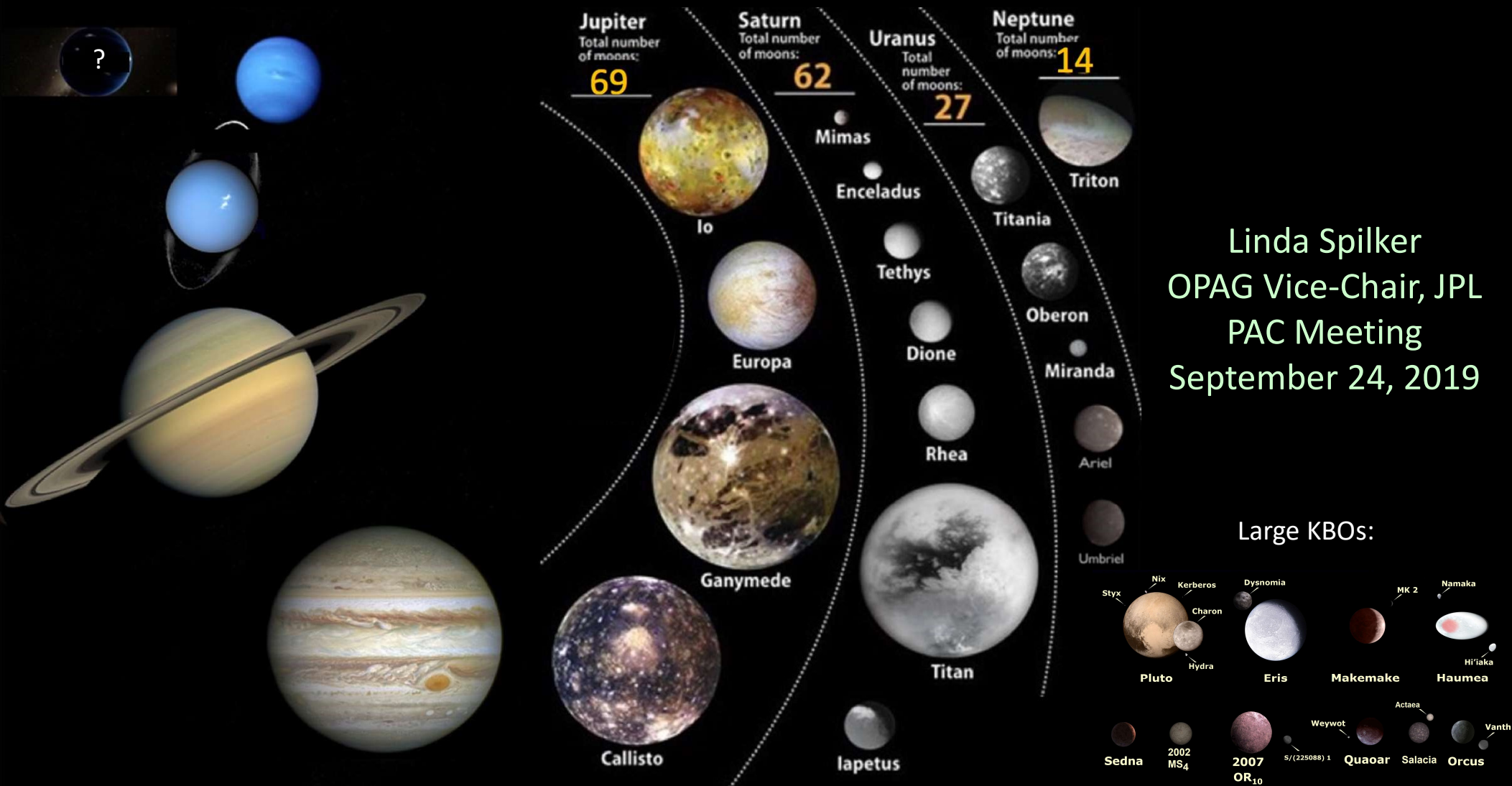


# OPAG Update to the Planetary Science Advisory Committee (PAC)

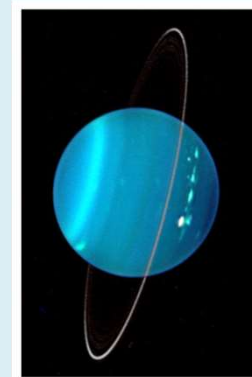


Linda Spilker  
 OPAG Vice-Chair, JPL  
 PAC Meeting  
 September 24, 2019

# Outer Planets Assessment Group (OPAG) Charter

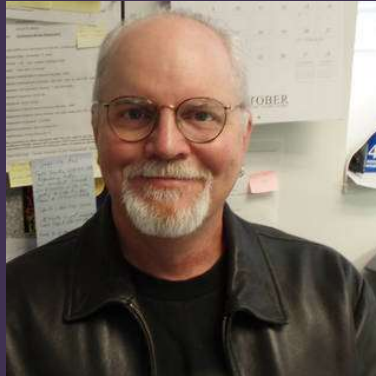
<https://www.lpi.usra.edu/opag/>

- NASA's community-based forum to provide science input for planning and prioritizing outer planet exploration activities for the next several decades
- Evaluates outer solar system exploration goals, objectives, investigations and required measurements on the basis of the widest possible community outreach
- Meets twice per year, summer and winter
  - Next meeting: Feb. 3-4, 2020, LPI, Houston, TX
- OPAG documents are inputs to the Decadal Surveys
- OPAG and Small Bodies Assessment Group (SBAG) have Joint custody of Pluto system and other planets among Kuiper Belt Objects



