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## Democratizing ocean technology: low-cost innovations in underwater robotics

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In comparison to the ocean's immense volume and diversity of research areas, the number of sensors required to make the majority of desired measurements is quite small. This inequality of supply and demand elevates prices, adding further barriers for developing nations or fledgling research programs with smaller budgets attempting ocean science. Our work aims to demonstrate the potential of combining commercially available, open-source products to create inexpensive, configurable, and user-friendly platforms that can be adapted for underwater navigation and integration with most commercial oceanographic sensors.

Specifically, we will highlight modifications made to a Blue Robotics BlueROV2, which we have configured for various missions including vertical profiling of a coastal fjord and three-dimensional mapping of crude oil spills. The BlueROV2 offers an easily modified platform for physical mounting of sensors and streaming of sensor data via its onboard computer, a Raspberry Pi. Our custom circuit board is "sensor-agnostic", powering sensors from a common source (the ROV battery) and using an Arduino that accepts analog or digital sensor inputs, allowing us to choose from a wide range of sensors. Physical modifications make use of inexpensive, readily available materials, and range from simple plastic brackets for small sensors to a skid for a sensor with half the ROV's original weight, which utilizes pop bottles for buoyancy.

While products such as Pixhawk, Raspberry Pi, Arduino, and BlueROV have inspired hobbyists and youth around the world, they paradoxically have not been as widely embraced in the academic community, who perhaps remain unaware of their research potential. Thus, while there has yet to be an analogous push to develop inexpensive, small, power-efficient, and open-source sensors, these platforms offer exciting opportunities to build a new generation of oceanographic tools with measurement abilities far exceeding those of their predecessors. We are at an ocean technology tipping point, and, as MacGyver says, "With a little bit of imagination, anything is possible."