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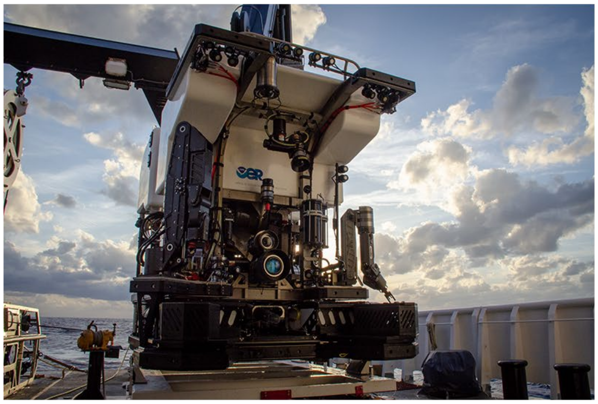
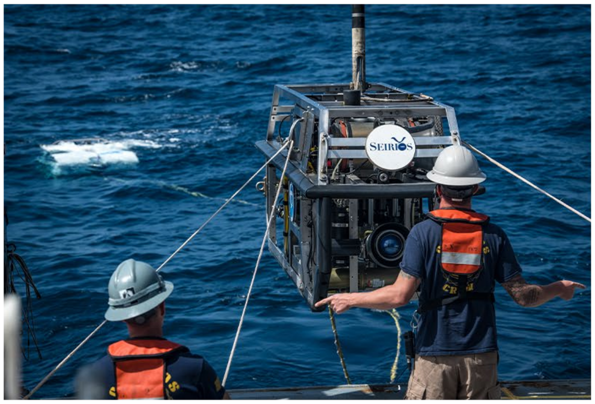
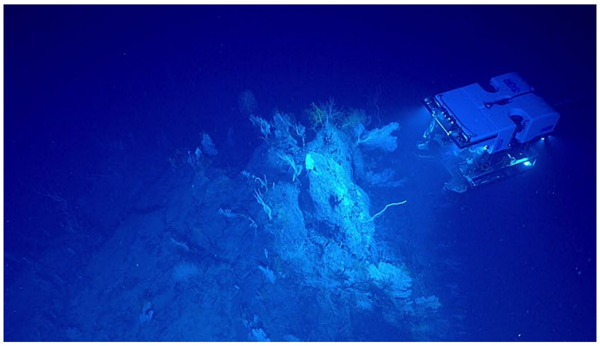
NOAA Ocean Exploration ROV and Telepresence Deepwater Exploration Procedures Manual







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This manual is based on NOAA Ocean Exploration's 2023 field season on NOAA Ship *Okeanos Explorer*. It will be updated over time as operations evolve. The most recent version is available at https://oceanexplorer.noaa.gov/data/publications/welcome.html.

Subsequent versions are expected to be developed as operations evolve. The current version is V.1 (2024).

For questions associated with this manual and the processes and reports noted herein, contact ex.expeditioncoordinator@noaa.gov.

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1. Introduction

NOAA Ocean Exploration is dedicated to exploring the unknown ocean, unlocking its potential through scientific discovery, technological advancements, and data delivery. By working closely with partners across public, private, and academic sectors, we are filling gaps in our basic understanding of the marine environment. This allows us, collectively, to protect ocean health, sustainably manage our marine resources, accelerate our national economy, better understand our changing environment, and enhance appreciation of the importance of the ocean in our everyday lives.

With priority placed on exploration of deep waters and the waters of the U.S. Exclusive Economic Zone, NOAA Ocean Exploration applies the latest tools and technologies to explore previously unknown areas of the ocean, making discoveries of scientific, economic, and cultural value. By making collected data publicly available in increasingly innovative and accessible ways, we provide a unique and centralized national resource of critical ocean information. And, through live exploration video, online resources, training and educational opportunities, and public events, we share the excitement of ocean exploration with people around the world and inspire and engage the next generation of ocean scientists, engineers, and leaders.

1.1 Purpose

NOAA Ocean Exploration produced this manual to describe its principles and procedures for ship-based remotely operated vehicle (ROV) and telepresence deepwater exploration (ROV expeditions). This manual is intended to:

- Improve transparency for ocean exploration stakeholders regarding NOAA Ocean Exploration's operations.
- Consolidate dispersed information into one document for ease of use and reference.
- Serve as a resource for other members of the ocean science and resource management communities who want to use ROVs to collect and share data that meet NOAA and national standards for public use.

For the purposes of this manual, deep water is defined as areas deeper than 200 m. It's at these depths, which represent the vast majority of Earth's ocean, where the equipment described herein is optimized, and where NOAA Ocean Exploration focuses its science, technology, and data collection activities. Nevertheless, these principles and procedures are applicable to exploration in all water depths.

This manual describes:

- Principles of ROV and Telepresence Deepwater Exploration
- ROV Expedition Planning
- ROV Expedition Staffing
- ROV and Related Equipment
- ROV Exploration
- ROV Expedition Data and Products
- ROV Expedition Data Management

Procedures, equipment, and data and product types have changed over the years as NOAA Ocean Exploration activities matured and evolved. This manual is based on operations in 2023, which were developed and refined by NOAA Ocean Exploration and partners while exploring on NOAA Ship *Okeanos Explorer*. Core partners critical to the development and maturation of these principles and procedures include NOAA's Office of Marine and Aviation Operations (OMAO), the University of Rhode Island's Inner Space Center, NOAA's National Centers for Environmental Information (NCEI), and the Global Foundation for Ocean Exploration (GFOE). This manual represents a snapshot in time, capturing current best practices and contributors, which are expected to evolve as partnerships and operational needs change. The procedures herein were designed to ensure the success of ROV operations on *Okeanos Explorer* and other ships, regardless of participating entities.

1.2. Exploration on NOAA Ship *Okeanos Explorer*

NOAA Ocean Exploration conducts ROV expeditions on *Okeanos Explorer* in unknown and poorly understood areas of the ocean identified as high priority by the ocean science and resource management communities. The purpose of these expeditions is to collect data that provide a multidisciplinary "first look" or initial assessment of an area's physical, chemical, biological, and maritime heritage features. These expeditions are not driven by the goals of any individual principal investigator or chief scientist. They support broader scientific and resource management issues and generate new questions and hypotheses to stimulate follow-on characterization activities. In addition, they are used to generate interest among the public in ocean exploration and the ocean sciences more broadly.

Primary operations during an ROV expedition include mapping of the seafloor, sub-bottom, and water column; *in-situ* ROV exploration; and the collection of samples and sensor-based data that provide baseline information about an area. Equipment used for these operations include four different types of mapping sonars that collect high-resolution data about the seafloor, sub-bottom, and water column (Hoy et al. 2020); a dual-body ROV system capable of diving to depths of 6,000 m; and various ancillary oceanographic sensors and systems.

A 24-hour-day operational tempo maximizes efficiency and data collection while at sea. Once the ROVs are recovered after a dive, operations switch to overnight mapping to fill bathymetric data gaps and collect higher resolution bathymetry in areas where existing bathymetric data quality is low.

2. Principles of ROV and Telepresence Deepwater Exploration

Based on its experience of more than a decade of ocean exploration on *Okeanos Explorer*, NOAA Ocean Exploration developed a unique model of community-driven exploration that serves broad community interests and addresses data gaps while being responsive to specific community, agency, administration, and global priorities and drivers. This "Explorer Model" brings together the ocean science and resource management communities to collaboratively plan expeditions and explore areas of the deep ocean where data are scarce (Cantwell et al. 2020).

The principles of the Explorer Model, which complement the exploration mapping principles described in the *NOAA OER Deepwater Exploration Mapping Procedures Manual* (Hoy et al. 2020), are:

- **Explore to meet community and national priorities:** Robust community engagement informs operating areas, data collection needs, and thematic priorities. High-quality, multidisciplinary data are collected that have diverse applications, meet stakeholder needs, and support national and NOAA priorities to understand the largely unknown ocean.
- **Take a scalable, systematic approach to exploration:** Operations include thematic and geospatial exploration of all characteristic ecosystems within a region and maximize site comparisons within and across regions. This approach begins with mapping operations in areas with no or low-quality multibeam bathymetry. These data are then used to inform strategic ROV operations to gather data about deep-ocean ecosystems and resources.
- **Share discoveries in real time:** Telepresence is used to collaborate and share data and products with scientists and resource managers around the world in real time during deep-ocean exploration as well as to inspire the public and the next generation of ocean explorers.
- **Embrace findable, accessible, interoperable, and reusable (FAIR) data principles:** Data are open access and archived in an open architecture framework with robust metadata records to ensure they are reported, archived, and easily discoverable. Quality-assured/

quality-controlled data, derived products, and robust metadata records are stored in open access formats and submitted to the NOAA archives within 120 days of an expedition.

- **Catalyze further exploration and generate hypotheses:** Expeditions result in discoveries and questions and transition data into knowledge rather than substantiate research or test hypotheses.
- **Demonstrate a commitment to diversity and cultivate an inclusive and respectful work environment:** Commitment to diversity, equity, inclusion, and accessibility is evident and demonstrated by investments in and the equal valuing of diversity of thought, background, and lived experience throughout exploration activities. Workplaces — both shipboard and shoreside — are respectful and safe (physically and psychologically).

Through telepresence-enabled exploration, NOAA Ocean Exploration can engage a theoretically unlimited number of shoreside scientists and managers in real time and support collaborative decision-making during an expedition. Scientists can join from anywhere with an internet connection, and members of the public can also access the livestream. In "The Explorer Model — Lessons from 10 Years of Community-led Ocean Exploration and Open Data," the authors provide additional information about how telepresence enables the Explorer Model and how telepresence and this model of operations can be used by other members of the ocean science and resource management communities.

3. ROV Expedition Planning

Leveraging the full capabilities of an ROV expedition requires effective planning and execution to optimize the return on investment. This section describes how NOAA Ocean Exploration works with a variety of partners and stakeholders (e.g., federal agencies, resource managers, local communities, indigenous communities, academic institutions, industry, and philanthropic organizations) to plan everything from campaigns down to individual dives. It also describes how NOAA Ocean Exploration complies with environmental and historical regulations and international requirements and responsibilities, which is a critical part of the planning process.

3.1 Community Engagement

NOAA Ocean Exploration's Explorer Model is based on continuous engagement with partners and stakeholders throughout the life cycle of an exploration activity (see **Figure 1**). These entities bring a diversity of expertise, perspectives, and needs to NOAA Ocean Exploration's planning (ensuring that expeditions on *Okeanos Explorer* are multidisciplinary in nature) and help secure buy-in from their respective communities. More specifically, they help develop exploration priorities, plan and execute expeditions to meet these priorities, collect the highest-value data, create value-added products (e.g., scientific papers and presentations, story maps), and use data collected to drive decisions and expand our understanding of the global ocean.

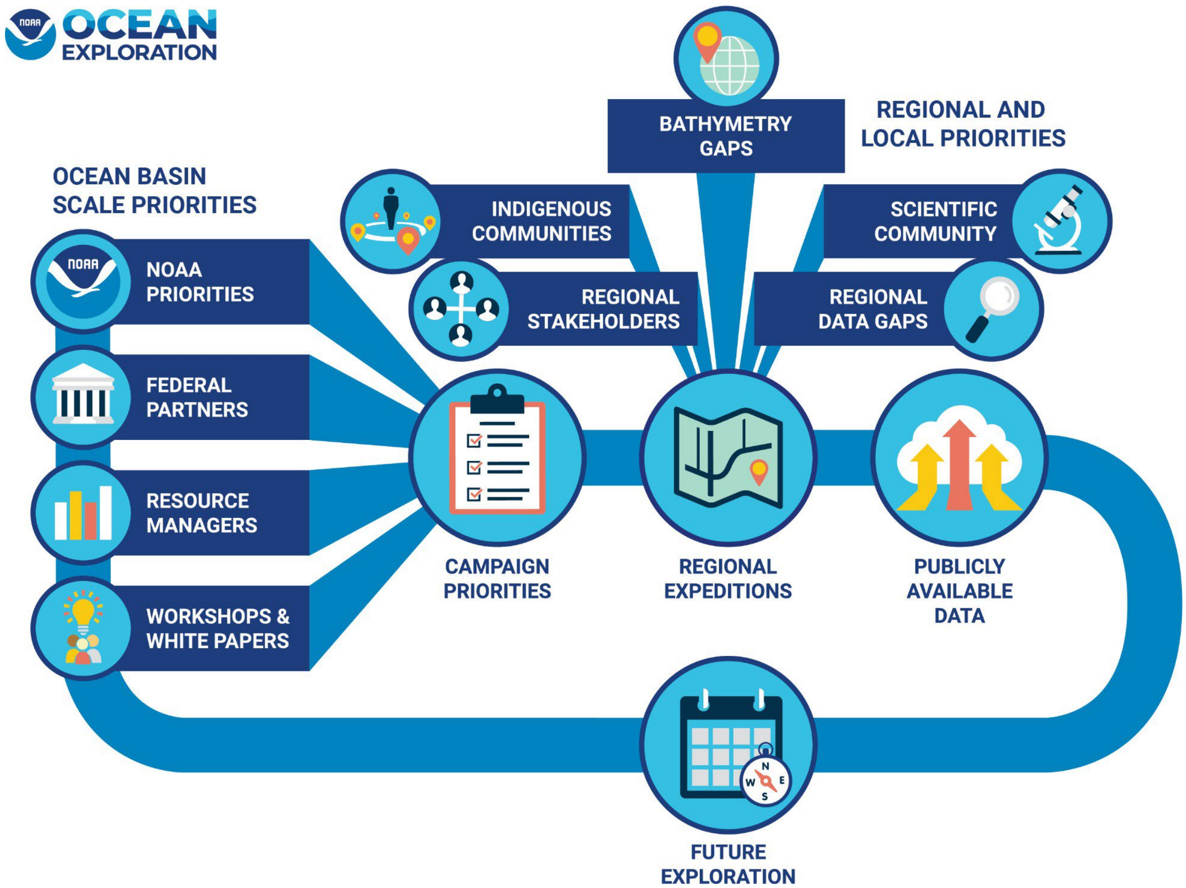

Figure 1. Schematic of how input is solicited from a wide variety of entities throughout the course of the expedition planning process (figure adapted from Cantwell et al. 2020).

3.2 Nested Planning Approach

NOAA Ocean Exploration uses a nested approach to expedition planning. This entails packaging individual weeks-long expeditions into a series of expeditions — and sometimes multiyear campaigns — where exploration priorities, partners and stakeholders, and geographic operating areas overlap. This systematic approach aligns expeditions to address large data gaps and leverage resources from one expedition to another (Cantwell et al. 2020). The terms associated with this approach are illustrated in **Figure 2** and defined as follows:

- **Campaign:** A "campaign" comprises multiple expeditions typically focused on a defined geographic region and is designed to bring about a particular result(s) and contribute to the broader understanding of the deep ocean. A typical campaign includes multiple partners and platforms, each with contributions that advance unifying themes or objectives in a specific region. Not all expeditions fall under a campaign.

