

OCEAN EXPLORATION CAPABILITIES OF NOAA SHIP OKEANOS EXPLORER



As the only federal program dedicated to ocean exploration, NOAA Ocean Exploration is leading national efforts in support of the [National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone](#). We are filling gaps in the basic understanding of the U.S. deep waters and seafloor and making ocean exploration more accessible. Using the latest tools and technology, we explore previously unknown areas of our deep ocean, making discoveries of scientific, economic, and cultural value to strengthen the economy, health, and security of our nation.

One of these tools is NOAA Ship *Okeanos Explorer*. *Okeanos Explorer* is the only federal vessel solely dedicated to exploring our largely unknown ocean for the purpose of discovery and the advancement of knowledge about the deep ocean. Such exploration supports key NOAA, national, and international goals to better understand and manage the ocean and its resources.

NOAA Ocean Exploration collaboratively plans expeditions on *Okeanos Explorer* using a community-driven process, dubbed the [Explorer Model](#), that incorporates input from partners and stakeholders with the goal of providing data about deepwater habitats, biology, and processes that will benefit NOAA, the scientific community, and the public. We design these expeditions to catalyze follow-on research, generate new hypotheses, and meet resource management needs, making open-access data available in real time (or near real time).

To maximize the value of an expedition, we have equipped *Okeanos Explorer* with telepresence technology that allows scientists to guide and participate in expeditions from shore, similar to how NASA's ground control interacts with the International Space Station. Using telepresence technology, internet-based collaboration tools, and a dedicated broadband satellite communications and data transmission system, data and information are quickly made available to interested parties on shore. This allows for any number of scientists, marine resource managers, educators, and students, as well as the public, to participate in expeditions in real time, strengthening and engaging the community of ocean explorers.

Okeanos Explorer is operated by the NOAA Commissioned Officer Corps and civilians as part of the NOAA fleet managed by NOAA's Office of Marine and Aviation Operations. Mission equipment is operated by NOAA Ocean Exploration in partnership with the Global Foundation for Ocean Exploration (GFOE). Data collected are managed by NOAA's National Centers for Environmental Information (NCEI).

This document provides detailed information about NOAA Ocean Exploration's operating principles, capabilities, and systems for expeditions on *Okeanos Explorer*.

