, that Voyager 2 had survived its closest approach to Neptune at 11:56 P.M. Thursday, Eastern daylight time.

They stayed up all night, drinking coffee and eating pizza, as the spacecraft flew behind Neptune and then emerged to start transmitting one picture of Triton after another. The closest approach to Triton, at a distance of 24,000 miles, came at 5:10 A.M. today.

Turning away from television monitors showing the stunning pictures of Triton, Dr. Eugene Shoemaker, a geologist on the Voyager team, said, "It's bizarre, and that's what makes this fun."

Dr. Laurence Soderblom of the United States Geological Survey, who is a specialist in the geology of moons, was even more exuberant, exclaiming, "Wow! What a way to leave the solar system!"

Voyager 2's successful rendezvous completed its "grand tour" of Jupiter, Saturn, Uranus and now Neptune. The one-ton spacecraft, which has been traveling through the outer solar system since 1977, is now headed out toward interstellar space. Engineers said the craft might be able to continue operating and sending data for 25 more years.

'A Very Historic Day'

"Everything went exceedingly well," said Norman R. Haynes, the project manager. "The spacecraft performed everything it was supposed to do. We couldn't be happier with the results."

At a celebration this morning, Vice President Dan Quayle, who is also chairman of the newly created National Space Council, congratulated officials and scientists at the Jet Propulsion Laboratory here and called this "a very historic day for America and America's space program."

With Voyager 2's passage of Neptune, all of the known planets expect Pluto have now been visited by spacecraft at least once. There are no immediate plans for missions to Pluto, but in the next decade or so American spacecraft are expected to revisit Venus, Mars and Saturn.

In a preliminary analysis of data

Continued on Page 8, Column 3

Rep. Frank Acknowledges Hiring Male Prostitute as Personal Aide

By ALLAN R. GOLD

Special to The New York Times

BOSTON, Aug. 25 — Representative Barney Frank of Massachusetts said today that without his knowledge a male prostitute he had hired to do personal errands had run a prostitution service from the Congressman's Washington apartment.

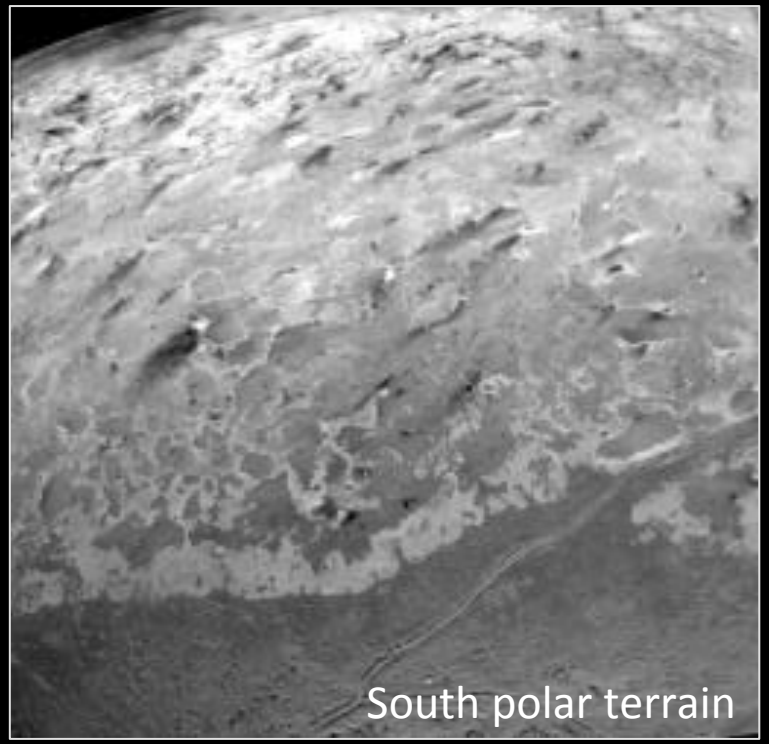
The Congressman said that to help Mr. Gobie, he hired him as a housekeeper and driver. Mr. Frank also said he made some calls and wrote letters, using Congressional stationery, to Mr. Gobie's probation officer in Virginia to let the office know he was employed

NASA Jet Propulsion La
California Institute of T
USRA LPI

State of knowledge: Voyager

Voyager showed that Triton's surface is:

- Young
  - Average surface age ~50 Ma, possibly <10 Ma (Schenk & Zahnle, 2007)
- Dynamic
  - Resurfacing via volcanic, tectonic, and sublimation processes; endogenic and exogenic (Kirk et al., 1990; Croft et al., 1995)
- Diverse
  - Several geological units, some appear unique (e.g., Schenk & Jackson, 1993)



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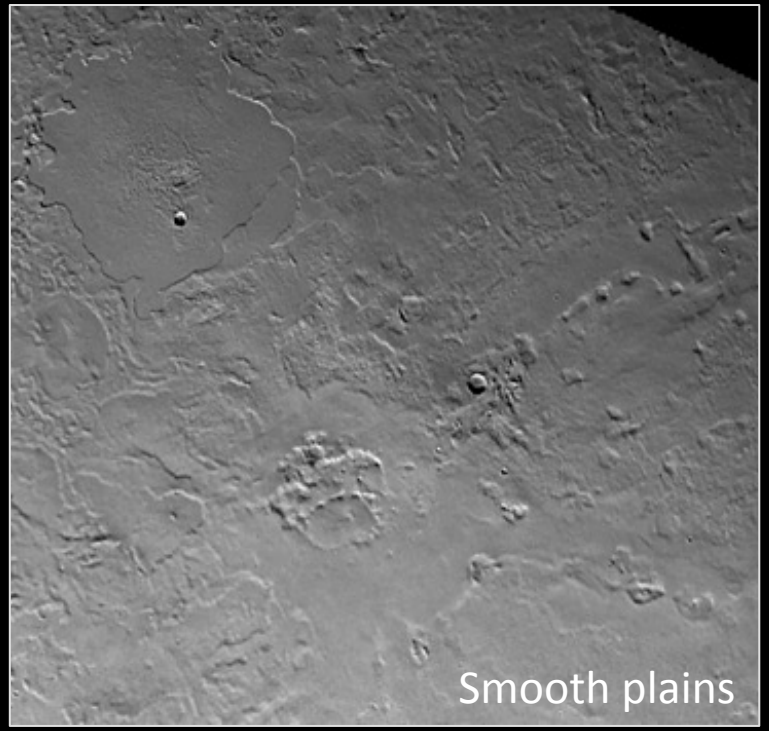

