

Roadmaps to Ocean Worlds (ROW)

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Background

NASA is supporting the House recommendation (Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2016) to create an Ocean Worlds program:

“Ocean Worlds Exploration Program.—The recommendation provides \$226,000,000 for Outer Planets, of which not less than \$140,000,000 is for the Jupiter Europa Clipper, or comparable mission, to support the process of finalizing the mission design concept that meets the scientific objectives described in the most recent Planetary Science decadal survey. To support sustained momentum in this program, NASA shall ensure that future funding requests are consistent with achieving a launch no later than 2022, with the goal of launching on a Space Launch System platform as discussed elsewhere in this report.

Many of NASA’s most exciting discoveries in recent years have been made during the robotic exploration of the outer planets. The Cassini mission has discovered vast oceans of liquid hydrocarbons on Saturn’s moon Titan and a submerged salt water sea on Saturn’s moon Enceladus. **The Committee directs NASA to create an Ocean World Exploration Program whose primary goal is to discover extant life on another world using a mix of Discovery, New Frontiers and flagship class missions consistent with the recommendations of current and future Planetary Decadal surveys.** “

OPAG strongly supports this basic idea and wants to help lay the scientific groundwork, as input to the Decadal mid-term review and next full survey.

Ocean Worlds Scientific Foundation

- Typical sequence of events leading to new missions:
 - AG-led science study
 - MEPAG calls them Science Analysis Groups (SAGs)
 - VEXAG calls them Topical Analysis Groups (TAGs)
 - SBAG and LEAG call them Special Action Teams (SATs)
 - NASA has suggested “Roadmap”
 - This study provides input to:
 - NASA, for technology and mission study support
 - The Decadal Survey, such as the mid-term review and the next major Decadal
 - Decadal recommends overall science and mission priorities
 - NASA forms Science Definition Teams (SDTs) to better define specific missions
 - NASA releases AOs based on some of the SDT studies
 - Previous SDT reports for Europa and Titan Flagship missions
- OPAG Charter:
 - OPAG is NASA's *community-based forum* designed to provide science input for planning and prioritizing outer planet exploration activities for the next several decades.
 - I think the ROW team should consider the long-term strategy, not what might happen in New Frontiers 4 or Europa mission add-ons.

How Are Teams Assembled?

- Typically there are 2 Co-chairs
 - For MEPAG, one is from JPL, one from “outside” science community
 - And JPL provides logistical support—scheduling meetings, telecons, writing assignments, nagging, formatting final document.
 - There is not yet a formal Ocean Worlds program that NASA has assigned to a particular center, so we should not assume the same structure
 - ROW would certainly benefit from logistical support
 - Note to Curt Niebur: help!
- Team members are experts in the subject matter
 - Mostly scientists, but engineers and managers also contribute
 - Typically ~10-20 members
- This is a major time commitment for the Co-Chairs
 - But no extra funding for people’s time
 - Hope for NASA funding for travel (~1 full meeting) and incidental expenses
- Does serving on a study team give you an advantage in future competitive opportunities?
 - It makes you well-informed, that’s all