- **Series of expeditions:** A “series of expeditions” refers to the fieldwork in a distinct region with similar unifying objectives and partners and stakeholders as a campaign but with a shorter time span and smaller geographic footprint.
- **Expedition**: An “expedition” is a single journey or excursion undertaken for a specific purpose. An expedition is platform and technology agnostic and may or may not be part of a larger campaign.

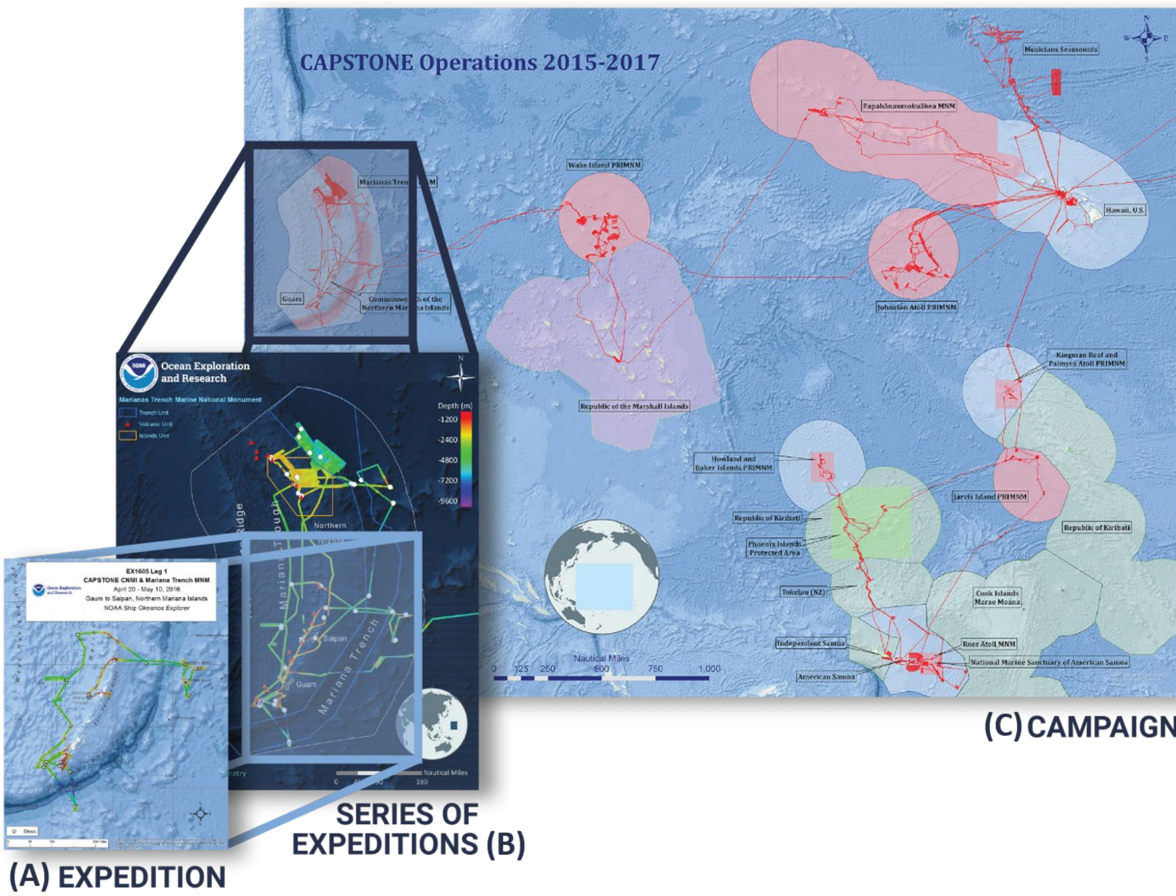

Figure 2. Schematic differentiating NOAA Ocean Exploration’s exploration levels of operation: Here, a single expedition (A) is shown in the context of the series of expeditions in the Mariana Islands in 2016 (B) and the overarching 2015-2017 Campaign to Address Pacific Science, Technology, and Ocean NEeds (C).

This approach relies on ocean science and resource management communities to help identify priorities and interests in the planned operating area(s) at each level of planning. It also provides multiple points of entry for these partners (i.e., they can contribute to a single expedition or a full campaign).

3.2.1 Campaign Development

NOAA Ocean Exploration campaigns are regionally focused and determined years in advance based on priorities and interests of domestic (e.g., the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone and the United States Bathymetry Gap Analysis) and international (e.g., Seabed 2030 and the Atlantic Ocean Research Alliance) policies and initiatives, as well as those raised at community workshops, listening sessions, and town halls and in scientific papers and discussions with partners, and general resource management needs and gaps in data coverage (Cantwell et al. 2020; see **Figure 1**).

Once a region is identified, the first step in the campaign planning process is a more thorough review of recent, relevant publications and workshop reports to establish a baseline of needs and potential partners. The next step entails engaging partners and regional stakeholders (e.g., Indigenous communities and resource managers) and working with them to:

- Identify other potential networks, partners, and stakeholders.
- Identify relevant exploration drivers (e.g., national strategies, executive orders, federal laws, NOAA strategies, international treaties, management issues, and regional data needs).
- Determine exploration priorities and focus areas based on these drivers.
- Establish campaign themes and objectives.

If there are no existing networks in the region or recent efforts to reference, NOAA Ocean Exploration may convene an introductory workshop (e.g., 2018 ASPIRE Workshop, 2020 Workshop to Identify National Ocean Exploration Priorities in the Pacific). Outputs from these workshops are used to identify targets, guide exploration, and develop ship schedules in the regions of interest.

3.2.1.1 Refinement of Campaign Operating Areas

Once campaign themes and objectives are established, NOAA Ocean Exploration issues a call for input to the broader ocean science and resource management communities.[1] A call for input typically includes several operating areas and is issued several months to over a year in advance of a campaign's first anticipated expedition. These requests invite individuals to recommend specific mapping and exploration targets that align with a campaign's objectives for NOAA Ocean Exploration to consider while planning individual expeditions.

[1] Call for input examples: Beyond the Blue: Illuminating the Pacific Campaign; 2024 Hawai'i and Johnston Atoll Exploration.

Each call for input is broadly distributed via an email list, posted on the NOAA Ocean Exploration website, and shared through NOAA Ocean Exploration's social media channels. A fact sheet is also produced to aid further distribution.

NOAA Ocean Exploration uses a cloud-based, geospatial planning tool, to collect input and engage as large a group of potential partners and stakeholders as possible in this process. Any scientist or resource manager can recommend areas to be mapped and ROV dive and CTD (conductivity, temperature, and depth) targets.

Recommendations may also be submitted directly to NOAA Ocean Exploration's Operations Team. Or, in the case of sensitive maritime heritage targets with restricted location information, recommendations may be submitted through the NOAA Ocean Exploration marine archaeologist. Unless expressly permitted by a submitter, only the NOAA Ocean Exploration Operations Team can access information about recommended maritime heritage targets.

3.2.2 Expedition Development

Approximately six months before an expedition, NOAA Ocean Exploration begins developing the expedition plan. Any interested scientist, student, or manager with relevant expertise is invited to join the expedition Science Team to participate in the expedition and expedition planning.

Expedition planning includes:

- Gathering and reviewing relevant input (e.g., white papers, workshop reports, responses to the call for input, direct input from scientists and resource managers) and existing regional mapping and exploration data and information (e.g., bathymetry, locations of past dives, expedition reports).
- Consulting with regional stakeholders in the region to better understand their priorities, interests, and general data needs.

NOAA Ocean Exploration uses this information to define the final operating area, initiate environmental and historical compliance processes, and establish mapping, ROV, and CTD priorities and objectives. For campaigns and series of expeditions, NOAA Ocean Exploration determines how to distribute priorities among the individual expeditions. Where possible, expeditions are planned to complement other research and ocean characterization projects in a region to maximize resources and avoid duplication of effort.

The Windows to the Deep 2019 story map illustrates this process with interactive maps that provide additional detail. Additional information about this process is in **Figure 3**.

Figure 3. Schematic of workflow for determining ROV dive exploration targets.

3.2.2.1 Refinement of Expedition Targets

Once an expedition's priorities and objectives are set, NOAA Ocean Exploration further refines and prioritizes proposed mapping and exploration targets. During this exercise, these targets (e.g., seafloor morphology or features, specific water column depth ranges, potential maritime heritage sites) are evaluated in the context of existing multibeam bathymetric data and other relevant geospatial information and past deep submergence vehicle dives (i.e., *in-situ* exploration)[2] to determine where new data may help close gaps in the general understanding of an area or ocean phenomena.

If more mapping and exploration targets are proposed than can be addressed during an expedition, they are prioritized for incorporation into the final expedition plan based on further evaluation. This process is designed to select targets that meet as diverse a set of exploration, science, and resource management objectives as possible (rarely are targets selected to meet the need of a single partner or stakeholder). Prioritization is based on exploration value and impact, logistical and operational considerations, and the degree to which the target addresses identified needs (see **Figure 3**) and also considers targets that may capture public interest (e.g., potential biodiversity hotspots such as seamounts).

NOAA Ocean Exploration retains a knowledge base of targets that are not incorporated into an expedition plan on file to inform other investments and partner opportunities.

3.3 Collaborative Dive Planning

Once exploration targets are set, ROV dive planning begins. This iterative process is designed to maximize the number of ROV dives for an expedition. It begins before an expedition starts and continues through a dive's completion in collaboration with an expedition's Science Team, both shipboard and shoreside.

Before each expedition, NOAA Ocean Exploration hosts an introductory call to provide the Science Team with an overview of the expedition plan, including operating areas and science objectives. This webinar is followed by a dive planning call. During this call, the Science Team is invited to provide fine-scale input on dive locations in the previously identified targeted areas (e.g., a specific seamount in a group, a specific depth range, a local topographic feature), including water column and maritime heritage dives when applicable, and to help draft preliminary dive tracks. Individual dive sites are selected and planned based on existing seafloor

[2] Given NOAA Ocean Exploration's focus on exploring new and poorly understood areas, ROV dives rarely revisit sites previously explored with a deep submergence vehicle. However, an exception may be made when a major event — such as an undersea eruption — may have significantly altered the seafloor habitat since the last visit or when a previous visit did not collect sufficient baseline data. An exception may also be made to address a national priority.

data (e.g., bathymetry, backscatter, and slope) and/or water column data and the locations of previous dives and known or suspected maritime heritage sites.

During an expedition, daily science meetings are held to update shoreside Science Team members about dive operations and discuss contingencies if needed. In addition to these meetings, round-the-clock email communications, online collaboration tools, and the distribution of products (e.g., dive plans, dive summaries, daily sampling summaries, and daily mapping products) ensure that the shoreside Science Team members are kept informed about ongoing and upcoming operations.

3.4 Environmental and Historical Compliance

Expeditions on U.S. government ships are required to comply with U.S. federal and state environmental laws, regulations, and policies and international agreements. Completing required analyses and obtaining permission from multiple levels of environmental managers are critical parts of the expedition planning process, and NOAA Ocean Exploration compliance staff typically begin this process at least eight months to a year prior to an expedition start date for expeditions in domestic waters. A similar advance timeline is followed to develop marine scientific research clearance requests for expeditions operating within another nation's exclusive economic zone, and these must be officially submitted no later than six months in advance of the expedition start date.

This section summarizes the primary federal environmental laws and regulations and international agreements that may apply to expeditions on *Okeanos Explorer* and what is required to be legally compliant.

Additional expedition-specific permits or permissions may also be required to conduct operations in other managed areas (e.g., marine protected areas, U.S. state-managed waters, other types of managed waters and sites) and to collect samples.

Records of compliance (e.g., permits, letters, licenses) are typically included as appendices or supplemental documents to project instructions and/or expedition reports and are also available upon request.

3.4.1 National Environmental Policy Act

Record of compliance: Analysis documentation of National Environmental Policy Act, categorical exclusion

The National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 *et seq.*) requires federal agencies to assess the environmental effects of actions they propose to fund, authorize, and/or conduct. The companion manual for NOAA Administrative Order 216-6A: Compliance with the

National Environmental Policy Act, et al. describes NOAA's specific procedures for NEPA compliance and helps users determine the appropriate level of NEPA analysis required (i.e., categorical exclusion (CE), environmental assessment (EA), or environmental impact statement (EIS)).

NOAA Ocean Exploration's detailed environmental analyses through January 2025 for expeditions on *Okeanos Explore*r determined that a categorical exclusion was the appropriate level of NEPA analysis, as no significant effects on the human environment were anticipated. Therefore, neither an environmental assessment nor an environmental impact statement were needed.

3.4.2 Endangered Species Act

Record of compliance: Section 7 concurrence letter

Section 7(a)(2) of the Endangered Species Act (ESA; 16 U.S.C. 1531 *et seq.*) requires federal agencies to ensure that any action they propose to fund, authorize, and/or conduct is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat. To ensure ESA compliance for its scientific research and oceanographic expeditions, NOAA Ocean Exploration consulted with NOAA Fisheries' Office of Protected Resources to evaluate whether expedition activities on *Okeanos Explorer* might affect an ESA-listed marine species or designated critical habitat and was issued a programmatic letter of concurrence on March 14, 2022 (NMFS No: OPR-2021-03453). If an expedition on *Okeanos Explorer* wishes to conduct activities, technologies, capabilities, species, or locations not covered under the programmatic letter of concurrence or addressed in the annual reporting/amendment process, they may be required to engage in additional consultations or reinitiation.

3.4.3 Essential Fish Habitat

Record of compliance: Consultation letter(s)

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 *et seq.*) requires federal agencies to conduct essential fish habitat (EFH) consultations when operations in an area will affect essential fish habitat. NOAA Ocean Exploration conducts regional EFH consultations that include evaluation of impacts on site-specific habitat area of particular concern (HAPC) with relevant NOAA Fisheries' regional offices to determine whether expeditions on *Okeanos Explorer* have the potential to adversely affect EFH or HAPCs within a given operating area. NOAA Ocean Exploration employs best management practices during all its expeditions on *Okeanos Explorer* to ensure they do not adversely affect EFH or HAPCs.

3.4.4 Marine Mammal Protection Act

Record of compliance: Completed analyses

The Marine Mammal Protection Act (MMPA; 16 U.S.C. 1361 *et seq.*) prohibits the taking and importation of marine mammals and marine mammal products, where "take" means to harass, feed, hunt, capture, or kill any marine mammal, or to attempt to do so. NOAA Ocean Exploration analyzes the potential impacts to marine mammals as a result of oceanographic research and seafloor mapping activities on *Okeanos Explorer* as they pertain to the MMPA. As of January 2025, NOAA Ocean Exploration determined that with continued implementation of office best management practices, operations are unlikely to meet the definition of harassment under sections 101(a)(5)(A) and (D) of the MMPA.

3.4.5 Marine Scientific Research Clearance for Foreign Waters

Record of compliance: Official authorization letter(s)

The Law of the Sea Convention establishes that a coastal state (i.e., country) has the right to regulate and authorize marine scientific research in its territorial sea and exclusive economic zone and on its continental shelf. Thus, consent of a coastal state is required before any marine scientific research can be conducted in its waters.