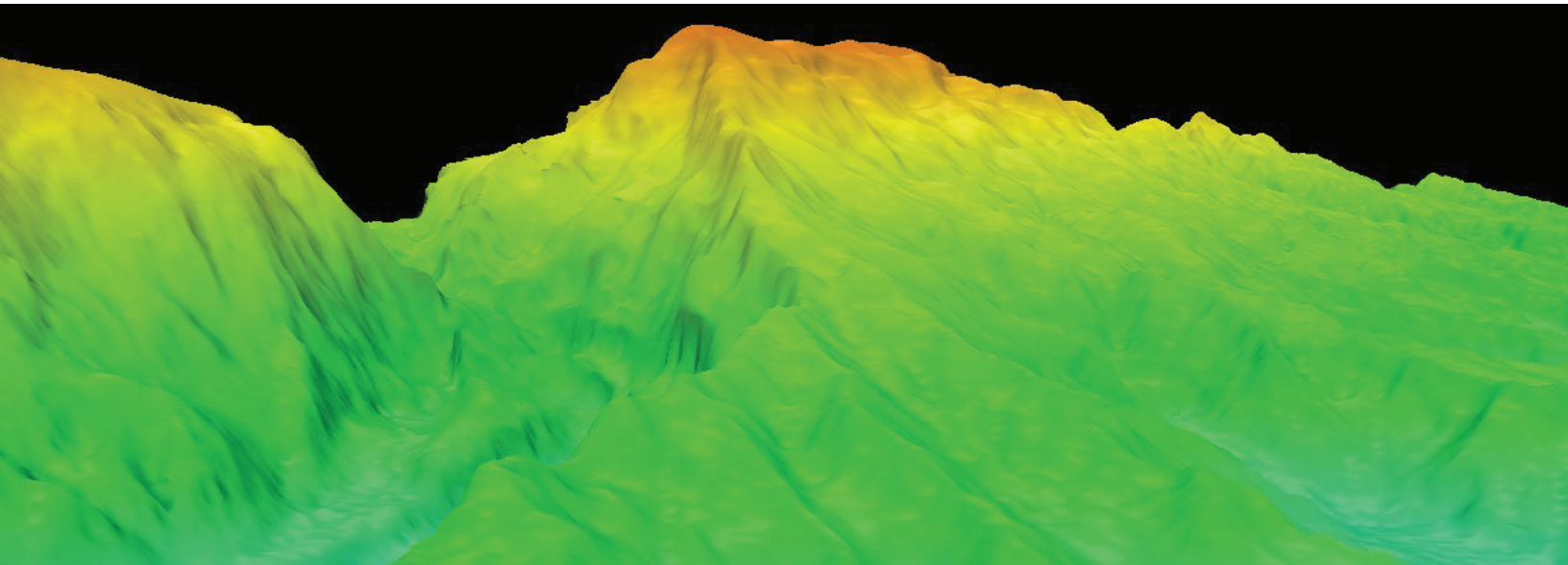


Exploration Operating Principles and Concept of Operations

NOAA Ocean Exploration uses a model of exploration on *Okeanos Explorer* that was developed with extensive input from the oceanographic community through workshops with NOAA and external partners and the [President's Panel on Ocean Exploration](#). Based on these discussions, we produced exploration core operating principles and a concept of operations. As technology advances, the reach of telepresence-enabled operations is expanding, but the guiding philosophy behind the [Explorer Model](#) remains the same. The Explorer Model brings together the science and resource management communities to collaborate in real time and explore areas of the deep sea where data is scarce.

Core Operating Principles

- Expand the footprint of exploration in unknown and poorly understood areas by systematically exploring areas identified by NOAA, other federal and state agencies, local stakeholders, and the broad exploration community
- Conduct interdisciplinary, collaborative expeditions informed by real-time expertise from marine scientists and resource managers around the world
- Collect and process standardized, high-quality data and information to meet scientific and management requirements
- Embrace findable, accessible, interoperable, and reusable (FAIR) data principles by sharing data and discoveries, making data publicly available in real time, or near real time
- Produce open access data with necessary metadata (see [NOAA's Public Access to Research Results plan](#)) to facilitate broad data use, increase collaboration, and engage the public
- Use platforms and systems to test, advance, and adopt new exploration systems, sensors, technologies, and methods
- Provide onshore and onboard opportunities for public engagement and training the next generation of ocean explorers