KBO planets

# OPAG Steering Committee

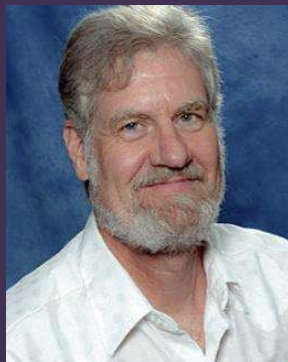


Jeff Moore  
OPAG Chair  
Ames Research Center



Linda Spilker  
OPAG Vice-Chair  
Jet Propulsion Lab

\* =New Member



Alfred McEwen  
University of Arizona



Lynnae Quick\*  
NASA Goddard



Kathleen Mandt\*  
Applied Physics Laboratory

# OPAG Steering Committee



Scott Edgington  
Jet Propulsion Lab



Amanda Hendrix  
Planetary Science Institute



Mark Hofstadter  
Jet Propulsion Lab



Terry Hurford  
Goddard Space Flight Center



Carol Paty  
Georgia Institute of Technology



# OPAG Steering Committee



Morgan Cable\*  
Jet Propulsion Lab



Britney Schmidt  
Georgia Institute of Technology



Kunio Sayanagi  
Hampton University



Tom Spilker\*  
Consultant



Abigail Rymer\*  
Applied Physics Lab

\* =New Member

## Recent and Upcoming OPAG-related Meetings

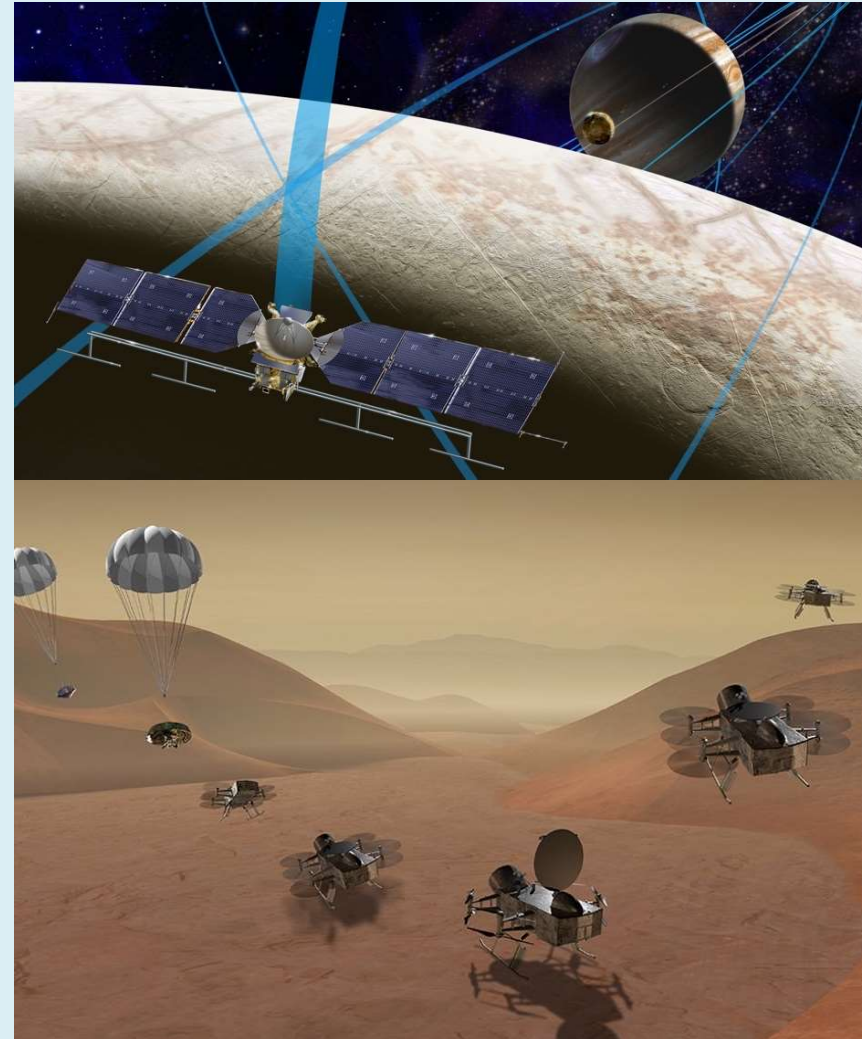
- ***OPAG Subsurface Needs for Ocean Worlds Workshop*** (August 19, 2019)  
University of Colorado's Laboratory for Atmospheric and Space Physics (LASP)  
Boulder, CO <https://www.lpi.usra.edu/opag/meetings/aug2019/SNOW-Agenda.pdf>
- ***OPAG Meeting*** (August 20-21, 2019)  
University of Colorado's Laboratory for Atmospheric and Space Physics (LASP)  
Boulder, CO <https://www.lpi.usra.edu/opag/meetings/aug2019/Agenda.pdf>
- ***Outer Planets Assessment Group (OPAG) Town Hall***, EPSC-DPS Joint Meeting  
September 20, 2019, Centre International de Conférences de Genève (CICG),  
Geneva, Switzerland

### ***Upcoming Meetings:***

- ***OPAG Meeting*** (February 3-4, 2020) Lunar and Planetary Institute, Universities  
Space Research Association (USRA) 3600 Bay Area Blvd, Houston, TX
- ***Joint VEXAG/OPAG/ExoPAG meeting*** (February 4-7, 2020) Lunar and Planetary  
Institute, Houston, TX

## Some Key Activities since Last PAC Meeting

- Dragonfly selected for New Frontiers-4 Zibi Turtle (PI)
- Juno Probe Completed 21st Orbit of Jupiter
- Europa Clipper completed PDR progressing towards 2023 (or 2025?) launch
- JUICE progressing towards 2022 launch
- Uranus and Neptune Ice Giants study completed
- Roadmap to Ocean Worlds (ROW) document completed
- **Revised OPAG Goals Document posted**



