Virtual Research Presentation Conference

Miniaturized High-Pressure Submersible Testbed

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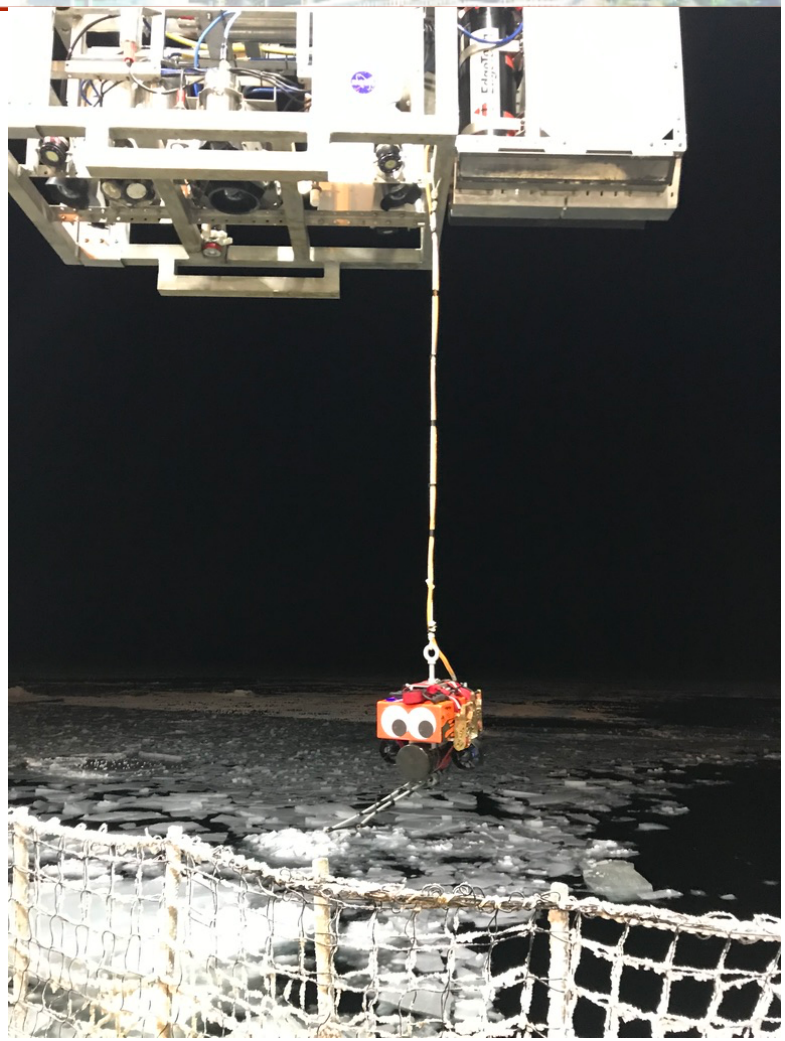
Tutorial Introduction

Abstract

In 2019, while attempting to rescue the Woods Hole Oceanographic Institution's (WHOI) NUI submersible, trapped unresponsive 4000m under the ocean, an ice-locked & ship-bound combined JPL / WHOI team built an emergency mini-submersible from spare parts to retrieve the larger vessel. By modifying thrusters and connectors never rated for depth, spare deep-water pressure housings, and assorted hobbyist electronics, the team brought together oceaneering and space exploration expertise to successfully build a marsupial explorer able to fly freely as a "smart hook". *This temporary vehicle – tested to 4000 m – showed the capacity for traditional ocean vehicles to be miniaturized using techniques developed for small spacecraft.* The significant expertise of the WHOI engineers regarding fittings and connectors used in a pressure environment combined with the newly available low-cost parts, leads to new techniques promising for Ocean Worlds research – or to reach unexplored regions of Earth's ocean. This effort builds on these findings to investigate and build a low-cost "pressure-environment" testbed exploiting new techniques and technologies.



Problem Description

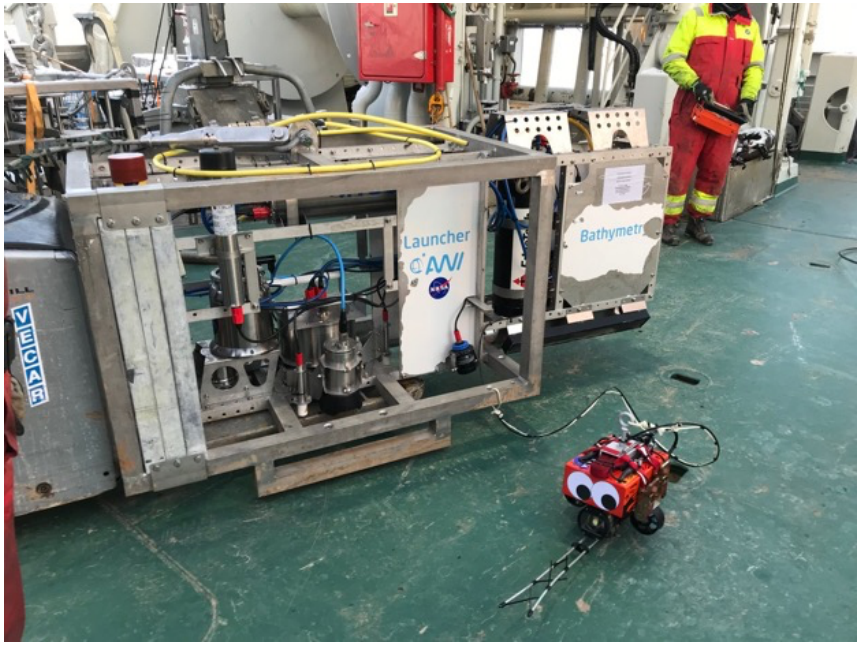
Context: Miniaturization of electronics and ocean technology enables new exploration possibilities:

- Utilized a familiar team and close collaborations from field expeditions. Focused on areas of JPL interest while producing a miniaturized vehicle motivating to WHOI.
- Pandemic provided unique opportunity when field travel was limited and personnel were available for design effort.