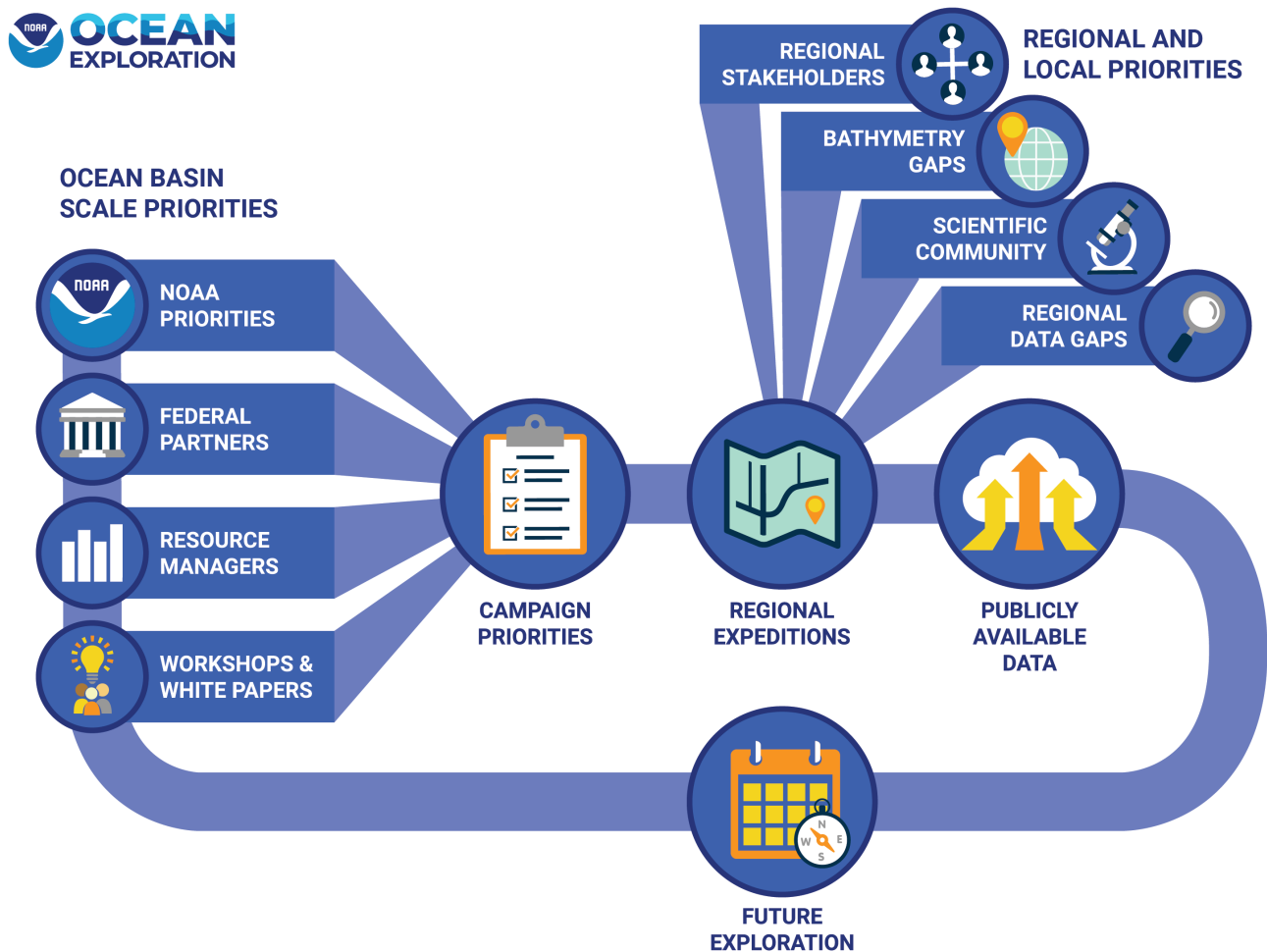


Concept of Operations

NOAA Ocean Exploration takes a multilevel approach to exploring the deep ocean. Each level builds on the previous one to increase understanding of an area.

Community Input

NOAA Ocean Exploration’s operations are driven by priorities identified by the resource management and broad science community through calls for input, workshops, and consultations with partners. We use this input to develop the annual schedule for *Okeanos Explorer*, refine operating areas, and identify specific targets for exploration.



Schematic of input solicited at multiple levels (e.g., federal agencies, state and local governments, industry partners, science and management communities, etc.) that create the foundation of objectives and goals that campaigns and expeditions are built upon.

Reconnaissance

NOAA Ocean Exploration begins initial exploration with reconnaissance using *Okeanos Explorer*’s nine scientific sonars. Systematic mapping operations reveal seafloor features and water column anomalies and can be used to identify specific features of interest for additional investigation. Mapping operations are typically focused on areas with no or poor quality multibeam bathymetry at depths deeper than 200 meters. Additionally, we optimize transits to maximize data collection through

areas with bathymetry gaps, wherever possible, making strategic decisions to tightly parallel existing transit lines and make minor course adjustments over long distances to map over key features such as seamounts without impacting transit efficiency.

Initial Site Exploration

NOAA Ocean Exploration uses collaborative, community-driven expedition planning to identify and refine targets for remotely operated vehicle (ROV) exploration to meet expedition objectives. We use our 6,000-meter-capable ROV system to assess the primary characteristics of the seafloor and water column, including, but not limited to, seafloor morphology and composition, physical properties and biological inhabitants of the water column, and biodiversity and distribution of benthic communities.

Core Capabilities

NOAA Ocean Exploration uses the following capabilities to map and explore unknown or poorly known deepwater ocean areas, features, and phenomena.

Seafloor and Water Column Mapping Systems*

Kongsberg EM 304 Multibeam Sonar

The 30 kHz Kongsberg multibeam sonar is capable of mapping broad swaths to collect seafloor bathymetry/backscatter data and detect water column features (e.g., gaseous seeps). This multibeam sonar is designed to map the seafloor in water depths ranging from 10 to 10,000 m and is an optimal sonar system for mapping canyons, seamounts, and other deep ocean features of interest – only the bottom of the deepest ocean trenches are out of its reach. The swath width of the system typically ranges between 3 and 5.5 times the water depth, with a typical maximum width of 8-9 km. This multibeam sonar is optimized for working in water depths of 500-8,000 m. In shallower water depths (less than 3,300 m), the sonar also uses multi-ping technology (dual swath), where two pings are simultaneously sent into the water, thereby increasing the sounding data density. Multibeam sonar data is used to generate 5-100 m resolution bathymetry maps of the seafloor, backscatter reflectivity mosaics revealing differences in seabed substrate character, and maps of georeferenced water column features such as gaseous bubble plumes. In January 2020, the multibeam sonar system was upgraded from an EM 302 to an EM 304.

