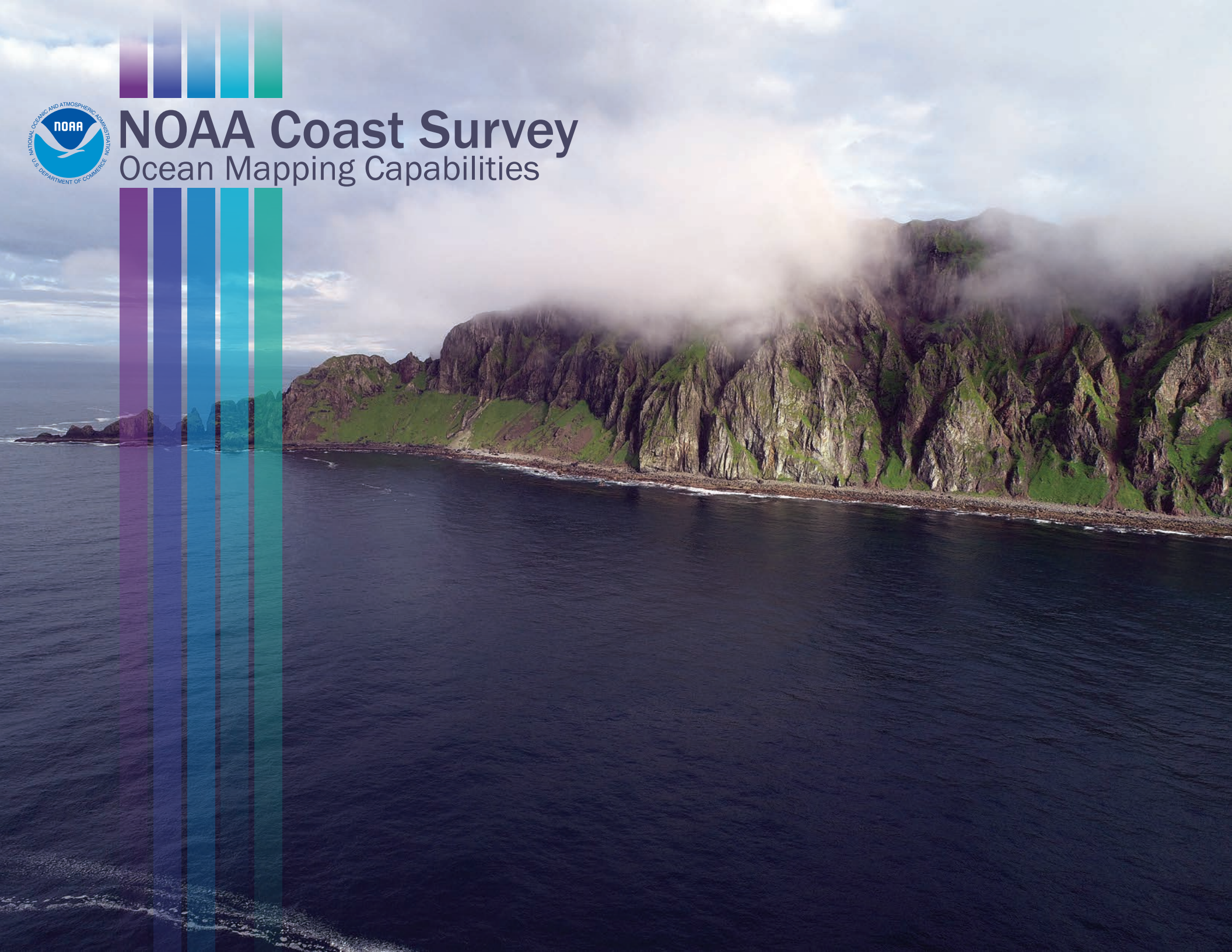




NOAA Coast Survey

Ocean Mapping Capabilities





Coast Survey leads and coordinates the United States seafloor mapping program, with a comprehensive set of capabilities. This document is a brief summary of these capabilities, which together represent a valuable national asset, available to advance societal aims in promotion of commerce, sustainable use of our oceans, conservation, and coastal resilience. Coast Survey has a long history of successful partnerships with National Oceanic and Atmospheric Administration (NOAA) programs and other federal and state programs in homeland security, biogeography, offshore energy, ocean exploration, geohazards, emergency response, and oceanographic circulation modeling.

NOAA Survey Ships

NOAA operates four large ships dedicated to hydrographic surveying: *Fairweather*, *Ferdinand R. Hassler*, *Rainier*, and *Thomas Jefferson*. Strategically placed around U.S. waters, NOAA ships are leaders in marine navigation safety and continue to provide essential data to our country. NOAA's hydrographic vessels are equipped with side scan sonar and multibeam echo sounders, which can measure ocean depths within 10 centimeter accuracy, as well as generate detailed images of the seafloor and its objects. The ships are also equipped with small, high endurance vessels called launches that survey shallow waters the larger ships cannot access.



