OPAG Presentation to CAPS: NF-5

20 May 2024

Amanda Hendrix, OPAG Chair
on behalf of the OPAG Steering Committee and the Outer Planets community

Topics – addressing the CAPS SoT

The National Academies of Sciences, Engineering, and Medicine will address the following questions:

- Has **scientific understanding** or external factors, such as programmatic developments or technological advances, significantly changed since the New Frontiers 5 (NF-5) mission themes or New Frontiers 6 (NF-6) mission themes were evaluated by most recent planetary science and astrobiology decadal survey, Origins, Worlds, and Life (OWL)?
- Has scientific understanding or **external factors, such as programmatic developments or technological advances**, been sufficiently substantial since the 2011 Visions to Voyages decadal survey to warrant **reconsidering or removing** any of these mission themes?
- Given that NASA anticipates the next New Frontiers Announcement of Opportunity (AO) will be released no earlier than 2026, **should NASA use the mission themes provided in the draft NF-5 AO (released 1 September 2023), the NF-6 mission themes as provided in OWL, or a hybrid of the these?**

Inputs here are based on community discussions and emails over the last ~2 years (see details in backup slides)

The NF program is critical for OP science!

- The New Frontiers Program is particularly important for the outer planets community as the cost cap for Discovery missions is typically not sufficient to enable outer planets missions, and Flagship missions occur at a low cadence.
  - No Discovery mission to an OP target has been selected… the Outer Planets community relies on NF
- We hope that outer planet destinations will continue to be accessible via NF-5 and future New Frontiers solicitations. While OPAG understands the need to control costs, the New Frontiers program is critical for outer planets missions.
- OPAG has discussed NF-5 at several meetings and townhalls… our findings and statements are included in the backup slides

Scientific advances since OWL have improved the cases for OP missions in NF (1 of 2)

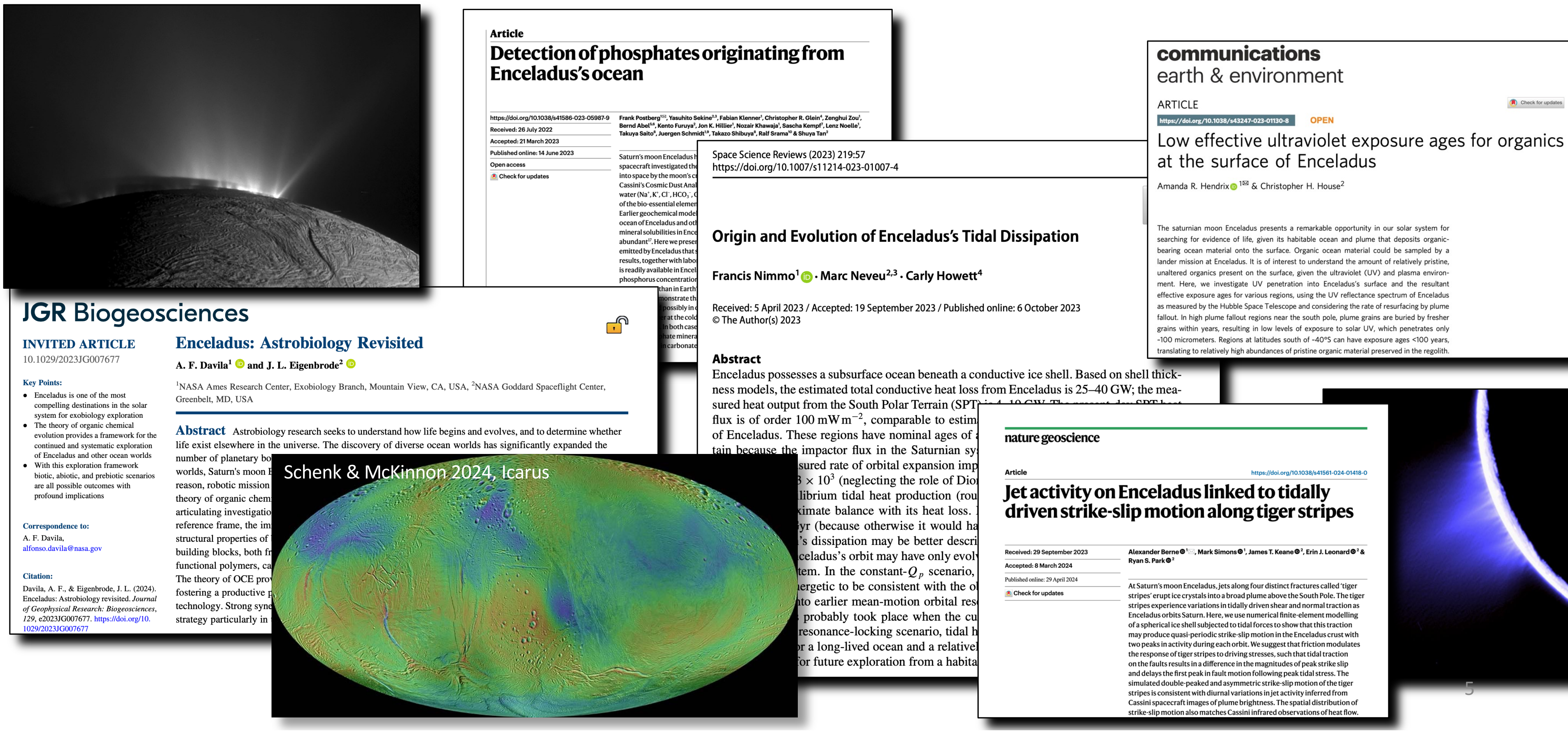
New results at Io (examples): de Kleer et al. (2024) have shown that isotope analysis can address the long-term evolution of Io and that its volcanism has been occurring for the age of the solar system; Rathbun et al. (2024) use IRTF to study Io hotspots showing activity not seen by Galileo

Flying gas and dust mass spectrometers through Io's atmosphere and plumes —possible via New Frontiers but not Discovery with its smaller cost cap—could lead to major advances not appreciated during OWL studies.

