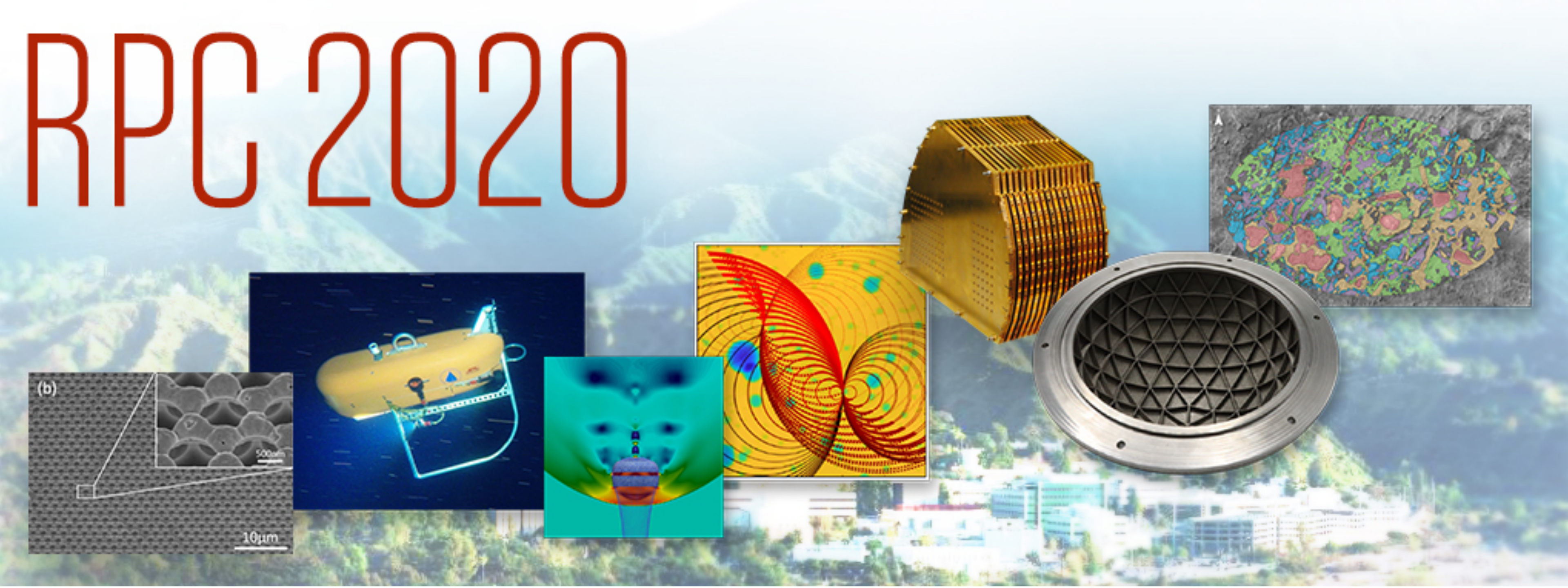

Virtual Research Presentation Conference

Ocean Worlds

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Program: Strategic Initiative