Nearshore Mapping in Remote Locations

Coast Survey is responsible for mapping nearshore in remote locations such as Alaska and the Pacific Islands. Safety concerns often prohibit the use of NOAA ships to survey these areas. NOAA's hydrographic vessels are outfitted with survey launches to reach and survey these locations. The ships' onboard acquisition and processing expertise and flexibility for a variety of operational tasking allows Coast Survey to access and map the remote, shallow areas confidently and efficiently. No other U.S. public or private hydrographic establishment has a collection of these capabilities.

Contract Survey Capability

Hydrographic survey contractors acquire about half of the area collected each year by Coast Survey. Our contracting partners are essential to taking on the challenge of mapping the U.S. Exclusive Economic Zone and to advancing the hydrographic surveying industry. Coast Survey's hydrographic services contracting program started in 1998 and awards contracts on a 5 year cycle with firm fixed price task orders. Coast Survey awarded the current contract (2014-2019) to eight contractors with a ceiling of \$250 million and will award the next 5 year contract in 2019 with the same ceiling. Coast Survey contracts hydrographic survey services such as singlebeam and multibeam echo sounding, side scan sonar, lidar, and backscatter acquisition by means of air and surface vehicles, autonomous underwater vehicles, and unmanned surface vehicles. Other related services include tide gauge installation and hydrographic surveying emergency response.



Navigation Response Teams

Navigation response teams conduct nearshore hydrographic surveys to update NOAA's suite of nautical charts. Designed to be mobile and flexible, the teams are capable of both routine hydrographic surveys and rapid maritime response to natural disasters – hurricanes, earthquakes and human made incidents including sunken vessels and lost aids to navigation. The teams operate trailerable survey vessels equipped with both multibeam and side scan sonar that help identify dangers to navigation. They are also capable of setting up survey equipment onboard vessels of opportunity or deploying an array of surface and subsurface unmanned survey vessels. During emergency responses, they provide time sensitive information to the U.S. Coast Guard or port officials, and transmit data to NOAA cartographers for updating Coast Survey's suite of nautical charts. The three person navigation response teams are located around the country and are on call 24/7 to respond to emergencies and to protect life and property from underwater dangers to navigation.

Autonomous Survey Systems

Coast Survey has been investigating the use of autonomous survey systems to augment hydrographic survey operations since 2004. The goal is to explore how autonomy provides more efficient and effective acquisition of hydrographic environmental data to support NOAA's navigation products and services.

Autonomous underwater vehicles are unmanned systems that operate below the water's surface. Coast Survey uses both small and mid sized vehicles to complement traditional survey platforms and conduct hydrographic surveys in support of navigation safety and NOAA science. Small autonomous underwater vehicles equipped with side scan sonar enhance Coast Survey's hydrographic response capabilities. These systems can be operated from shore or small boats with minimal equipment setup and survey independently, which can free the host vessel to perform additional surveys or other necessary work. Mid sized autonomous underwater vehicles equipped with multibeam echo sounders can collect hydrographic data in depths greater than 500 meters and at a resolution much higher than possible with shipboard systems. This capability makes Coast Survey's mid sized vehicles well suited for interdisciplinary seafloor mapping missions in support of a broad range of NOAA science.



Coast Survey uses unmanned surface vehicles — autonomous systems that operate on the water's surface — equipped with multibeam echo sounders and side scan sonars. These systems complement our navigation response survey capabilities by surveying in shallow water not safely accessed by manned survey vessels. Coast Survey, with its academic partners at the University of New Hampshire and the University of Southern Mississippi, is evaluating large purpose built unmanned surface vehicles to augment manned survey platforms conducting routine hydrographic surveys. Additionally, Coast Survey is converting some shipboard hydrographic survey launches to operate as either manned or unmanned vessels. This will allow NOAA to make efficient use of current shipboard capabilities and expertise while incrementally adopting unmanned technology to increase survey efficiency and best manage personnel resources.

Expert Hydrographic Workforce

Coast Survey holds one of the largest communities of ocean mapping professionals in the federal government including NOAA Commissioned Corps officers, physical scientists and technicians. They manage all elements of the hydrographic surveying process from project planning, development of technical requirements, mobilization and calibration of survey systems, data acquisition, data quality assurance and control, and final reporting and chart product creation. Coast survey also retains project planning and management expertise, data archive capabilities, and contract vehicles/management.