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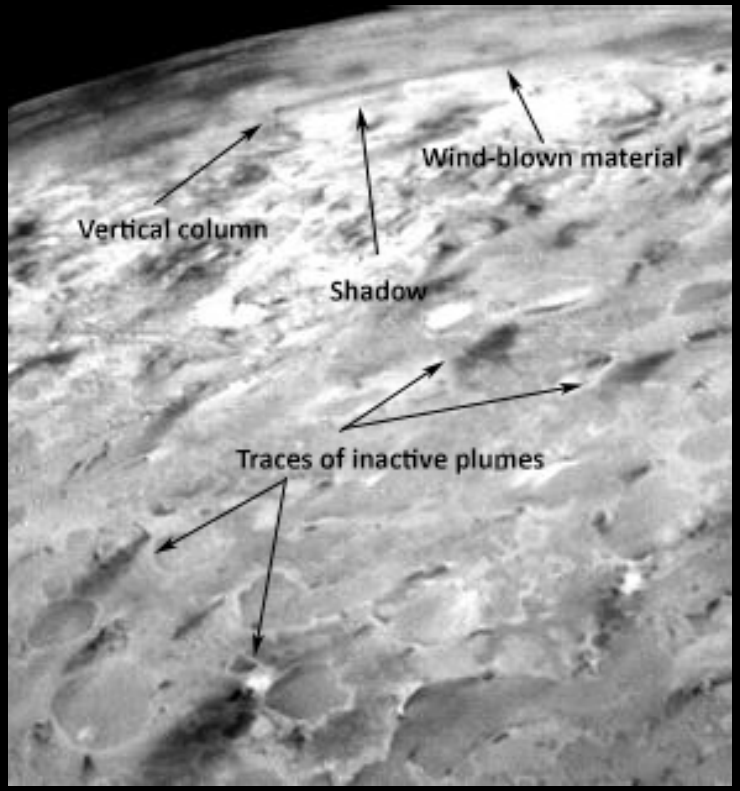
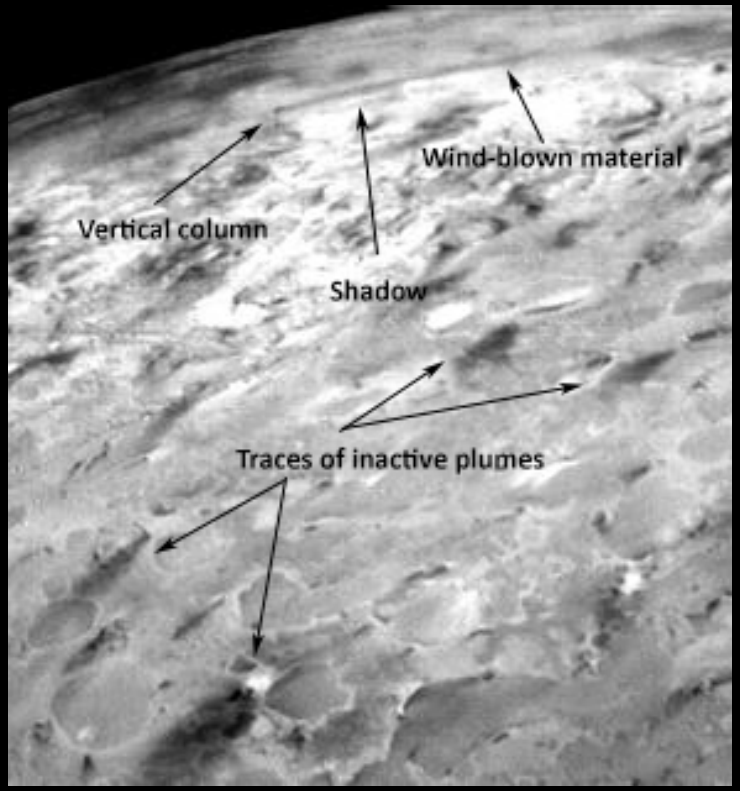
Triton's plumes



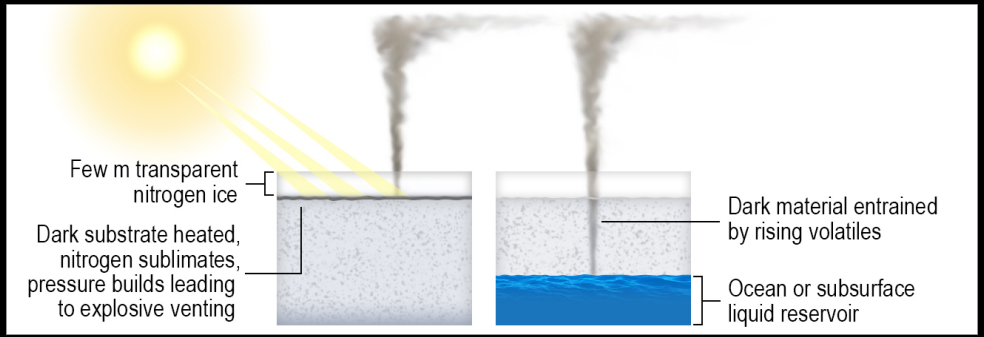
- Form within a few degrees of subsolar latitude
- Found on volatile-rich south polar terrain
- Interpreted to result from sublimation-driven explosive venting of dark material from beneath transparent ice (Kirk et al., 1995)

The origin of Triton's plumes



Triton`s plumes: Solid state greenhouse or a product of cryovolcanism? Origin has different implications for Triton's shell structure and current thermal state