# New Frontiers has been good for exploration of Outer Planets

- Missions from the 1<sup>st</sup> Decadal survey:
  - New Horizons
  - Juno
- Approved candidate missions in 2<sup>nd</sup> Decadal (V&V) to outer solar system:
  - Saturn Probe
  - Ocean Worlds: Enceladus and Titan
  - **Dragonfly to Titan selected for NF-4**
  - Io Observer (only in NF-5)
- **More New Frontiers missions to Outer Planets and Ocean Worlds are a top OPAG priority**



Dragonfly





## OPAG Goals Document: 2018

- First draft written in 2006, recently posted update: August 2019
- Revised Introduction
  - Ocean Worlds emphasis, but not the only emphasis
- Recent sections:
  - Planets in the Kuiper Belt
  - Ocean Worlds and the Search for Life
  - OPAG Relevance to Worlds not in the Outer Solar System
  - Telescopic Observations
  - Workforce Issues
  - Summary Recommendations for Next Decadal Survey
- OPAG science priorities address the relevant subset (8/10) of the key questions from “Vision and Voyages”
- Document posted: <https://www.lpi.usra.edu/opag/goals-08-28-19.pdf>

# Scientific Goals for Exploration of the Outer Solar System

## *Explore Outer Planet Systems and Ocean Worlds*

### EXECUTIVE SUMMARY

#### 1.0 INTRODUCTION

1.1 The Outer Solar System in Vision and Voyages

**1.2 New Emphasis since the Decadal Survey: Exploring Ocean Worlds**

#### 2.0 GIANT PLANETS IN OUR SOLAR SYSTEM

2.1 Jupiter and Saturn

2.2 Uranus and Neptune

#### 3.0 GIANT PLANET MAGNETOSPHERES

#### 4.0 GIANT PLANET RING SYSTEMS

#### 5.0 GIANT PLANETS' MOONS

5.1 Pristine/Primitive (Less Evolved?) Satellites' Objectives

5.2 Ganymede Science Objectives

5.3 Europa Science Objectives

5.4 Io Science Objectives

5.5 Enceladus Science Objectives

5.6 Titan Science Objectives

5.7 Triton Science Objectives

#### **6.0 PLANETS IN THE KUIPER BELT**

#### **7.0 OCEAN WORLDS AND THE SEARCH FOR LIFE**

**7.1 Ocean Worlds: Understanding Oceans and Habitability Worlds**

#### **8.0 OPAG RELEVANCE TO WORLDS NOT IN THE OUTER SOLAR SYSTEM**

#### 9.0 TECHNOLOGY

#### **10.0 TELESCOPIC OBSERVATIONS**

#### **11.0 WORKFORCE ISSUES**

#### **12.0 SUMMARY RECOMMENDATIONS FOR NEXT DECADAL SURVEY**

Key References

New Sections in Green

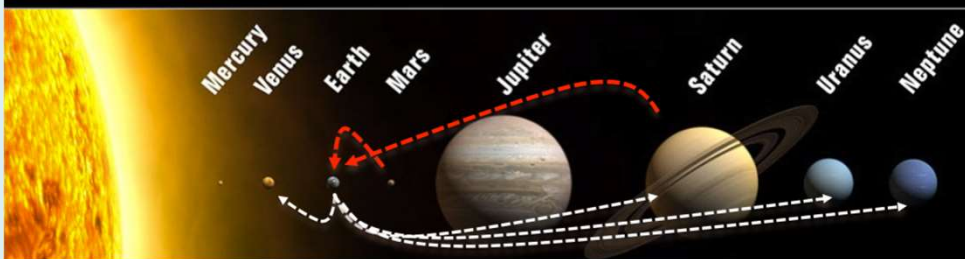
## Purposes of OPAG Goals Document

- Describes the science objectives for exploration of outer solar system
- Consistent with the 2013 Decadal Survey “Vision and Voyages” but kept up-to-date as new missions are approved, new discoveries are made, models evolve, our understanding of solar system processes changes, and new questions are posed
- Will be used as a resource for defining technology development directions and needed laboratory experiments, modeling, and other research
- Resource for mission and instrument science objectives
- Guides our preparation for the outer solar system portion of the next decadal survey
  - Including mission studies being done in preparation for that survey
- *The emphasis for future exploration of the outer solar system is to understand giant planet systems and ocean worlds*

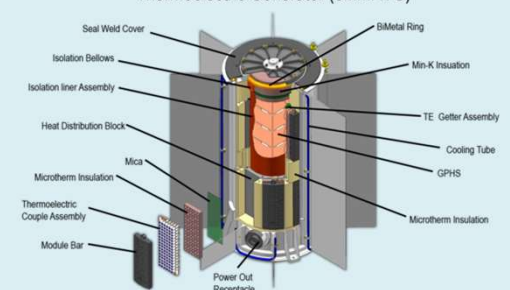
## Priority Technologies for OPAG

- Current or recent programs are advancing instrumentation:
  - Instrument Concepts for Europa Exploration (ICEE), Homesteader, ColdTech, ICEE-2 (for Europa Lander), in addition to PICASSO and MatISSE
- **Technology development for power is a high priority to OPAG**
  - In V&V Decadal Survey, the highest priority for multi-mission technology investment was more efficient radioisotope power (was ASRGs, now eMMRTG)
  - High efficiency LILT solar cells can decrease area and mass for all solar missions.
  - Lightweight solar array structures help at Jupiter (and potentially Saturn)
    - Roll-Out Solar Arrays (ROSA) recently demonstrated on Space Station
- **Technology development is urgently needed for potential Ocean Worlds Missions** such as Europa Lander
  - Including *miniaturization and new life detection instrumentation*
- **Continue developing the technologies needed for Ice Giant mission**
  - eMMRTG, HEET, and low power, high data rate Ka-band Telecommunication systems