Simrad EK60 and EK80 Split-Beam Sonars

The Simrad EK split-beam sonar transducers operate at the following frequencies: 18, 38, 70, 120, and 200 kHz. The 38 and 70 kHz systems are EK80s that can be operated in wideband mode (as well as narrowband mode) using multiple frequencies to obtain higher resolution data. All other sonars are EK60s, which operate in narrowband mode only. Water column backscatter data from the EKs are highly effective at detecting anomalies in the water column such as gaseous seeps, fish schools, and dense biological aggregations. Multiple frequencies of EKs enable better detection of water column targets at various scales, collect calibrated measurements on the target strength of features in the water column, and provide insights into the biological productivity of a region.

Knudsen Chirp 3260 Sub-Bottom Profiler

The Knudsen Chirp 3260 (3.5 kHz) sonar provides echogram images of surficial geological sediment layers underneath the seafloor to a maximum depth of about 80 m below the seafloor. The sub-bottom profiler is normally operated to provide information about the sedimentary features and the bottom topography being simultaneously mapped by the multibeam sonar. The data generated by this sonar help geologists interpret the shallow geology of the seafloor. Collecting this data within project areas provides greatly improved insights into the geology of the region and supplements existing magnetometer and gravity measurements obtained by other vessels.

Teledyne RDI Workhorse Mariner and Ocean Surveyor Acoustic Doppler Current Profilers

The two acoustic Doppler current profilers (ADCPs) are a Teledyne RDI Workhorse Mariner (300 kHz) and an Ocean Surveyor (38 kHz). Hull-mounted ADCP transducers project four beams to record backscatter from the water column and compare the Doppler shift between the four beams to generate profiles of water velocity at various depths. ADCP measurements are of critical importance in characterizing an area's physical oceanography and identifying small to mesoscale ocean current features. In addition to these scientific benefits, the ADCPs are used to assess currents near ROV dive locations to inform dive planning and ensure safe ROV deployment and recovery operations. The 300 kHz Workhorse Mariner ADCP has a typical range of approximately 110 m and a maximum range of 165 m, while the 38 kHz Ocean Surveyor ADCP has a range between 900 and 1,000 m depending on operating mode and oceanographic conditions.

Summary bathymetric and backscatter map products created with the processed acoustic data are generated on a daily basis and immediately made available for operational use to collaborating scientists on shore via the ship's telepresence system. At the conclusion of each expedition, all collected [raw sonar data, finalized summary map products, and associated metadata](#) are delivered to NCEI, where they are archived and typically made available to the public within 90 days.

*For more information about the acoustic seafloor, sub-seafloor, and water column mapping equipment and data acquisition and processing procedures, see the [Deepwater Exploration Mapping Procedures Manual](#).