Assigned Presentation # R17043

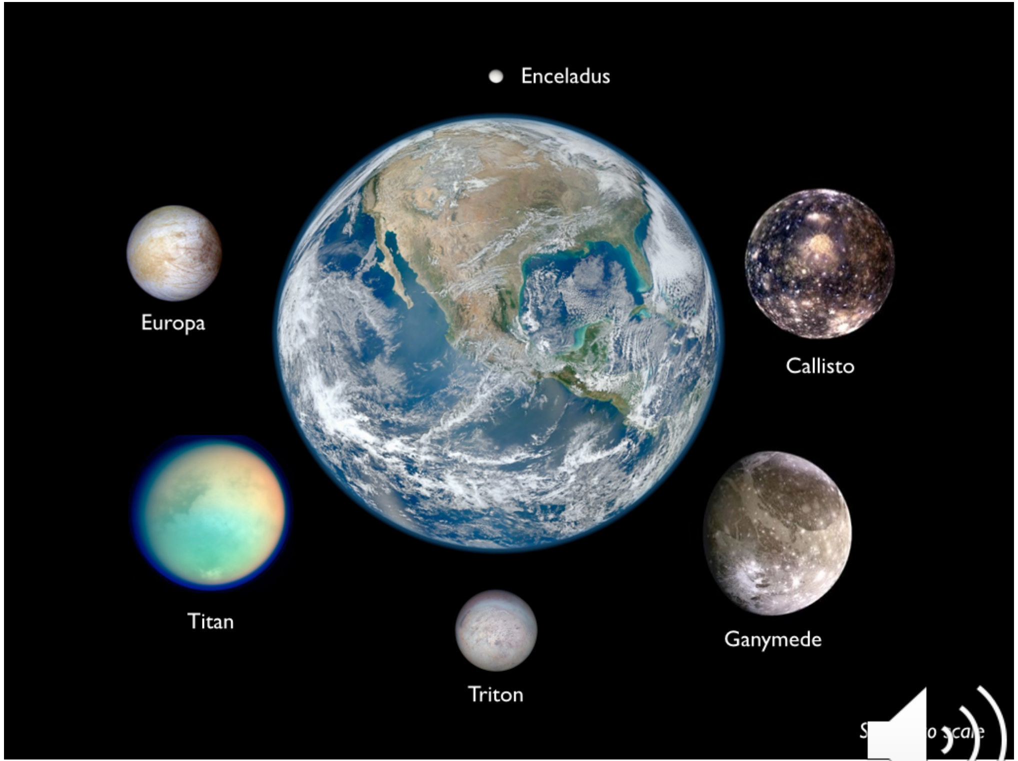
Jet Propulsion Laboratory
California Institute of Technology

Introduction

Ocean Worlds

At the highest level, our objective is to enable the detection of life, if it exists, on and within ice-covered ocean worlds, while simultaneously advancing our capability to make long-duration, semi-autonomous measurements in some of the most difficult to access regions in Earth's ocean and cryosphere.

Derived from this high level objective, our goals were to develop, test, and demonstrate techniques, instruments, and platforms for future Ocean Worlds missions.

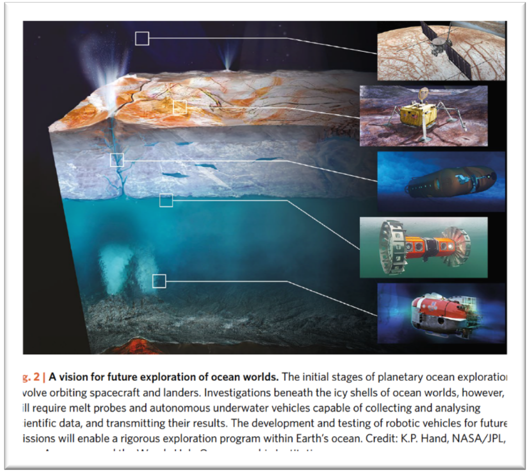


Problem Description

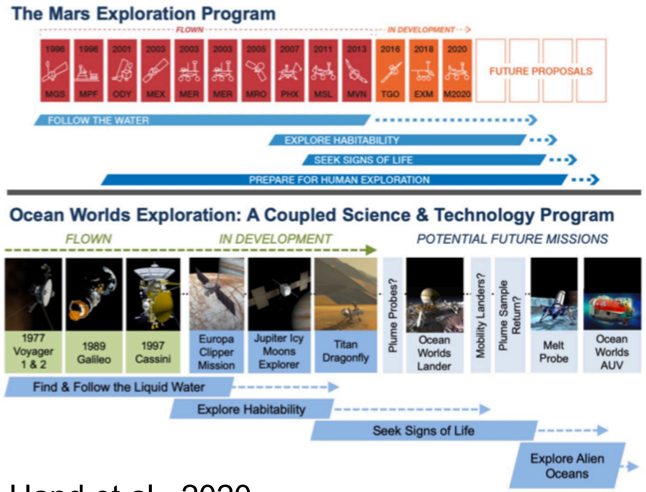
a) Ocean Worlds, such as Europa and Enceladus, are arguably the best places to search for extant life in our solar system.

b) The 'state-of-the-art' is large, cumbersome, submersibles and ROVs that grab samples and return to the ship. Very little science is done in situ.

c) Our efforts help build the science and technology pathway for Ocean Worlds in a manner analogous to the systematic approach of the Mars Exploration Program.



