

# Twilight Zone Observation Network: A Distributed Observation Network for Sustained, Real-Time Interrogation of the Ocean's Twilight Zone

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## ABSTRACT

The ocean's twilight zone (TZ) is a vast, globe-spanning region of the ocean. Home to myriad fishes and invertebrates, mid-water fishes alone may constitute 10 times more biomass than all current ocean wild-caught fisheries combined. Life in the TZ supports ocean food webs and plays a critical role in carbon capture and sequestration. Yet the ecological roles that mesopelagic animals play in the ocean remain enigmatic. This knowledge gap has stymied efforts to determine the effects that extraction of mesopelagic biomass by industrial fisheries, or alterations due to climate shifts, may have on ecosystem services provided by the open ocean. We propose to develop a scalable, distributed observation network to provide sustained interrogation of the TZ in the northwest Atlantic. The network will leverage a "tool-chest" of emerging and enabling technologies including autonomous, unmanned surface and underwater vehicles and swarms of low-cost "smart" floats. Connectivity among in-water assets will allow rapid assimilation of data streams to inform adaptive sampling efforts. The TZ observation network will demonstrate a bold new step towards the goal of continuously observing vast regions of the deep ocean, significantly improving TZ biomass estimates and understanding of the TZ's role in supporting ocean food webs and sequestering carbon.

## Vision and Potential Transformative Impact

Our Ocean-Shot vision is a series of scalable TZ observation networks emplaced in critical locations throughout the global ocean, beginning with a pilot observation network off the continental shelf of southern New England. Our team will deploy modular optical, acoustic, and geochemical sensor packages on apex predators, swarms of robots and "smart" floats, and tow bodies deployed from oceanographic vessels and other vessels of opportunity. Network sensors will log biophysical measurements at sub-Hz frequencies across 250,000 square kilometers over several years. In-water assets will connect to autonomous surface vehicles to facilitate data acquisition and assimilation in real time complemented by miniaturized multiple-frequency acoustic receivers that detect sound emitted by sources deployed on an array of moorings for tracking assets throughout the water column. Data from sensor packages deployed on apex predators will lead us to "hotspots" of activity and inform locations for intensive field operations using conventional shipboard technologies. The network will stimulate rich opportunities for advancement of scientific equipment, engineering, and data analysis that will drive new knowledge. The resulting data will transform efforts to inform policy and implement strategies for conservation and sustainable fisheries management in the high seas, as well as predicting the impacts of climate change.

## Realizable, With Connections to Existing U.S. Scientific Infrastructure, Technology Development, and Public-Private Partnerships

Woods Hole Oceanographic Institution (WHOI) is well positioned to lead the development of an international TZ observation network. The WHOI community of scientific and technical staff, ships' crew and officers, and support staff facilitates several large projects funded by public and private sources with relevance to our Ocean-Shot. We have started Year 3 of a six-year, \$32m OTZ Project funded by philanthropic sources. The Northeast U.S. Shelf (NES) Long-Term Ecological Research (LTER) project, funded by NSF, is also based at WHOI. The LTER integrates observations, experiments, and models to understand how planktonic food webs are changing in shelf ecosystems adjacent to the proposed OTZ Observation Network. Finally, WHOI is lead organization for the Ocean Observing Initiative's Pioneer Array that is also located on the NES. We will leverage the knowledge gained, technologies under development, and engineering and technical capabilities from these efforts to ensure that our vision is realizable.