	Mars	Enceladus	Triton
Material	CO_2	H_2O	N_2
Mass flux	0.15 kg/s	300 kg/s (total)	400 kg/s
Duration	<2 hours	Sustained?	Unknown

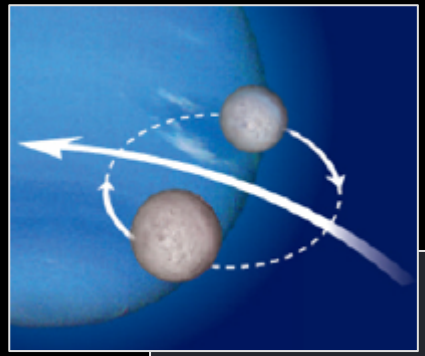


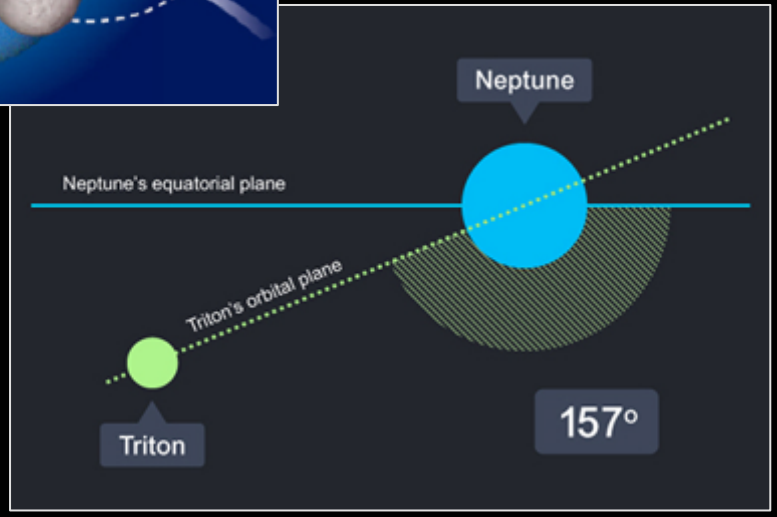
State of knowledge: Origin and ocean

On the basis of its composition and orbit, Triton is likely a captured Kuiper Belt Object

- Substantial heating would have resulted from capture (McKinnon, 1984, 1995; Agnor and Hamilton, 2006)

- Triton's high inclination results in significant obliquity, which is predicted to be sufficient to maintain an internal ocean (Chen et al., 2014; Nimmo and Spencer, 2015)





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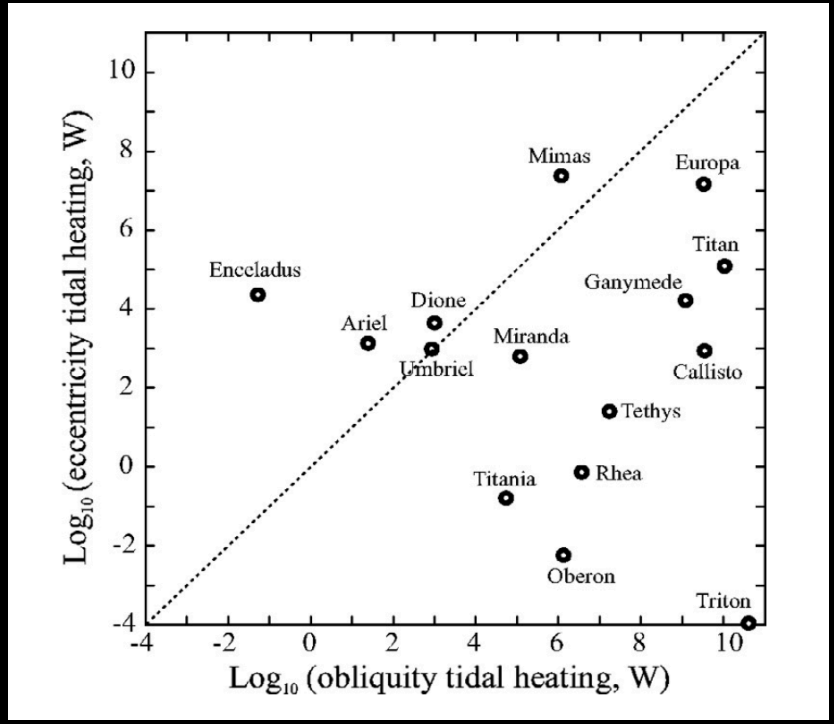
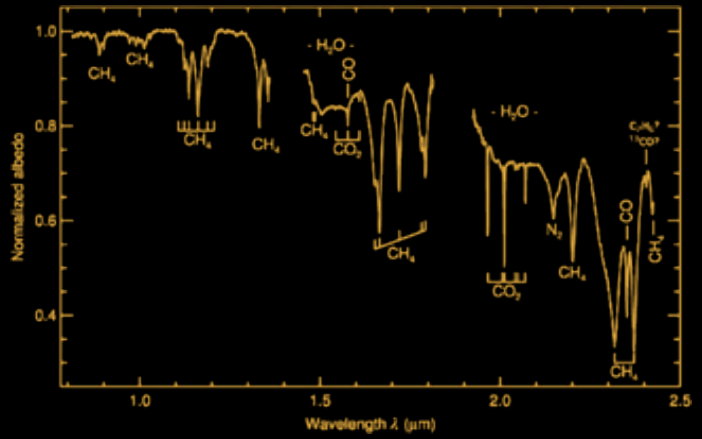