Heat Shield for Extreme Entry Environment Technology (HEEET) for Near-Term Robotic Science Missions and Longer-Term Human Missions



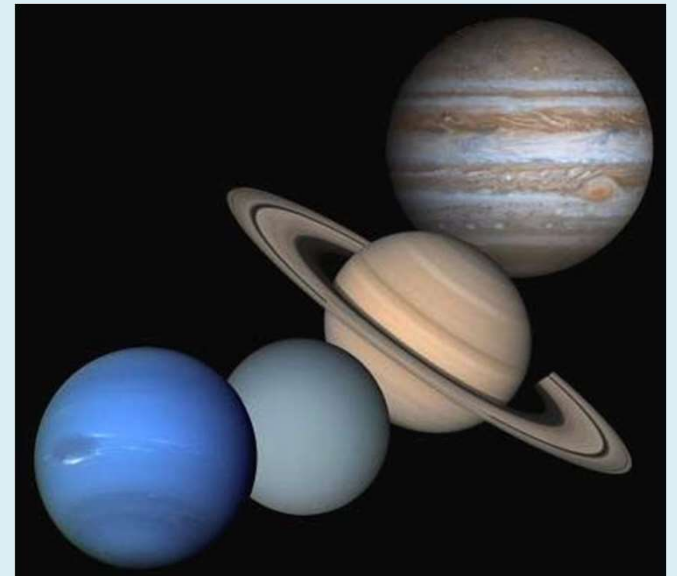
Enhanced Multi-Mission Radioisotope Thermoelectric Generator (eMMRTG)





# OPAG Findings Summary Slide

- 4 sets\* of OPAG findings since last PAC presentation in 2018
  - February 2018 (F18): 8
  - September 2018 (S18): 8
  - March 2019 (special findings) (M19): 2
  - April 2019 (A19): 13
  - August 2019: Working on findings from last meeting
- Findings broken into categories, some findings cover more than one categories
  - Decadal Survey: 10
  - Europa Clipper: 5
  - Ocean Worlds: 3
  - Juno: 2
  - Discovery/New Frontiers: 4
  - Ice Giants: 4
  - Cassini: 3
  - Other: 3



Some key OPAG Findings highlighted in **Green** on next slides  
\* Detailed findings provided in backup material

## Decadal Survey Findings

### Decadal Survey

- Clarify Process to Identify Mission Studies for Decadal Survey (F18)
- *Quickly Execute Decadal Mission Studies Prior to Start of Decadal (S18)*
- *Commission a Workplace Climate Survey and Include Workforce Issues in Decadal Statement of Tasks (F18, S18, A19)*
- *Include EDI as Study Topic in Next Decadal (A19)*
- Solicit Assessment Groups' Inputs on Decadal Statement of Tasks (S18)
- *Involve Community in Formulation of and Feedback on Decadal Statement of Tasks (A19)*
- Include Planetary Representation on Astrophysics Decadal Survey Panel (S18)
- Explain Implications of Potential New Start for Mars Sample Return for Next Decadal (A19)

# Europa Clipper and Ocean Worlds Findings

## Europa Clipper

- *Support Earliest Feasible Arrival Date for Europa Clipper (F18, S18)*
- Maintain Robust Europa Clipper Payload (A19)
- Perform CAPS Investigation of ICEMAG Termination Process and Rationale (M19)
- *Brief Community to Raise Transparency of ICEMAG Termination Process (A19)*

## Ocean Worlds

- Ask NAS to Assess Science Value of Ocean Worlds Exploration Program (F18, A19)
- *Establish Early Definition of Planetary Protection Requirements for Ocean Worlds Missions (A19)*

# Juno, Discovery/New Frontiers and Ice Giants Findings

## Juno

- Adequately Fund and Sustain Cassini DAP and New Frontiers DAP (F18)
- *Select more Juno Participating Scientists from Selectable Proposals (A19)*

## Discovery/New Frontiers Future Missions

- *Open New Frontiers Program to All Mission Concepts (S18, A19)*
- *Support RPS Usage in Future Discovery Missions (F18)*
- *Provide a Sustained Technology Program for Outer Planet Missions (F18)*

## Ice Giants

- Invest in Ice Giant Mission Technology and Ground-based (F18)
- *Provide a Sustained Technology Program for Outer Planet Missions (F18)*
- *Support Scientifically Compelling Ice Giant System Flagship Mission (S18, A19)*



## Cassini and Other Findings

### Cassini

- *Adequately Fund and Sustain Cassini DAP and New Frontiers DAP (F18)*
- Adequately support Cassini DAP program for Years to Come (A19)
- Provide Adequate Transition Funding to Cassini to Minimize Mission Impact (M19)