Regional Navigation Managers

Coast Survey's navigation managers are stationed strategically in port areas along U.S. coasts and Great Lakes and work directly with pilots, mariners, port authorities, and recreational boaters. They are Coast Survey's eyes and ears helping to identify navigational challenges facing the marine transportation system, and providing the resources and services that promote safe and efficient navigation. They are the vital link between Coast Survey's stakeholders and our technical experts, and serve as a conduit for gathering requirements for emerging survey or charting requests and for developing new products and services. Navigation managers also lend their expertise prior to, during, and after emergencies. They regularly participate in disaster preparedness exercises and are vital to the coordination of emergency response efforts.



Specifications and Deliverables Document

NOAA's Hydrographic Surveys Specifications and Deliverables document contains the detailed technical requirements for hydrographic surveys performed by either NOAA or its contractors. Coast Survey updates the specifications annually and bases them in part on the International Hydrographic Organization's Standards for Hydrographic Surveys, Special Publication S-44. The specifications outline requirements for datums, hydrographic positioning, tides and water levels, depth soundings, acoustic backscatter, and deliverables.

NOAA's Field Procedures Manual provides best practices and standard operating procedures for field units conducting hydrographic surveys, and processing and generating hydrographic survey deliverables. These guidelines help field units meet specifications delineated in NOAA's Hydrographic Surveys Specifications and Deliverables document. Procedures outlined in the manual include system preparation and maintenance, data acquisition and processing, and data management and survey deliverables.



Hydrographic Training Program

Coast Survey's community of ocean mapping professionals is unlike any other in the U.S. We manage all components of the hydrographic surveying process from project administration, to data acquisition/processing, quality assurance/control, and new workflow/technology research and implementation. Coast Survey maintains its expertise through its annual hydrographic training. The introductory program — available to new survey technicians, NOAA Corps officers, physical scientists, and federal or state agencies — introduces hydrography as conducted by NOAA. Students come away from the course with a basic understanding of the theory behind the profession of hydrography, an improved sense of operational context, and an understanding of the resources available to them for further development. The advanced program for experienced user keeps Coast Survey's hydrographers current on the latest hydrographic surveying technologies and methods.

Risk-based Prioritization

Coast Survey defines and prioritizes hydrographic survey plans based on a hydrographic health model, a risk based model that takes into account navigational risks, including both the likelihood of a risk (traffic density and known hazards to navigation) and the consequence of a risk (proximity to search and rescue stations, proximity to reefs or marine sanctuaries). The model also considers the necessary quality of data to support modern traffic relative to what is currently available, given the seafloor changes over time. Using historic knowledge of seafloor changeability, the model can also approximate the future quality of survey data and assess how often an area needs resurveying.

Free Public Access to Archived Hydrographic Data

NOAA's National Centers for Environmental Information maintains the digital data archive for all hydrographic data collected by Coast Survey of the coastal waters and the U.S. Exclusive Economic Zone. More than 6,600 surveys dating back to 1837 are publicly available. Users can search for bathymetric attributed grid files, descriptive reports, smooth sheet images, survey data images, textual gridded data, geo referenced side scan sonar mosaics, metadata, and survey statistics. Seabed descriptions are also available for some surveys. These products support not only Coast Survey's nautical chart products, but also other disciplines such as habitat mapping, mineral and resource exploration, renewable energy development, tsunami modeling, coastal hazard planning, and management. The National Centers for Environmental Information is also a scientific steward for other sources of bathymetric and ocean depth data collected by other agencies.