Draft ROW Charter

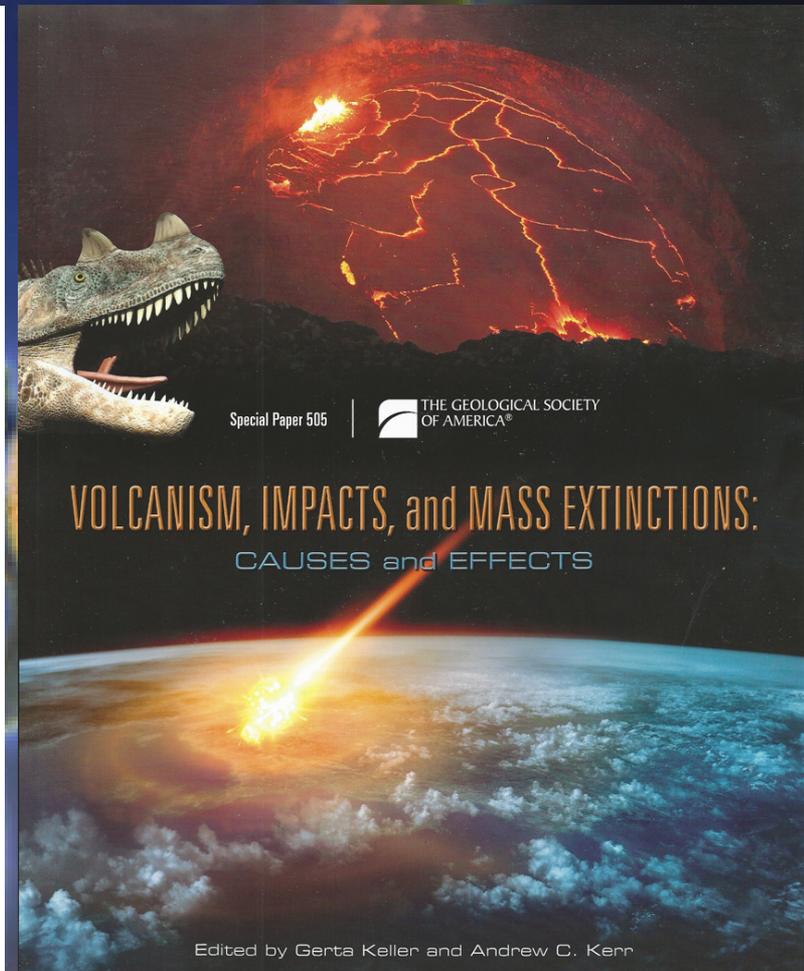
- **Prioritize science objectives, tied to Decadal Survey, for example:**
 - Understand origin and evolution of ocean worlds
 - Understand habitability (current processes and composition)
 - Search for and characterize life
- **Prioritize worlds to explore**
 - Europa, Enceladus, and Titan are mentioned in Congressional language
 - Recommend also considering Triton, Ganymede, other moons, Pluto
 - ROW Team needs to decide on emphasis
 - Consider **accessibility** to habitable environments
- **Summarize mission concepts**
 - Many pre-existing studies (see next slide)
 - Consider mission dependencies; examples:
 - Discover and characterize plumes before planning plume fly-through and sample collection
 - Characterize surface before planning landed missions
 - Consider international cooperation
 - International members of ROW Team?
 - Define measurement requirements
- **Design Roadmaps (mission sequences)**
 - Understand the world, potential habitability, discover life, characterize life
 - For each world separately; let Decadal recommend priorities between worlds?
 - Subgroup for each world; subgroup leads
- **Recommend Technology development and detailed mission studies**
 - Supporting Decadal Survey

Prior Ocean World Mission Concepts

- OPAG website—many documents of interest
 - Look in pages for Europa Mission Concepts, Resources, Archive Documents, Decadal Survey Documents
 - We will make a new page for Ocean Worlds studies
- Earlier SDT and Flagship studies:
 - EJSM: <http://www.lpi.usra.edu/opag/JJSDTNASAReport.pdf>
 - TSSM: http://solarsystem.nasa.gov/docs/08_TSSM_Final_Report_Public_Version.pdf
 - <http://sci.esa.int/tandem-tssm/44033-tssm-nasa-esa-joint-summary-report>
 - 2007 Titan Flagship report: https://solarsystem.nasa.gov/multimedia/downloads/Titan_Explorer_Public_Report_FC_opt.pdf
- Papers:
 - McKay, 2008, An Approach to Searching for Life on Mars, Europa, and Enceladus. *Space Science Reviews* 135, 49-54.
 - Collision and UK Penetrator Consortium, 2008, Planetary Penetrators - The Vanguard for the Future Exploration of the Solar System. *Journal of the British Interplanetary Society*, vol. 61, p. 198-202
 - Coustenis et al., 2009, TandEM: Titan and Enceladus mission. *Exp. Astron.* 23, 893-946.
 - Rampelotto, 2011, A mission to Titan, Europa, or Enceladus? *J. Cosmology* 13, 3765-3775.
 - Bunte, 2013, Utilizing Science and Technology to Enhance a Future Planetary Mission: Applications to Europa. PhD dissertation, ASU.
 - Mitri et al., 2014, The exploration of Titan with an orbiter and a lake probe. *Planetary and Space Science* 104, 78-92.
 - Tobie et al., 2014, Science goals and mission concept for the future exploration of Titan and Enceladus. *Planetary and Space Science* 104, 59–77.
 - Konstantinidis et al., 2015, A lander mission to probe subglacial water on Saturn's moon Enceladus for life. *Acta Astronautica* 106, 63-89.

