Overview

NOAA Ship Okeanos Explorer is the only federal vessel dedicated to exploring our largely unknown ocean for the purpose of discovery and the advancement of knowledge about the deep ocean. Exploration supports key NOAA, national, and international goals to better understand and manage the ocean and its resources. The Okeanos Explorer generates real or near real-time, open-access data to better understand deepwater habitats, biology, and processes. Exploration expeditions are planned collaboratively, with input from partners and stakeholders, and with the goal of providing data that will benefit NOAA, the scientific community, and the public. NOAA Office of Ocean Exploration and Research (OER) ocean exploration expeditions are designed to catalyze follow-on research, generate new hypotheses, and to meet management needs.

The Okeanos Explorer is equipped with telepresence technology which allows teams of scientists to guide and participate in expeditions from shore, similar to NASA's ground control interaction 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 widely available to scientists, educators, the media, and the public. This allows for any number of interested scientists, marine resource managers, educators, students, and the public to participate in expeditions in real-time, strengthening and engaging the community of ocean explorers.

OER provides and maintains the mission systems aboard Okeanos Explorer and the Office of Marine and Aviation Operations provides and maintains ship systems and personnel.

This document provides detailed information on the mission operating principles, capabilities, and systems of NOAA Ship Okeanos Explorer.
Exploration Operating Principles and Concept of Operations

The Okeanos Explorer model of exploration was developed with extensive input from the oceanographic community through workshops with NOAA and external partners and the president’s panel report on Ocean Exploration. These discussions produced exploration operating principles and a concept of operations.

Core Operating Principles

- Systematically explore unknown and poorly known priority areas identified by NOAA, other federal and state agencies, and the broader exploration and research community
- Conduct interdisciplinary expeditions informed by real-time expertise from marine scientists around the world
- Collect and process standardized, high-quality data and information and make it publicly available in real-time, or as near to real-time as possible, to meet immediate scientific and management requirements; all data are managed under NOAA’s Public Access to Research Results (PARR) plan
- Use platforms and systems to utilize, test, and advance new exploration systems, sensors, technologies, and methods
- Provide onshore and onboard opportunities for public engagement and training

Concept of Operations

Reconnaissance — (1) search unknown areas for anomalies and initiate site characterization; (2) maximize operations during transits through poorly known deepwater areas

Site Characterization — focus on specific poorly known targets with an aim to define the primary characteristics of the seafloor and water column including, but not limited to, seafloor morphology and processes, physical characteristics of the water column, and biodiversity

Water Column Exploration — (1) advance capabilities to characterize water mass properties; (2) improve capabilities to search for anomalies; (3) image and identify midwater fauna to increase understanding of distribution and diversity of life in the water column

Exploration Projects of Opportunity — (1) opportunistic data collection; (2) test new exploration capabilities; (3) deploy and test innovative sensors and technology; all of which are supported by outside scientists and do not impact the scheduled operations of the ship
Core Capabilities
The *Okeanos Explorer* utilizes the following capabilities to explore and characterize unknown or poorly known deep water ocean areas, features, and phenomena from depths ranging from 250 to 6,000 meters.

Mapping and Water Column Characterization Systems

**Kongsberg EM302 Multibeam Sonar**
The *Okeanos Explorer* is equipped with a 30 kHz Kongsberg EM302 multibeam sonar capable of mapping broad swaths for seafloor bathymetry/backscatter and water column feature detection (e.g. gaseous seeps). This multibeam is designed to map the seafloor in water depths ranging from 10 to 7,000 meters, and is an optimal sonar system for mapping canyons, seamounts, and other deep ocean features of interest—leaving only the bottom of the deepest ocean trenches out of the EM302’s reach. The swath width of the system typically ranges between 3 - 5.5x the water depth, with a typical maximum width of 8 kilometers. The multibeam sonar is optimized for working in water depths of 500 to 6,000 meters. In shallower water depths (less than 3,300 meters), the sonar also utilizes multi-ping technology (dual swath) where two pings are simultaneously sent into the water, thereby increasing the sounding data density. Data from the multibeam is used to generate 25 - 100 meter resolution bathymetry maps of the seafloor, backscatter reflectivity mosaics revealing differences in seabed substrate character, and map geo-referenced water column features such as gaseous bubble plumes.