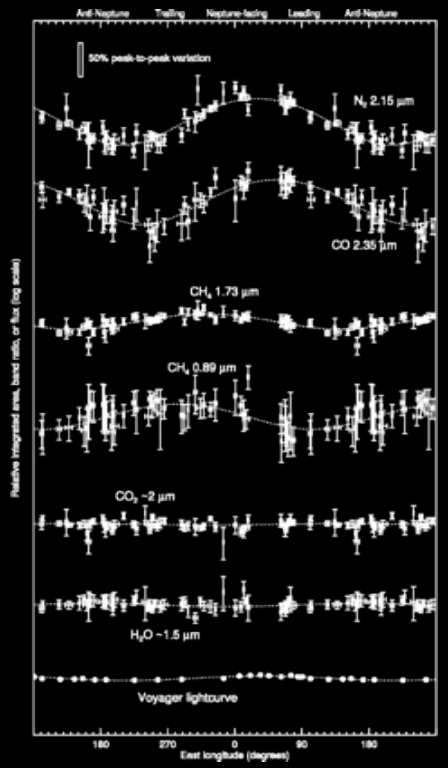
Chen et al., 2014

State of knowledge: Astronomy

Ground-based astronomy has yielded overall surface composition and hints of change, but spectra are limited

- Surface is primarily composed of N_2, H_2O, CO_2, CH_4, and CO (Grundy et al., 2010)
- Surface atmosphere volatile interchange, and potentially dramatic climate change happening over obliquity and/or seasonal timescales (e.g. Trafton, 1984; Buratti et al., 1994, 1999, 2011)
- Photochemical products expected, hints of C_2H_6 and HCN
- Few observations beyond 2.5 µm



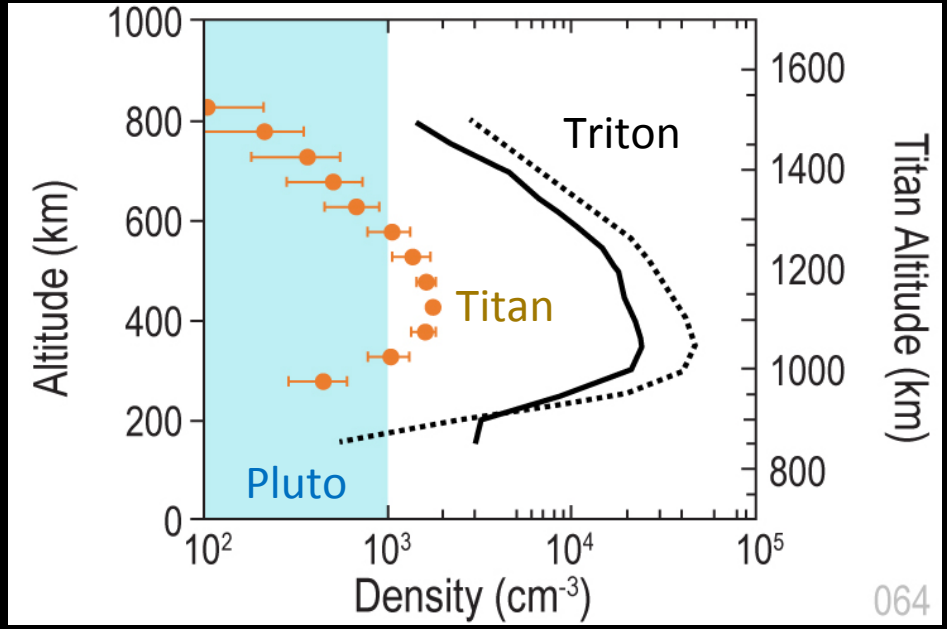


Grundy et al., 2010

Trident's unusually intense ionosphere

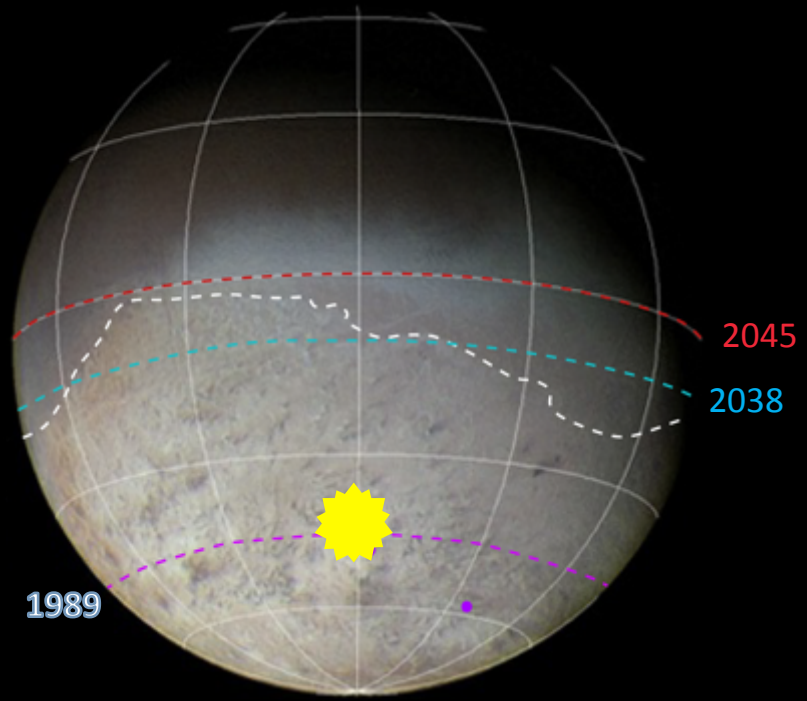
Triton's ionosphere is supercharged!:

- Voyager data shows a peak electron concentration of 46 x 10^9 m^{-3} at 340 km altitude (Tyler et al., 1989), greater than any other moon or icy world by over an order of magnitude
- The energy source for all other known ionospheres in the Solar System is the sun - however, Triton is at 30 AU
- Could the ionosphere be driven by particles from Neptune's magnetosphere?