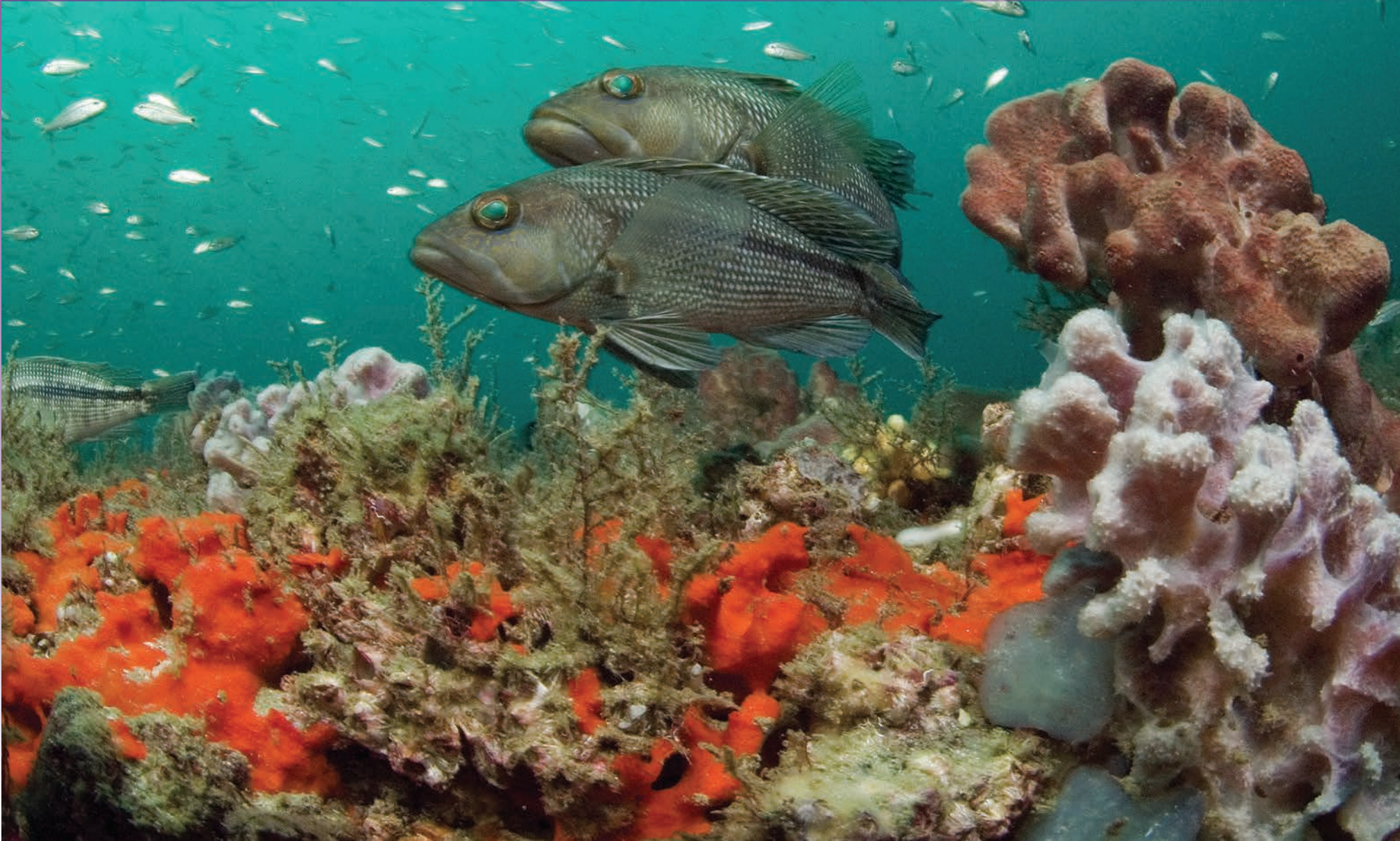
International Coordination

Hydrography underpins global commerce, recreation, transportation, conservation, and exploration. Since 1926, the United States has been a leading member state of the International Hydrographic Organization, an intergovernmental organization established to promote collaboration and partnership to map the world's oceans and protect the marine environment. As the principal national hydrographic authority for the nation, Coast Survey leads the development of policy, standards, and directions for this community of nearly 100 nations. Coast Survey represents the United States on the Regional Hydrographic Commissions of North America, Arctic, Meso American and Caribbean, and the Southwest Pacific with the aim of building capacity for ocean mapping, promoting broad availability of data, and coordinating navigation services. Together with our governmental, scientific and private sector partners, Coast Survey innovates and develops the next generation best practices supporting navigation, safety, and broader geospatial services.