The Law of the Sea Convention further provides that "appropriate official channels" be used to obtain consent for marine scientific research. NOAA Ocean Exploration works with the U.S. Department of State through the Research Application Tracking System to seek advanced consent from relevant coastal state(s) for marine scientific research planned in foreign exclusive economic zones. If additional permits are required (e.g., to conduct activities in a foreign marine protected area), they also must be obtained prior to commencing operations in that area.

3.4.6 Convention on International Trade in Endangered Species of Wild Fauna and Flora

Records of compliance: Permits, certificates, exemption documents, licenses

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was designed to ensure that the international trade of animals and plants does not threaten their survival in the wild. A permit or certificate allowing collection of CITES-listed species must be issued by a coastal state in whose waters the species may be collected. CITES species that may be collected by U.S. scientists from the high seas require permission from the U.S. Fish and Wildlife Service (USFWS). Additional permits or certificates are also required when importing and exporting CITES-listed species between U.S. waters, the waters of other countries, and the high seas, and when offloading them at a port other than a designated wildlife port.

Records of compliance for CITES collections are included in the final project instructions for an expedition on *Okeanos Explorer*. Biological samples collected during an expedition are curated and archived by the Smithsonian National Museum of Natural History unless specifically requested by the coastal state (for samples collected in international waters). If requested by the coastal state, a duplicate sample may be collected and delivered to that state's repository of choice.

3.4.7 U.S. Fish & Wildlife Service Title 50 Wildlife Declarations

Record of compliance: Declarations, exemption permits

Title 50 Chapter 1 Subchapter B Part 14 Importation, Exportation, and Transportation of Wildlife requires entities to declare wildlife (including their parts and products) before importing them into or exporting them from the United States.

NOAA Ocean Exploration declares biological samples collected during expeditions on *Okeanos Explorer* to the USFWS in accordance with the uniform rules and procedures each time the ship crosses out of or into U.S. waters (i.e., each time we cross exclusive economic zone boundaries) and each time the ship enters and exits a port with samples aboard.

These declarations are made via the USFWS Office of Law Enforcement's Electronic Declarations (eDecs) website and are separate from any other permit issued by the USFWS. Ships are required to pull in to designated ports so USFWS agents can physically board and inspect wildlife. If *Okeanos Explorer* is not pulling in to a designated port, NOAA Ocean Exploration obtains a designated port exemption permit in advance of the port call.

3.4.8 Compliance for Maritime Heritage Sites

Record of compliance: Permit

NOAA Ocean Exploration adheres to a number of laws, regulations, and executive orders that apply to the archaeological activities of federal agencies as well as those that are federally financed, licensed, or permitted.

NOAA Ocean Exploration's maritime heritage activities support the initial phases of exploration, discovery, and site characterization of maritime heritage sites — referring to historic or ancient traces of human existence that are fully or partially underwater — often through multidisciplinary investigations. Information about maritime heritage sites obtained from projects on *Okeanos Explorer* are used to identify the resources; determine origin where possible; evaluate sites for their archaeological or historical significance according to U.S. National Register of Historic Places eligibility criteria; work with federal, state and foreign governments to determine whether such sites merit protection under pertinent state, national or international legislation, treaties, or executive orders; or identify whether additional information is required to make such determinations.

Maritime heritage operations on *Okeanos Explorer* are predominantly nondisturbance activities and include geophysical surveys using hull-mounted sensors and site documentation using ROVs *Deep Discoverer* and *Seirios* (and on rare occasions, autonomous underwater vehicles) that do not include physical contact, sampling, site excavation, or artifact collection. NOAA Ocean Exploration adheres to the research standards and management practices directed by the National Historic Preservation Act of 1966 (NHPA, 54 U.S.C. 300101 *et seq*.). In addition, we follow the guidelines in the Rules Concerning Activities Directed at Underwater Cultural Heritage, an annex to the United Nations Educational, Scientific and Cultural Organization's (UNESCO's) Convention on the Protection of the Underwater Cultural Heritage.

While exploration activities on *Okeanos Explorer* have no potential to directly cause impacts to maritime heritage resources, project data and information may contain site location information that could lead to adverse impacts. The primary concern with maritime heritage sites is the potential harm that may be inflicted on them if their locations are revealed. NOAA Ocean Exploration consults with the appropriate maritime heritage and site jurisdiction managers in advance, during, and after *Okeanos Explorer* expeditions to determine whether maritime heritage site information (e.g., the location and character of resources) needs to be protected as directed by NOAA Ocean Exploration's *Restricted Data Management SOP for Underwater Cultural Heritage* . If information should remain restricted, established procedures are in place to protect sensitive information during all phases of expedition planning, execution, reporting and archiving. These established procedures balance the need to protect both the safety of maritime heritage resources and the safety of the ship and expedition team (i.e., the automatic identification system is not turned off during operations).

In U.S. state waters, NOAA Ocean Exploration's maritime heritage activities may also require and be subject to research permits issued by the relevant U.S. State Historic Preservation Office. When operating in foreign waters, permission to conduct planned maritime heritage activities are obtained from the relevant cultural and historic preservation office in advance and initiated through the Marine Scientific Clearance process (section 3.4.5).

4. ROV Expedition Staffing

NOAA Ocean Exploration has defined its positions/teams and associated roles and responsibilities for its expeditions and series of expeditions on *Okeanos Explorer*. Responsibilities and locations (shipboard vs. shoreside) are subject to change as needed (e.g., based on the size and complexity of an expedition), and improvements in telepresence technology enable the inclusion of additional team members via increased shoreside operations. **Appendix B** summarizes the roles, responsibilities, and locations of positions/teams as of the 2023 field season.

In some respects, these positions/teams are different from traditional research expeditions. At NOAA Ocean Exploration, expedition managers and coordinators act on behalf of engaged communities, fulfilling the typical chief scientist role. They develop partnerships, engage stakeholders, identify priorities in an operating area, facilitate collaboration, and oversee data collection. Each ROV expedition on *Okeanos Explorer* also includes two science leads who represent, engage with, and coordinate the participation of a team of shoreside experts — from a variety of oceanographic science disciplines — in expedition planning and execution.

In addition to science operations, NOAA Ocean Exploration also dedicates staff members to outreach and education activities during an expedition. Historically, the skills needed for additional technical support were met by external partners, GFOE and the University of Rhode Island's Inner Space Center provide the shoreside technical support necessary for the telepresence operations on *Okeanos Explorer*.

Additional terms used in this manual to describe expedition-specific staff include:

- Mission Team: The Mission Team includes those individuals who contribute to exploration- vs. ship-specific objectives and are typically on board during an expedition.
- Science Team: The Science Team includes the Mission Team plus all individuals contributing to exploration objectives from shore via telepresence.

5. ROV and Related Equipment

One of the primary tools NOAA Ocean Exploration uses for ocean mapping and exploration is *Okeanos Explorer*, a 224-foot retrofitted U.S. Navy ocean surveillance ship (T-AGOS class) and America's only federal ship dedicated to ocean exploration. This section details the equipment and systems used by NOAA Ocean Exploration and partners during ROV expeditions on *Okeanos Explorer*.

5.1 ROVs

The ROV operations described here are specific to the needs and goals of NOAA Ocean Exploration. ROV configurations for other programs depend on those programs' needs.

NOAA Ocean Exploration's *Deep Discoverer* and *Seirios* (see **Figure 4**) operate together as a two-body system deployed from *Okeanos Explorer*. This system is capable of exploring depths up to 6,000 m and offers a variety of ocean surveying and sampling capabilities (Egan et al.

2021). The pair have completed over 475 dives together in the Pacific and Atlantic oceans, the Caribbean Sea, and the Gulf of Mexico.

Deep Discoverer (see **Figure 4A**) is used to collect video, samples, and other data. *Seirios* (see **Figure 4B**) serves primarily as a camera and light platform, providing additional lighting and an aerial view of *Deep Discoverer*'s seafloor investigations.

The neutrally buoyant *Deep Discoverer* is tethered to the negatively buoyant *Seirios* with a 33-meter-long electro-optical neutral buoyancy cable (1.73 cm diameter) (see **Figure 4C**). This configuration allows *Seirios* to absorb the heave from the ship, which keeps *Deep Discoverer* stable and allows for its precise maneuvering by the ROV pilots. During ROV operations, dynamic positioning is used to keep *Okeanos Explorer* stationary, and an ultra-short baseline tracking system (USBL) is used to track vehicle position relative to the ship.

Figure 4. (A) ROV *Deep Discoverer* with select sampling tools displayed and labeled. (B) ROV *Seirios*. (C) Schematic representation of the general relationship of *Deep Discoverer* and *Seirios* to the ship and of the telepresence technology as used by NOAA Ocean Exploration on *Okeanos Explorer*.

5.1.1 Imaging Equipment

There are 15 video cameras between the two ROVs, including 10-high-definition cameras. Forty-six LED lamps produce more than 355,400 lumens of light. Video is transmitted from the ROVs to the ship via the electro-optical umbilical cable.

5.1.1.1 *Deep Discoverer*

Deep Discoverer's main high-definition camera is an Insite Pacific Zeus Plus on a custom pan and tilt system. Paired lasers (10 cm apart) are mounted on this camera for *in-situ* size and scale determinations. Eight other high-definition cameras assist with situational awareness and manipulation tasks (data from these cameras are often not recorded or used for scientific operations). *Deep Discoverer*'s suite of cameras also includes a custom packaged Canon R3 still camera.

The unique lighting system on *Deep Discoverer* consists of 28 LED lamps. Eight are on swing arms, which allows pilots to adjust the position and angle of the light (e.g., to accommodate terrain and clarity conditions) for optimal imaging.

Deep Discoverer's main high-definition Zeus Plus camera is color corrected for each dive using a video waveform monitor and vectorscope and a custom chip chart designed in partnership with DSC Labs. This is typically done near the seafloor or when it's determined that the camera has reached its stable operating temperature, which depends on the depth and the surrounding temperature (Gregory et al. 2016). The procedures below are designed to ensure the colors are as true to life and unbiased as possible.

1. The chart is mounted on *Deep Discoverer*'s port-side manipulator arm and positioned as far forward as possible and square to the camera lens in an attempt to simulate a typical close up shot.
2. The lights are adjusted to obtain optimum and even lighting on the chart.
3. The iris is closed and the black balance adjustments are performed.
4. The iris is opened and the white balance adjustments (100%) are performed.
5. The gains, gammas, glares, and, if necessary, the various color matrices are adjusted to optimize the accuracy of color reproduction.

Typically, once the camera has been color corrected, only the focus, iris, and pedestal or master black level are adjusted to optimize video information. To ensure the colors are the same throughout a dive, the color balance controls are not modified unless something changes (e.g., the turbidity). During a water column only dive, color and white balancing is done when the vehicles reach the general operating depth and the camera has reached its stable operating temperature.

5.1.1.2 *Seirios*

Seirios is equipped with a high-definition Insite Pacific Zeus Plus camera, which is aimed forward and downward with an average 45° camera angle; five standard-definition video cameras, including a 180° tilt-rotate video camera; and LED lamps. These lamps augment *Deep Discoverer*'s more focused light pool, adding diffused light to the seafloor surrounding *Deep Discoverer* and illuminating the neutrally buoyant tether connecting the two vehicles for situational awareness.

5.1.2 Sampling Equipment

Deep Discoverer is equipped with the following to collect biological, geological, and water samples:

- Two hydraulic manipulator arms:
  - A seven-function Kraft Telerobotics Predator manipulator arm, which is primarily used to collect samples and features custom-built coral cutter jaws with intermeshing fingers to grasp rocks, tools, and rigging. The cutter jaws have a set of scissor-like blades and urethane grippers to snip and clamp delicate branches of coral and other fragile biota.
  - A seven-function Schilling Orion manipulator arm, which is used as a backup for sampling operations and carries the color card for white balancing and color correcting video.
- A rotary suction sampler to collect soft biological and small, unconsolidated geological material from the seafloor and water column.

Samples are stored aboard the ROV during a dive in the containers described in **Table 1**. Approximately 10 kg of payload is available for samples on *Deep Discoverer*.

Table 1. Sampling containers on *Deep Discoverer* that can be used during a dive.

Type of Sample Container	Number of Containers	Approximate Dimensions of Each Container	Primary Use
Biobox	4	48 x 40 x 33 cm	Biology
Rock Box	2	Portside: 51 x 48 x 20 cm Starboard: 48 x 40 x 20 cm	Geology
Rotary Suction Sampler Jars	5	2.7 liters	Biology/Geology

Type of Sample Container	Number of Containers	Approximate Dimensions of Each Container	Primary Use
Niskin Bottles	5	1.7 liters	Water

Additional information about sampling is in Section 6.5 and the [NOAA Ocean Exploration Sampling Procedures Manual](#).

5.1.3 Other ROV-Related Equipment

Deep Discoverer and *Seirios* are also equipped with navigation systems. *Deep Discoverer*'s high-resolution ROV navigation system uses a Teledyne RDI Workhorse Navigator 600 kHz Doppler velocity log (DVL) bottom lock, an iXblue Phins north-seeking fiber optic gyro compass, a quartz crystal pressure (depth) transducer, a TrackLink USBL acoustic tracking system, a Tritech PA500 altimeter, a Lord MicroStrain 3DM inertial motion unit (IMU), and a BlueView multibeam sonar. A high-resolution dual-frequency (900/2250 kHz) imaging sonar (Teledyne BlueView M900-2250-130-Mk2) is used for situational awareness beyond the field of view of *Deep Discoverer*'s video cameras and lights. For additional situational awareness, *Seirios* and *Deep Discoverer* are also equipped with a Tritech SeaKing scanning sonar.

Both vehicles are also equipped with sensors to measure exploration variables such as salinity, water temperature, depth, and dissolved oxygen, which provide additional information about the ocean to help characterize the areas explored. Sensors aboard *Deep Discoverer* include a Sea Bird Electronics SBE-911plus CTD system with dissolved oxygen and oxygen reduction potential sensors. High-temperature probes supplement ambient water conditions logged by the CTD to make targeted measurements of vents or brine flows. Sensors aboard *Seirios* include an SBE-911plus CTD system with a dissolved oxygen sensor. CTD sensors from both ROVs are calibrated annually.

On occasion, *Deep Discoverer* and/or *Seirios* may be equipped with additional sensors or other equipment to augment NOAA Ocean Exploration's existing capabilities and test emerging technologies.

5.2 Telepresence

NOAA Ocean Exploration's telepresence operations integrate specialized protocols for near real-time data (greater than 60-second delay) sharing and communication, high-speed satellite networks, internet-based collaboration tools, broadcast industry standard video/audio management, standards-based data management systems, terrestrial networks (Internet2, shoreside servers), commodity internet streaming, and web and social media interfaces. NOAA Ocean Exploration collaborates with GFOE and the Inner Space Center to develop, maintain, and operate these systems, including shoreside systems at exploration command centers. Current configurations allow for real-time engagement of shoreside Science Team members with a two-three second delay.