Hand & German, 2017



Hand et al., 2020

Methodology

a) Task 1 - Ice-water interface: Continue the development of our ice-water interface robotic vehicle for in situ chemical and biological analyses of sea ice and lake ice in the Arctic.

b) Task 2 - Deep Refuge: Continue the development of the joint JPL/WHOI deep ocean robotic vehicle Orpheus, which is a ‘Cubesat for the Sea’, in partnership with campus and WHOI.

Left: BRUIE (Buoyant Rover for Under Ice Exploration)

Right: Orpheus Hadal Trench Vehicle

Results: Task 1

a) Accomplishments versus goals

- a) Deployed three times at the Casey Warf site, under sea ice. Each deployment was >3 hours.
- b) Operated on tether largely as a safety measure (uncertainty of new environment and sea ice stability).
- c) Tested and successfully utilized underwater GPS system for tracking BRUIE and achieving high science return with under-ice ground tracks (i.e., mowing-the-lawn).
- d) Tested coordinated operations, recovery, and deployment of BRUIE with Blue ROV. This is an important demonstration for delivering BRUIE to e.g. grounding lines and distant targets beneath ice sheets.
- e) Deployed in O’brien’s Bay under sea ice for two days.
- f) Collected depth, temperature, conductivity, dissolved oxygen, and imagery/video.
- g) Crossed-calibrated with standard YSI core-hole measurements.
- h) ‘Mowed-the-lawn’ and collected science data over four tracks and approach to grounding line.
- i) Demonstrated robustness of BRUIE to fractures in the ice.

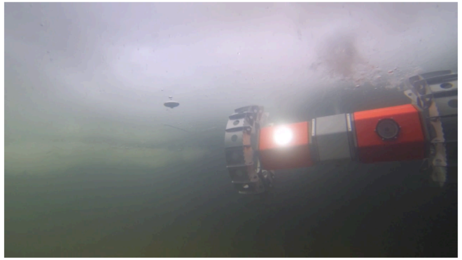
b) Significance: Enables new and unique measurements for Earth science while preparing the way for ocean worlds exploration. Work featured in JPL’s Annual Report and in the New York Times.

c) Next steps: We have no funding to continue this work.

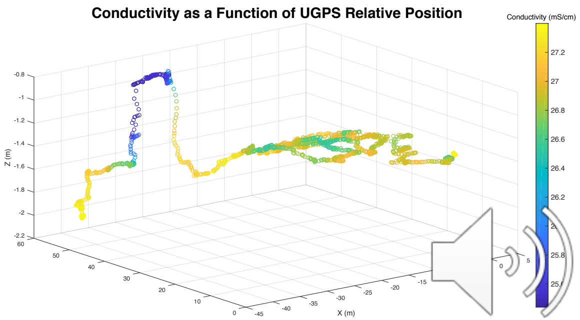
The New York Times

This Robot’s Journey to an Icy Alien Moon Starts Beneath Antarctica

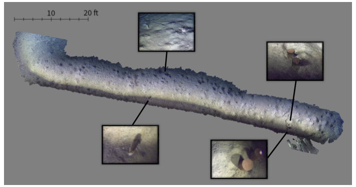
NASA scientists completed field tests in November of a floating rover they hope will one day travel to Europa, the frozen ocean moon of Jupiter.



A prototype of NASA’s Jet Propulsion Laboratory’s Buoyant Rover for Under-Ice Exploration, a technology that could one day explore oceans under the ice layers of planetary bodies, being tested in a lake near Utqiagvik, Alaska.