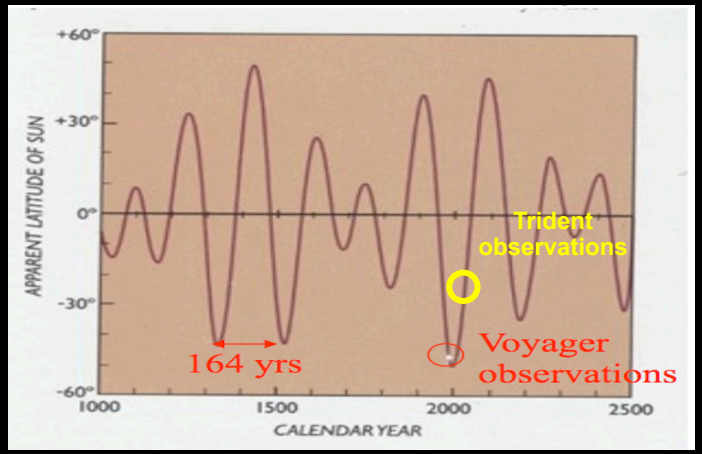
Tyler et al., 1989; Mandt et al., 2012; Hinson et al., 2018

Why Now? Seasonal volatile transport and plume origin

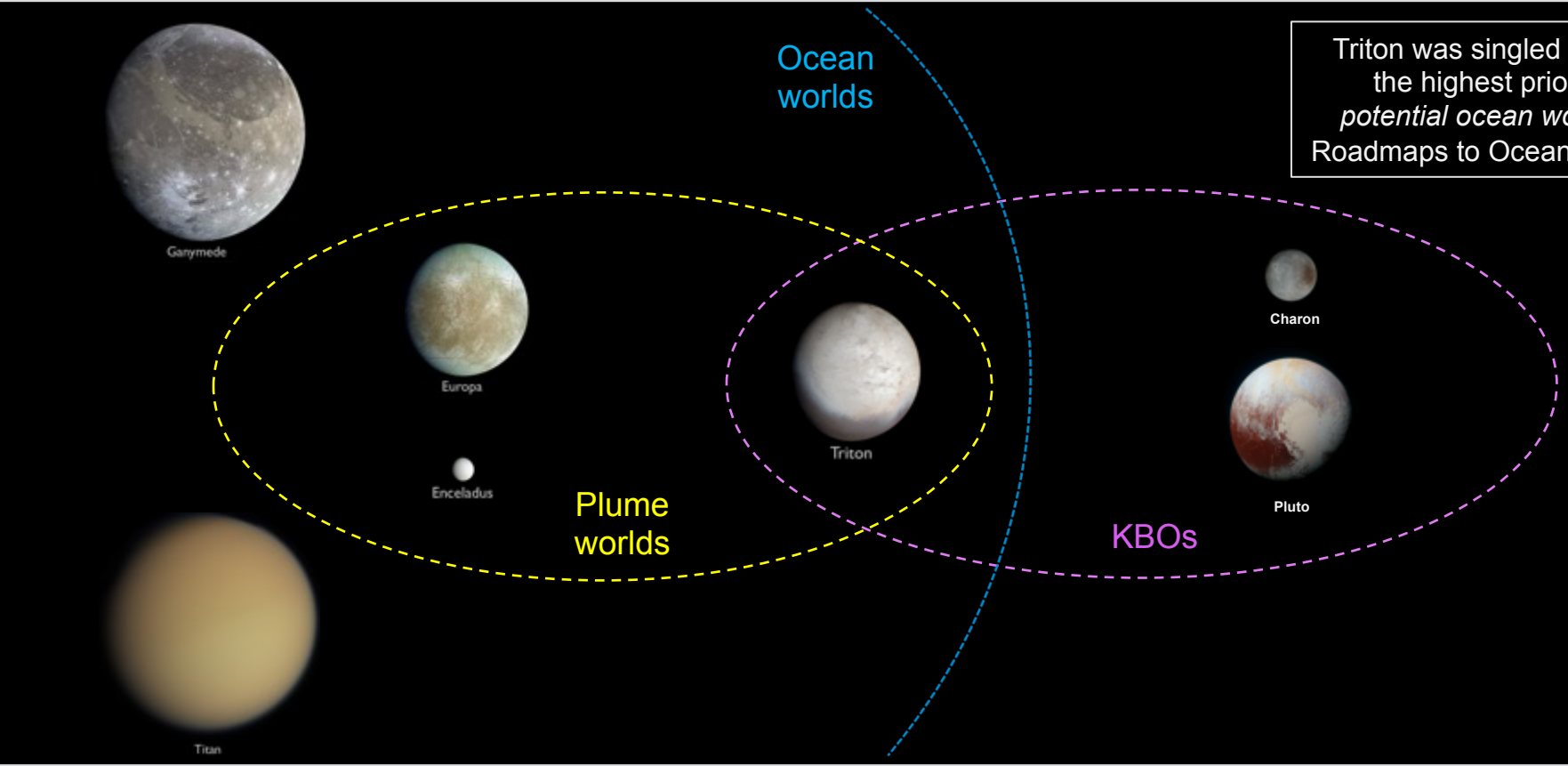


The subsolar latitude was at summer solstice during Voyager. Trident encounters Triton one full season later – just before the subsolar point migrates northward off the edge of the south polar terrain

- Allows investigation of seasonal volatile migration
- Allows test of sublimation-driven plume model



Why Triton? A member of three distinct populations



Triton was singled out as the highest priority *potential ocean world* in Roadmaps to Ocean Worlds

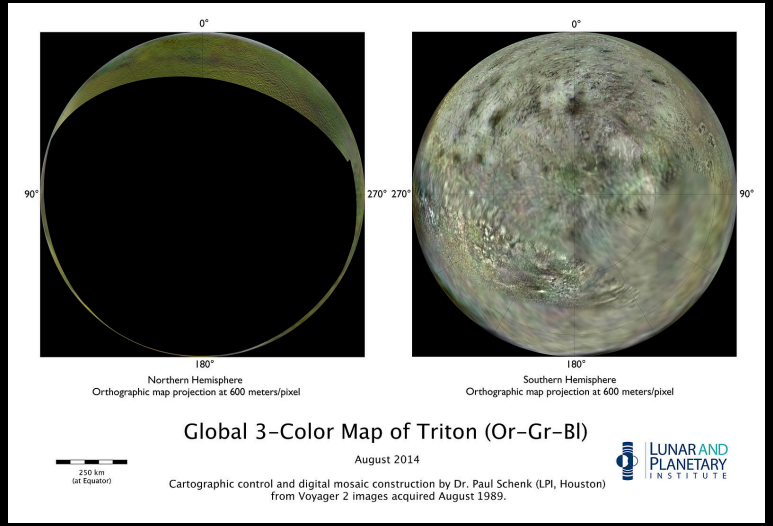
Trident concept

- Discovery mission cost target
- Return science data from flyby in a “reasonable time” ala New Horizons
- We have identified an optimized solution to enable a New Horizons-like fast flyby of Triton that fits within the Discovery 2019 cost cap
- Launch: 2026, arrive at Triton 2038
  - Long duration, 12-year cruise
- Ballistic trajectory
- 2 MMRTGs, large battery for encounter operations