**Simrad EK60 Split-beam Sonars**
The *Okeanos Explorer* is equipped with Simrad EK60 split-beam sonar transducers operated at the following frequencies: 18 kHz, 38 kHz, 70 kHz, 120 kHz, and 200 kHz. Water column backscatter data from the EK60s are highly effective at detecting anomalies in the water column such as gaseous seeps, fish schools, and dense biological aggregations. Multiple
frequencies of EK60s 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 3260 Subbottom Profiler**
The primary purpose of the Knudsen Chirp 3260 (3.5 kHz) sonar is to provide echogram images of surficial geological sediment layers underneath the seafloor to a maximum depth of about 80 meters below the seafloor. The sub-bottom profiler is normally operated to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the multibeam sonar. The data generated by this sonar is fundamental in helping geologists interpret the shallow geology of the seafloor. Collecting this data within project areas will provide greatly improved insights into the geology of the region, and supplement existing magnetometer and gravity measurements obtained by other vessels.

**Teledyne RDI Workhorse Mariner and Ocean Surveyor Acoustic Doppler Current Profilers (ADCPs)**
The *Okeanos Explorer* uses two ADCPs: 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 therefore critically useful in characterizing the physical oceanography of an area and identifying small to mesoscale ocean current features. In addition to these scientific benefits, the *Okeanos Explorer* uses ADCPs to assess currents near remotely operated vehicle (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 meters and a maximum range of 165 meters, while the 38 kHz Ocean Surveyor ADCP has a range between 900 - 1000 meters depending on operating mode and oceanographic conditions.

Summary 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 and finalized summary map products, as well as associated metadata, are delivered to the National Centers for Environmental Information (http://www.ncei.noaa.gov), where they are archived and made available to the public within 90 days.

**Conductivity, Temperature, and Depth (CTD) & Expendable Bathythermograph (XBT) Systems**
The *Okeanos Explorer* is equipped with a CTD rosette system for collecting oceanographic data and water samples. The Seabird Electronics (SBE) Model 9/11+ CTD is packaged with a 12-position rosette carousel containing 12 10L Niskin bottles. The SBE 9+ underwater unit is depth rated to 6,800 meters and possesses a dual conductivity and temperature sensor pair. This system has four ports available for up to eight auxiliary sensors. Additional sensors installed on the CTD include: altimeter, Light Scattering (LSS), Dissolved Oxygen (DO), and Oxygen Reduction Potential (ORP).

A Lockheed Martin Sippican MK-21 XBT system with a portable hand-held launcher is used for obtaining sound speed, temperature, and salinity profiles while underway. 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 characterization data. Sound speed at the multibeam transducer face is also measured with a Reson SVP probe.

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

**Remotely Operated Vehicles (ROVs)**

OER’s dedicated, fully integrated, dual-body ROV system, the *Deep Discoverer* (*D2*) and *Seirios*, were first integrated in 2013, are capable of diving to 6,000 meters, and *D2* has a 200-pound (in air) scientific payload for additional sensors. *D2*’s primary data set is high-definition video collected by six HD cameras. In addition, *D2* carries a Sea Bird 9/11+ CTD with Light Scattering (LSS), Dissolved Oxygen (DO), and Oxygen Reduction Potential (ORP) sensors. *D2* has a unique lighting design with LED lights located on four swing arms that allow pilots to adjust the position and angle of the light for optimal imaging. In total, *D2* brings 144,000 lumens of light to the high-resolution ROV navigation using Doppler (DVL) bottom lock and PHINS inertial navigation.

*D2* is equipped with two manipulator arms: Shilling “Orion” and a seven-function Kraft Telerobotics Predator II manipulator arm. The Predator is considered one of the industry’s most capable and dexterous manipulators for specimen collecting, and is currently the only arm in
its class with force-feedback capability. The Predator is outfitted with custom-built coral cutter jaws with intermeshing fingers to grasp rocks, tools, and rigging, and they also have a set of scissor-like blades and urethane grippers that can snip and clamp a delicate branch of coral.

Frame extensions and sample storage volumes are located on the vehicle's lower frame, outboard of the main camera's field of view to ensure the ability to capture top-quality imagery. For normal piloting and imaging, the sample drawer is retracted aft and the storage boxes are stowed outboard. During sample collections, the entire sample storage platform is extended forward into the camera's view and within easy reach of the manipulators. D2 is currently equipped with four storage boxes: two containers for stowing geological specimens or sampler/sensor deployments/recoveries and two sealed and insulated containers for storing biological specimens (with dividers creating four compartments total).

The second body of the system is the camera platform Seirios, which provides additional lighting and an "aerial" view while D2 investigates the seafloor. Seirios carries one HD camera, a Sea Bird 9/11+ CTD with a dissolved oxygen sensor, and 108,000 lumens of light.