### Other

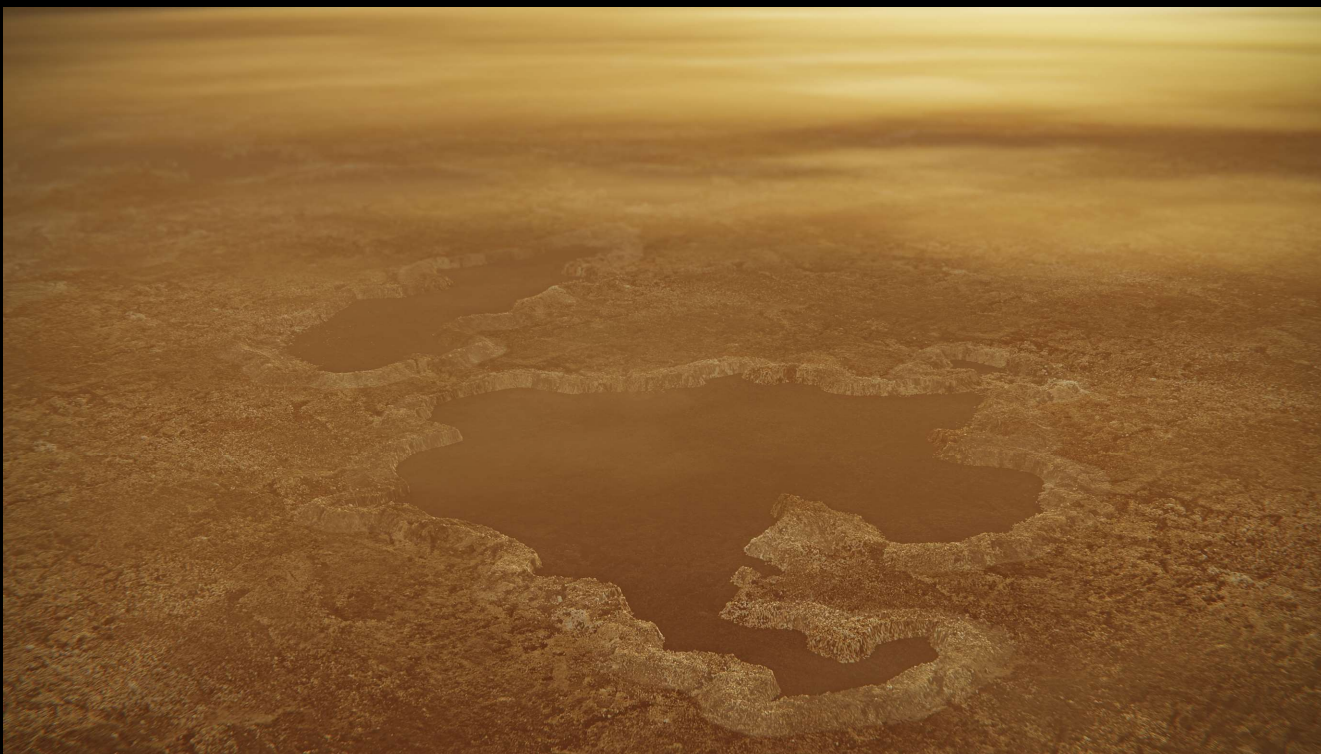
- Continue Europa Lander Pre-Phase A Development (S18)
- *Reinstate AG Chairs or Deputies as Members of PAC (S18)*
- Define and Share Clear Process for Terminating Mission Funding that Minimizes Impact on Mission Science and Personnel (A19)



## Deep and Methane-rich Lakes On Titan

- On Cassini's final Titan flyby, RADAR revealed small liquid lakes perched atop plateaus and filled with liquid methane
- Lakes are surprisingly deep (~100 m) and perched 100s of meters above sea level
- No inflow/outflow channels visible implying possible subsurface transport
- Most likely filled by methane rainfall

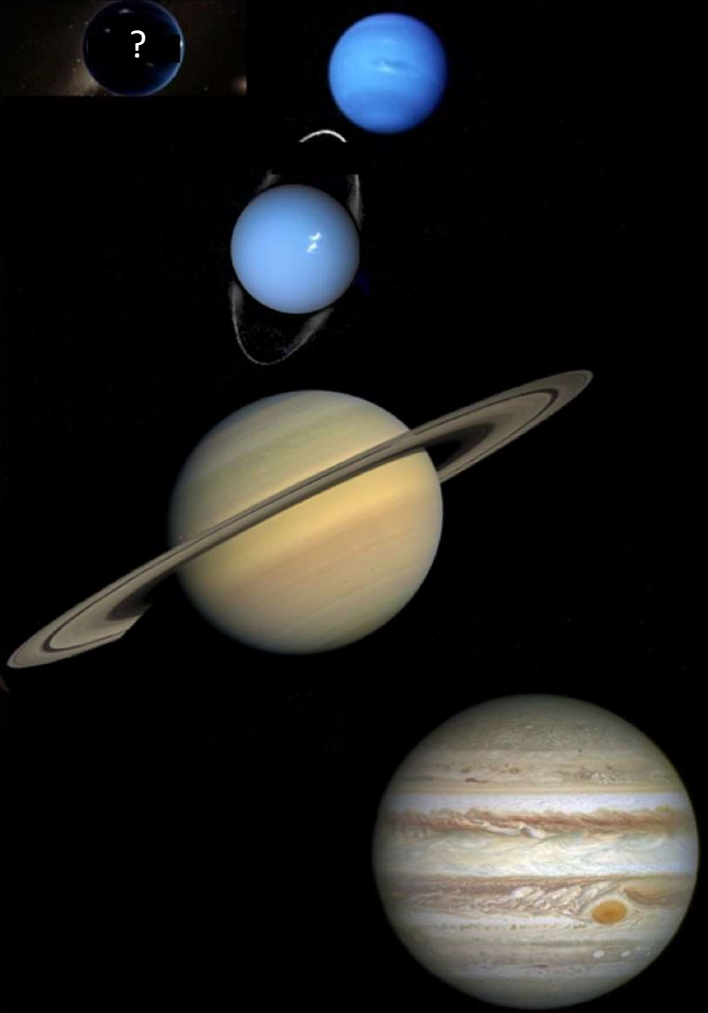
# Small Titan Lakes May Be Explosion Craters