Conductivity, Temperature, and Depth and Expendable Bathythermograph Systems

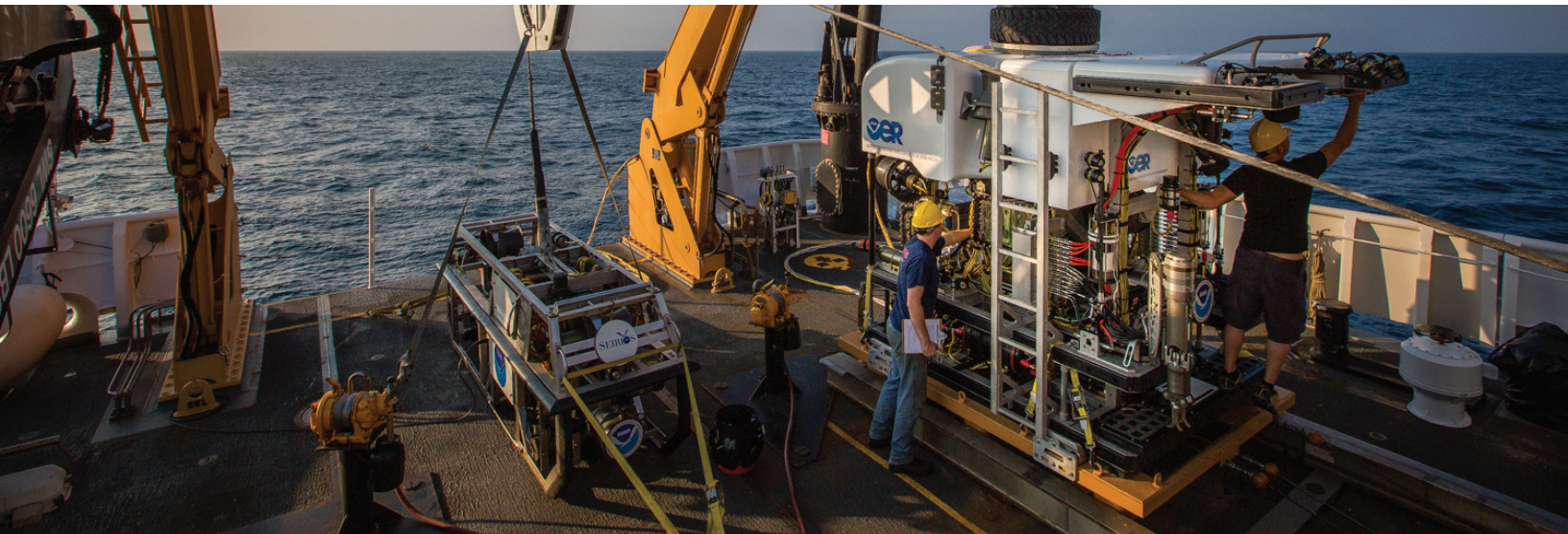
The conductivity, temperature, and depth (CTD) rosette system collects oceanographic data and water samples. The Seabird Electronics (SBE) Model 9/11+ CTD is packaged with a 12-position rosette carousel containing 12 10-liter Niskin bottles. The SBE 9+ underwater unit is depth rated to 6,800 m and possesses a dual conductivity and temperature sensor pair. This system has four ports available for up to eight auxiliary sensors. Additional sensors



currently installed on the CTD measure altitude, light scattering (LSS), dissolved oxygen (DO), and oxygen reduction potential (ORP).

Lockheed Martin Sippican Deep Blue expendable bathythermograph (XBT) probes are used for regular sound velocity profiling. These probes take temperature readings through the water column down to 760 m. Probes are launched off the fantail using the automated XBT launcher system designed by NOAA's Atlantic Oceanographic and Meteorological Laboratory, which allows for control room watchstanders to launch probes remotely through software. A Lockheed Martin Sippican MK-21 XBT system connected to a portable hand-held launcher is available as a backup. Three hand-held launchers are maintained on board. Sound speed profiles are used to account for refraction of the acoustic beams due to changes in water density with depth. In addition, XBT data can provide valuable water column data. Sound speed at the multibeam transducer face is measured with a Reson SVP-70 probe.

The onboard Scientific Seawater System provides a continuous flow of seawater through the SBE 38 remote temperature probe and the SBE 45 microthermosalinograph (TSG). This system provides temperature, conductivity, salinity, and sound velocity of the sea surface and is used as a backup sea surface sound speed source. Additional raw seawater connections in the wet lab are also available for adding other sensors.