Io science goals are well documented in a recent wave of review articles/books, including:

- 2021: de Pater et al., "A 2020 Observational Perspective of Io," Annual Review of Earth and Planetary Science, https://doi.org/10.1146/annurev-earth-082420-095244.
- 2022: Elements special issue "Exploring Jupiter's Moon Io" https://pubs.geoscienceworld.org/elements/issue/18/6
- 2023: "Io: A New View of Jupiter's Moon," Springer, Editors: Lopes et al., https://link.springer.com/book/10.1007/978-3-031-25670-7

Scientific advances since OWL have improved the cases for OP missions in NF (2 of 2)



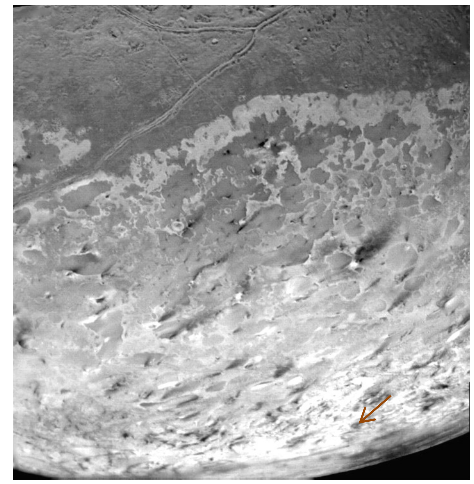
Changes in external factors and technological development since OWL warrant reconsideration of Triton as a target

Triton was not included on the OWL NF6 list **solely because the assumed NF6 launch window did not align with a Jupiter Gravity Assist (JGA)** – not because of scientific priorities

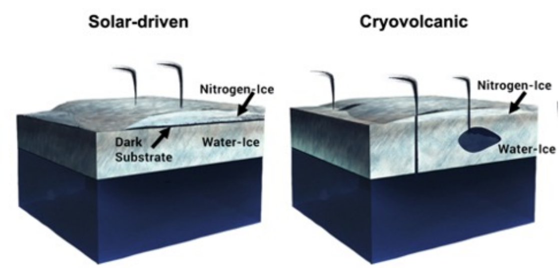
The delays, advances, and developments since then have invalidated this constraint.

The OWL assumptions are no longer valid.

Study of Triton's southern hemisphere and in particular its plumes drives the urgency of a Neptune/Triton mission… **arrival before 2060 is critical**



- Two hypotheses for what drives Triton's plumes:
  - Solar-Driven like Mars?
  - Endogenic like Enceladus?
- *What volatile reservoir do they access*?



See Hofgartner et al. (2022) *Icarus* 375:114835

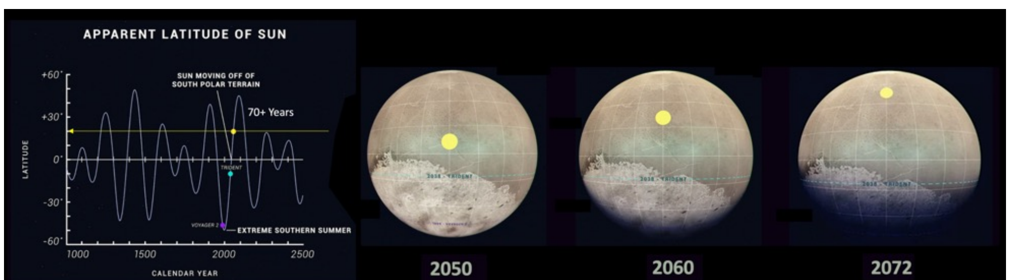


Figure 2 *70 Plus Years of Solar Latitude Higher than 20 degrees*

After ~2060, illumination of southern hemisphere degrades significantly

New non-JGA trajectories to Triton! *the benefit from a Jupiter gravity assist is less significant than assumed*, and non-JGA trajectories are enabling. (use multiple inner solar system gravity assists)