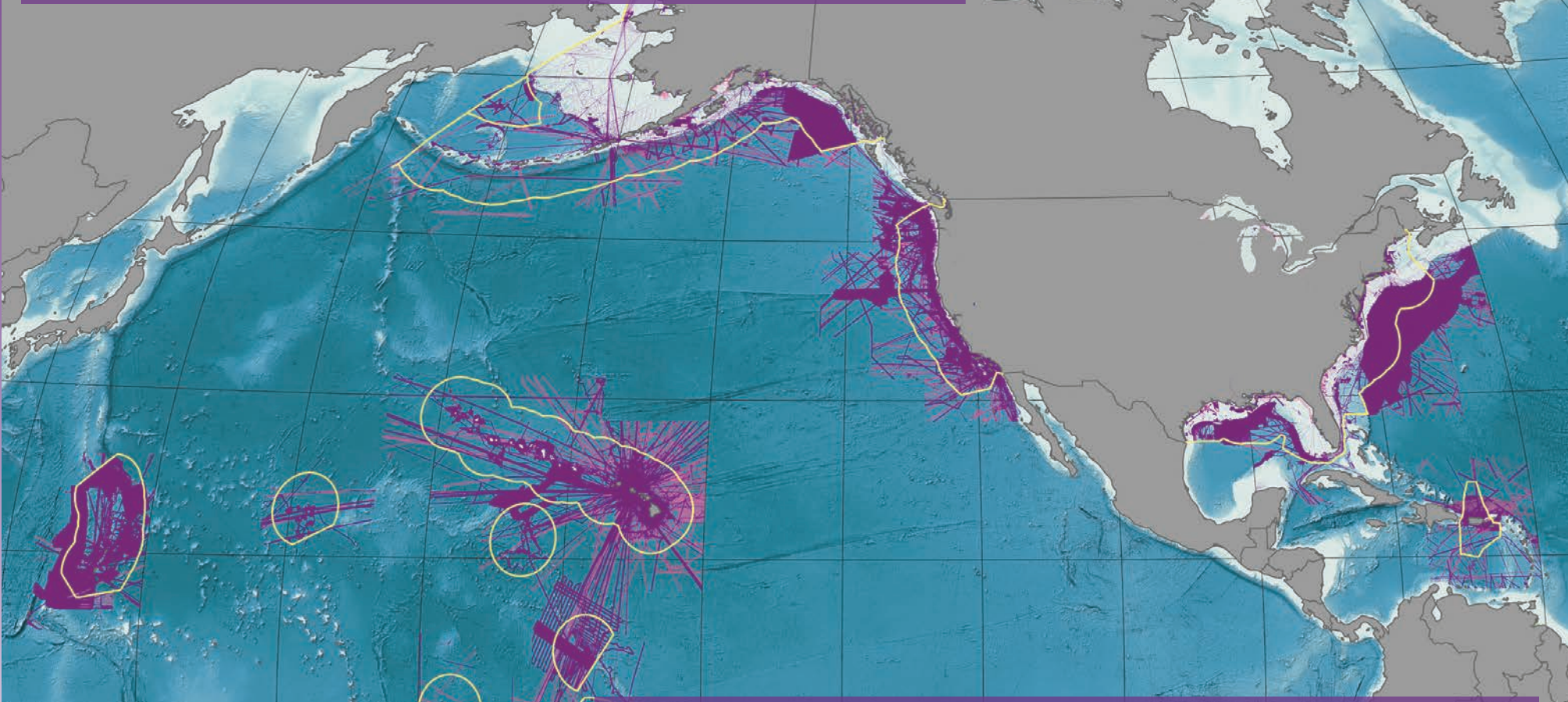
Environmental Compliance

Like all mariners, Coast Survey has a responsibility to operate with care for our shared environment. Coast Survey consults with our colleagues at the National Marine Fisheries Service, the Fish and Wildlife Service, other federal agencies, coastal states, and Native American tribes' legal counsel to ensure that we comply with environmental and historic preservation laws during our field projects. Coast Survey crews also follow best management practices that reduce or eliminate impacts to our coasts and seas, including our water, air, marine animals, and cultural resources. New technologies allow Coast Survey to collect data in environmentally friendly ways. For example, autonomous vehicles and drones consume less fuel and are less disruptive than crewed vessels. Coast Survey also uses cameras to characterize the seafloor, rather than collecting sediment samples that could damage sensitive resources such as coral.



National and International Ocean Mapping Strategies

Coast Survey, working with National Centers for Environmental Information, maintains an inventory of the current state of ocean mapping in United States waters. Coast Survey also maintains a publicly accessible crowdsourced bathymetry database to encourage public participation in ocean mapping and to capture bathymetry in remote parts of U.S. waters. Coast Survey coordinates mapping projects and data availability with our neighbors in North America, the Arctic, the Caribbean, and across the Pacific.