Results: Task 2



a) Accomplishments versus goals

   a) Demonstrated autonomous mission execution from script and altitude-hold functionality even in the case of strong disturbance currents and varying terrain (including over the side of an underwater canyon)

   b) Built "Baby-Orpheus" vehicle to test all electronics in a portable vehicle, including terrain relative navigation – 15kg vehicle for multi-hour local testing rather than 200 kg vehicle.

   c) Tested sequences in Oct 2019 Orpheus dives off of Massachusetts. SLAM point-cloud and maps generated from recorded data. "Baby Orpheus" now allows for similar constructs with simplified testing. Though only rated to 300m, vehicle has full Orpheus capability for local testing without requiring more than a single person.

   d) Preparations of the vehicle for expected summer testing with cruise supported by NOAA. Awaiting pandemic end for cruises to test on full-size vehicle in trench environments.

   e) Continued lab analyses and developed Ocean Worlds website and online database. Lab work culminated in cover article for the journal Deep Sea Research (see the publication list below).

   f) Completed science goals/STM synthesis with payload and published article on the future pathways for ocean exploration.

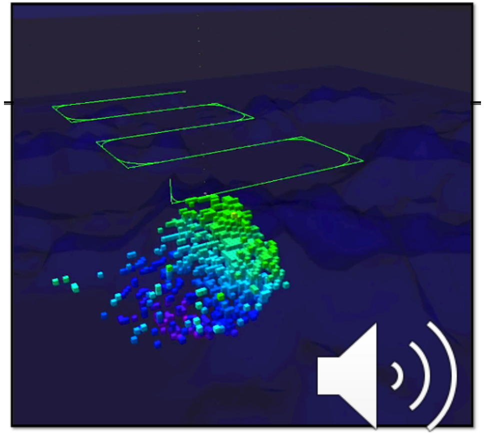
b) Significance: Enables new and unique measurements for Earth science while preparing the way for ocean worlds exploration. Work featured in JPL's Annual Report and in numerous media outlets. NOAA and NSF are very interested in using our design.

c) Next steps: We have no funding to continue this work.

NASA is testing a new submarine that will hunt for undiscovered sea life — and scientists eventually want it to look for aliens on Europa