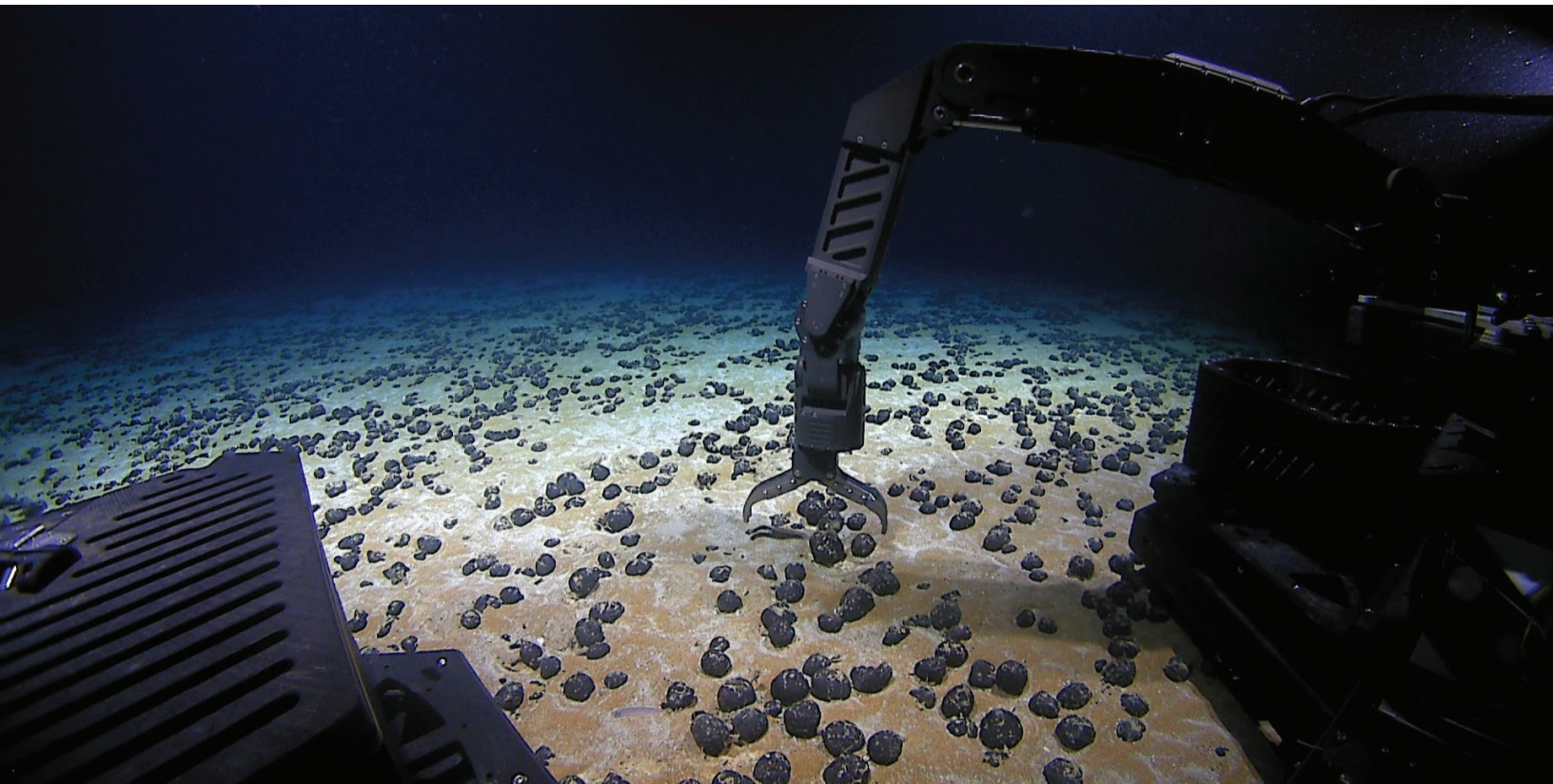


Remotely Operated Vehicles

NOAA Ocean Exploration conducts ROV exploration from 250 to 6,000 m using our dedicated, fully integrated, dual-body ROV system, which consists of ROVs *Deep Discoverer* and *Seirios*. *Deep Discoverer* has a 300-pound (in air) scientific payload for additional sensors. It's primary dataset is high-definition video collected by five high-definition cameras. *Deep Discoverer* is also outfitted with a Sea Bird 9/11+ CTD with light scattering (LSS), dissolved oxygen (DO), and oxygen reduction potential (ORP) sensors. *Deep Discoverer* has a unique lighting design with LED lights on four swing arms that allow pilots to adjust the position and angle of the light for optimal imaging with over 190,000 lumens of light. The high-resolution ROV navigation system uses Doppler velocity log (DVL) bottom lock, a north-seeking fiber-optic gyro compass, a quartz-crystal pressure (depth) transducer, and ultra-short baseline (USBL) acoustic tracking.

Deep Discoverer is equipped with two manipulator arms: a Schilling Orion manipulator arm and a seven-function Kraft Telerobotics Predator II manipulator arm. The Predator II manipulator arm is used to collect specimens and is outfitted with custom-built coral cutter jaws with intermeshing fingers to grasp rocks, tools, and rigging. The cutter jaws also have a set of scissor-like blades and urethane grippers to snip and clamp delicate branches of coral. *Deep Discoverer* is also equipped with a suction sampler that can collect soft biological and geological objects from the seafloor.