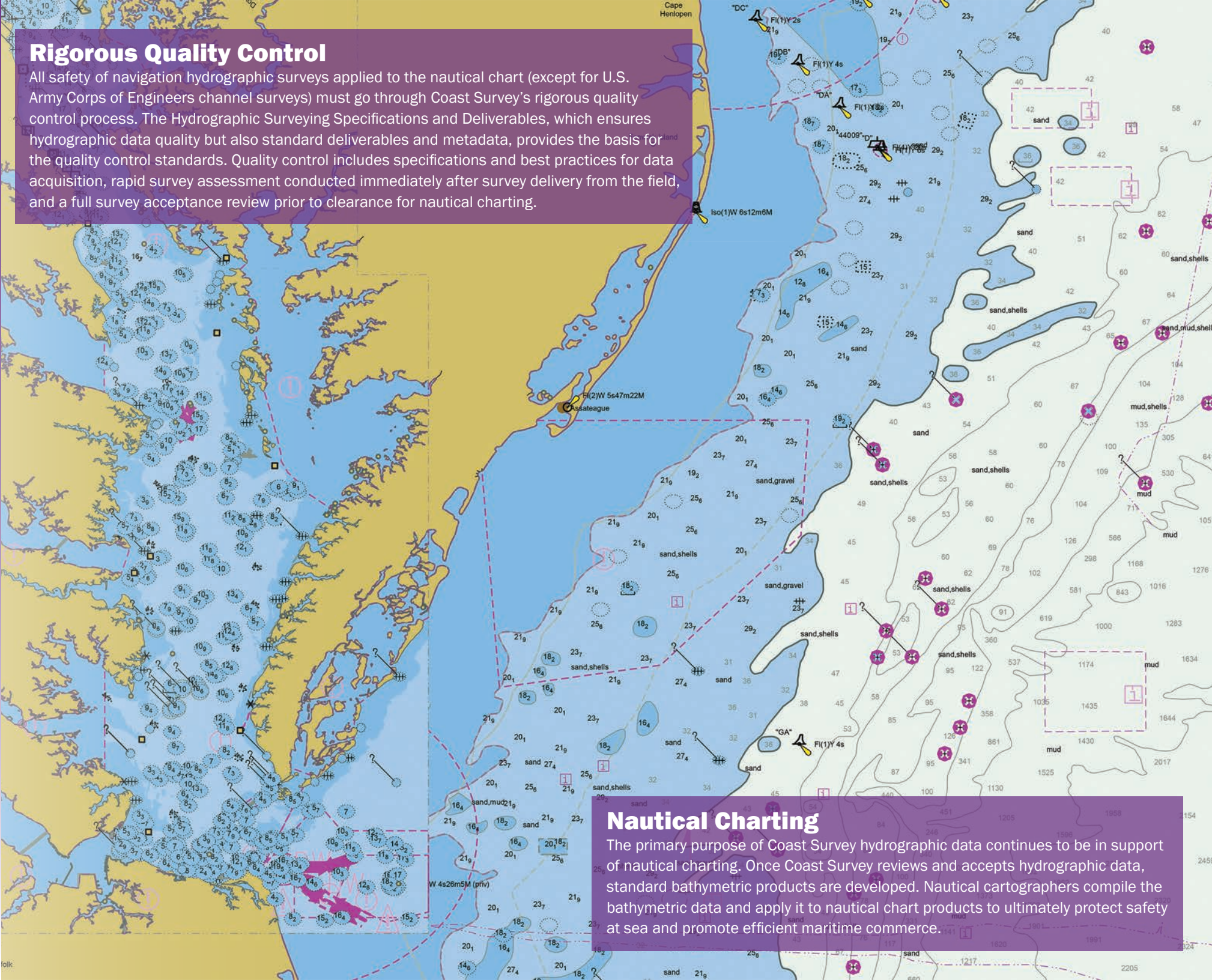
Map depicting the NOAA geospatial web services display. Areas shown in pink represent depth values derived from a single sounding. Purple areas represent depth values derived from multiple soundings.

Integrated Ocean and Coastal Mapping

Coordination is an essential element of ocean and coastal mapping operations. Coast Survey partners with federal, state, and local governments and non governmental organizations to develop mapping standards and techniques, improve data management and access, and implement cooperative projects to meet more than one mapping need while eliminating redundant efforts. These partnerships include specific projects, joint research efforts, and established ocean policy groups such as the federal Interagency Working Group on Ocean and Coastal Mapping and the 3D Elevation Program, which work together to coordinate mapping requirements and plans in support of local to global initiatives. Integrated Ocean and Coastal Mapping's goal is to help federal agencies and our partners collaborate for more opportunities to *Map Once, Use Many Times*.

Rigorous Quality Control

All safety of navigation hydrographic surveys applied to the nautical chart (except for U.S. Army Corps of Engineers channel surveys) must go through Coast Survey's rigorous quality control process. The Hydrographic Surveying Specifications and Deliverables, which ensures hydrographic data quality but also standard deliverables and metadata, provides the basis for the quality control standards. Quality control includes specifications and best practices for data acquisition, rapid survey assessment conducted immediately after survey delivery from the field, and a full survey acceptance review prior to clearance for nautical charting.



Nautical Charting

The primary purpose of Coast Survey hydrographic data continues to be in support of nautical charting. Once Coast Survey reviews and accepts hydrographic data, standard bathymetric products are developed. Nautical cartographers compile the bathymetric data and apply it to nautical chart products to ultimately protect safety at sea and promote efficient maritime commerce.

Precision Navigation

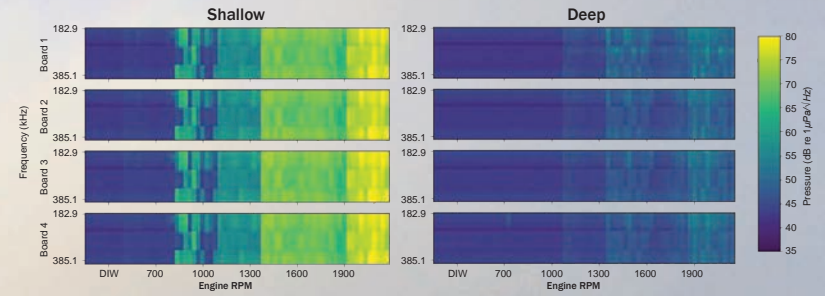
Today's ships are moving through U.S. ports with little room under their keels — in some cases, less than one foot. As vessel drafts increase, the navigation margins become smaller and the need for more accurate information increases. The *just-in-time* supply chain upon which the U.S. economy depends demands that ports operate efficiently. However, delays and lightering due to the uncertainties posed by environmental factors equate to millions of dollars a year in lost revenue for shipping companies and ports.