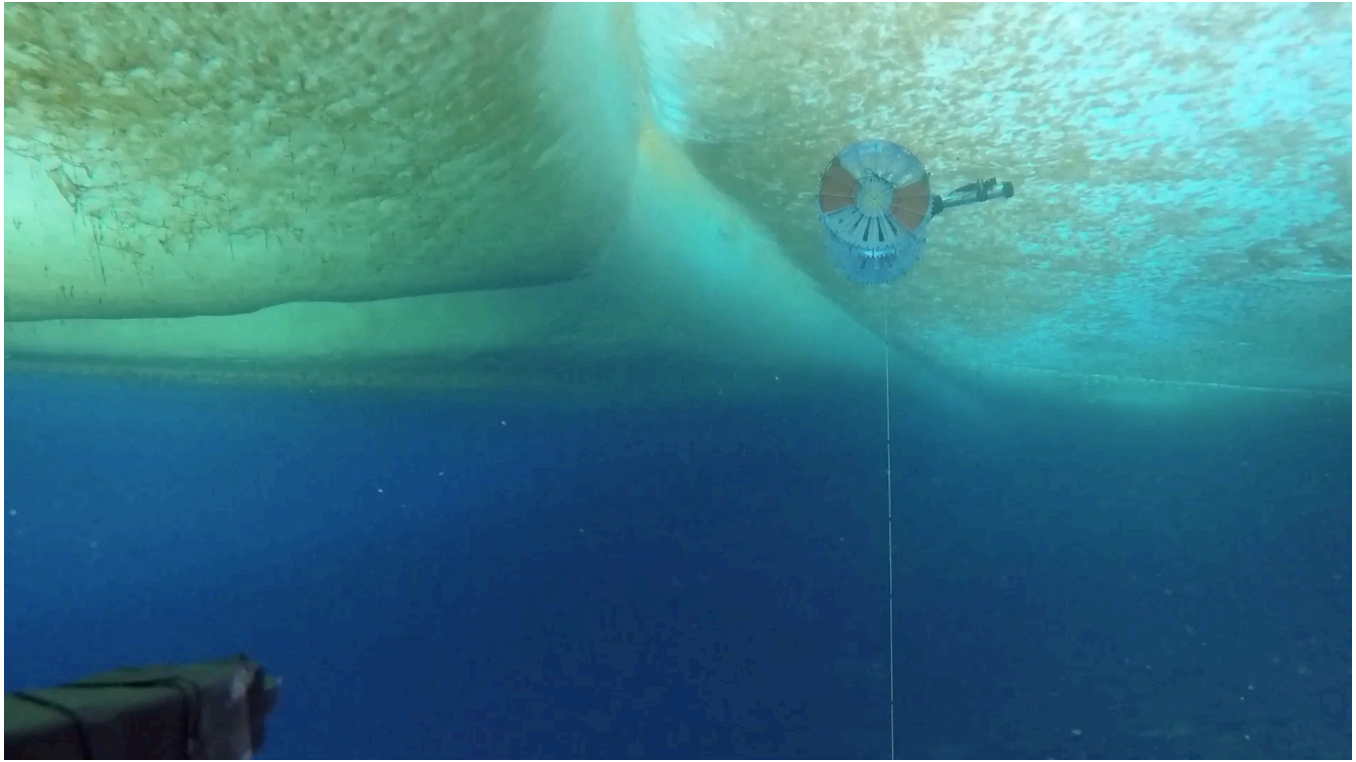
Hilary Brueck Feb. 21, 2019, 1:58 PM

The Orpheus drone was launched into the waters of the Atlantic Ocean near Cape Cod in September. Bobby Foster for OceanX/Bloomberg Philanthropies



Orpheus following lawnmower path with VINS

Results: BRUIE under sea ice in Antarctica



Results: BRUIE under sea ice in Antarctica

Publications and References

The following publications have come out of this SRTD work to date:

1. Hand, K. P., Sotin, C., Hayes, A., & Coustenis, A. (2020). On the Habitability and Future Exploration of Ocean Worlds. Space Science Reviews, 216(5), 1-24.

2. Hand, K. P., Bartlett, D., Fryer, P., Peoples, L., Williford, K., Hofmann, A, & Cameron, J. (in revision, 2019). Discovery of novel structures at 10.7 km depth in the Mariana Trench may reveal chemolithoautotrophic microbial communities. Deep Sea Research I.

3. Hand, K. P., & German, C. R. (2018). Exploring ocean worlds on Earth and beyond. Nature Geoscience, 11(1), 2.

4. Santibáñez, P. A., Michaud, A. B., Vick-Majors, T. J., D'Andrilli, J., Chiuchiolo, A., Hand, K. P., & Priscu, J. C. (2019). Differential Incorporation of Bacteria, Organic Matter, and Inorganic Ions into Lake Ice during Ice Formation. Journal of Geophysical Research: Biogeosciences.

5. Carnevali, P. B. M., Herbold, C. W., Hand, K.P., Priscu, J. C., & Murray, A. E. (2018). Distinct Microbial Assemblage Structure And Archaeal Diversity In Sediments Of Arctic Thermokarst Lakes Differing In Methane Sources. Frontiers in Microbiology, 9.

6. Matheus Carnevali, P., Rohrssen, M., Williams, M.R., Michaud, B., Adams, H., Berisford, D., Love, G.D., Priscu, J.C., Rassuchine, O., Hand, K.P., Muray, A.E. (2015) Methane sources in arctic thermokarst lake sediments on the North Slope of Alaska. Geobiology. doi: 10.1111/gbi.12124.

7. Jakuba, M.V., German, C.R., Bowen, A.D., Whitcomb, L.L., Hand, K., Branch, A., Chien, S. and McFarland, C., 2018, March. IEEE Teleoperation and robotics under ice: Implications for planetary exploration. In 2018 IEEE Aerospace Conference. pp. 1-14.