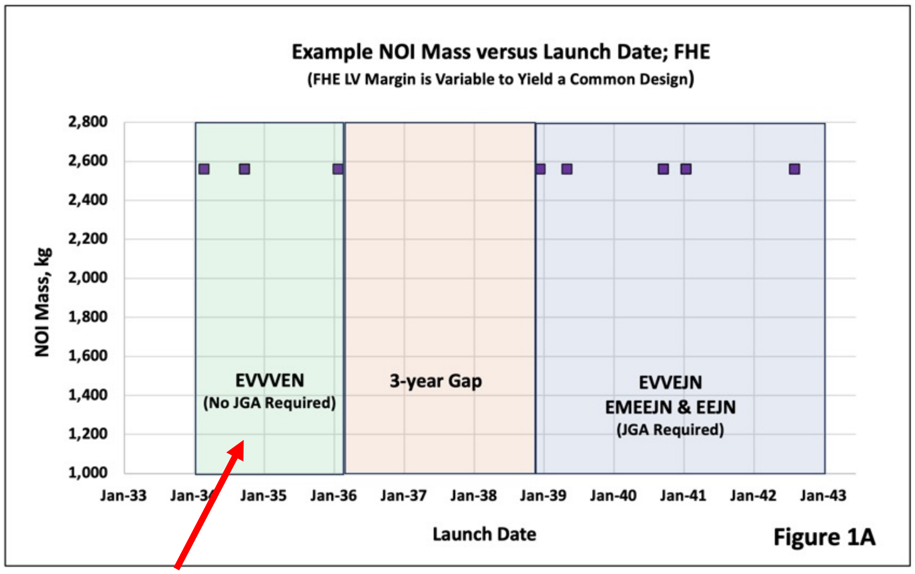


Figure 1A

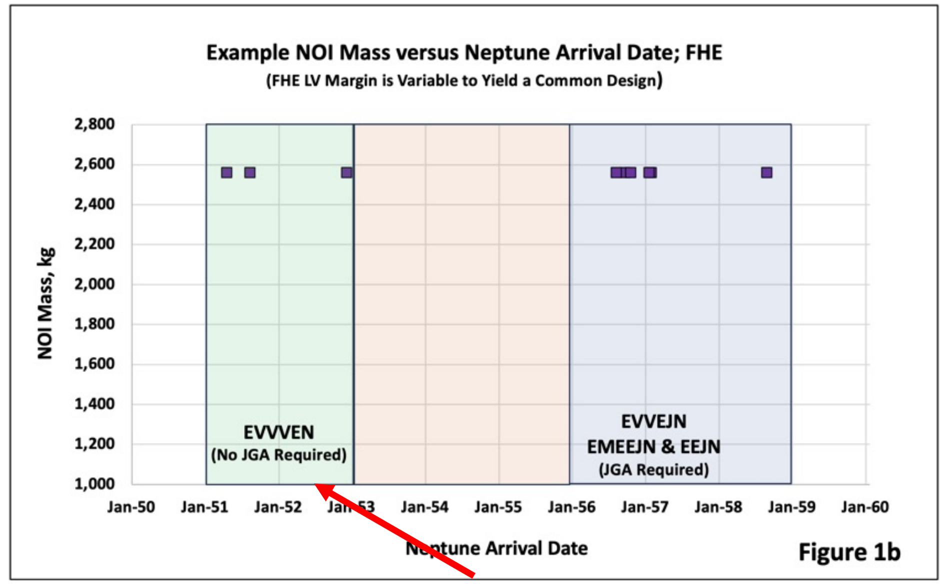


Figure 1b

Trajectories to Neptune/Triton *that do not require a JGA* are possible in the 2034-2036 timeframes, with arrival in the 2051-2053 timeframe

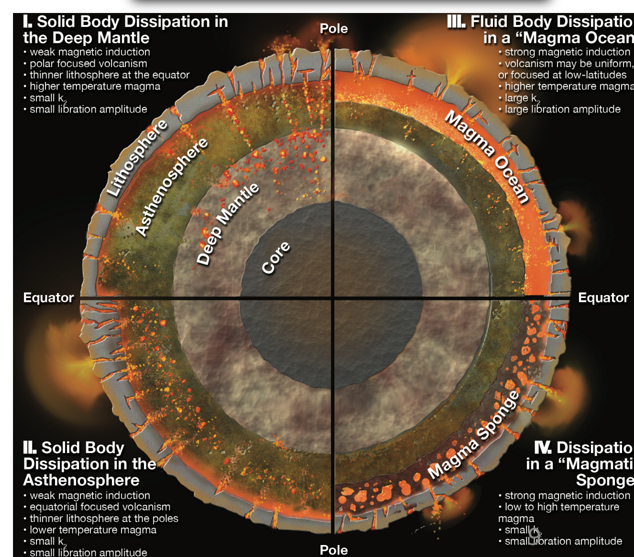
New trajectories (left) have been found since the Decadal Survey study, capable of delivering greater mass payloads into Neptune orbit prior to the 2060s (right) using multiple inner solar system gravity assists. NOI Mass (2580 kg) assumes a Falcon Heavy Expendable (FHE), but adequate mass (1900 kg) would also be delivered for all trajectories assuming the “high performance” curve in Draft NF-5 AO (equivalent to a Vulcan VC-6).

- Based on this new trajectory information, and driven by the delays in the NF-5 call that have led to OWL assumptions being invalidated, it is respectively requested that Triton-OWS be added as a mission concept to the NF-5 AO.

There are NO examples in which scientific understanding or external factors have been sufficiently substantial since the 2011 V&V decadal survey to warrant reconsidering or removing any of the OP mission themes.