The telepresence system aboard *Okeanos Explorer* streamlines other data management tasks through a custom suite of software and standard operating procedures that automatically collect raw and some processed data from acquisition computers and move those data to a central server called the data warehouse, an enterprise-grade file storage system accessible to all computers on the GFOE-managed science network. Then, a subset of the data is automatically moved to a shoreside repository (for access by shoreside Science Team members) over the satellite connection as bandwidth is available.

As telepresence technology advances, NOAA Ocean Exploration is committed to incorporating enhanced capabilities into its operations to improve operational control from shore and enhance the science user experience.

More information about how telepresence enables the Explorer Model is in "The Explorer Model — Lessons from 10 Years of Community-led Ocean Exploration and Open Data."

5.2.1 Very Small Aperture Terminal (VSAT) Dish Antenna

Remote participation in operations aboard *Okeanos Explorer* is made possible through several technologies. The foundation for telepresence is satellite telecommunications technology. A 2.4 m very small aperture terminal (VSAT) dish antenna is the critical link between the ship and the geosynchronous satellites that relay information to shore, where scientists and the public are able to engage with an expedition. The VSAT antenna is enclosed in a large, climate-controlled radome to protect the equipment from the elements and sits atop the ship's main mast to minimize physical obstructions (**Figure 5**).

On the ship, computers, motors, and other hardware make constant adjustments that compensate for the ship's heave, roll, and pitch to keep the VSAT antenna pointed toward the appropriate communications satellite. Radio transmitters and receivers connected to the VSAT antenna operate on "C-band" frequencies.

Figure 5. The VSAT antenna (within the large dome) on the deck of *Okeanos Explorer*.

The VSAT antenna provides network connectivity speeds of up to 20 Mbps ship-to-shore and shore-to-ship. Its bandwidth enables real-time video streaming to shore, rapid data transfers, shipboard internet, and real-time communication with shoreside scientists.

During ROV operations, three simultaneous, high-definition video feeds are used to stream video to shore, typically with a total delay of fewer than three seconds. These streams use an encoder on the ship to convert high-definition serial digital interface (HD-SDI) video into a web-enabled h.264 transport stream for transmission to the Inner Space Center, where they are transcoded into a format readable by web browsers on computers and mobile devices.

As NOAA Ocean Exploration looks to the future, switching from geosynchronous communication satellites to the new low earth orbiting (LEO) constellation is expected to provide several major advantages. The first LEO advantage will be the reduction in latency. Normal latency for a geosynchronous based system ranges from 400-900 milliseconds. Latency for an LEO system is estimated to range from 30-90 milliseconds, reducing latency by an order of magnitude. Another advantage of LEO is a potential increase in bandwidth, which will likely improve from 15-20 Mbps to several hundred Mbps. These operational improvements will also come with a lower cost and reduced equipment-size requirements (a VSAT antenna larger than 2 m will not be necessary). In addition, improvements in bandwidth and latency will open the door for a host of other telepresence-related operational enhancements.

5.2.2. Live Video Feed Configuration

During ROV expeditions, each of the video feeds has a dedicated purpose:

- The primary video feed (Camera 1) typically comes from the main high-definition camera on *Deep Discoverer*. It provides up close investigation of individual organisms, geological features, and maritime heritage sites.
- The second video feed (Camera 2) typically comes from the high-definition camera on *Seirios*. It provides situational awareness and a landscape view of the surrounding area.
- The third video feed (Camera 3) changes depending on operations, the preference of the Science Team, and the objectives of a particular dive.
    - The feed typically shows computer screens in the control room, views from other cameras on the ROVs, and datastreams from navigation systems, sonars, and oceanographic sensors.
    - It may also show data from the ROV-mounted forward-facing sonar, video from cameras oriented toward the manipulator arms during sampling, and the pilot's control screen (a customizable and dynamic graphical user interface that provides a variety of information about ongoing operations).
    - During non-ROV hours, this feed typically shows mapping data acquisition screens and/or a replay of the ROV dive, though bandwidth for video feeds may be reduced to increase the ability to transmit data to shore.

5.3 Mapping Equipment

ROV expeditions also include standard mapping operations and rely on acoustic data to select dive sites that maximize discovery potential and safety. These data are collected during a previous mapping expedition or just before an ROV dive and provide information about the morphology, steepness, and relative hardness of the seafloor and water column anomalies.

Okeanos Explorer is equipped with several hull-mounted sonars designed for deep-ocean and water column exploration:

- A Kongsberg EM 304 MKII multibeam sonar (26 kHz) collects seabed bathymetry and backscatter data and water column backscatter data.
- A suite of five Simrad EK60/80 split-beam fisheries sonars (18, 38, 70, 120, and 200 kHz) supports further water column exploration.
- A Knudsen 3260 chirp sub-bottom profiler (3.5 kHz) collects sub-seafloor data.
- Two Teledyne acoustic Doppler current profilers (ADCPs) (38 and 300 kHz) reveal information about ocean currents (up to a depth of approximately 1,200 m).

During standard mapping operations, the multibeam, split-beam, and sub-bottom sonars are synchronized to collect concurrent water column, seafloor, and sub-seafloor data. The ADCPs remain off during standard operations due to issues of interference with the other sonars.

Mapping equipment may vary from one field season to the next due to technological advancements and/or operating status. Annual mapping readiness reports describe the specific setup for a field season. Mapping readiness and calibration reports are archived in the NOAA Institutional Repository. A detailed description of NOAA Ocean Exploration's principles, equipment, and procedures for deepwater ocean exploration acoustic mapping is in the *NOAA OER Deepwater Exploration Mapping Procedures Manual*.

5.4 CTD Systems and Sound Velocity Profiling

CTDs are used primarily to collect physical and chemical oceanographic data and water samples. CTD data are collected in three ways during ROV expeditions:

- Sensors on *Deep Discoverer* and *Seirios*.
- The ship's Seabird CTD rosette system.
- A ship-based handheld Castaway CTD (up to 100 m depth).

The CTD rosette system has 12 10-liter Niskin bottles and four ports for up to eight auxiliary sensors. Installed sensors measure altitude, light scattering, dissolved oxygen, and oxygen reduction potential. Typically, two suites of sensors are aboard during the field season, with one in use and one as a spare. At the end of the field season, used sensors are sent to their manufacturers for calibration. Upon their return, the original calibration documents are stored with the boxed sensors and electronic copies are stored on the ship's server and included in mapping data packages submitted to NCEI.

Lockheed Martin Sippican Deep Blue expendable bathythermograph (XBT) probes are used for regular sound velocity profiling down to approximately 1,000 m.

The onboard scientific seawater system provides a continuous flow of seawater through a remote temperature probe installed near the seawater intake and a thermosalinograph. This system provides temperature, conductivity, salinity, and sound velocity of the sea surface and is used as a backup sea surface sound speed source.

5.5 Scientific Computing System

The Scientific Computing System (SCS) software used on *Okeanos Explorer* was developed at NOAA Headquarters specifically for the NOAA fleet (OMAO 2023). The SCS is a data acquisition system designed for displaying, compiling, and transmitting select meteorological, oceanographic, and navigational data from the ship's integrated sensors. The collection of SCS data generally begins the day before the ship gets underway and ends after the ship reaches the pier. Once the SCS is shutdown, a compressed data package is created and submitted to NCEI.

The SCS data are collated by a software program that allows for integration of data from the ship's oceanographic, meteorological, and navigational sensors into systems on the science network, which is separately managed by GFOE. These data are then incorporated into automated data processing scripts to provide situational awareness for ROV pilots.

SCS data also feed into internet-based real-time data displays hosted by NCEI (e.g., the Okeanos Explorer Live Operations Map).

6. ROV Exploration

During expeditions on *Okeanos Explorer*, ROV dives are primarily conducted during the day (Kennedy et al. 2019), with a routine schedule that maximizes efficiency of operations. Dives are executed based on the collaborative planning conducted before and during an expedition and may be refined or changed based on at-sea conditions, new data, or unforeseen circumstances.

Once the ship arrives at the general dive site location, the EM 304 multibeam sonar and sub-bottom profiler are secured and the ADCPs are turned on to provide current information to guide safe deployment, operation, and recovery of the ROVs. EK60/80 split-beam sonars remain on throughout the duration of a dive.

Dives typically last eight hours, but length may be impacted by changing at-sea conditions or scientifically interesting discoveries or observations.

Benthic-focused dives make up the majority of the *in-situ* exploration during expeditions on *Okeanos Explorer*. However, recognizing the importance of the water column, NOAA Ocean Exploration frequently dedicates some of the available dive time to exploring the water column. Occasionally, dives on potential maritime heritage sites are also incorporated into expedition plans.

6.1 Benthic Exploration

Seafloor geomorphology plays a major role in dive site selection. NOAA Ocean Exploration conducts dives on a variety of geomorphological features and deep-ocean seafloor habitats (e.g., hydrothermal vents, deep-sea coral reefs, submarine canyons, seeps).

During a benthic dive:

- *Deep Discoverer* typically travels approximately 0.1-0.3 km.
- *Seirios* typically operates approximately 10-18 m above and behind *Deep Discoverer*.

- *Deep Discoverer's* altitude depends on the type of imaging being performed (e.g., capturing a close-up, determining habitat extent, obtaining an overarching view of a cultural or geological feature).
- *Deep Discoverer* is typically deployed at the base of a feature with an inclined plane and is then piloted up and along the feature.
- Transects are typically relatively linear.
- Repeat transects are not done unless they are required to meet exploration objectives for a site (e.g., shipwreck photogrammetry).
- *Deep Discoverer*'s high-resolution cameras are generally set on a wide-angle view to document habitat features, species occurrences, and behaviors.
- Detailed video of a feature or organism of high interest to a Science Team member is collected (to facilitate taxonomic identification in the case of an organism) while Science Team members discuss it.
- Sample collections are attempted when there is general consensus among the Science Team that collection is warranted (e.g., it's a potential new species, it supports species connectivity studies, it's of geological importance).

6.2 Water Column Exploration

NOAA Ocean Exploration dedicates time to exploring the water column as part of regular operations. This is done through acoustic and ROV exploration and happens during dedicated full-day water column dives as well as augmented benthic dives.

A typical dedicated water column dive is eight hours and consists of transects at standard depths in addition to variable transects.

- The standard depth transects are conducted at 300, 500, 700, and 900 m. These standard depths were chosen to maintain consistency among dive sites.
- Variable transects are based on site-specific acoustic and environmental features detected in the water column. The EK60/80 echosounders (set to 1.024 ms pulse length at max power) are used to detect the backscatter returns of benthic and water column acoustic scatterers and specifically the location of the deep scattering layer (DSL). Ideally, a minimum of one transect is conducted above, within, and below the DSL. Additional transects may be conducted based on the depth of the seafloor at a site and unique water column features observed in *Deep Discoverer*'s CTD data.

Transect length for both standard depth and variable transects is usually 10-30 minutes, but may be longer or shorter. Final transect length and depths are determined during the dive planning call for a site and are dependent on the dive location and time available.

During a typical water column dive, the first set of transects begins at 300 m during the descent. This is the depth of the shallowest standard depth transect. Subsequent transects are progressively deeper, increasing in 200 m increments, until the final standard depth transect is conducted at 900 m. After the 900m transect, the ROVs ascend to the depth of the shallowest variable transect for the next set of descending transects. **Figure 6** illustrates this process. Conducting transects during descent and on ascent after a benthic dive allows for comparison of observations and optimizes dive time.

During an individual transect, the ROVs move slowly and horizontally through the water column at a constant depth (±2 m from target depth) and against the current (e.g., in the direction of incoming particles). At the request of a Science Team member, they may be stopped to image or sample an organism of interest. To ensure the best imagery possible, the lighting on *Deep Discoverer* is set to give broad forward coverage, camera focus is set for the largest depth of field, and the camera lens is set at a wide angle, when possible (some transects may need to be conducted at partial zoom to reduce glare).

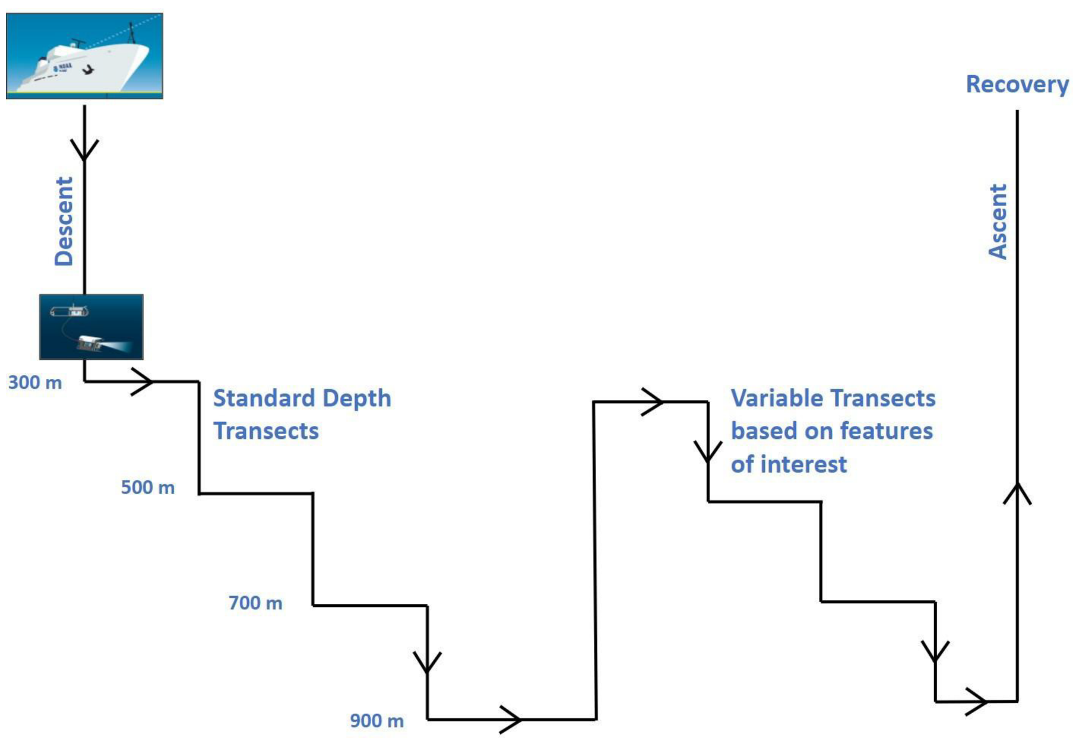

Figure 6. General schematic of a dedicated water column dive. All dive plans are subject to change based on targets of interest, logistical constraints, and weather conditions.

For water column exploration during an augmented benthic dive, transects are determined based on the methods previously described (standard depth transects are typically prioritized over variable transects) and begin immediately after the benthic portion of a dive as part of the ascent. After benthic exploration, *Deep Discoverer* ascends to the depth of the first (deepest) transect, and the water column exploration begins. Each subsequent transect is shallower than the one before it as the ROVs ascend toward the ship.