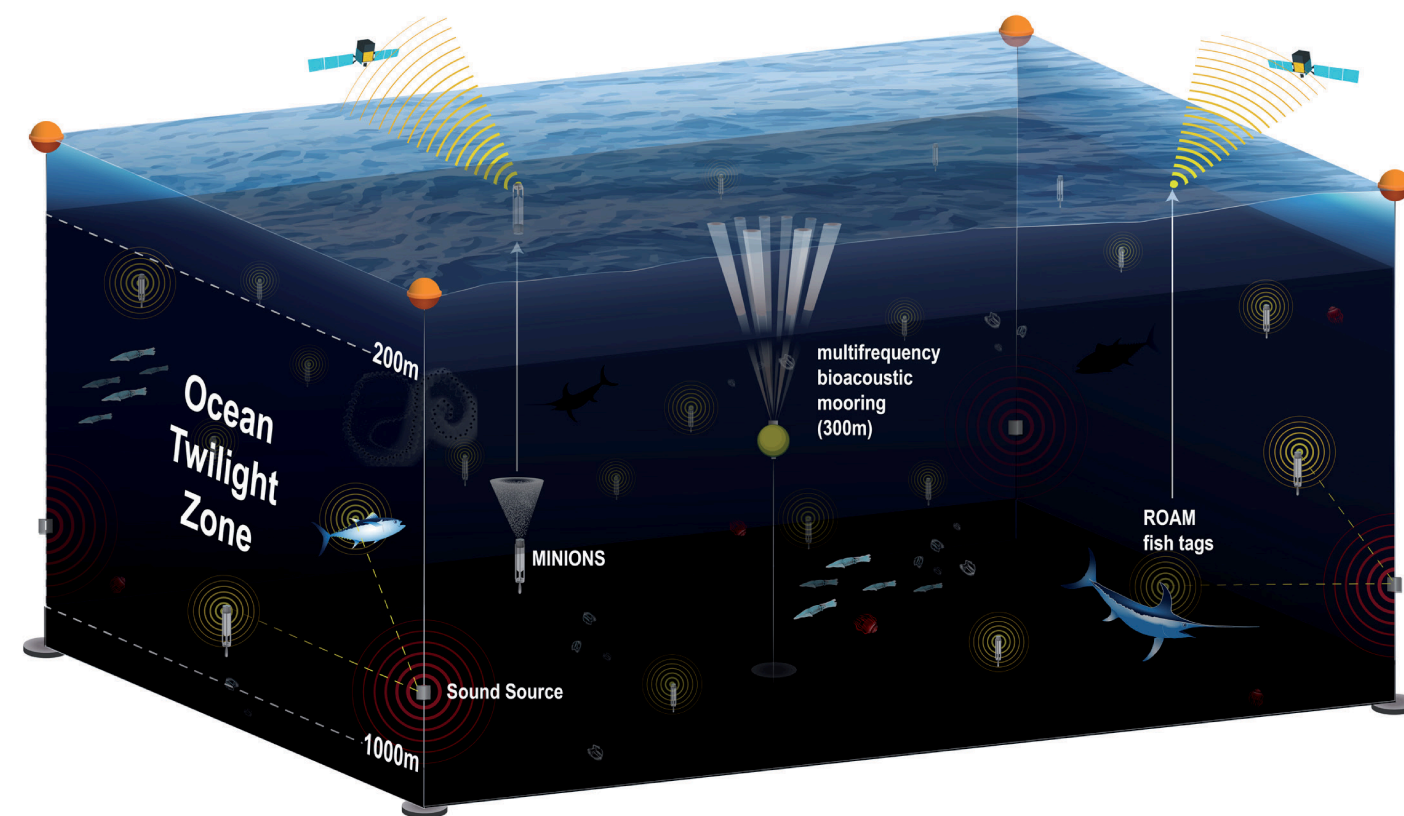


Figure 1. Artistic representation of the Twilight Zone Observation Network that will allow biological and autonomous assets to be tracked throughout the water column in the open ocean. Assets will communicate with each other and data from new smart sensors will be delivered to researchers in near-real time through satellite telemetry.

## Scientific/Technological Sectors Engaged Outside of Traditional Ocean Sciences

Our TZ observation network aligns with the Defense Advanced Research Projects Agency's (DARPA) Ocean of Things (OoT) initiative that aims to "enable persistent maritime situational awareness over large ocean areas by deploying thousands of low-cost, environmentally friendly, intelligent floats that drift as a distributed sensor network." Their goal is to establish real-time communications with swarms of floating and swimming sensors. The sensors will use common technologies including GPS sensors, accelerometers, microphones, temperature sensors, and cameras. Several private companies are also invested in OoT. There are natural synergies between our Ocean-Shot and OoT that will be formalized during program development.

## Opportunities for International Participation and Collaboration

International scientific interest in the mesopelagic zone is expanding rapidly. For instance, in the past year an informal organization called the Joint Exploration of the Twilight Zone Operational Network (JETZON) has been established to serve as an international coordinator and focal point for mesopelagic studies. This Ocean-Shot would invite members of the JETZON group that aims to bring together all researchers in the field, from PhD students to those involved in, and leading large multinational projects. This OTZ Observation Network will serve as a testbed for the development of similar arrays distributed across TZs throughout the global ocean.

## Develops Global Capacity and Encourages the Development of the Next Generation of Ocean Scientists, Engineers, and Technologists

We often speak of the "democratization" of data, enabling scientists from around the globe to access raw data to advance their own scientific interests. This OTZ observation network aims to set a new standard as one of the tenets of our current OTZ project is open sharing of data. This project will also advance the vision of the OTZ project to reduce "barriers to entry" for ocean science institutions in the developing world by developing low-cost pervasive sensors. We are hopeful that this democratization will also help to inspire prospective ocean scientists from these nations to seek further education opportunities.

**Funding:** This research is part of the Woods Hole Oceanographic Institution's Ocean Twilight Zone Project, funded as part of The Audacious Project housed at TED. 