Trident Concept: Goals and objectives

Three overarching goals:

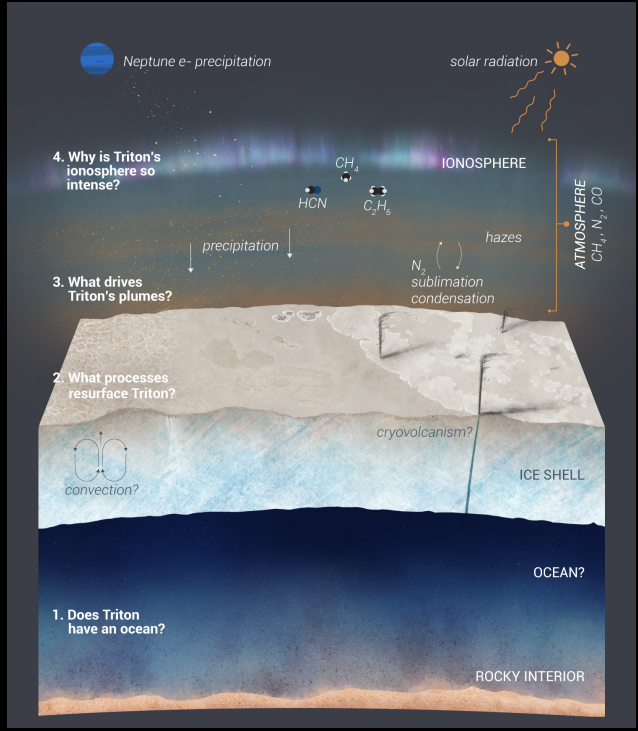
1. Explore evolutionary pathways towards habitable worlds
2. Explore what drives processes on active worlds
3. Explore vast, unseen lands



Trident Concept: Goals and objectives

Four objectives:

1. Is there an ocean?
2. What processes resurface Triton?
3. What drives Triton's plumes?
4. Why is Triton's ionosphere so intense?



Trident Payload

INSTRUMENTS

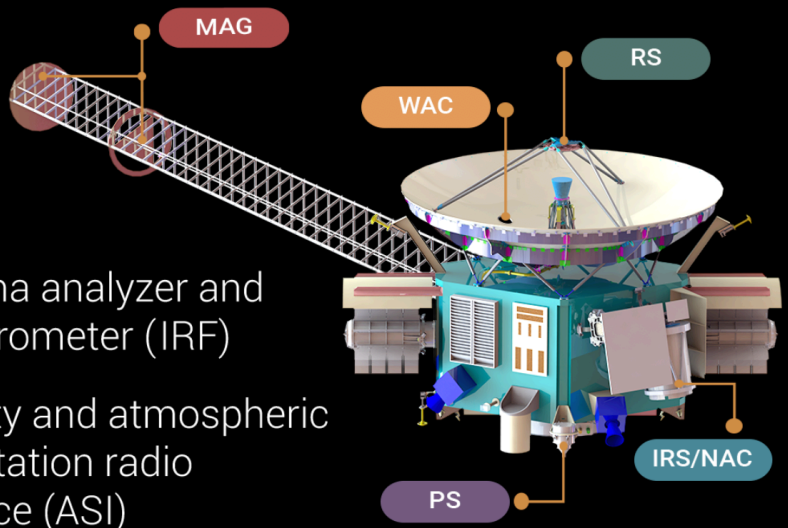
MAG Enables detection of subsurface ocean (UCLA)

IR SPEC-NAC Spectral and optical imaging of surface features (Ball)