Juno's close flybys provided a tantalizing preview of Io but will not address the full breadth of science goals for the New Frontiers 5 Io Observer objectives:

- Juno's only science objective for Io is to measure Io's gravitational Love number (k_2), to test whether Io has a magma ocean. While we may learn a lot from this measurement, determination of k_2 alone will not be sufficient to distinguish between the range of possible hypothesized interior structures and determine how/where tidal heat is dissipated.
- The goals of Io Observer are broader than just whether Io has a magma ocean or not. V&V defined 7 science goals for Io observer, of which the magma ocean only contributes directly to ~2.
- Juno possesses an impressive suite of instruments that may provide tantalizing views of Io—but there are many limitations that inhibit their ability to accomplish Io science. For example, Juno's flybys limit spatial resolution, coverage, and viewing geometries. Juno's instruments were also optimized for Jupiter observations, and not satellites.
- Juno lacks many of the instruments necessary for Io science. Most notably, Juno does not have an instrument that is capable of directly measuring Io's chemistry (e.g., a mass spectrometer).



OPAG encourages a hybrid of NF-5/6 and NF-7 mission themes.

- New Frontiers 5
  - Comet Surface Sample Return (CSSR)
  - Lunar South Pole–Aitken Basin (SPA) Sample Return (pending Artemis landing site selection(s) and science objectives)
  - Ocean Worlds (only Enceladus)
  - Saturn Probe
  - Venus In Situ Explorer
  - Io Observer
  - Lunar Geophysical Network (LGN)
- New Frontiers 6
  - Centaur Orbiter and Lander (CORAL)
  - Ceres Sample Return
  - Comet Surface Sample Return (CSSR)
  - Enceladus Multiple Flyby (EMF)
  - Lunar Geophysical Network (LGN)
  - Saturn Probe
  - Titan Orbiter
  - Venus In Situ Explorer (VISE)

New Frontiers 7

- Triton Ocean World Surveyor (TOWS)

OPAG strongly supports Titan Orbiter! It is an excellent concept and Titan is so complex that more coverage/understanding is needed than is provided by Dragonfly. However there is not an urgency to move to NF-5.

On these lists, we highlight in color the OPAG-relevant missions, all of which are compelling & important.

CSSR, CORAL and Ceres SR certainly are of interest to OPAG as well; we do not take a position here regarding their inclusion on the NF-5 list.

Additional Remarks

- We note that the NF-5 and NF-6/7 mission definitions vary in the number/specificity of objectives, and the “shall address all # objectives” language that appears in the OWL NF6/7 definitions.
  - Combining lists can be tricky from this perspective
- OPAG encourages CAPS to recommend to NASA that NASA allow proposers flexibility in how they address objectives defined by the Decadal. **The focus of the AO should be on the science rather than being too prescriptive with objectives.**

- **We thank CAPS for undertaking this study and for taking feedback from the community!**

Backup material

There are NO examples in which scientific understanding or external factors have been sufficiently substantial since the 2011 V&V decadal survey to warrant reconsidering or removing any of the OP mission themes.

- **Transformative Io exploration is possible on a New Frontiers budget.**
  - IVO's selection for Phase-A in the last Discovery round provides some credibility that Io science can be accomplished in Discovery. This has led to the perception that Io exploration is best done in Discovery, and not in New Frontiers.
  - However, while IVO may have fit in the Discovery 2019 cost cap and costing structure, there's no guarantee that it will fit in the Discovery 2026+ if the AO changes. Likewise, it may be unwise to remove a potentially "low cost" New Frontiers option from the New Frontiers list, especially given NASA's repeated statements that New Frontiers costs have grown too large.
  - Finally, it is worth noting that many past New Frontiers missions were preceded by Discovery proposals. For example: Juno (then INSIDE Jupiter) was proposed to Discovery three times before selection in New Frontiers 2; OSIRIS-REx (then OSIRIS) was proposed twice in Discovery before selection in New Frontiers 3.

    Discovery proposals can be an important step in maturing concepts for New Frontiers.

There are NO examples in which scientific understanding or external factors have been sufficiently substantial since the 2011 V&V decadal survey to warrant reconsidering or removing any of the OP mission themes.

- **Since the Decadal Survey, there have been new innovative ideas for accomplishing Io science, including Io sample return, that require a New Frontiers budget.**
  - Recent work (e.g., Ogliore et al. 2023) has demonstrated that it may be possible to return samples from Io. This approach would utilize a spacecraft to fly through one or more of Io's active plumes, collect plume material (not unlike how Stardust collected material from a cometary coma), and return those samples to Earth for analysis in terrestrial laboratories. This would enable a caliber of geochemistry investigations hitherto unimagined. This represents a new programmatic/technological development since the OWL Decadal Survey. Accomplishing sample return from Io may require a New Frontiers class budget.
  - Retaining Io on the New Frontiers list will motivate the community to come up with innovative new ideas for exploring Io, which can be refined through the competitive AO process.

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Triton: Fascinating Moon, Likely Ocean World, Compelling Destination!