6.3 Maritime Heritage

NOAA Ocean Exploration works with the ocean science and resource management communities to locate, explore, and characterize maritime heritage sites and resources in U.S. waters and around the world (Hartmeyer et al. 2024).

During planning for an expedition in state waters, the NOAA Ocean Exploration expedition coordinator and marine archaeologist works with relevant state historic preservation officers or history/archaeology contact(s) at NOAA's Office of National Marine Sanctuaries to request information on maritime heritage sites in the planned operating area whose exploration may be of interest to the maritime heritage community — and to secure permits for exploration activities as required by law (see Section 3.4.7).

Exploration of maritime heritage sites and resources begins with visual reconnaissance of a site to identify operational hazards and determine the site's extent or boundaries, including any associated debris field. The ROVs are then used to conduct noninvasive observations, collecting environmental data and high-definition imagery of diagnostic artifacts, features, and marine organisms associated with the site. To avoid potential harm to the site, no physical samples of any kind are collected during maritime heritage dives.

Some maritime heritage data, including ROV or ancillary data containing sensitive location information, may not be available in real time. The NOAA Ocean Exploration marine archaeologist, expedition coordinator, and relevant project partners review maritime heritage data to ensure compliance with the National Historic Preservation Act and make data release determinations at the end of an expedition.

On occasion, NOAA Ocean Exploration or partners may want to create photogrammetric models of a site to serve as digital surrogates for researchers and also as teaching tools (Irion, Sorset, and Bowman 2018; Phipps, Hartmeyer, and Cantelas 2024). **Appendix C** describes the protocols used by NOAA Ocean Exploration for collecting ROV video footage for the purpose of photogrammetry.

Detailed information and associated documents related to maritime heritage exploration during expeditions on *Okeanos Explorer* are included in each expedition's project instructions, when applicable.[3]

6.4 Video and Image Collection

NOAA Ocean Exploration collects video and images during expeditions on *Okeanos Explorer* (primarily from ROV dives) for scientific and outreach/educational purposes.

6.4.1 Video

During an ROV dive, high-definition video is collected by cameras on both ROVs and automatically saved in five-minute segments:

- Video from *Deep Discoverer* is saved as ProRes 422 at 147 Mbps, 1920x1080 interlaced video with a 29.97 frame rate.
- Video from *Seirios* is saved as ProRes 422 Proxy at 33 Mbps, 1920x1080 interlaced video with a 29.97 frame rate.

This video is used to produce three types of video products, which are used largely for outreach/education (e.g., NOAA Ocean Exploration website and social media):

- Highlight videos showcase discoveries and other compelling observations. They are produced on board by GFOE video editors and are typically 15-90 seconds. A highlight video is typically produced for every dive. In some instances, more than one highlight video may be produced for a dive or video from related dives may be combined into a single video.
- Expedition long-form videos are produced by GFOE video editors and are typically 3-5 minutes long. One long-form video is produced during an expedition and summarizes the highlights and accomplishments of an expedition. Additional long-form videos are produced throughout a field season and provide a more in-depth focus on individual topics relevant to an expedition or field season. Long-form videos typically include a mix of music and embedded audio and may also include interviews with Science Team members, crew, and other expedition participants or experts.
- Social media shorts are produced by NOAA Ocean Exploration Outreach and Education staff. They are typically less than a minute and are produced largely to supplement GFOE videos for social media purposes.

[3] An example of project instructions that include maritime heritage exploration, is available upon request to ex.expeditioncoordinator@noaa.gov.

6.4.2 Images

During an ROV dive, the onboard Video Team clips images from the full-resolution video and collects additional images using the still camera on *Deep Discoverer*. A video editor selects and color corrects 10-20 highlight images from the frame grabs and the still camera that best represent a dive or area of particular visual interest.

6.5 Sampling

NOAA Ocean Exploration conducts limited sampling operations during benthic and water column ROV dives (typically 4-11 samples per dive). The purpose of these operations is to collect a limited number of biological, geological, and water (for environmental DNA) samples for the sole purpose of broadly characterizing a dive site/area of interest. Sampling operations are designed to balance a dive's distance covered, imagery obtained, and samples collected in a way that minimizes negative impacts on the local environment and marine life. Ideally, only a subsample is taken of a biological organism (e.g., only a piece of a sponge or a branch of a coral).

The types and sizes of physical samples collected are limited to those that can be safely and efficiently collected with *Deep Discoverer*'s manipulator arms and associated tools and stored in the bioboxes, rock boxes, rotary suction sampler jars, and Niskin bottles. Samples are processed and stored on the ship for the duration of an expedition (Dunn et al. 2024). After an expedition, samples are shipped to designated repositories for archiving and made available to scientists for research purposes. More information about NOAA Ocean Exploration's sampling procedures is in the *NOAA Ocean Exploration Sampling Procedures Manual*.

6.6 Ship-to-Shore Collaboration

For more than a decade, NOAA Ocean Exploration and partners have been designing, evaluating, and refining ways to solidify the connection and collaboration between the shipboard and shoreside Science Team members to maximize exploration and dissemination of information in real time. Today, in addition to using telepresence to provide shoreside scientists with near real-time data, NOAA Ocean Exploration also uses telepresence to meaningfully engage shoreside Science Team members in seagoing science operations via a suite of internet-based collaboration tools.

Prior to each field season, members of the ocean science and resource management communities are invited to sign up for a collaboration tools account to enable them to receive information about and participate remotely in expeditions of interest to them. Among the primary collaboration tools used to conduct science during expeditions on *Okeanos Explorer* are a shoreside data repository, an instant messaging chat room for scientists (the "science chat room"), a voice over internet protocol (VOIP)-enabled teleconference line, and a scientific annotation system.

In addition to the collaboration tools, person-to-person communication from ship to shore is also supported and possible through:

- VOIP-enabled phone lines.
- Various video conferencing platforms.
- *Okeanos Explorer*'s RTS intercom system (although with the exception of communicating with the Inner Space Center, it's rarely used).

6.6.1 Shoreside Repository

A subset of the data collected during expeditions on *Okeanos Explorer* is transmitted to a shoreside repository where it can be accessed by shoreside Science Team members through a secure file transfer protocol (SFTP) portal in near real time. These data include images, compressed video files, raw and processed multibeam data, and raw EK60/80 water column data. Importantly, data in the shoreside repository are not considered final. Data are only considered final once they are processed, have undergone quality control, and are made available through the NOAA archives. The shoreside repository is not intended to be an archive.

6.6.2 Science Chat Room and Teleconference Line

During a dive, the science chat room and a VOIP-enabled teleconference line allow shipboard and shoreside Science Team members to collaborate in real time and communicate with each other and to the public.

- Shipboard and shoreside Science Team members use the internet-based science chat room to communicate about observations and operations and access sensor data (location, depth, temperature, salinity, dissolved oxygen, and turbidity). Anyone logged into the system can contribute to the conversation and have side conversations with individuals or small groups. All chat room entries are logged and timestamped (UTC) and can later be correlated to the operations, location, and data feeds coming off the ship at that time. Prior to the introduction of SeaTube in 2017, real-time taxonomic observations were logged in the chat room. These data remain available for analysis.
- Science Team members also use the teleconference line, which is embedded in the video, to engage with each other as part of a dive broadcast as well as to help narrate a dive, including sharing comments and identifications made in the science chat room, for the science and resource management communities as well as the public.

6.6.3 Scientific Annotations

Annotations complete a dive's metadata record, make video data more discoverable, and are archived and made publicly available for a variety of purposes (e.g., for further research, as teaching tools, and as inputs for training datasets for artificial intelligence). NOAA Ocean Exploration uses a cloud-based, crowdsourced annotation system developed by Ocean Networks Canada (ONC) called SeaTube to document biological, geological, and maritime heritage observations made during ROV dives on *Okeanos Explorer*.

SeaTube (2017-present):

- Enables registered users, regardless of where they are, to record time-stamped observations and instantly share those observations (Jenkyns et al. 2015; Cantwell et al. 2020; Malik et al. 2020).
- Allows for the production of a common set of annotations with corresponding geospatial and sensor data, which are automatically captured by SeaTube, in real time that can be cross-referenced with the time-stamped chat room logs.
- Permits users to browse ROV dive videos, add annotations, edit annotations, search for annotations, and download annotation data and images — both during and after an expedition.

The integrity of annotations made in SeaTube relies on a manual quality control process to ensure data are accurate and as complete as possible. Once they go through this process, annotations are submitted to the NOAA archives (NCEI).

During the Campaign to Address Pacific Monument Science, Technology, and Ocean NEeds (CAPSTONE, 2015-2017), with support from NOAA's Deep Sea Coral Research and Technology Program, the Hawaiʻi Undersea Research Lab (HURL) at the University of Hawaiʻi analyzed and annotated benthic videos following each expedition. They used a customized version of the Monterey Bay Aquarium Research Institute's Video Annotation and Reference System (VARS) (Schlining and Stout 2007) to create records for the animals observed on the seafloor with the corresponding *in-situ* environmental data (i.e., habitat, substrate, water chemistry, and geographic location). They cross-referenced all records against the World Register of Marine Species (WoRMs) and subjected them to quality control (Kennedy et al. 2019). These records are all available in SeaTube as of the publication of this manual.

After CAPSTONE, ONC made several enhancements to the SeaTube interface. Among these enhancements was the standardization of observational data, including biological identifications automatically linked to WoRMS, landform and substrate observations based on the Coastal and Marine Ecological Classification Standard (CMECS), and the addition of operational notes (e.g., when sampling occurred, when the ROVs left the seafloor, when equipment malfunctioned).

During the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) campaign (2017-2022), participating Science Team members added benthic and water column annotations directly to SeaTube. After each expedition, the France Lab at the University of Louisiana Lafayette conducted quality control of the benthic annotations directly in SeaTube (see **Appendix D**).

In 2023, NOAA Ocean Exploration also used SeaTube to crowdsource annotations during the EXpanding Pacific Research and Exploration of Submerged Systems (EXPRESS) and Seascape Alaska campaigns. Annotations for these expeditions underwent quality control at the University of Hawaiʻi's Deep-Sea Animal Research Center (DARC) using VARS. NOAA Ocean Exploration is continuing this approach and partnership with DARC for the Beyond the Blue: Illuminating the Pacific campaign, which launched in 2024.

6.6.4 Exploration Command Centers

When NOAA Ocean Exploration first started telepresence-enabled exploration, the primary way to connect with shoreside scientists was through exploration command centers (ECCs) with specialized equipment (Cantwell et al. 2020). These centers allow for scientists to gather and have the same interdisciplinary interactions with their colleagues as they would have while at sea on a traditional research expedition. As technology has evolved, scientists no longer need to gather at an ECC to access high-quality, low-latency data and a direct audio connection to the ship, but the social aspect of an ECC remains an important draw for scientists participating in an expedition from shore (Cantwell et al. 2020).

An ECC is a cost-effective way to add value to shoreside scientific participation in an expedition. Though ECC setups vary by location, the basic requirements include:

- A high-speed internet connection.
- Large TVs, computer monitors, and/or a projection system to run three video streams (this could include three independent monitors or one large networked monitor).
- Computers to access the collaboration tools.
- A computer with video and/or audio calling capabilities or a high-quality speaker phone with a mute function.

An ECC does not require long-term dedicated space. It could be a repurposed space (e.g., a media room) that serves as an ECC for a campaign, series of expeditions, or individual expedition and then reverts to its primary use. An ECC can be used to bring scientists together and as a venue to engage and train students.

6.7 Post-Expedition Wrap Up

After an ROV expedition:

- The expedition coordinator leads a call with the Science Team to discuss the expedition, notable scientific observations and findings, other expedition highlights, and sample and data availability and archives, specifically.
- The expedition coordinator works with NOAA Ocean Exploration's Outreach and Education staff to produce a summary fact sheet for the ocean science and resource management communities that is emailed to the Science Team and posted on NOAA Ocean Exploration's website.

NOAA Ocean Exploration encourages Science Team members to present expedition-specific findings at conferences and workshops and in peer-reviewed papers. In collaboration with Science Team members, NOAA Ocean Exploration often submits session topics to conferences and workshops to provide a platform for Science Team members and bring together the ocean science and resource management communities to discuss expedition-related scientific findings.

After a campaign or series of expeditions, NOAA Ocean Exploration may work with relevant partners and stakeholders to hold or contribute to a workshop(s) to solicit feedback from the ocean science and resource management communities, discuss areas of interest for follow-on research, and share lessons learned.

7. ROV Expedition Data and Products

For every expedition, NOAA Ocean Exploration collects data and develops products to plan, execute, and document the expedition. During an expedition, operational data and products (some preliminary) are available to Science Team members in the shoreside repository in near real time (data type/product dependent). After an expedition, final data and products are archived and made publicly available or are available upon request.

This includes value-added products produced by NOAA Ocean Exploration's Data Management Team at NCEI using data collected during expeditions on *Okeanos Explorer*. These products include geospatial products that summarize operations as well as enhance the visualization and analysis of NOAA Ocean Exploration data both during and after an expedition.

This section describes when and where to access data and products related to ROV expeditions on *Okeanos Explorer*. Information about accessing NOAA Ocean Exploration data and products is also on the NOAA Ocean Exploration website.

Appendix E. provides a comprehensive list of expedition data and products.

7.1 Mapping Data and Products

Mapping data are available during and after an expedition:

- During an expedition, mapping data are available to Science Team members through the shoreside repository and the Okeanos Explorer Live Operations Map (view only).
- After an expedition, mapping data are archived and made publicly available through the NOAA Ship Okeanos Explorer data landing pages and the NOAA Ocean Exploration Data Atlas.

These mapping data are described in detail in the *NOAA OER Deepwater Exploration Mapping Procedures Manual*.

7.2 Video and Images

Video is available during and after an expedition:

- During an expedition, raw video and low-resolution highlight videos are available to Science Team members for viewing and download through the shoreside repository. Full-resolution (ProRes) video may be available upon request. Highlight videos and social media shorts are publicly available for viewing and download on the NOAA Ocean Exploration website.
- After an expedition, raw video and highlight and long-form videos in full and low resolution are archived and made publicly available for download through the NOAA Ocean Exploration Video Portal. Low-resolution video is also available for download from the NOAA Ship Okeanos Explorer data landing pages and the NOAA Ocean Exploration Data Atlas. Long-form videos are available for download and viewing, along with the highlight videos and social media shorts, on the NOAA Ocean Exploration website.
- Both during and after an expedition, full-length, low-resolution video can be viewed, saved, downloaded, and shared on SeaTube.

Images are available during and after an expedition:

- During an expedition, all clipped and still camera images are available to Science Team members for viewing and download through the shoreside repository. Select images are publicly available on the NOAA Ocean Exploration website.
- After an expedition, all clipped images collected using the ROVs are archived and made publicly available for download by dive from the NOAA Ship Okeanos Explorer data landing pages and the NOAA Ocean Exploration Data Atlas.

- Both during and after an expedition, snapshots can be taken and downloaded from the video on SeaTube.

7.3 Science Chat Room Logs

Science chat room logs provide context for and situational awareness about a dive as well as informal observations and identifications.