The second body of the system is the camera platform *Seirios*, which provides additional lighting and an “aerial” view of *Deep Discoverer*’s seafloor investigations. *Seirios* is equipped with one high-definition camera and a Sea Bird 9/11+ CTD with a dissolved oxygen sensor and can provide approximately 180,000 lumens of light.



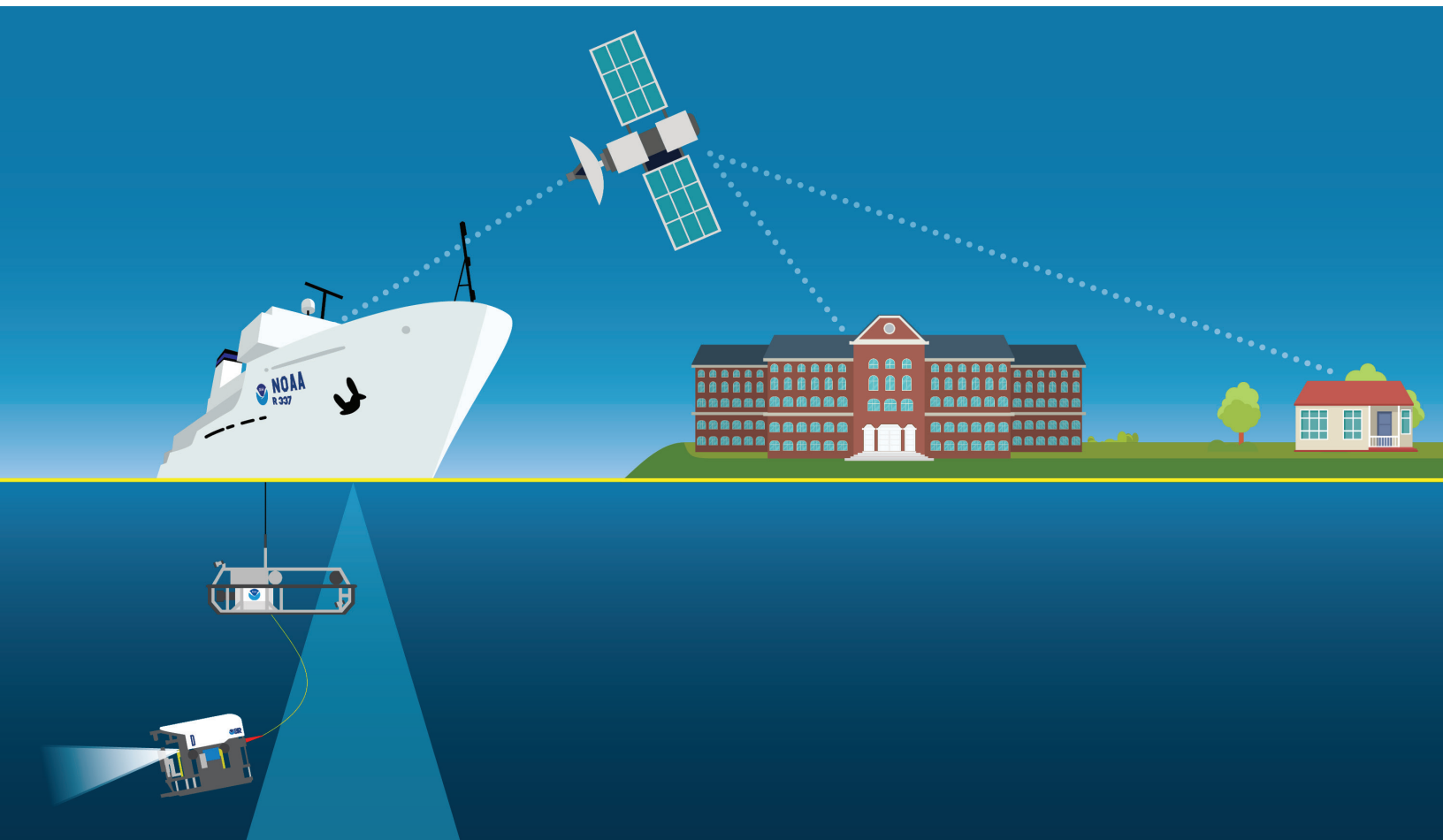
Sampling Operations

Limited sampling operations are conducted during expeditions on *Okeanos Explorer*. The objective of these sampling operations is to maintain a balance between covering adequate distance during a dive, obtaining sufficient close-up imaging, and collecting limited samples in a minimally invasive way while recognizing the scientific need for physical, biological, and geological sample collection.