Candice J. Hansen[1], J. Castillo-Rogez[2], W. Grundy[3], J. D. Hofgartner[2], E. S. Martin[4], K. Mitchell[2], F. Nimmo[5], T. A. Nordheim[2], C. Paty[6], L. C. Quick[7], J. H. Roberts[8], K. Runyon[8], P. Schenk[9], A. Stern[10], and O. Umurhan[11]
[1] Planetary Science Institute, AZ, USA; cjhansen@psi.edu

Research Paper

Volatile transport modeling on Triton with new observational constraints

T. Bertrand [a b], E. Lellouch [a], B.J. Holler [c], L.A. Young [d], B. Schmitt [e], J. Marques Oliveira [a], B. Sicardy [a], F. Forget [f], W.M. Grundy [g], F. Merlin [a], M. Vangvichith [f], E. Millour [f], P.M. Schenk [h], C.J. Hansen [i], O.L. White [l b], J.M. Moore [b], J.A. Stansberry [c], A.V. Oza [j k], D. Dubois [b], E. Quirico [e]... D.P. Cruikshank [b]

Research Paper

Hypotheses for Triton's plumes: New analyses and future remote sensing tests

Jason D. Hofgartner [a], Samuel P.D. Birch [b], Julie Castillo [a], Will M. Grundy [c d], Candice J. Hansen [e], Alexander G. Hayes [f], Carly J.A. Howett [g], Terry A. Hurford [h], Emily S. Martin [i], Karl L. Mitchell [a], Tom A. Nordheim [a], Michael J. Poston [j], Louise M. Prockter [k], Lynnae C. Quick [h], Paul Schenk [l], Rebecca N. Schindhelm [m], Orkan M. Umurhan [n]

Earth and Space Science

RESEARCH ARTICLE
10.1029/2021EA002034

Single- and Multi-Pass Magnetometric Subsurface Ocean Detection and Characterization in Icy Worlds Using Principal Component Analysis (PCA): Application to Triton

C. J. Cochrane[1], R. R. Persinger[2], S. D. Vance[1], E. L. Midkiff[1], J. Castillo-Rogez[1], A. Luspay-Kuti[3], L. Liuzzo[4], C. Paty[5], K. L. Mitchell[1], and L. M. Prockter[3]

Key Points:

- A novel sub-surface ocean detection and characterization method has been developed based on Principal Component Analysis processing of

remote sensing MDPI

Article

Triton: Topography and Geology of a Probable Ocean World with Comparison to Pluto and Charon

Paul M. Schenk [1,*], Chloe B. Beddingfield [2,3], Tanguy Bertrand [3], Carver Bierson [4], Ross Beyer [2,3], Veronica J. Bray [5], Dale Cruikshank [3], William M. Grundy [6], Candice Hansen [7], Jason Hofgartner [8], Emily Martin [9], William B. McKinnon [10], Jeffrey M. Moore [3], Stuart Robbins [11], Kirby D. Runyon [12], Kelsi N. Singer [11], John Spencer [11], S. Alan Stern [11] and Ted Stryk [13]

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Increasing the Usability and Accessibility of Voyager 2 Images of Triton

Michael T. Bland[1], Emily S. Martin[2], and Alex Patthoff[3]
[1] U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ 86001, USA
[2] Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institute, Washington, DC 20560, USA

RESEARCH ARTICLE
10.1029/2021JA029958

Formation of a Displaced Plasma Wake at Neptune's Moon Triton

Sven Simon[1], Peter Addison[1], and Lucas Liuzzo[2]

[1]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, USA, [2]Space Sciences Laboratory, University of California, Berkeley, CA, USA

Peter Addison and Lucas Liuzzo contributed equally to this study.

This article is a companion to Liuzzo et al. (2021), https://doi.org/10.1029/2021

JGR Space Physics

RESEARCH ARTICLE
10.1029/2021JA029740

Triton's Variable Interaction With Neptune's Magnetospheric Plasma

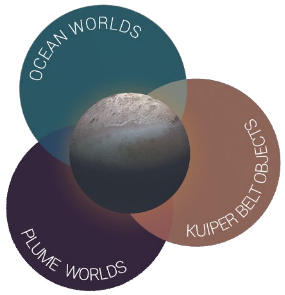
Lucas Liuzzo[1], Carol Paty[2], Corey Cochrane[3], Tom Nordheim[3], Adrienn Luspay-Kuti[4], Julie Castillo-Rogez[3], Kathleen Mandt[4], Karl L. Mitchell[3], Mats Holmström[5], Peter Addison[6], Sven Simon[6], Andrew R. Poppe[1], Steven D. Vance[3], and Louise Prockter[4]

Key Points:

- We constrain the time variability in signatures associated with plasma interaction and induction at Triton, Neptune's largest moon

ROW, Trident Discovery, T-OWS, and Neptune Odyssey have inspired a resurgence in Triton interest and research activity across multiple sub-disciplines of planetary science, despite 35 years having passed since the Voyager 2 flyby.

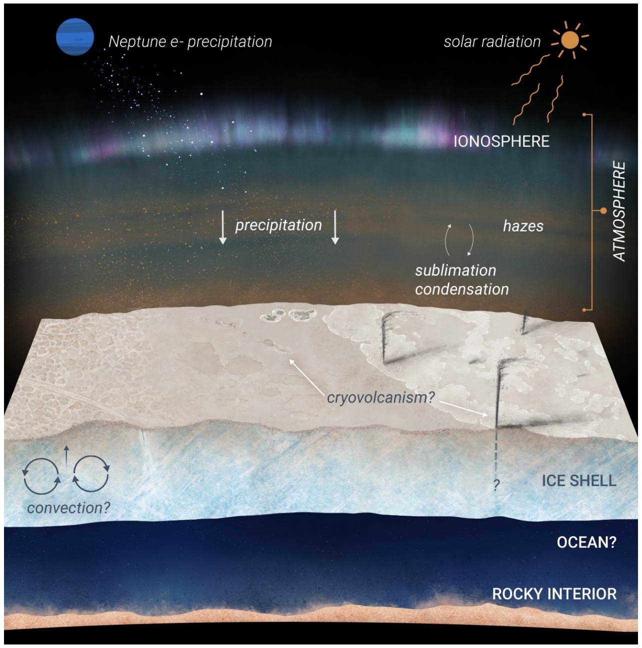
Triton ocean world science is compelling