Chat room logs are preserved as .txt files and available during and after an expedition:

- During an expedition, chat room logs are available to Science Team members through the shoreside repository.
- After an expedition, chat room logs are archived and made publicly available through the NOAA Ship Okeanos Explorer data landing pages, the NOAA Ocean Exploration Data Atlas, and SeaTube.

7.4 Scientific Annotations

Scientific annotations are available in SeaTube during an expedition, but it's not until after an expedition that they undergo quality control. After that, they're archived and made publicly available through the NOAA Ship Okeanos Explorer data landing pages and NOAA Ocean Exploration Data Atlas and incorporated into the NOAA Ocean Exploration Video Portal as metadata.

7.5 ROV Dive Geospatial Data

Geospatial data associated with an ROV dive are recorded to document where a dive took place, where the ROVs entered and exited the water, the dive track, and features of interest, operational developments, and obstacles encountered during a dive.

- During an expedition, ROV dive locations (in water, on bottom, off bottom, out water) and tracks are available to Science Team members through the shoreside repository and the Okeanos Explorer Live Operations Map.
- After an expedition, all ROV dive-related geospatial data are archived and made available through the NOAA Ship Okeanos Explorer data landing pages and NOAA Ocean Exploration Data Atlas. In addition, the NOAA Ocean Exploration Data (NCEI) ArcGIS online group on NOAA's Geoplatform includes ROV dive location, dive track, sampling site, and entry/exit point layers (as well as other expedition-related data layers). Many of these layers have been simplified for web optimization and are available for download in a variety of nonproprietary formats. Users can also access these geospatial products via GIS desktop applications (Esri ArcMap or Pro) for more sophisticated analyses, often

without having to download the data. For added convenience, users with an ArcGIS Online account can request to join the online group.

7.6 Sampling Data and Products

Sampling data and products, digital and physical, vary in availability during and after an expedition. Additional information about sampling operations, data archiving procedures, and reporting requirements is in the *NOAA Ocean Exploration Sampling Procedures Manual*.

7.6.1 Digital Sampling Data Products

Before physical samples are archived and made publicly available after an expedition, sampling data products serve as the digital collection records.

- During an expedition, a daily sample report, a daily list of sample video and images by sample ID, video, and *in-situ*, close-up, and laboratory images are available to Science Team members through the shoreside repository.
- After an expedition, a record of all samples collected, associated data, preparations, planned archives, and associated video and image file names (.xlsx) is made publicly available for download through the NOAA Ship Okeanos Explorer data landing pages along with links to the repositories for the physical samples. The locations of sample collections are saved in an ROV Samples layer, along with information about individual collections and a link to the relevant repository, on the NOAA Ocean Exploration Data Atlas and is available through the NOAA Ocean Exploration Data (NCEI) ArcGIS Online group.

7.6.2 Biological and Environmental DNA Samples

Biological and environmental DNA (eDNA) samples are archived in the collections of the Smithsonian National Museum of Natural History, which catalogs, curates, and makes them publicly available.

- Biological samples of invertebrate organisms are archived in the Department of Invertebrate Zoology's Collections.
- Biological samples of fish are archived in the Department of Vertebrate Zoology's Division of Fishes Collections.
- Tissue samples collected during at-sea sample processing for later genomic analysis are archived in the Biorepository.
- eDNA collected during at-sea operations are archived in the Biorepository.

7.6.3 Geological Samples

Geological samples are archived in the Marine and Geology Repository at Oregon State University (OSU). The repository provides online metadata information about each geological sample in their NOAA Collection. Information on how to request access to these geological samples is through the OSU Request Samples website.

7.7 Expedition Plans and Reports

The confidence in, and interpretation of, exploration data is contingent upon the thorough and accurate reporting of all activities associated with data collection. NOAA Ocean Exploration generates a variety of plans and reports that describe planned operations and document systems testing, daily operations, and procedures. These plans and reports are Section 508-compliant[4] and provide key context and metadata to enable future data users of varying expertise to assess the quality of the data and determine appropriate additional analysis or applications of the data.

7.8 Benthic Deepwater Animal Guide

NOAA Ocean Exploration's Benthic Deepwater Animal Identification Guide is a collection of *in-situ* images of marine animals clipped from seafloor video taken during expeditions on *Okeanos Explorer* using cameras on *Deep Discoverer*. This guide has become a popular and trusted ocean science community resource and is used (and contributed to) by ocean scientists around the world to help identify deepwater animals seen during ROV dives, supporting scientists annotating ROV videos and those conducting the annotation quality control. It's also being used to train artificial intelligence to automate animal detection in underwater video, educate the next generation of ocean scientists, and generate ocean interest among the public. This training dataset is publicly available and can be accessed on the FathomNet GitHub.

The guide is based on input from taxonomic experts who specialize in deepwater animals. Identifications were made during live ROV dives as well as after, following close examination of images as well as collected samples. It will continue to be enhanced and expanded upon, with new functionalities and new images. Identifications are updated periodically to correct errors reported by experts and reflect taxonomic revisions and new descriptions accepted in WoRMS.

The Benthic Deepwater Animal Guide is maintained in collaboration with the Deep-Sea Animal Research Center at the University of Hawaiʻi, NOAA's Deep Sea Coral Research and Technology Program, and NCEI.

[4] Section 508 is an amendment to the US Workforce Rehabilitation Act of 1973 — a federal law that mandates all federal agencies make their electronic and information technology (such as publications, presentations, software, and websites) accessible to people with disabilities.

8. ROV Expedition Data Management

Since the inception of NOAA Ocean Exploration in 2001, the NOAA Ocean Exploration Data Management Team at NCEI has been guided by the recommendations in the 2000 report of the president's panel on ocean exploration, which prioritized rapid and unrestricted data sharing. Today, national policy and international standards also guide NOAA Ocean Exploration's data management to ensure timely and broad public accessibility to our data.

In 2009, Public law 111-11 [Section XII Ocean Exploration] reinforced and expanded NOAA Ocean Exploration's data management objectives, continuing to stress the importance of sharing unique exploration data and products to improve public understanding of the ocean and for research and resource management purposes.

NOAA Ocean Exploration data management practices are available for review and are shared with the broader ocean science and resource management communities, including the National Science Foundation's Rolling Deck to Repository Program, the NOAA Data Governance Committee, and the Integrated Ocean and Coastal Mapping Program. More about the management of NOAA Ocean Exploration's data is on NCEI's NOAA Ocean Exploration Data Management web page.

Each field season, NOAA Ocean Exploration works with NCEI to develop a strategy for managing data collected during that season's expeditions on *Okeanos Explorer* (i.e., identifying, collecting, displaying, archiving, and publishing). These data management plans, which may vary slightly from year to year, are available through the NOAA Institutional Repository.

8.1 File Naming Conventions

Successful data management requires that data files follow a strict naming convention and are organized within predetermined folder structures. This standardization allows for automation and easier data management. Folder and file names provide basic metadata that clearly describes folder and file contents. NOAA Ocean Exploration's standard directory structure and folder and file naming conventions for data collected during ROV expeditions are on its naming convention and standards web page.

8.2 Path to Archive for Digital Data

Immediately after an expedition, digital data are transferred to the NOAA archives (NCEI) and the shoreside repository for redundancy. At NCEI, the data are archived into data packages so each data type goes through the appropriate ingest workflow. NCEI performs quality control on the data packages, runs post-processing procedures, generates robust metadata records, updates geospatial products, and archives the data. NCEI also archives metadata for the biological and geological samples collected during an expedition. Archived data are made available through various sources (see **Appendix E**).

8.2.1 Oceanographic, Meteorological, and Navigational Data Archive Pipeline

SCS data from hull-mounted oceanographic, meteorological, and navigational sensors, integrated oceanographic sensors on the ROVs, and navigational instrumentation on both the ship and the ROVs are monitored and recorded by redundant systems on two physically separate networks using a suite of custom software. The two systems receive the exact same data input via an active serial splitting matrix and timestamp the data as it arrives. Data are recorded 24 hours a day while underway and continuously synchronized to the SCSData folder in the onboard repository where all expedition data are gathered before they are sent to shore and where they are saved in a .csv file with a “RAW” file extension.

After an ROV dive, several ROV data streams are used to produce an ROV navigation dive track. This entails combining and interpolating navigation, depth, and altitude data using a time-based interpolation. These data are then downsampled to produce a 1 Hz ROV navigation .csv file that can easily be used to create a dive track.

Oceanographic, meteorological, and navigational sensor data are pulled from the shoreside repository by NCEI for archiving.

At NCEI, SCS data are used to generate NetCDF-4 files (using NetCDF-3 “classic” internal organization). The NetCD4 files are then ingested into an NCEI-hosted Thematic Real-Time Environmental Distributed Data Services server for user discoverability and access. The oceanographic, meteorological, and navigational data are also used to generate robust metadata records for the videos archived in the NOAA Ocean Exploration Video Portal.

8.2.2 Video Archive Pipeline

Full-resolution video is collected by *Deep Discoverer* and *Seirios* from launch to recovery via the onboard video system. From this video, a lower resolution copy is generated. The video (both resolutions) is divided into five-minute segments for ease of download. In addition, onboard videographers preserve additional video segments from the secondary cameras on the ROVs and cameras strategically located on the ship using the video system’s instant replay. All video files are saved according to a strict, metadata-rich file-naming system that includes expedition name, date/time in UTC, and camera ID.

Files are stored internally on a shipboard server during an expedition. At the conclusion of an expedition, the original ProRes, raw, and processed files are copied to hard drives and shipped to NCEI for archiving and future analysis.

NCEI runs metadata extraction routines to extract information from SCS data files, SeaTube, the science chat room logs, and other sources to generate an ISO metadata record for each individual video file. These ISO-19115-2 standardized metadata are loaded into NCEI geoportals that contribute to the discoverability of the video in the NOAA Ocean Exploration Video Portal.

Full-resolution videos are stored in NOAA's Comprehensive Large Array-Data Stewardship System.

More information about the NOAA Ocean Exploration Video Portal is in the Video Data Management Modernization Initiative report.

8.2.3 Digital Sampling Data Archive Pipeline

Following sample collection, details are input to the Sampling Operations Database Application (SODA). This application was developed in Microsoft Access to capture metadata about samples and their associates, to print museum quality labels, and to generate sampling-focused reports and documentation.

After an expedition, sampling data are exported for sample tracking, reporting, and metadata generation. These sample reports and sample metadata exports are archived within NCEI's Oceanographic Archive.

More information about sampling data collection, processing, and management are in the *Sampling Operations Database Application (SODA) Manual 2023*.

8.3 Sensitive Data

During expeditions on *Okeanos Explorer*, NOAA Ocean Exploration occasionally collects sensitive data on maritime heritage sites that are not for public release. NOAA Ocean Exploration defines sensitive data as data that NOAA Ocean Exploration and its partners believe could result in harm to a maritime heritage site that is eligible for or is listed on the National Register of Historic Places if publicly disclosed (e.g., location, character, or ownership).

To ensure these data are properly protected, NOAA Ocean Exploration developed Restricted Data Protection for Underwater Cultural Heritage Standard Operating Procedures that guide collection of sensitive data. This resource identifies relevant legislation and processes to ensure sensitive data are appropriately managed, while maximizing the amount of maritime heritage site data available to the public. Site location information and evidence of human remains, though rare, are the most common types of sensitive data. Occasionally, the collection of sensitive data may affect operational, data sharing, and data archiving processes described in this manual.

For more information about maritime heritage-related sensitive data, contact archaeology.oceanexploration@noaa.gov.

9. Conclusion

Since 2008, NOAA Ocean Exploration has invested heavily in developing and pioneering the use of state-of-the-art technologies for efficient and seamless exploration of our ocean. In particular, video imaging and telepresence have proven essential for exploring the deep ocean and observing and documenting biological and geological characteristics of the seafloor and water column (as well as maritime heritage sites). This manual provided an overview of NOAA Ocean Exploration's ROV expeditions on *Okeanos Explorer*, including the technologies used and the associated data flows from the deep ocean to the data archives. NOAA Ocean Exploration will continue to improve upon these operations, working with a variety of partners both government and nongovernment, to best address needs for easily accessible and authoritative deep-ocean data and products. This manual will be updated accordingly.

NOAA Ocean Exploration hopes this manual will be useful to other organizations in planning and conducting their ROV expeditions.

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Appendix A. Acronyms and Abbreviations

2D	two-dimensional
3D	three-dimensional
BOEM	Bureau of Ocean Energy Management
CAPSTONE	Campaign to Address Pacific monument Science, Technology, and Ocean NEeds
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMECS	Coastal and Marine Ecological Classification Standard
CTD	conductivity, temperature, and depth
DSL	deep scattering layer
ECC	exploration command center
EFH	essential fish habitat
ESA	Endangered Species Act
FAIR	findable, accessible, interoperable, reusable
GFOE	Global Foundation for Ocean Exploration
MMPA	Marine Mammal Protection Act
NCEI	National Centers for Environmental Information (NOAA)
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
ROV	remotely operated vehicle
SCS	Scientific Computing System
USBL	ultra-short baseline
USFWS	U.S. Fish and Wildlife Service
UTC	Coordinated Universal Time
VSAT	very small aperture terminal
VOIP	voice over internet protocol
WoRMS	World Register of Marine Species

Appendix B. Staffing Models for Deep-Ocean Exploration

During a remotely operated vehicle (ROV) expedition, responsibilities are distributed among the expedition coordinator and other at-sea and shoreside members of the Science Team. **Tables B1 and B2** describe roles and responsibilities, which are subject to change with time and may vary by expedition, based on NOAA Ocean Exploration's 2023 operations on NOAA Ship *Okeanos Explorer*.

Table B1. Operational roles and responsibilities as of 2023 (non-engineering).

Position/Team	Roles and Responsibilities	Operating Location (Shoreside/Shipboard)
Expedition Manager	● Identify priorities with science, management, and Indigenous communities and other regional stakeholders to address regional data gaps and needs ● Develop and manage regional partnerships ● Develop and coordinate common exploration themes and objectives across expeditions	Shoreside or Shipboard (expedition-dependent)
Expedition Coordinator	● Plan and manage interdisciplinary, at-sea expeditions on behalf of partners and stakeholders ● Oversee at-sea data collection operations to support priorities identified by engaged communities and participants ● Coordinate execution of expedition objectives across NOAA Ocean Exploration's divisions and external partners ● Oversee staffing and training of expedition staff ● Oversee expedition data archiving and reporting ● Conduct post-expedition data quality control	Shipboard
Mapping Team	● Maintain, operate, process, and evaluate mapping systems and onboard mapping data in collaboration with NOAA's Office of Marine and Aviation Operations and onboard survey technician(s) ● Collect and assess expedition-relevant mapping data	Shipboard

Position/Team	Roles and Responsibilities	Operating Location (Shoreside/Shipboard)
Science Advisor	• Provide advice on scientific matters at the campaign level, including improving capabilities and value from expeditions and data • Serve as initial external NOAA Ocean Exploration contact for ocean science and resource management communities • Contribute to shoreside scientific annotations and post-expedition quality control of data and samples collected during an expedition • Aid in training science leads • Provide scientific consistency between all expeditions associated with a campaign	Shoreside/Shipboard
Science Leads	• Serve as science ambassador on behalf of ocean science and resource management communities during expedition planning, execution, and wrap-up • Engage experts from a variety of oceanographic science disciplines for Science Team participation • Share data and discoveries with ocean science and resource management communities and the public through narration of live video feeds	Shipboard
Outreach and Education Staff	• Develop, manage, and share expedition-related content on NOAA Ocean Exploration website and social media channels • Foster relationships with education and outreach partners and stakeholders • Coordinate outreach and educational events for at-sea personnel to engage diverse public and science communities	Shoreside
Data Management Team	• Develop yearly and expedition-specific data management plans • Receive, curate, and archive all data • Manage Sampling Operations Database Application • Work with Mission and Data Management teams to produce high-quality records of collected samples (sample data manager) • Provide needed sample logging, preparation, and processing support to science leads (sample data manager)	Shipboard/Shoreside

Table B2. Engineering and Video teams' operational roles and responsibilities as of 2023.