Deep Discoverer is outfitted with four insulated bioboxes, two rock boxes, and a five chamber suction sampler. Biological specimens are collected to meet expedition and dive-specific goals. They typically represent suspected new species, new records for the region, dominant morphotypes in a habitat, or unusual morphologies; support connectivity studies; or are otherwise determined appropriate by the science leads. All associates brought up with a primary specimen are preserved and subsampled, whenever possible, for inclusion in the [Smithsonian’s National Museum of Natural History Biorepository](#) for future barcoding and DNA extraction. All voucher specimens and subsamples are

sent to the [Smithsonian's National Museum of Natural History Department of Invertebrate Zoology](#) for long-term archiving and public access.

Geological samples are collected to support expedition goals and to provide the scientific community with access to samples that can later be used for geochemical composition and dating analysis. After an expedition, samples can be accessed through the [Marine and Geology Repository at Oregon State University](#), where they are photographed and entered into the university's online database. Thin and polished sections are made for each hard-rock sample, unless specified otherwise, and included in the database.



Telepresence

Okeanos Explorer is a leading platform for collaborative telepresence-enabled exploration, which allows shore-based scientists and students to fully engage in an expedition.

In partnership with the GFOE, NOAA Ocean Exploration's telepresence operations integrate years of development and investment in specialized protocols, high-speed satellite networks, internet-based collaboration tools, broadcast industry standard video/audio management, standards-based data management systems, terrestrial networks (Internet2, shore-based servers), commodity internet streaming, and web and social media interfaces. We collaborate with the GFOE and the University of Rhode Island's Inner Space Center as part of the [NOAA Ocean Exploration Cooperative Institute](#) (OECI), to develop, maintain, and operate these systems, including shore-based systems at exploration command centers and the terrestrial and satellite links.

Our telepresence-enabled exploration model can be used to engage a theoretically unlimited number of scientists and managers on shore in real time and support collaborative decision-making during mapping, CTD, and ROV operations. Participating scientists can join from anywhere with an internet connection. Simultaneously, public viewers can tune in online to watch and listen to the ongoing exploration.

Collaboration Tools

A suite of internet-based collaboration tools brings the experience of being at sea to the shore, empowering the science team to guide operations and play an active role in collaborative decision-making. Three 720p high-resolution video feeds are streamed to shore with approximately two-three second latency. During ROV dives, these feeds usually display imagery from the ROVs' two main high-definition cameras on video streams 1 and 2 (Cameras 1 and 2). Stream 3 (Camera 3) is primarily used to provide situational awareness for shoreside participants and can be customized with different data feeds to fit the objectives of the dive. Overnight and during dedicated mapping expeditions or legs, these feeds display data acquisition to allow for collaborative participation from shore, remote watchstanding, and telepresence-enabled mapping.

An instant messaging chat room allows scientists to discuss observations, participate in operations without a dedicated phone line, and access real-time output from the environmental sensors on the vehicles. Additionally, a dedicated FTP server syncs hourly, bringing larger data files to shore in near real time, allowing shore-side scientists to immediately begin working up the data. Scientific observations are cataloged using the cloud-based annotation system [SeaTube](#), which was developed by Ocean Networks Canada and is used for NOAA expeditions. Scientists can add annotations to an active expedition in real time and to any expedition since 2017, which allows collaboration to continue beyond the conclusion of an expedition.

Technology Demonstrations

In addition to expeditions focused on mapping and ROV operations, NOAA Ocean Exploration also leverages expeditions on *Okeanos Explorer* to advance and test novel approaches or emerging technologies for ocean science and exploration. We incorporate new approaches and technologies into regularly scheduled operations as logistics allow or, occasionally, on dedicated technology demonstration expeditions in partnership with the private sector, academia, and others, including the OEI. We also invite project submissions to our [Exploration Project of Opportunity process](#). Such projects must have limited scopes, footprints, and berthing requirements.

For More Information

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