Program Options to Explore Ocean Worlds

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1. Introduction

Our solar system contains at least a dozen ‘ocean worlds’ of multiple types [1, 2], where liquid water poses astrobiological potential. Some of these worlds may be habitable, and all of them are extreme: one with ubiquitous life even deep in the crust; relict ocean worlds that had surface water (Mars) and interior mud oceans (Ceres); multiple large and small icy moons of the gas giants Jupiter and Saturn, and even distant Kuiper Belt Objects like Triton, Pluto, and Charon where liquid water clearly drives geology. Since these worlds contain the sum total of all tangible evidence available to humanity in our quest to find life beyond Earth, we must likely explore them all to “learn the limits of life” in the cosmos [2]. Given other priorities, and the daunting space flight technology challenges involved, gradual exploration of these tantalizing places could take centuries.

Alternatively, a structured ‘ocean worlds exploration program’ (OWEP) conducted over many decades starting now could become a defining scientific pursuit for the 21st century, a grand challenge energized by its existential significance for humankind’s view of our place in the universe. Structured programs require strategic planning and organization, which requires in turn a scientific-strategic roadmap that lays out options, multiple paths, and priorities capable of aligning and focusing effort and investments. This presentation summarizes strategy analysis performed in 2016-17 to inform OWEP planning.

2. Analysis

The analysis treats in turn the major elements of a structured program, including how they differ from precedent, how they could be adapted for the OWEP purpose, and implications of implementing them.

2.1. Target priorities

Among the confirmed ocean worlds, three stand out as the primary targets for a combination of scientific and programmatic reasons: Europa (likely the most propitious place for life to have arisen); Enceladus (known to be habitable by today’s standards and by far the easiest place to look directly for biosignatures); and Titan (extensive organics synthesis, with possible interaction with a vast interior salt-water ocean). Each world would advance different aspects of the total quest, and all are targets of NASA mission plans and proposals.

2.2. Technical constraints

The three primary ocean worlds are all harder to explore than the surface of Mars. Europa is 2-5 years from Earth and orbits within Jupiter’s harsh radiation environment. Enceladus and Titan are more benign, but also have thick, cryogenic ice crusts and are 5-10 years from Earth. Each world introduces unique considerations and challenges, but six key capabilities needed to explore all three are not yet matured for space flight: planetary protection of and from ocean-world material; ‘life-detection’ measurement techniques and instruments; sample acquisition, handling, and preservation; cryogenic mechanisms and electronics; modular radioisotope power sources; and autonomous exploration that can conduct complex science investigations out of touch with Earth.

2.3. Lessons from MEP

The closest precedent for a structured scientific exploration program is NASA’s Mars Exploration Program (MEP), which offers both positive and cautionary lessons. Six points of comparison allow mapping MEP lessons to the unique challenges of an OWEP: 1) almost all OW mission concepts are technically more challenging than Mars missions, which collectively have cost NASA about ~$10B (FY17) over a quarter century; 2) OW missions cannot respond to emergent results on the half-decade timescale Mars missions can, due to celestial mechanics; 3) core technologies and capabilities should be developed outside the framework of individual flight projects, to assure strategic objectives and cadence are met; 4) ongoing operational infrastructure ‘lowers the bar’ for individual missions, and in the case of distributed OW exploration this primarily means heavy-life launch and in-space propulsion; 5) sheltering individual flight projects within a budget-line-item would give the managing agency planning and replanning flexibility; and 6) a class of medium-size, ‘directed purpose’ missions can form ‘connective tissue’ that sustains progress on a strategic roadmap.

2.4. OWEP program options

The analysis describes, compares, and estimates the cost of six potential, progressive scenarios for an OWEP, ranging from the status quo, through the strategic use and adaptation of the New Frontiers program, to creation of a $1B directed-purpose mission class and strategic OW technology program, to establishment of a formal OWEP. The most aggressive of these case studies would cost about 1/40th more than today's NASA budget. The value proposition of this investment can be compared to other types of investments by society.

3. Conclusions

The half-century of planetary exploration done to date has yielded a trove of important places to conduct detailed science investigations that can reveal the limits of life in the cosmos. Given today's state of technology and program opportunities, pursuing this quest among the ocean worlds of our solar system will take a very long time. For example, under today's constraints, a principal investigator active today, born in 1960, would be 75 years old by the time the first biosignature results could be returned from Europa or Enceladus, or both, in about 2035. A structured OWEP would allow the planetary science and astrobiology communities to increase the velocity, scope, and depth of this grand challenge.

4. References

[1] ROW (Roadmaps to Ocean Worlds), Goals, Objectives and Investigations for Ocean Worlds. May 2017. Archived at http://www.lpi.usra.edu/ opag/ROW.
[2] Lunine, J.I., Ocean worlds exploration. Acta Astronautica 131 (2017) 123–130.
http://dx.doi.org/ 10.1016/j.actaastro.2016.11.017.
[3] Sherwood, B., Lunine, J., Sotin, C., Cwik, T., and Naderi, F., Program Options to Explore Ocean Worlds, (full paper), GLEX-17,6.4x36541. Presented at the Global Space Exploration Conference, Beijing, 6 June 2017.

Short Summary

Strategic analysis of options for a structured program to explore the ocean worlds of our solar system. These worlds contain all the tangible evidence humanity can access regarding the existence and nature of life beyond Earth. Only a structured program can yield results in our lifetime.