- New model using radar data suggests that steep-rimmed lakes are created from nitrogen explosions
- Warming nitrogen could create basins in Titan's crust with rims 100's of meters high
- These basins fill with methane to form small lakes 10's of km across

Mitri et al., Nature Geoscience (2019)

# Outer Solar System: Many Worlds to Explore



We are the Comparative Planetology AG





Back up slides

## OPAG Findings: Feb. 2018, Hampton, Virginia

1. **Support Earliest Feasible Arrival Date of Europa Clipper**: OPAG supports the earliest possible arrival date for Europa Clipper, to maintain a healthy outer planets science community. OPAG further supports continued technology development towards follow-up ocean worlds missions such as Europa Lander
2. **Adequately Fund and Sustain Cassini DAP and New Frontiers DAP**: OPAG is concerned about the sustainability of CDAP and NFDAP programs. In particular, we encourage NASA to ensure that these programs are funded at or above their current levels now and in the future and thereby optimize the science outputs from these successful missions and maintain the vibrant research community needed to support future exploration.
3. **Invest in Ice Giant Mission Technology and Ground-based Science**: OPAG encourages NASA to continue investment in the technologies and groundbased science that enhance an Ice Giants mission. We also encourage NASA and ESA to refine estimates of the programmatic factors related to such a mission (e.g. cost, partnerships, launch time-frames) and undertake a follow-up mission study focused on optimizing the science return within the current best estimate of available resources.
4. **Include Workforce Issues in Decadal Statement of Tasks**: OPAG supports the inclusion of workforce issues in the next planetary decadal survey. Specifically, OPAG asks that a survey of workforce issues be included in the Statement of Tasks.

## OPAG Findings: Feb. 2018, Hampton, Virginia

5. **Support RPS Usage in Future Discovery Missions:** OPAG supports NASA's reconsideration of allowing RPS in future Discovery mission AOs, even if the number of MMRTGs is limited to only one or two units, as nuclear power is necessary to open up the solar system beyond Jupiter or Saturn to new exploration.
6. **Ask NAS to Assess Science Value of Ocean Worlds Exploration Program :** The OPAG committee finds that NASA should initiate a formal National Academies study to explore how NASA can create an exploration strategy addressing Ocean Worlds.
7. **Clarify Process to Identify Mission Studies for Decadal Survey:** OPAG requests clarification of the process NASA intends to use for identifying targets for mission studies. Specifically, we encourage NASA to provide timely input regarding the scope, prioritization, and limiting number of new mission studies that can be completed in time to be useful to the next Decadal Survey.
8. **Provide a Sustained Technology Program for Outer Planet Missions:** OPAG encourages PSD to have a sustained technology program for outer planetary missions. ColdTech has been advantageous, but it was a single call and should be repeated with direct application to the OPAG goals. A sustained investment in these technologies is needed.

## OPAG Findings: Sept. 2018, Pasadena, CA

1. **Quickly Execute Decadal Mission Studies Prior to Start of Decadal:** OPAG encourages NASA to quickly devise an approach to execute mission studies that would enable broad participation from the planetary science community in providing input for future mission directions and assessment. We also encourage consideration of Decadal Survey mission studies not on the CAPS list
2. **Solicit Assment Groups' Inputs on Decadal Statement of Tasks:** OPAG encourages NASA to engage all the Assessment Groups and ask for an opportunity to comment on the Statement of Task prior to the next planned Decadal Survey, and determining the structure of the Decadal Survey.
3. **Open New Frontiers Program to All Mission Concepts:** OPAG strongly encourages that NASA open the New Frontiers program to all mission concepts that address high-priority science questions from the Decadal Survey in time for the NF5 call.
4. **Support Scientifically Compelling Ice Giant System Flagship Mission:** OPAG strongly supports an Ice Giant System Flagship mission as the scientifically compelling, next logical step after Europa Clipper. OPAG prioritizes the Neptune system as the mission's target, and finds there is a need to begin work prior to 2020 due to trajectory concerns for reaching Neptune that require a launch date in the late 2020's.
5. **Support Earliest Feasible Arrival Date for Europa Clipper:** OPAG supports the earliest feasible arrival date for Europa Clipper, with its present scientific payload manifest, in part to help maintain a healthy outer planets science community.

## OPAG Findings: Sept. 2018, Pasadena, CA

6. **Continue Europa Lander Pre-Phase A Development:** OPAG finds the current cost-constrained Europa Lander mission concept to be a worthwhile first step for exploration of Ocean Worlds, and supports continuation of pre-phase-A development of the lander concept with evaluation of ICEE-2 proposals for the payload. Furthermore, we consider continued science evaluations worthwhile to influence final decisions on the payload and science priorities if the mission is approved to proceed.
7. **Perform Workforce Survey for Decadal Survey:** OPAG suggests that any workforce survey that feeds into the next Decadal Survey includes demographics with respect to multiple axes of representation in planetary science, including, but not limited to, race, gender, ethnicity, disability status, career stage, national origin, etc. Furthermore, where possible, the survey should also consider the intersection of multiple identities.
8. **Reinstate AG Chairs or Deputies as Members of PAC:** OPAG encourages NASA to reconsider the PAC charter so to include representation of the larger planetary science community. This could include reinstating AG chairs or deputy chairs as members of PAC, as they represent broad community views.
9. **Include Planetary Representation on Astrophysics Decadal Survey Panel:** Representation from the planetary community would be valuable as part of the Astrophysics Decadal Survey panel composition, in considering priorities in the next decade.