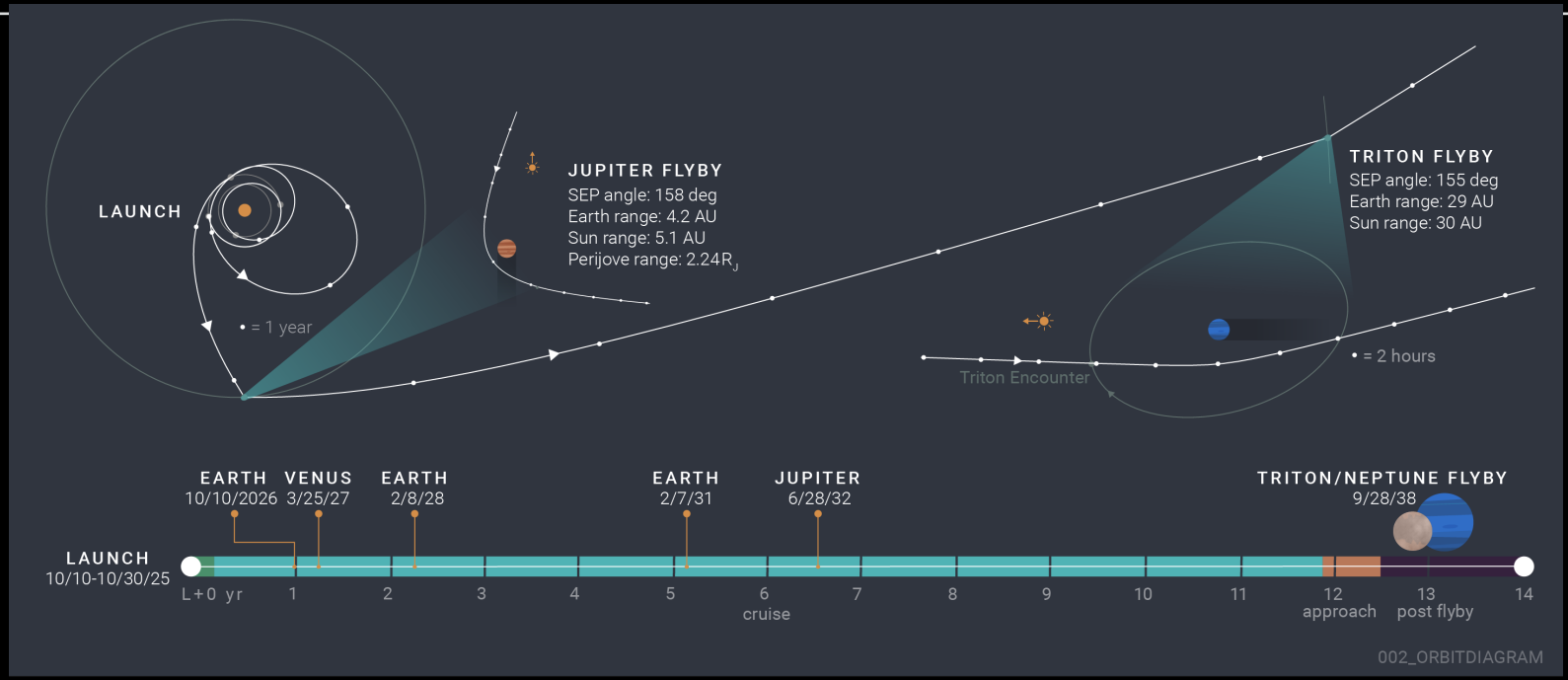
WAC Wide-angle eclipse imager (JPL)

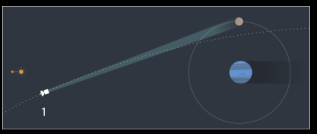
PS Plasma analyzer and spectrometer (IRF)

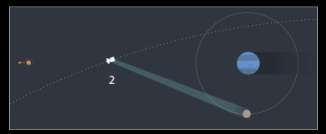
RS Gravity and atmospheric occultation radio science (ASI)