SOA: The majority of undersea vehicles are the size of phonebooths not phonebooks!

Motivation: Advance JPL's capability for survivable systems for extreme environments, e.g., >600 bar. (Extreme Environment Technologies for Future Space Science Missions report (e.g., gas-giant probes & sub-surface Ocean Worlds).

- Extend missions through the use of miniaturization, (2019 JPL Strategic Technologies document *"to realize savings and enhanced capabilities, JPL will continue to focus on developing miniaturized systems at the component, subsystem, and system level. To function as a fully integrated miniaturized system, every aspect of the technology must survive the environmental challenges")*



Example of SpongeBob SpareParts next to AWI's OFOBS undersea camera system. The entirety of the highly maneuverable vehicle on the right is about the size of a single high resolution camera on a traditional vehicle.

Methodology

Blend techniques from oceaneering and space systems to build a mini-submersible testbed based on the electronics developed for “Baby-Orpheus”, JPL’s existing low-cost <100m-rated submersible testbed with TRN capability.

- Performed trade study of open- vs oil-compensated vs epoxy-filled housings to minimize expensive pressure-housings.
- Pressure tested motor controller and microcontroller electronics with multiple cycles to 11,000m seawater equivalent pressure
- Approach design from tight volume constraints and expand when violation noted (thruster sizing drove buoyancy foam needs)
- Create a hybrid power system for tether or battery operations
- Utilize oil-filled junction box for connectors to prevent sea-water intrusion at depth

Results

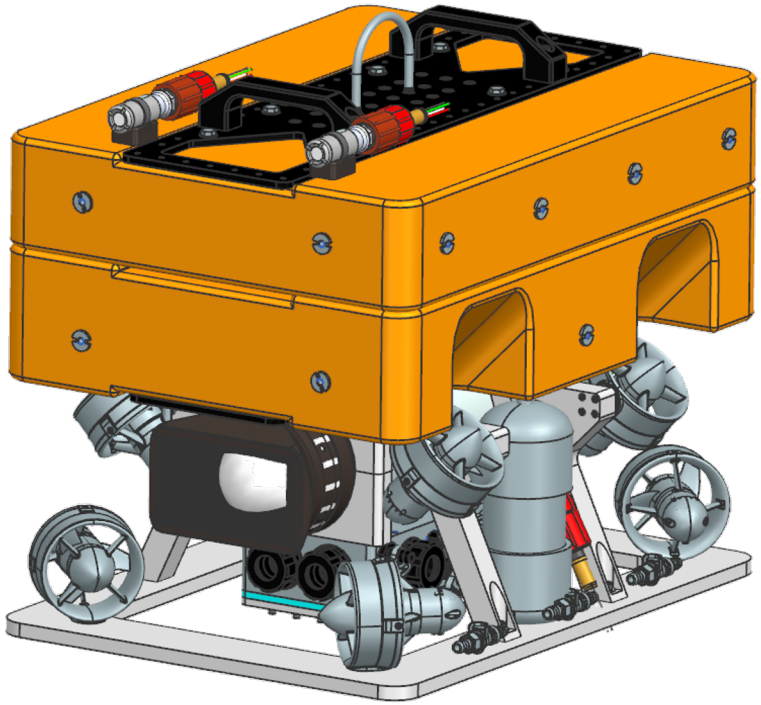
Designed and built 11,000m-class submersible packable within 2x TSA-checkable Pelican cases – with primarily COTS parts

- 8-thruster mobility for 6DOF with onboard TRN computation
- Primary motor control and sensing electronics full-ocean pressure rated (allows for operation without pressure vessel over short tether)
- Extensible for additional payload and testing in ROV or AUV mode

Smallest full ocean explorer yet built – with majority of parts low-cost and COTS

Next steps:

- Multiple possible demonstration & test cruises
- Investigating options for “daughtership” use for external cameras or lights, as well as scientific payloads of interest
- Collaboration with WHOI and other institutions seeking further funding
- Pressure-tolerant batteries and tether management systems still of interest



Publications and References

Bünz, Stefan and Ramirez-Llodra, Eva, “RV Kronprins Håkon (cruise no. 2019708)”, available at: https://haconfrinatek.files.wordpress.com/2020/01/cruise-report-hacon19.pdf

Drake, Nadia, “If Alien Life Exists It Might Look Like This”, National Geographic, 2019, available at: https://www.nationalgeographic.com/science/2019/11/if-alien-life-exists-in-solar-system-may-look-like-this-aurora-hydrothermal-vent/

HACON Cruise Team, “Deep Vents Under Ice: The Story of a Successful Cruise”, available at: https://haconfrinatek.com/2019/11/04/deep-vents-under-ice/