NOAA's Precision Navigation program aims to seamlessly integrate high-resolution bathymetry, high accuracy positioning, and shoreline data with real-time observations, near-term predictions, and forecast data. This combined data is then presented in a format that can be easily accessed and integrated into pilot units or commercial-off-the-shelf electronic navigation decision support tools. As a result, mariners are better equipped to make critical navigation decisions and seaports can increase capacity and efficiency while improving safety.



Sonar Acceptance and Calibration

Coast Survey supports and performs multibeam sonar acceptance testing and calibrations for the NOAA fleet of hydrographic vessels. Systematically performed since 2013, the process has resulted in a standardized methodology developed in conjunction with the U.S. Academic Research Fleet based Multibeam Advisory Committee. This standardization allows for comparisons among platforms, facilitates characterizations of systematic issues, and provides guidance for future installations. Coast Survey documents all tests and system details in an acceptance testing report, which provides a reference for the vessel and forms a baseline for subsequent testing. Through a user-friendly testing interface, the platforms can replicate acceptance tests to monitor system health and troubleshoot issues through delivery of the results to Coast Survey or the system manufacturers.

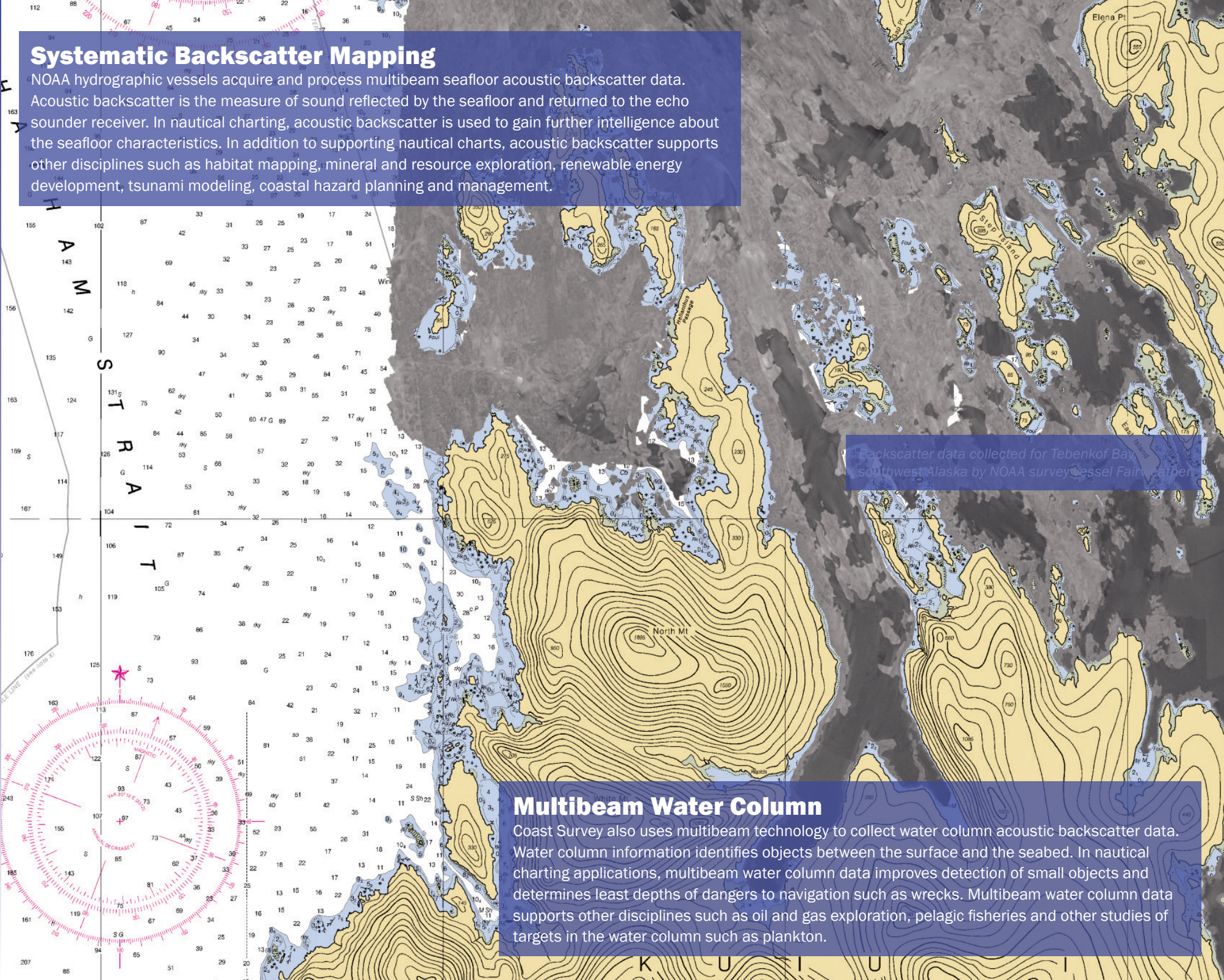


Noise test results from NOAA Ship Fairweather Launch 2806 sonar acceptance for Kongsberg EM2040 multibeam sonar. Shows noise generated by the vessel at different speeds and frequencies in areas with shallow (less than 15 meters) and deep (greater than 100 meters) water.



Systematic Backscatter Mapping

NOAA hydrographic vessels acquire and process multibeam seafloor acoustic backscatter data. Acoustic backscatter is the measure of sound reflected by the seafloor and returned to the echo sounder receiver. In nautical charting, acoustic backscatter is used to gain further intelligence about the seafloor characteristics. In addition to supporting nautical charts, acoustic backscatter supports other disciplines such as habitat mapping, mineral and resource exploration, renewable energy development, tsunami modeling, coastal hazard planning and management.



Backscatter data collected for Tebenkof Bay southwest Alaska by NOAA survey vessel Fairweather

Multibeam Water Column

Coast Survey also uses multibeam technology to collect water column acoustic backscatter data. Water column information identifies objects between the surface and the seabed. In nautical charting applications, multibeam water column data improves detection of small objects and determines least depths of dangers to navigation such as wrecks. Multibeam water column data supports other disciplines such as oil and gas exploration, pelagic fisheries and other studies of targets in the water column such as plankton.

Datums, Water Level Measurement, and Modeling