- Magnetometric ocean detection (flyby) → Magnetometric ocean characterization (multiple flybys)
- Comprehensive surface composition and morphological mapping
  - Test if 2-way ocean ↔ surface transport
  - Heat flux → quantification of tidal heating as driver of internal evolution
  - Composition of potentially exposed salt → main ocean environment properties (pH, T)
  - Composition of photochemistry-borne organics that may be introduced into the ocean

KEY: Definitive, observation-based evidence; Partial or indirect observational evidence	Identify Ocean Worlds		Characterize Oceans		Assess Habitability		Search for Life	
	Energy Sources	Ocean Signatures	Solvents	Rock/Ocean Interface	Energy for Life	Physicochemical Conditions for Life	Ongoing surface access	Biomarkers
Voyager (flyby)	Partial	Partial						
Trident (Discovery/flyby)	Partial	Definitive	Definitive	Partial			Partial	
T-OWS (NF orbiter)	Definitive	Definitive	Definitive	Definitive	Definitive	Partial	Definitive	

Table based on the NASA Roadmap to Ocean Worlds "investigations roadmap" (Hendrix+, 2019).



A Neptune-orbiting New Frontiers mission to the most distant tidally-driven ocean world represents a substantial advance to ocean world science at the most distant tidally-driven candidate ocean world in the Solar System.

Events/discussions on which OPAG is basing our report/testimony to CAPS:

- Presentations (e.g. Candy Hansen) at June 2022 OPAG meeting (DC)
- November 2022 community meeting held at LPI
- Feb 2023 virtual townhall to gather feedback on draft NF-5 AO
  - Presented to PAC Feb-Mar 2023
- April 2023 community meeting held at APL
  - Presented to PAC June 2023
- Townhall at DPS Oct 2023
  - Presented to PAC Nov 2023
- November 2023 community meeting held at LASP/CU
- Townhall at AGU Dec 2023
  - Presented to PAC March 2024
- LPSC 2024 NASA townhall … Lori Glaze stated that including NF-7 targets/concepts is within the purview of CAPS

PAC Feb-Mar 2023: The 4th finding from the November 2022 OPAG community meeting

- **OPAG encourages NASA to consider updating New Frontiers lists based on scientific, as opposed to schedule-based, considerations.**
- OPAG is concerned that, depending on the timing of future AOs, rigid assignment of mission themes to specific New Frontiers opportunities may not follow the scientific intent of the Origins, Worlds, and Life (OWL) decadal survey. Focusing on science would mean that targets that are linked to time-constrained mission opportunities would not be locked into a particular NF# list, thus allowing for more launch flexibility.
- The New Frontiers budget has historically enabled missions to the outer solar system with moderate-size payloads and long flight times. However, several scientifically compelling targets (e.g., Neptune/Triton, Uranus, and KBOs) require the use of gravity assists (e.g., Jupiter) to reduce flight time, and/or include launch vehicle requirements in order to fit into a New Frontiers envelope. Given that the required gravity assists are only periodically available, these requirements present a significant challenge when it comes to the exploration of particular outer planets targets. If schedules and/or budgets require shifting of pre-planned launch readiness dates (LRDs) even slightly, trajectories to certain targets can suddenly become unavailable. Similarly, shifting LRDs can also make trajectories to certain compelling targets suddenly available (e.g., Triton is unexpectedly accessible within the current NF5 LRD range).
- A specific example is the case of the Triton Ocean World Surveyor (OWS), which was recommended by OWL for inclusion in the NF7 list but not the NF6 list. As stated in OWL, this recommendation was based not on its scientific priority but on the fact that the assumed LRD range for NF6 did not include the required gravity assists to permit an appropriate trajectory. Given that the date range for NF6 assumed by OWL is almost certainly not going to be the actual LRD range, the justification for excluding OWS from NF6 is already likely obsolete.

PAC Feb-Mar 2023 OPAG concerns with draft NF5 AO

- A number of issues in the draft NF5 AO may put Outer Planet (OP) concepts at a disadvantage
- A 2-hr remote OPAG community town hall was held on Feb 16
- The community provided feedback on topics in draft AO
- OPAG S.C. is assembling the community feedback into a formal set of comments for NASA ahead of the March 3 due date for community comments
- Because costs are a concern for everyone
  - OPAG may suggest NASA to do more PMCS studies throughout the decade to prepare for future NF concepts & cost challenges
- The NF program is critical for OP science!
  - We do not have an Outer Planets Program, nor an Ocean Worlds Program
  - No Discovery mission to an OP target has been selected… we rely on NF

PAC Feb-Mar 2023 **ESA Contributions**

- Draft Language:
    - “A list of various hardware contributions in five cost bins is provided in the Program Library.”
    - “Proposers will not engage directly with ESA until Phase A after selection”
    - “After Step-1 selection ESA will select, in consultation with NASA and the PI(s), a minimum of two scientists from ESA member states to join each of the teams conducting a Concept Study.”