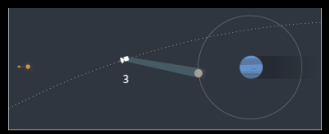


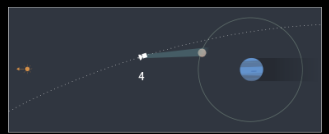
Trident Trajectory

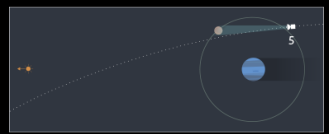


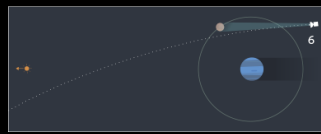






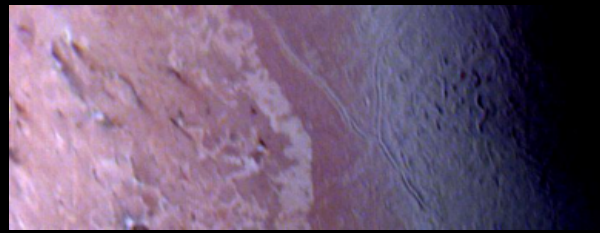


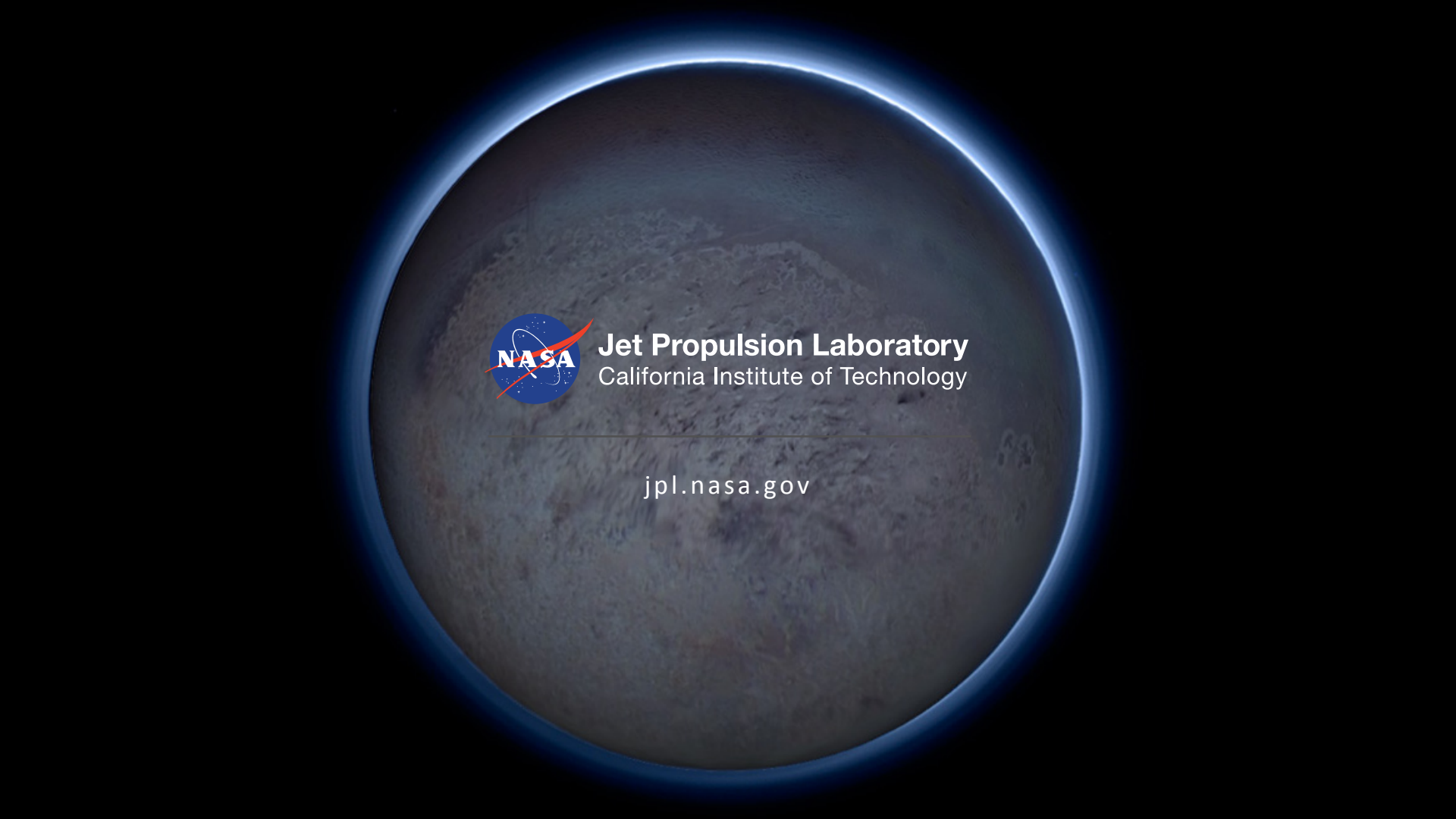




Summary

- Triton is likely an exotic ocean world, with a unique history in the solar system
- Trident provides an optimized solution, enabled by MMRTGs and a straightforward ballistic trajectory, to enable a Discovery-class mission to visit Triton within the next two decades
- This would allow confirmation of an ocean, understanding of resurfacing processes including plume origins, investigation of material transport between the surface and atmosphere, determination of the energy sources driving the ionosphere, and detection of changes since Voyager




NASA
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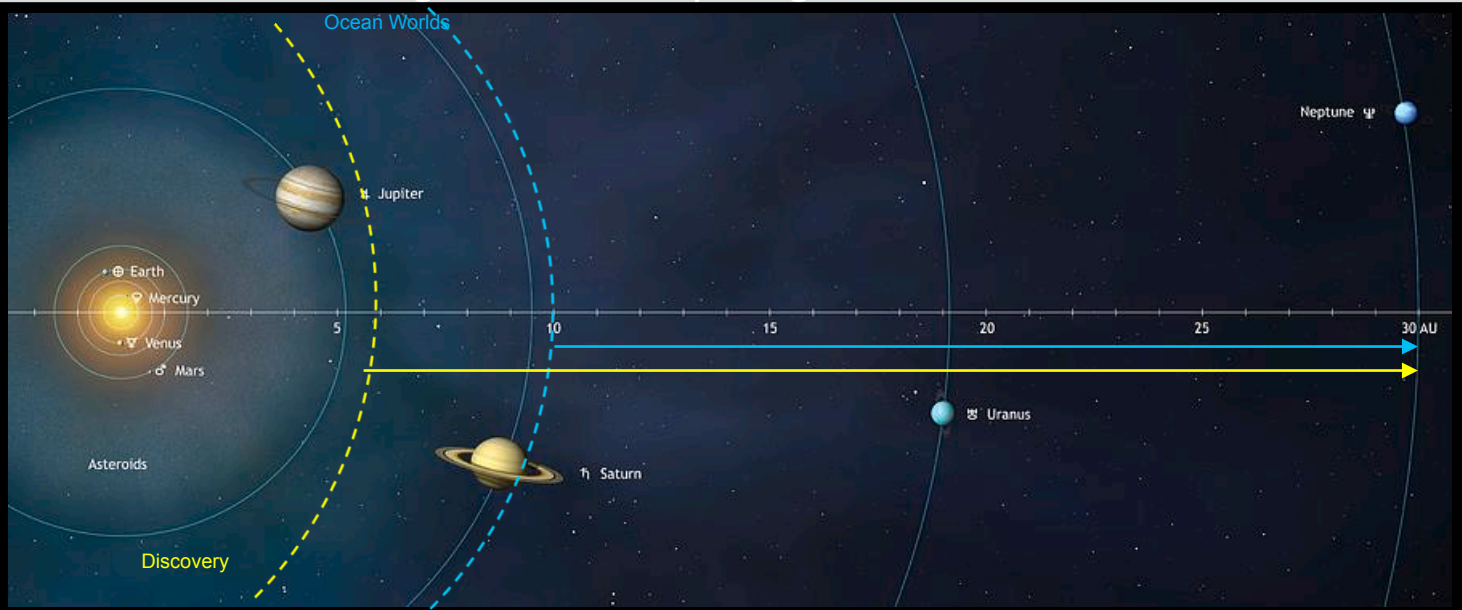
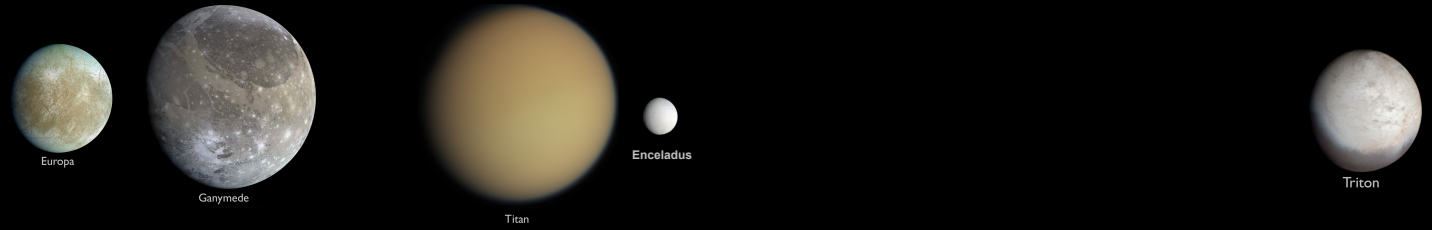
jpl.nasa.gov

Why Triton?

Taking the Discovery Program to 30 AU