Connections to Earth

- National Geographic workshop summary: “There is considerable synergy between the planetary and Earth ocean exploration communities.”
- Understanding and mitigation of Earth global change will be an imperative in coming decades, so keeping planetary science relevant is extremely important.
- ROW Team and OPAG should work to understand and foster these synergies.
- Need oceanographers and biologists as part of the ROW Team.



Ocean acidification resulting in the carbonate crisis considered to be the primary cause for four of the five Phanerozoic mass extinctions. (Keller and Kerr, editors, GSA SP 505, 2013).

Planetary Protection?

- Does ROW Team want to address this issue?
- At least recommend technology development needed to address PP.
- Resources:
 - Raulin et al., 2010 Exobiology and Planetary protection of icy moons. Space Sci. Rev. 153, 511-535.
 - 2015 COSPAR study: [COSPAR Planetary Protection for Icy Moons - Science ...](#)
 - <http://science.nasa.gov/science-committee/subcommittees/nac-planetary-protection-subcommittee/>
 - <http://planetaryprotection.nasa.gov/documents>

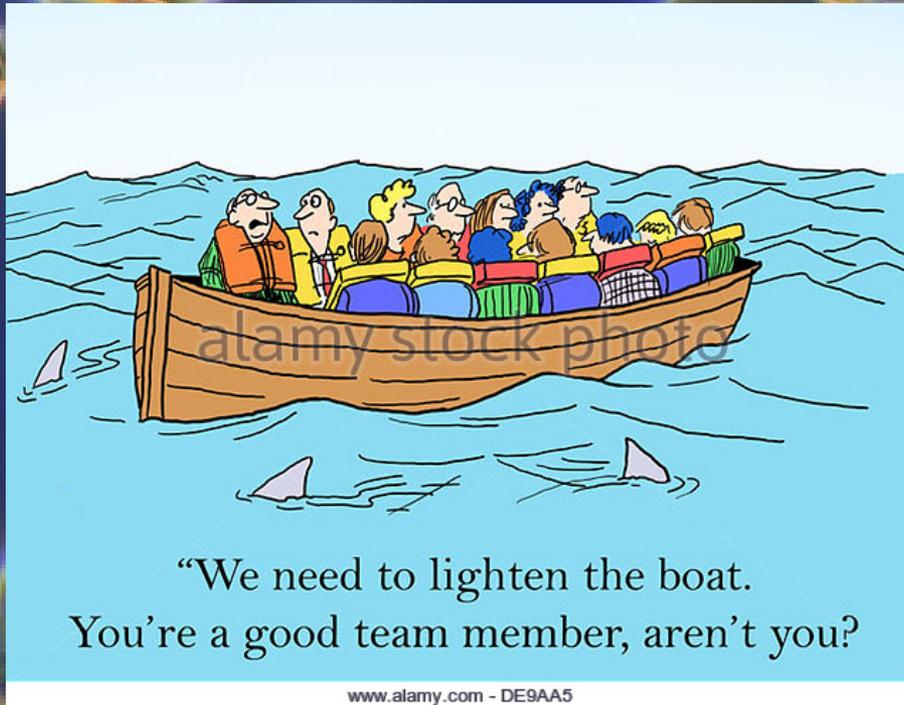
ROW Schedule

- First presentation of findings at next OPAG meeting
 - Summer 2016
- Final report due by end of year
 - Near start of Planetary Decadal Mid-Term review
 - Can be submitted to peer-reviewed journals
- Is a faster schedule needed to support New Frontiers or Europa lander instrument proposals?
 - Alfred's opinion is no—ROW should focus on the long-term roadmap



Next Steps

- Anyone interested in ROW Team, please email mcewen@lpl.arizona.edu
 - Say what you can contribute in a paragraph, add your CV
 - Tell us if you are interested in co-chairing ROW
 - Mention any major schedule constraints over next 11 months
- Anyone with comments or suggestions for this study can also email, or speak up at the OPAG meeting



Lets' get ROWdy!