## OPAG Findings: March 2019, Special Findings

1. **Perform CAPS Investigation of ICEMAG Termination Process and Rationale:** OPAG urges NASA to request the Committee on Astrobiology and Planetary Science (CAPS) of the National Academies to investigate the ICEMAG termination process and rationale, and to potentially assess and make recommendations to NASA SMD about how to define a clear and transparent process for potential termination of PI-led flight experiments.
2. **Provide Adequate Transition Funding to Cassini Minimize Mission Impact:** OPAG encourages NASA to provide sufficient transition funding to support an adequate closeout of the Cassini project that will minimize the impact on young scientists and other investigators who would be disproportionately impacted by this large, abrupt funding cut. OPAG welcomes NASA's efforts to work with the Cassini project to provide the needed funds for impacted scientists, as well as almost completed higher-order archival products, and to develop a smooth transition plan that does not force researchers to seek their funding outside of the planetary program.

## OPAG Findings: April 2019, Washington, DC

1. **Brief Community to Raise Transparency of ICEMAG Termination Process:** OPAG invites NASA to further engage the community to raise the transparency on the ICEMAG termination process at the next OPAG meeting. In particular, we suggest that NASA present to OPAG the termination rules-and-procedure briefing that was given to the Europa Clipper leadership group, and inform us how the ICEMAG termination process is being reviewed and what lessons have been learned.
2. **Explain Implications of Mars Sample Return for Next Decadal:** OPAG requests NASA to explain the implications of a potential new start for Mars Sample Return for the next Decadal Survey.
3. **Define and Share Clear Process for Terminating Mission Funding that Minimizes Impact on Mission Science and Personnel:** OPAG requests NASA to develop and publicly share a clear process for terminating mission funding that involves time for collaborative, thoughtful discussions between the project and NASA HQ before final decisions are made. This process should include an evaluation of lost science and the development of a smooth transition plan. This plan should strive to minimize science loss, impact on young scientists, and loss of critical science data products.
4. **Involve Community in Formulation of and Feedback on Decadal Statement of Tasks:** OPAG requests that NASA involve members of the planetary science community in the formulation of the Decadal Survey Statement of Task, and provide opportunities for the community to give feedbacks about the Statement before the Statement is finalized.

## OPAG Findings: April 2019, Washington, DC

5. **Select more Juno Participating Scientists from Selectable Proposals:** 1. Given that about 10 Juno PS proposals were selectable, OPAG requests the timely selection of additional Juno PS proposals from those that were considered selectable by the review panel. 2. OPAG requests insight into where the additional funds allocated for the Juno PS program were used (were the funds given to the Juno mission for instance, or used for some other program?) 3. Given the Juno PSP experience, OPAG requests NASA to review the PS process, from the draft AO through selection, to improve the implementation of the PS process in general, including a timelier PS announcement after the proposal review process.
6. **Open New Frontiers Program to All Missions:** OPAG joins several other NASA Assessment Groups in strongly advocating that NASA open the New Frontiers program to all mission concepts that address high-priority science questions from the Decadal Survey in time for the NF5 call.
7. **Establish Early Definition of Planetary Protection Requirements for Ocean World Missions:** OPAG supports the early definition of Planetary Protection requirements for future outer planets missions, in particular those that will study Ocean Worlds, and encourages the Planetary Protection Office to establish a process that engages the science community in the definition of PP standards and bioburden and other risk assessments in order to enable the search for life in our solar system.
8. **Commission a Workplace Climate Survey:** OPAG requests that NASA commissions a professionally conducted workplace climate survey for the Europa Clipper Project within the next six months, and periodically conduct surveys for each of the other NASA planetary science mission projects to monitor the workplace environment. NASA should use the survey to identify and quickly address workplace climate issues to reduce risk to mission success, improve the mission team workplace environments, and identify and replicate best practices.

## OPAG Findings: April 2019, Washington, DC

9. **Include EDI as Study Topic in Next Decadal:** OPAG thanks NASA for supporting Dr. Rathbun's work on EDI, and requests NASA to implement the following: 1. OPAG urges NASA to continue to make resources and funding available in the upcoming fiscal years to study barriers to participation in the planetary science workforce. 2. OPAG encourages inclusion of EDI as a study topic in the upcoming Planetary Science Decadal Survey. 3. OPAG urges NASA to continue their efforts to enhance workforce diversity along multiple axes. These efforts should include, but are not limited to, initiatives that support gender diversity, and establish programs to broaden participation of ethnic and racial minorities who are extremely underrepresented in NASA-funded science communities and in the planetary science workforce.
10. **Adequately support CDAP program for Years to Come:** OPAG applauds the spectacular success of the Cassini mission at Saturn and asks NASA to adequately support and increase CDAP funding to ensure optimum science output from this mission. In addition: 1. In the coming years, augmentation in the CDAP budget is needed to take full advantage of the rich, high science-value data set returned by the Cassini mission and to prepare for future outer planet missions, especially those to the Saturn system. CDAP funding is especially needed for the development and archiving of critical higher-order science and engineering data products, specifically those related to the final year of the mission, which will aid future scientists in the analysis of Cassini data. 2. Cassini, with its 13 years of archived Saturn system data, should have a continued dedicated data analysis program for many years to come, helping to bridge the large gap before the next large Outer Solar System mission and ensuring that a knowledgeable cadre of outer planet scientists will be ready to analyze data from the Europa Clipper mission, as well as other future outer planet missions.