Limited sampling operations are conducted during Okeanos Explorer expeditions. 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 and biological sample collection. Limited biological specimens are collected in order to meet expedition goals, and are typically suspected new species or new records for the region, the dominant morphotype in a habitat, unusual morphologies, samples that support connectivity studies, or are otherwise determined appropriate by the Science Team Lead. 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.

**Telepresence**

The Okeanos Explorer is the leading platform for collaborative telepresence-enabled exploration, enabling a shore-based team of scientists and students to fully engage in an expedition.

With the help of the Global Foundation for Ocean Exploration (GFOE), 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 (Internet 2, shore-based servers), commodity Internet streaming, and web and
Telepresence: Sending Imagery from the Seafloor to Your Screen

As you sit at home or in your office watching the live video from NOAA Ship Ocean Explorer, you are seeing information between 0.5 and 30 seconds after it is captured by NOAA’s remotely operated vehicle (ROV) Deep Discoverer (D2). There is no surface light deep in the ocean, so D2 produces light in order for the cameras to illuminate the area around the ROV.

Before imagery recorded by D2 on the seafloor arrives on your screen, the content has been encoded, transformed, re-encoded, retransmitted, and decoded numerous times during a more than 50,000-mile journey from the seafloor to your eyes. Let’s follow, in simplified terms, the path of one photon of information produced by D2.

1 seconds

The camera on D2 captures a photon, a particle of visible light, recording its properties like wavelength and intensity, and then converts that information into an electrical current. That electrical current is then turned into a digital signal, which is transferred to photons. Using a laser, the information travels up the eight-kilometer cable that connects D2 to the Okeanos Explorer.

0.00003 seconds

Once the photon is released off the ship, the information it carries is converted back into an electrical signal that travels over copper cables around the ship until it reaches the video encoders. The encoders take the digital video signal contained in the electrical signal and convert that information into a type of digital information known as IP (Internet Protocol)-based video.

0.5 seconds

The encoder sends the new IP-based video out on Ethernet cables to the satellite modem where the digital signal is encoded on a radio wave. The radio waves are then amplified several times and transmitted to a geosynchronous satellite that is about 22,000 miles above the Earth’s surface.

2.5 - 5 seconds

After the satellite receives the signal and then retransmits it back to Earth, there is another modem in Maine that receives the radio signals from the satellite. The receive modem takes the information contained in the radio waves and converts it back to an electrical signal.

3 seconds

The information travels from Maine to the Inner Space Center (ISC) in Rhode Island over a dedicated connection. Once it reaches the ISC, the traffic is handed off to Internet2, which is a special high-bandwidth Internet that is run and maintained by universities across the country. In addition to using Internet2, scientists with specialized access can view the videos with minimal latency through the commodity internet as well.

4 seconds

After the electrical signal leaves the teleport, the information flows from Maine to the Inner Space Center’s (ISC) Inner Space Center (ISC) High Bandwidth 1 Internet2 connection. Once it reaches the ISC, it is then transmitted to the University of Rhode Island through another link to the Inner Space Center, which is a special high-bandwidth Internet that is run and maintained by universities across the country. In addition to using Internet2, scientists with specialized access can view the videos with minimal latency through the commodity internet as well.

20 - 30 seconds

For those without Internet2 access, there are a few more steps before you get to see the video. The Inner Space Center at the University of Rhode Island takes the video off Internet2 and rebroadcasts it for a different type of IP-based video that will work on the standard Internet. This signal is then sent to YouTube.

When you open your web browser and hit play on the video window, your computer sends a request to YouTube for that person to send a copy of the video to your computer. Once your computer receives the signal from YouTube, it converts the signal into photons that travel from your screen into your eye.

After more than 50,000 miles of travel in less than 30 seconds, the information from the bottom of the seafloor has been converted from photon to electron, back to photon, to an electron, then to a radio wave, then back to an electron when it reaches your computer. Finally, your computer uses the “information” that was encoded on all these different signals to create one last photon that represents one pixel of your screen that is transmitted to your eye. This photon is the same wavelength and a similar relative intensity as the original photon that was captured 30 seconds ago (2.5 seconds on Internet2) in the middle of nowhere on the bottom of the ocean.

Social media interfaces. OER provides the expert staff to develop, maintain, and operate these systems, including shore-based systems at Exploration Command Centers (ECCs) and the University of Rhode Island’s Inner Space Center and the terrestrial and satellite links.

The Okeanos Explorer model uses telepresence to engage a theoretically unlimited number of scientists and managers on shore in real-time, minute-to-minute, collaborative decision making during mapping, CTD, and ROV operations. These participating scientists can join from anywhere with an Internet connection. Simultaneously, tens of thousands of public viewers can tune in online to watch and listen to the ongoing exploration.

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