A datum is any reference system against which measurements are made and forms the basis of all hydrographic survey work. Coast Survey collaborates with the Center for Operational Oceanographic Products and Services and the National Geodetic Survey to coordinate measurements and modeling of water levels and datums. Continuous measurements supply real-time tidal data and long-term datum relationships at discrete points along the U.S. coastline. The National Spatial Reference System includes a network of permanently marked points; a consistent, accurate, and up-to-date national shoreline; a network of Continuously Operating Reference Stations which supports 3D positioning activities; and a set of accurate models describing dynamic, geophysical processes that affect spatial measurements. Water levels and datums enable monitoring of seafloor and coastal change, and are required for accurate hydrographic survey data.



Ocean Mapping Research and Development Program

The Joint Hydrographic Center at the University of New Hampshire is a research partnership funded and operated to develop innovative technology for hydrography and ocean mapping. Research at the center spans a wide range of topics including processing and analysis of hydrographic data; acoustic, lidar, and optical characterization of seafloor habitat and water column; multi dimensional visualization of coastal and ocean data; effective display of electronic navigation information; and autonomous surface vessels for ocean mapping.

Data Visualization Research Laboratory at the Joint Hydrographic Center's semi-immersive, large format tiled display, showing ocean currents from the Navy Coastal Ocean Model.

The Joint Hydrographic Center and the associated University of New Hampshire Center for Coastal and Ocean Mapping are responsible for major advances in hydrographic science. These include the widely used CUBE algorithm for bathymetric data processing, the GeoCoder algorithm for seafloor characterization, and algorithms for the detection and display of seafloor gas seeps with bathymetric echo sounders — a technology that has proven valuable to the commercial sector. The center's transition of technology from research to operations functions primarily through the Center for Coastal and Ocean Mapping's industrial partnership program with more than 40 major hydrographic and ocean mapping corporations and institutions.



Ocean Mapping Research and Development Program

The Hydrographic Science Research Center at the University of Southern Mississippi works to expand the use of autonomy technology in seabed mapping and ocean cartography. The center performs research funded by grants through the Northern Gulf Institute. Autonomous solutions can be far more efficient than traditional methods of hydrographic surveys. Unmanned surface vehicles, unmanned aerial vehicles and autonomous underwater vehicles can be deployed from almost anywhere. Their state of the art guidance systems speed survey progress, and reduce the need for infill lines. Autonomous systems do not require ports and can access areas that are either too hazardous or too difficult for conventional vessels to get to, expanding the extent of survey coverage and enabling safer operations.

Contact and Information

Office of Coast Survey
nauticalcharts.noaa.gov

Center for Coastal and Ocean Mapping/Joint Hydrographic Center
ccom.unh.edu

University of Southern Mississippi
usm.edu

National Ocean Service
oceanservice.noaa.gov

National Oceanic and Atmospheric Administration
noaa.gov