- OPAG Concerns:
    - There is currently no program library, and NASA has stated that it will not begin to populate it until April. How can proposers design missions without knowing specifics of potential hardware contributions?
    - Not being allowed to engage with ESA until Step-2 presents a planning challenge; How can proposers design missions without engaging with major component providers? (component spec sheets might not be sufficient)

- Possible Resolution:
    - OPAG encourages NASA to release the Program Library information as soon as possible, without introducing disadvantages to technically challenging OP mission proposals.
    - OPAG encourages NASA to clarify details about ESA contribution list specs and consider facilitating preliminary communication with European providers before Step-2 to refine and resolve questions on specs
    - OPAG suggests NASA to elaborate the (newly introduced) ESA-selected co-I process, perhaps modeling it after the Participating Scientist program

PAC Feb-Mar 2023 **Launch Vehicles**

- Draft Language:
  - The draft AO indicates that only the 4m fairing options are free. For 5m fairings the cost ranges from $13M to $72M. (Draft AO p.58 Section 5.9.2.1)
  - The Launch Vehicle performance curves are referred to, but not yet posted in the NF Library (deferred to April).

- OPAG Concerns:
  - Currently there are no launch vehicles with 4m fairing that are capable of supporting Outer Planets missions (I,e. with high C3 performance with reasonable mass delivered to target). Thus, this puts Outer Planets concepts at a cost disadvantage.
  - This potentially prevents proposing teams from selecting a launch vehicle, identifying available mass, and closing their point designs – until very late in the process.

- Possible Resolution:
  - OPAG requests that NASA post Launch Vehicle performance curves in the NF Library as soon as possible and to clarify the cost structure for available launch vehicles, with a consideration that does not disadvantage Outer Planets missions (fairing size, high C3 performance, delivered mass). For example, we urge NASA to consider providing free high C3 launch vehicle options to proposers that could deliver a usable mass to the Outer Planets, in line with the delivered mass capabilities for NF5 lunar concepts. (As there are only 5 m fairing options that exist for launch vehicles capable of supporting Outer Planets missions, this would remove the cost penalty and level the field with other NF5 concepts to near targets.)

PAC Feb-Mar 2023 **Phase A-D Cost Cap**

- Draft Language:
  - The PI-Managed Mission Cost (PIMMC) for Phases A-D will be capped at $900M in NASA Fiscal Year 2022 dollars (FY22$). These caps do not include the cost of a standard launch vehicle and launch services or any contributions. Application of AO-specified incentives and/or charges may result in a proposal-specific Adjusted AO Cost Cap.

- OPAG Concerns:
  - The $900M NF5 cost cap represents a 12.5% decrease as compared to NF4 ($1029M FY22 or $850M FY15). This is an issue for new teams as well as for those who plan to re-propose from NF4.
    - Proposal teams that are re-bidding have to shed $~130M off of their already mature designs. This puts them at a disadvantage.
  - It is not clear whether this ~$130 M reduction would be even partially offset by the ESA contribution (TBD) and free launch vehicle, which has challenges (or could be simply inapplicable) for Outer Solar System missions (separate discussion).
    - This creates a bias toward missions that can make use of the ESA list and/or free (i.e., 4-m fairing) launch vehicle; as already discussed, there are currently no launch vehicles with 4m fairing that are capable of supporting Outer Planets missions.

- Possible Resolution:
  - Closely tied to ESA Contributions, Launch Vehicles

PAC Feb-Mar 2023 **Phase E Cost Cap**

- Draft Language:
  - The PI-Managed Mission Cost (PIMMC) for Phase E will be capped at $300M in FY22$
  - Reserve posture: Traditionally, Phase E required no less than 15% reserves and required proposals to justify the reserve amount. NF5 AO requires 25% reserves, further reducing available funds.
- OPAG Concerns:
  - The Phase E cost cap penalizes missions with longer (especially active) cruise phases needed to reach outer planet targets and thus creates an unequal playing field – this biases against long-duration missions and is thus a **huge** problem for OP missions with their longer cruise times
  - The Phase E cap is especially problematic as the validation models (e.g., MOCET) are based on past flights. Validation models won't reflect novel efforts to meet the new cap.
  - *“I don't see at all how there can be an equitable reasonable proposal evaluation between an inner planet and outer planet when there is a Phase E cost cap”* (quote from a town hall participant)
  - Phase E cost cap could also limit the amount of people on the team itself, limiting the diversity of the proposal team
- Possible solutions:
  - Adding a credit for cruise duration could correct this imbalance.
  - Alternative to Phase E cap is to do more review of Phase E plans

PAC Feb-Mar 2023 **Radioisotope Power Systems (RPS)**

- Draft Language:
  - "Two technologies are under consideration for electrical power: the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) and the Next Generation Radioisotope Thermoelectric Generator (RTG). Up to two MMRTG units or a single Next Generation RTG unit will be made available to proposers. Only one of these technologies will be offered, and NASA will communicate its decision **no later than the release of the final New Frontiers 5 AO**." (Draft AO Section 5.9.3 & SOMA NF5 Draft AO Q&A 2/16/2023)

- Implications for OP missions:
  - Teams proposing an RPS-enabled concept will have to carry two separate designs until the final AO, then have just a few months to choose the allowed option and write the proposal … a logistical and proposal development cost challenge! This adversely affects OP missions, which tend to be more dependent on RPS.