Role	Simplified Description/Responsibilities	Operating Location (Shoreside/Shipboard)
Global Foundation for Ocean Exploration (GFOE) Team Lead	● Oversee and coordinate all onboard GFOE personnel and operations to ensure safety and meet mission requirements ● Collaborate with expedition coordinator on development of expedition objectives and coordinate logistics ● Act as point of contact for all big picture ROV-related responsibilities (e.g., data, video, ROV operations and mechanics, etc.)	Shipboard
GFOE Dive Supervisor	● Oversee all ROV dive operations (rotational role assigned on a dive by dive basis) ● Oversee vehicle and related systems maintenance (along with GFOE team lead) ● Work directly with ship's officers and crew (command, engineers, and deck department) to ensure safety of vehicle systems and personnel during launch and recovery	Shipboard
GFOE VSAT/Telepresence Engineering Team	● Oversee VSAT and telepresence equipment ● Work with Shoreside Telepresence Team to ensure communication is working efficiently and effectively from ship to shore and vice versa	Shipboard
Shoreside Telepresence Team	● Maintain shoreside telepresence equipment and technical aspect of communications from ship to shore ● Work with GFOE and University of Rhode Island's Inner Space Center Telepresence Engineering teams to ensure all communications and data streams are working effectively and efficiently	Shoreside
GFOE Video Editing Team	● Produce high-quality video products for use by ocean science and resource management communities and the public, including dive highlight videos, topical videos, and summary videos ● Collect and curate video and images for archiving	Shipboard
GFOE Video Engineering Team	● Oversee and manage all ROV video-related equipment and in the rack room, control room, and dry lab ● Operate all shipboard and subsea cameras and imagery equipment during dive operations	Shipboard

Role	Simplified Description/Responsibilities	Operating Location (Shoreside/Shipboard)
GFOE Mechanical Engineering Team	● Manage and maintain ROV-related mechanical systems and ancillary equipment ● Support dive operations as pilots, co-pilots, and/or navigators during ROV operations ● Support ROV launch and recovery operations	Shipboard
GFOE Electrical Engineering Team	● Manage and maintain ROV-related electrical systems, fiber optic systems, and ancillary equipment ● Support dive operations as pilots, co-pilots, and/or navigators during ROV operations ● Support ROV launch and recovery operations	Shipboard
GFOE Data Engineering Team	● Monitor and facilitate data transfer from ship to shore ● Administer shore repository exdata.tgfoe.org ● Conduct quality assurance of data transfers from shipboard acquisition systems and file organization and naming ● Support and administer onboard computer systems and mission network, file repository, and shoreside repository ● Support and administer shipboard file storage and backup systems ● Support dive operations as pilots, co-pilots, and/or navigators during ROV operations ● Support ROV launch and recovery operations	Shipboard/Shoreside

Appendix C. Photogrammetry: Structure From Motion

With technological advances in remotely operated vehicles (ROVs) and underwater videography, highly detailed surveys of shipwrecks are now possible. Computer technology has reached the point where photo-real and hyperaccurate 3D models can be created from 2D imagery. Photogrammetry allows for the transformation of 2D thinking into a 3D realm akin to archaeological activities on land. The resulting products enable easy viewing and study of a shipwreck site. The Bureau of Ocean Energy Management (BOEM) has produced photogrammetry maps and models using NOAA data and posted the results in 3D, video, and hyperaccurate 2D orthorectified mosaics in their virtual archaeology museum.

Photogrammetry is defined as making maps from light, so conducting these activities in the deep ocean is particularly complex and difficult. Furthermore, any errors made during the video collection can have extreme consequences since archaeologists may not be able to revisit a site to correct them. To minimize the chance of errors, NOAA Ocean Exploration uses the BOEM protocols developed by BOEM archaeologist Scott Sorset specifically for collecting ROV video footage for the purpose of photogrammetry. These protocols are based on the recommendations in Agisoft Metashape Professional's manuals, forums, and FAQs, elements from Kotaro Yamafune's 2016 doctoral dissertation and NOAA Ocean Exploration's internal photogrammetry recommendations:

- Fix the ROV camera's focal length to the extent possible because zooming may affect scale and confuse the modeling software.
- Face the ROV camera downward as much as possible. Ensure no portion of the ROV is in the visible frame. Do not mount the camera to face completely downward because this creates holes in the model.
- Record video at the highest resolution possible.
- Turn off any other sources of light to minimize shadow. Ensure no shadow from the ROV is in the visible frame.
- Turn off lasers during photogrammetry passes, but collect laser-scaled imagery at the conclusion of photogrammetry passes to allow for accurate scaling of the orthomosaic maps.
- Ensure at least 60-80% overlap from one video pass to the next. The number of passes is affected by the height of the ROV and the amount of structure in view during each pass. The closer the ROV is to the seafloor, the higher the quality of the model and map. The minimum overlap is 60%.
- Record each pass again at 180° of the first. Record subsequent transects at 90° offsets from the first pass to gain critical perspective for both orthomosaic map generation and 3D modeling.

- Maintain a consistent ROV distance from the object being mapped, when possible. Past projects have ranged from 0.3 m to 1.5 m from the object (see **Figure C1**). Height offset depends on adequacy of lighting as light diffuses quickly in water.
- Conduct off-bottom circular passes, with at least 80% overlap, around objects of significant height while attempting to maintain consistent ROV distance from the object being mapped.
- Keep ROV speed fairly slow to ensure imagery is not torn and to avoid motion blur. During video collection, set video settings to minimize the normally desirable and cinematic motion blur (known as the 180° rule). This requires adjusting shutter speed or frame rates of the ROV camera (if possible).

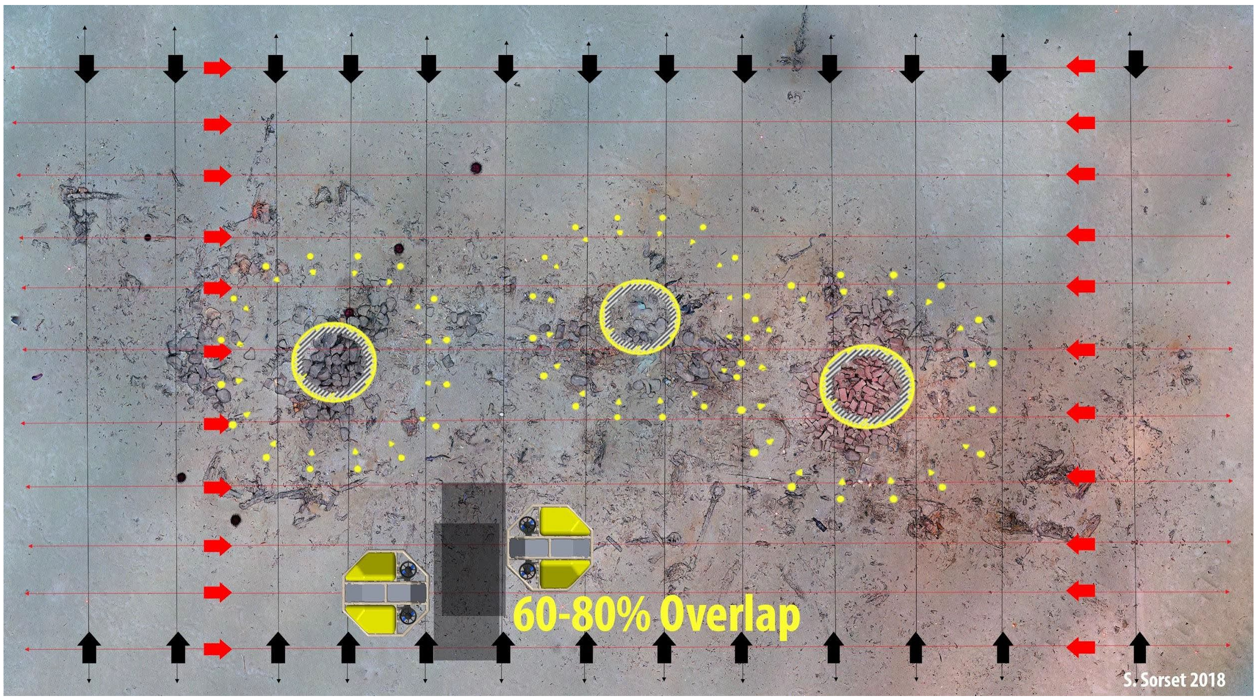

Figure C1. Overview image of a site with a gridded overlay to display ROV passes necessary to achieve the best photomosaic results.

Reference

Yamafune, Kotaro. 2016. "Using Computer Vision Photogrammetry (Agisoft Photoscan) to Record and Analyze Underwater Shipwreck Sites." PhD diss. Texas A&M University. https://oaktrust.library.tamu.edu/handle/1969.1/156847?show=full.

Appendix D. Annotation Quality Control

During the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) campaign, benthic video annotations underwent quality control in the lab of the ASPIRE science advisor, Scott France, at the University of Louisiana Lafayette. During this process, graduate students (reviewers) replayed ROV dive video in SeaTube; reviewed each annotation, correcting them where necessary; and added annotations where none existed. Specific reviewer tasks included:

- Adjusting annotation time stamps to ensure there is no lag between an observation and the corresponding annotation, as necessary. This is particularly important for observations near the end of the five-minute video segments to avoid associating an annotation with the subsequent video segment, which may not feature the target observation.
- Ensuring the taxonomy of all biological annotations conforms to the World Register of Marine Species (WoRMS) and confirming identification against available taxonomic guides and conferring with experts.
- Consulting the science chat room logs to determine if expert identifications were made that were not annotated on video and vetting and adding them, as appropriate.
- Identifying and adding annotations for biological organisms that are not identified by annotation or in the chat room logs at the taxonomic level of greatest confidence (e.g., family or genus) in consultation with the NOAA Ocean Exploration Benthic Deepwater Animal Identification Guide.
- Deleting duplicate annotations if a particular individual is seen continuously across multiple five-minute video segments, leaving only one annotation per individual.
- Adding or correcting behavior- or ecology-related information, as necessary.
- Ensuring that each five-minute video segment has at least one annotation characterizing the geological setting of the area that conforms to the Coastal and Marine Ecological Classification Standard (CMECS).
- Checking the “To be reviewed” box on SeaTube when unsure about a particular annotation to flag it for later review and correction, if needed.
- Updating the status of the “ROV Dive Annotation QA/QC Status” document when review of a dive is completed.

It’s difficult to estimate how long the quality control process takes as it largely depends on the specifics of each of the individual dives (e.g., length of dive, density and diversity of biological observations, number identifications made in the chat room versus SeaTube, number of annotations made, and level of difficulty of identification). One estimate for how long it takes a single reviewer to complete this process is approximately 15-20 hours per dive.

Appendix E. Expedition Data and Products

NOAA Ocean Exploration ensures public access to the diverse scientific data collected and products produced during expeditions on NOAA Ship *Okeanos Explorer*. Data and products vary by expedition. However, most expedition data and products include oceanographic and geophysical data, video and images, samples, supporting documentation, secondary products, and published works. Information about NOAA Ocean Exploration data and products is available on NOAA Ocean Exploration's website.

E.1 Location of Data and Products

NOAA Ocean Exploration collects and produces a wealth of data and products before, during, and after a remotely operated vehicle (ROV) expedition. Primary sources for these data and products, both internal and external to NOAA, are shown in **Table E1**.

Table E1. The locations of data and products available before, during, and after a NOAA Ocean Exploration ROV expedition on *Okeanos Explorer*.

Location	Description	Managing Organization
NOAA Ocean Exploration Data Atlas*	Searchable, interactive map that provides access to the continuously updated archive of NOAA Ocean Exploration data, information, and products	NOAA's National Centers for Environmental Information
NOAA Ship Okeanos Explorer data landing pages*	Direct access links to archived data and products from expeditions on *Okeanos Explorer*, by expedition, with dedicated sub-pages for each ROV dive	NOAA's National Centers for Environmental Information
NOAA Ocean Exploration Video Portal*	Web portal that enables users to search for, discover, and access low- and full-resolution video data (with critical metadata) collected during ROV expeditions on *Okeanos Explorer*	NOAA's National Centers for Environmental Information
NOAA Ocean Exploration Data (NCEI) ArcGIS Online group*	ArcGIS Online group that provides access to geospatial data products from expeditions on *Okeanos Explorer*, including near real-time and historical ship tracks (2D), multibeam survey polygons, ROV dive sites, ROV dive tracks (3D), ROV sample collection sites, and a station log	NOAA's National Centers for Environmental Information
SeaTube	Web-based annotation interface for remotely operated vehicle operations on expeditions on *Okeanos Explorer*	Ocean Networks Canada
NOAA Ocean Exploration website	Website designed to provide the public with information related to ocean exploration, including expeditions on *Okeanos Explorer*	NOAA Ocean Exploration

Location	Description	Managing Organization
Shoreside Repository (account required for access)	Shoreside location for a subset of expedition data for access by shoreside Science Team members during expeditions on *Okeanos Explorer*; the shoreside repository is not an archive	Global Foundation for Ocean Exploration
NOAA Institutional Repository	Digital space for the collection and dissemination of materials published by NOAA authors; it's the archive for NOAA Ocean Exploration plans, reports, and other expedition-related publications	NOAA Library
Smithsonian National Museum of Natural History Department of Invertebrate Zoology's Collections	Biological samples of invertebrate organisms collected during ROV expeditions on *Okeanos Explorer*	Smithsonian National Museum of Natural History
Smithsonian National Museum of Natural History Department of Vertebrate Zoology's Division of Fishes Collections	Biological samples of fish collected during ROV expeditions on *Okeanos Explorer*	Smithsonian National Museum of Natural History
Smithsonian National Museum of Natural History Biorepository	Tissue samples and eDNA collected during ROV expeditions on *Okeanos Explorer*	Smithsonian National Museum of Natural History
Oregon State University Marine Geology Repository	Geological samples collected during ROV expeditions on *Okeanos Explorer*	Oregon State University

*The timing of the availability of data and products archived at NOAA's National Centers for Environmental Information depends on the level of processing required. Data and information are made available over time as quality-control measures are completed, data are released, and publications and related materials are published. Thus, not all data are made available at the same time. Data access web pages and portals do not state when data collections are pending archive. Data needs that cannot be filled through these tools may be submitted to NOAA Ocean Exploration's Data Management Team through the NOAA Ocean Exploration Data Access Request Form. Requests for further information or assistance can be sent to oer.info.mgmt@noaa.gov.