## OPAG Findings: April 2019, Washington, DC

- 11. Maintain Robust Europa Clipper Payload:** OPAG advocates maintaining the robust and synergistic scientific payload of the Europa Clipper Mission. NASA should ensure that scientific priorities drive any decisions that might affect the payload complement and its functionality. OPAG continues to support the earliest feasible arrival date for Europa Clipper, to ensure a healthy Outer Planets program. OPAG encourages NASA to add a gravity science team to the mission, to ensure success in achieving this top-level priority to confirm and understand the ocean.
- 12. Ask NAS to Assess Science Value of Ocean Worlds Exploration Program:** OPAG would like NASA to request that the National Academies assess the science value of an Ocean Worlds exploration program and how it fits in with broader solar system exploration. This NAS assessment, provided as input at the start of the Planetary Decadal Survey process, will allow the Survey panels to consider the results as part of their deliberations.
- 13. Support Scientifically Compelling Ice Giant System Flagship Mission:** OPAG strongly supports an Ice Giant System Flagship mission as the scientifically compelling, next logical directed mission after Europa Clipper. OPAG prioritizes the Neptune system as the mission's target, and finds there is a need to begin work prior to 2020 due to trajectory concerns for reaching Neptune that require a launch date in the late 2020's. OPAG encourages NASA to rapidly advance its discussions with ESA so that a high-level mission architecture and target can be selected. OPAG also encourages continued, rapid advancement of HEEET and next generation RPS technologies, and maturation of aerocapture techniques, as these can significantly enhance the science return of an ice giant mission.



## Three Big Questions\*

### OPAG issues to consider in Decadal Survey Statement of Tasks

**Big Question #1: What is the distribution and history of life in the solar system?**

**Big Question #2: What is the origin, evolution, and structure of planetary systems?**

**Big Question #3: What present-day processes shape planetary systems, and how do these processes create diverse outcomes within and across different worlds?**

## **Cross-Divisional Theme: How can knowledge of the solar system advance our understanding of Earth, Sun, and Exoplanets?**

- How does knowledge gleaned from studying the outer solar system make us better stewards of our own planet?
- How does the study of our planet inform our understanding of the outer planets and their moons?
- How do studies of the diverse present-day oceans in the solar system advance biological, chemical and physical oceanography?
- How does the study of the solar wind interaction at bodies in the outer solar system improve our understanding of the Sun and the propagation and evolution of its dynamic atmosphere?
- How can solar system bodies inform our understanding of bodies in exoplanetary systems?

## Importance of Equity, Diversity and Inclusion (EDI) in Decadal Survey

- **The OPAG community believes in the critical importance of equity, diversity, and inclusion in formulating the statement of task for the Decadal Survey and in the composition of the Survey leadership (especially in the chair(s) and steering committee). OPAG suggests that the statement include language such as the following:**
- *“The composition of the Decadal Survey panels - particularly the Chairs and Steering Committee - should take full advantage of the diversity of the planetary science community in factors such as area of expertise, gender, race, ethnicity, career stage, types and sizes of institutions, geographic distribution, and disability status.”*
-

## Two Co-Chairs for Planetary Decadal Survey?

- We note that Astro2020 has two co-chairs, rather than a chair and a vice-chair; many members of OPAG believe this would be a good approach for the Planetary Decadal Survey as well, particularly given the wide range in topics and targets covered.

## Three Big Questions\*

### OPAG issues to consider in Decadal Survey Statement of Tasks

Three “Big Questions” are listed below along with example bulleted, high-level, OPAG-specific sub-questions:

#### **Big Question #1: What is the distribution and history of life in the solar system?**

- Does life or do habitable conditions exist beyond the Earth?
- What controls the habitability of ocean worlds?
- Do ocean worlds host life now, or did they in the past?
- What is the potential for prebiotic chemistry in ocean worlds, and how far towards life has this progressed?
- What role did the giant planets play in the emergence of life on Earth or elsewhere in the solar system?



## Big Question #2: What is the origin, evolution, and structure of planetary systems?

- What was the initial chemical profile of the protoplanetary disk as informed by noble gas content in the giant planets, and how did this profile impact the overall formation and evolution of our solar system?
- What are the possible architectures of planetary systems, and how do these different configurations affect planet formation and evolution (e.g., giant planet migration, tidal evolution, etc.)?
- What controls the formation, evolution and internal structures of gas giants (Jupiter, Saturn), ice giants (Uranus, Neptune), planetary satellites (particularly ocean worlds), rings, and small bodies in the outer solar system?
- How do planetary crusts/cryospheres, oceans, atmospheres, and magnetospheres form and evolve in the outer solar system, and how do they influence the evolution of bodies in those systems?

## **Big Question #3: What present-day processes shape planetary systems, and how do these processes create diverse outcomes within and across different worlds?**

- How do the chemical and physical processes in the solar system scale with planet size and location within the solar system?
- What is the dynamic relationship between the planets, rings, and moons of giant planet systems, and how do these relationships influence their constituent members?
- How do the magnetospheres of gas and ice giants influence the dynamics, composition and structure of the atmospheres, rings, and moon surfaces?
- How do the aurorae and induced magnetic fields of ocean worlds characterize the coupling between planets, moons, and magnetospheres?

## Big Question #3: (continued)

- What are the mechanisms, drivers, and rates for transporting heat and materials within, and ejecting them from, (cryo-)volcanically active worlds?
- How does coupled orbital evolution and tidal heating affect the interior structures and activity of satellites, and how does the interior evolution of the primaries affect this evolution (e.g., resonance locking)?
- What drives the transport of energy and materials within the deep interior of the giant planets?
- How do the atmospheric dynamics, cloud microphysics, radiative transfer, and chemistry interact to form stable and transient features observed in outer planet and satellite atmospheres?
- How do the ice giant magnetospheres and atmospheres respond to the impulsive solar wind forcing created by their unusual geometries, and what effect does solar insolation play on weather and upper atmospheric structure?