- Possible Solution:
  - OPAG encourages NASA to finalize the RPS option by the end of May, 2023, at the latest.

PAC Feb-Mar 2023 **Radioisotope Heater Units (RHU)**

- Draft Language:
  - *Table 4* adds $5M to the mission cost for use of <43 RHU and $18M for >43 RHUs
  - *Table 2:* Use of RHUs will incur a cost of $25-39M
  - *Table 2 footer:* Use of RHUs will also incur a cost of $11M for nonstandard launch services.
  - *Page 28:* "Typical cost estimates to prepare an EIS involving RPSs or RHUs can be $1M+ and require more than one year to complete."
  - *<u>Bottom Line:</u>* Use of RHUs could add up to $56M (for no sample return, and for < 43 RHUs, and more if one needs more); this is a $51M cost upper (above the $5M unit cost); and an extra $13M if more than 43 RHUs are used.

- OPAG Concerns:
  - This primarily affects missions with no RTGs, only RHUs … more likely to negatively affect OP missions
  - With long cruise times and low power availability and with potential thermal design challenges, OP missions will be penalized for RHU usage with an additional $51M-64M cost upper in the edge case scenario. This RHU-only cost is on par with using RPSs + RHUs, without having the benefit of RPSs.
  - These RHU-only costs are in family with NF4 - but whereas such costs might have been accommodatable in NF4, with all the other costs and cap reduction in NF5, this could become a hardship in NF5.

- Possible solution:
  - OPAG encourages NASA to review the RHU cost information provided in the draft AO, and provide clarification and/or revision to the cost structure as soon as possible

PAC Feb-Mar 2023 **Target List**

- Draft AO language
  - (Sect. 2.4, p. 4). Proposals prepared in response to this AO must describe an investigation that addresses at least one out of any of the six mission themes described below. These themes, listed without priority, are:
    - Comet Surface Sample Return
    - Io Observer
    - Lunar Geophysical Network
    - Lunar South Pole-Aitken Basin Sample Return
    - Ocean Worlds (only Enceladus), and
    - Saturn Probe

- Community Discussion:
  - Given the timing concerns for many targets in the outer solar system (that led to OPAG's November 2022 4th Finding - see slide 2), the NF5 target list was a topic of discussion
  - The community has a desire to ensure that the NF5 stays on schedule
  - The community discussed opening the ocean worlds targets or at least broadening the focus on Enceladus science more generally instead of just focusing on search for life
  - It was noted that moving targets from future NF calls to NF5 (or NF6) is different than adding brand new targets

From OPAG presentation to PAC June 2023

- **NF-5 concerns.** OPAG awaits the response from NASA HQ on our concerns about the NF-5 cost cap and fixed Phase E cost reported in response to the draft AO in March 2023, as well as clarifications on questions submitted to HQ by the community. We reiterate that the New Frontiers Program is particularly important for the outer planets community as the cost cap for Discovery missions is typically not sufficient to enable outer planets missions, and Flagship missions occur at a low cadence. We hope that outer planet destinations will continue to be accessible via NF-5 and future New Frontiers solicitations. While OPAG understands the need to control costs, the New Frontiers program is critical for outer planets missions and we urge PSD to strike a balance to allow for outer planet science in the New Frontiers program.

From OPAG presentation to PAC Nov 2023 based on DPS townhall

- NASA/CAPS should focus on science rather than making the list too prescriptive

Nov 2023 finding presented to PAC March 2024

Considering the most recent delay, the final New Frontiers 5 (NF5) Announcement of Opportunity (AO) is slated for No Earlier Than (NET) 2026, placing final selection (end of Step 2) NET 2028. OPAG shares the HQ concerns that NF5 currently reflects the priorities of the *Visions and Voyages* (V&V) Decadal Survey even though the NET time for selection occurs halfway through the purview of the current OWL Decadal Survey. **OPAG endorses the current HQ plan to ask the Committee on Astrobiology and Planetary Science (CAPS) to augment the NF5 mission list with OWL-recommended mission concepts from the NF6 lists as soon as possible, and strongly encourages that NF7 targets also be considered.** For instance, Triton was not included on the OWL NF6 list solely because the assumed NF6 launch window did not align with a Jupiter Gravity Assist; the delays, advances, and developments since then have potentially invalidated this constraint.

The NF5 delay has been very challenging on the OPAG community, and it should be noted that NF is the primary—and potentially only—funding path for competed outer planets missions.

It is also important to highlight that, according to OWL, the recommended NF6/7 mission concepts will necessitate an increased cost cap. Furthermore, the most recent NF5 community announcement stated a potential cost cap that represented a significant reduction (inflation- adjusted) as compared to NF4, and that makes it difficult to propose a mission to ***almost*** any of the targets on the current list. Launch window opportunities for outer planets targets additionally need strong consideration given the shift in timelines.

In addition, relaying critical AO parameters, such as target list, radioisotope power systems (RPS) availability, cost cap, international (e.g., ESA) contribution policies, launch vehicle options with performance curves and costs, and launch readiness date (LRD) range, to the community as early as possible is extremely important to proposal teams.