Archived data from NOAA Ocean Exploration expeditions on *Okeanos Explorer* are also available through Google's Dataset Search and Data.gov.

E.2 Planning and Promotional Products

Table E2. Products produced during planning and to promote a NOAA Ocean Exploration ROV expedition on *Okeanos Explorer*. For access to products prior to archiving, email ex.expeditioncoordinator@noaa.gov.

Product	Description	Format	Access Location
Call for Input	Request for input from the ocean science and management communities on priorities and specific areas of interest within the region of a campaign or expedition	Online geospatial portal/tool	Email to ocean science and management communities, NOAA Ocean Exploration Website

Product	Description	Format	Access Location
Annual Data Management Plan	Document describing the planned data management, including: what instruments may be used, file formats, quality control procedures, transfer methods, and final access points	.pdf	NOAA Institutional Repository
EK60/80 Calibration Report	Document providing all the information for the calibration of the Simrad EK60/80 echosounders on *Okeanos Explorer*, typically conducted during the annual mapping shakedown expeditions	.pdf	NOAA Institutional Repository
Mapping Readiness Report	Document describing the acoustic mapping hardware and software capabilities of *Okeanos Explorer* and the performance evaluations conducted by NOAA Ocean Exploration in advance of each field season.	.pdf	NOAA Institutional Repository
Project Instructions	Standardized document including expedition-specific information, including project period, objectives, regions of interest, operating area, days at sea, participating institutions, personnel (mission team), additional records of environmental compliance, data management plan, points of contact, operational instructions, equipment, inventory of supplies (including hazardous materials), and responsibilities	.pdf	NOAA Institutional Repository
Framework Document	Overview of a campaign or expedition(s) for ocean science and management communities, including objectives, operating area (with map), timelines, goals, and contact information for key personnel	.pdf	Email to ocean science and management communities, NOAA Ocean Exploration website
ROV Dive Sheet	Spreadsheet shared with science team members to plan and briefly summarize ROV dives; this is a "living document" and is updated throughout expedition planning and execution	Shared Google Sheet	Shared Google Sheet, Expedition Report (see E.7)
Dive Plans	Standardized document that describes plans and objectives for a predetermined dive site (which are subject to change if circumstances — e.g., weather, shifts in currents — warrant)	.pdf	Emails to science team members, Dive Summary (see E.6)
Expedition Website	Public-friendly web pages that provide information about an expedition or series of expeditions	.html	NOAA Ocean Exploration Website

E.3 Mapping Data and Products

Table E3. Mapping data and products available during and after a NOAA Ocean Exploration ROV expedition on NOAA Ship *Okeanos Explorer*. More information about mapping data products is in the *NOAA OER Deepwater Exploration Mapping Procedures Manual*. This information is current as of 2024. For future reference, please see the Annual Data Management Plan.

Data/Product	Description	Format	Location and Availability (D=During, A=After)
Level-00 EM 304 Multibeam Data	Full resolution bathymetry, seafloor backscatter, and water column backscatter data stored in native sensor format with the water column data separated from seabed data	.kmall (seabed), .kmwcd (water column)	Shoreside repository (D*), NOAA Ocean Exploration Data Atlas (A)
Level-01 EM 304 Multibeam Data (field processed)	Field processed and full-resolution bathymetry and backscatter data in generic sensor format that have not been through quality control	.gsf	Shoreside repository (D)
Level-01 EM 304 Multibeam Data	Final processed and full-resolution bathymetry and backscatter data in generic sensor format	.gsf	NOAA Ocean Exploration Data Atlas (A)
Level-02 EM 304 Multibeam Bathymetry and Bottom Backscatter Grids	Gridded processed bathymetry data and backscatter mosaics (as available)	Bathymetry: .xyz, .tif, .tif (floating point), .sd, .kmz Backscatter mosaics: .tif, .sd, .tif (floating point)	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
Level-02 Daily Bathymetry Products (field processed)	A gridded product of each day's bathymetry coverage, used to populate the near real-time bathymetry GIS layer.	.sd, .xyz, .kmz, .tif, .tif (floating point)	Shoreside repository (D, A) and Okeanos Explorer Live Operations Map (D, A)
Level-02 EM 304 Multibeam Backscatter Data (field processed)	Where appropriate and upon request, site-specific backscatter data (seafloor/water column backscatter as needed)	.geotiff	Shoreside repository (D)
Level-02 EM 304 Multibeam Data Coverage Polygons	Survey coverage shapefile used to calculate square km mapped and to show *Okeanos Explorer* activities	.shp	NOAA Ocean Exploration Data (NCEI) ArcGIS Online group (A)

Data/Product	Description	Format	Location and Availability (D=During, A=After)
Level-00 EK60/EK80 Split-Beam Data	Raw water column data in native sensor format	.idx, .raw	Shoreside repository (D), NOAA Ocean Exploration Data Atlas (A)
EK60/EK80 Split-Beam Calibration Data	Calibration files and report from the preseason readiness shakedown	.idx, .raw, .xml, .pdf	NOAA Ocean Exploration Data Atlas (A)
Level-00 Sub-Bottom Profiler Data	Raw sub-bottom profiler sonar data in native sensor format	.sgy, .keb, .kea	Shoreside repository (D), NOAA Ocean Exploration Data Atlas (A)
Level-01 Sub-Bottom Profiler Data	Processed vertical curtain and sub-bottom track	.jpg, .shp	NOAA Ocean Exploration Data Atlas (A)
Mapping Data Processing Log	Excel sheet of metadata describing mapping data files information, notes, processing checklist, and confirmation of quality control	.xlsx	NOAA Ocean Exploration Data Atlas (A)

*Depending on bandwidth availability, water column data may not be available in the shoreside repository during ROV expeditions.

E.4 Video and Image Data and Products

Table E4. Video and images available during and after a NOAA Ocean Exploration ROV expedition on *Okeanos Explorer*. Still camera and highlight images are available upon request from ex.expeditioncoordinator@noaa.gov.

Product	Description	Format	Location and Availability (D=During, A=After)
Live video	Real-time (2-30 seconds delay, depending on access point) video streamed over three video channels	Live video feed	NOAA Ocean Exploration Website (D), YouTube (D), SeaTube (D)
ROV Video	Five-minute segments of end-to-end ROV video from *Deep Discoverer* and *Seirios;* video file names include expedition number, date, time, and camera information	.mov (full resolution), .mp4 (low resolution)	Shoreside repository (D), NOAA Ocean Exploration Video Portal (A), NOAA Ship Okeanos Explorer data landing pages (A)
Highlight Videos	Dive highlights, usually from a specific dive	.mov (full resolution), .mp4 (low resolution)	Shoreside repository (D), NOAA Ocean Exploration Website (D,A), NOAA Ocean Exploration Video Portal (A)

Product	Description	Format	Location and Availability (D=During, A=After)
Social Media Shorts	Short, informal videos produced for immediate use on social media	.mp4	NOAA Ocean Exploration Website (D,A)
Expedition Long-Form Videos	Videos summarizing an expedition and/or focused on expedition-specific topics	.mov (full resolution), .mp4 (low resolution)	Shoreside repository (D), NOAA Ocean Exploration Website (D,A), NOAA Ocean Exploration Video Portal (A)
Video with Annotations	End-to end, searchable low-resolution dive video with annotations (quality control is completed approximately one year after an expedition), associated environmental data, and snapshot capability	.mp4	SeaTube
ROV Dive Images — Low Resolution	Images clipped from the high-definition video; image file names map to the corresponding video	.jpg	Shoreside repository (D), NOAA Ship *Okeanos Explorer* data landing pages (A), NOAA Ocean Exploration Data Atlas (A), NOAA Ocean Exploration Website (select; D,A)
ROV Dive Highlight Images — Low Resolution	10-15 images clipped from each dive's high-definition video and color corrected; image file names map to the corresponding video with "CC" added to the file name	.jpg	Shoreside repository (D), NOAA Ocean Exploration Website (select; D,A)
ROV Dive Images — High Resolution	Still camera images; image file names map to the corresponding video	.jpg, .dng	Shoreside repository (D), NOAA Ocean Exploration Website (select; D,A)
Topside Images	Color-corrected and edited images documenting mission activities	.jpg	Shoreside repository (D), NOAA Ocean Exploration Website (select; D,A)

E.5 Sampling Data and Products

Table E5. Sampling data and products available during and after a NOAA Ocean Exploration ROV expedition on NOAA Ship *Okeanos Explorer*.

Product	Description	Format	Location and Availability (D=During, A=After)
Daily Sample Report	Daily output from the Sampling Operations Database Application that includes information about every sample, including lab preparation and associated video and images	.pdf	Shoreside repository (D)

Product	Description	Format	Location and Availability (D=During, A=After)
Daily List of Sample Video and Images by Sample ID	List of samples and associated dive video segments and clipped images by dive	.txt	Shoreside repository (D)
Video	Video of samples taken *in situ* and during collection	.mp4, .mov	Shoreside repository (D)
Images	Images of samples taken *in situ* and during and after collection, including with a color pallet and sample label, as well as images taken with a Caltex LX-100 series digital microscope	.jpg	Shoreside repository (D)
Specimens Collected	Record of all samples collected, associated data, preparations, planned archives, and associated video and image file names	.cvs	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A), Expedition Report (A)
ROV Sample Locations	Geospatial layer that shows where a sample was collected	.lyr	NOAA Ocean Exploration Data Atlas (A), NOAA Ocean Exploration Data (NCEI) ArcGIS Online group (A)
Biological Samples — Invertebrates	Invertebrate samples collected during an expedition	Samples	Smithsonian National Museum of Natural History Invertebrate Zoology Collection (A)
Biological Samples — Fish	Fish collected during an expedition	Fish	Smithsonian National Museum of Natural History Department of Vertebrate Zoology's Division of Fishes Collections (A)
Biological Samples — Tissue Samples	Tissue samples taken from biological samples collected during an expedition	Tissue samples	Smithsonian National Museum of Natural History Biorepository (A)
Environmental DNA Samples	Environmental DNA filtered from water samples collected during an expedition	eDNA	Smithsonian National Museum of Natural History Biorepository (A)
Geological Samples	Geological samples collected during an expedition	Sample	Oregon State University Marine Geology Repository (A)

E.6 Other ROV-Specific Data and Products

Table E6. Other ROV-specific data and products available during and after a NOAA Ocean Exploration ROV expedition on NOAA Ship *Okeanos Explorer*.

Data/Product	Description	Format	Location and Availability (D=During, A=After)
ROV Dive Plan	Document that describes dive plan, including site, rationale, and objectives	.pdf	Email to science team members (D)
ROV Dive Locations	Layer providing the locations of *Okeanos Explorer* ROV dive sites, including dives from ROV *Little Hercules* (2010-2013) and ROV *Deep Discoverer* (2013-current)	.jpg, .lyr	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A), NOAA Ocean Exploration Data (NCEI) ArcGIS Online group (A)
ROV Entry/Exit Points	Layer providing the "In Water/Out Water" and "On Bottom/Off Bottom" locations for ROV *Deep Discoverer*	.lyr	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A), NOAA Ocean Exploration Data (NCEI) ArcGIS Online group (A)
ROV Dive Tracks	File containing XYZ + T (1 min avg.) data of an ROV during a dive	.csv, .kml, .jpg, .kml, .lyr	Shoreside repository (D); NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A), NOAA Ocean Exploration Data (NCEI) ArcGIS Online group (A)
Full Dive Recording with Integrated Data	ROV video, environmental data, and scientific annotations with snapshot capability	Various	SeaTube (D,A)
Dive Annotations	Annotations of biological, geological, and other observations made during an ROV dive; after an expedition, annotations undergo quality control for archiving	.csv	Initial (before quality control): Shoreside repository (D), SeaTube (D) Archived: NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A) Ongoing: SeaTube (A)

Data/Product	Description	Format	Location and Availability (D=During, A=After)
Science Chat Room Log	Log of science team's chat during a dive with UTC time-coded and stamped observations and associated latitude, longitude, and depth	.txt	Shoreside repository (D), NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
Dive Summary	File that records dive type; times and locations in the water, on bottom, off bottom and out of the water; dive duration; bottom time; maximum vehicle depth; minimum seafloor depth; distance traveled)	.txt	Shoreside repository (D)
ROV Dive Summaries	Detailed summary of each ROV dive, including observations, sample collections, and maps	.pdf	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A), NOAA Institutional Repository (A)
Raw Oceanographic Datasets and ROV Navigation and Sensor Data	Raw oceanographic data from ROVs, including Scientific Computing System outputs; conductivity, temperature, and depth; dissolved oxygen; light scattering; oxygen reduction potential; etc.	Various formats	Shoreside repository (D), NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
ROV Ancillary Data	Additional data from each ROV dive, including in-water and out-of-water locations and time, dive duration, bottom time, depth information, ROV navigation and sensor data, and Hypack Targets	Various formats	NOAA Ship Okeanos Explorer data landing pages (by dive, (A)

E.7 Other Data and Products

Table E7. Other data and products available during and after a NOAA Ocean Exploration ROV expedition on NOAA Ship *Okeanos Explorer*.

Data/Product	Description	Format	Location and Availability (D=During, A=After)
Expedition Summary Map	Map showing bathymetry data collected, ROV dive sites, CTD casts, and other operations (when appropriate)	.jpg	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
Expedition Ship Track	Cumulative track of NOAA Ship *Okeanos Explorer* for each expedition	.jpg	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)

Data/Product	Description	Format	Location and Availability (D=During, A=After)
Expedition Web Summary	Summary of major initial expedition findings for the public	.html	NOAA Ocean Exploration Website (A)
Expedition Summary Fact Sheet	Summary of major initial expedition findings for the science community	.pdf	Email to science team members (A), NOAA Ocean Exploration Website (A)
Expedition Report	Report summarizing the operations and results of an expedition	.pdf	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A), NOAA Institutional Repository (A)
CTD Cast Summaries	Summary of each CTD cast, including observations and sample collections	.pdf	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
Water Column Profile Data	Water column profiles of sound velocity, XBT, and CTD data collected for mapping	.asvp, .txt, .cnv	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
Oceanographic Datasets	Raw oceanographic data, including Scientific Computing System outputs; conductivity, temperature, and depth; dissolved oxygen; light scattering; oxygen reduction potential; etc.	Various formats	NOAA Ship Okeanos Explorer data landing pages (A), NOAA Ocean Exploration Data Atlas (A)
Peer-Reviewed Publications	Published research studies that use NOAA Ocean Exploration data	.pdf	NOAA Institutional Repository (A)