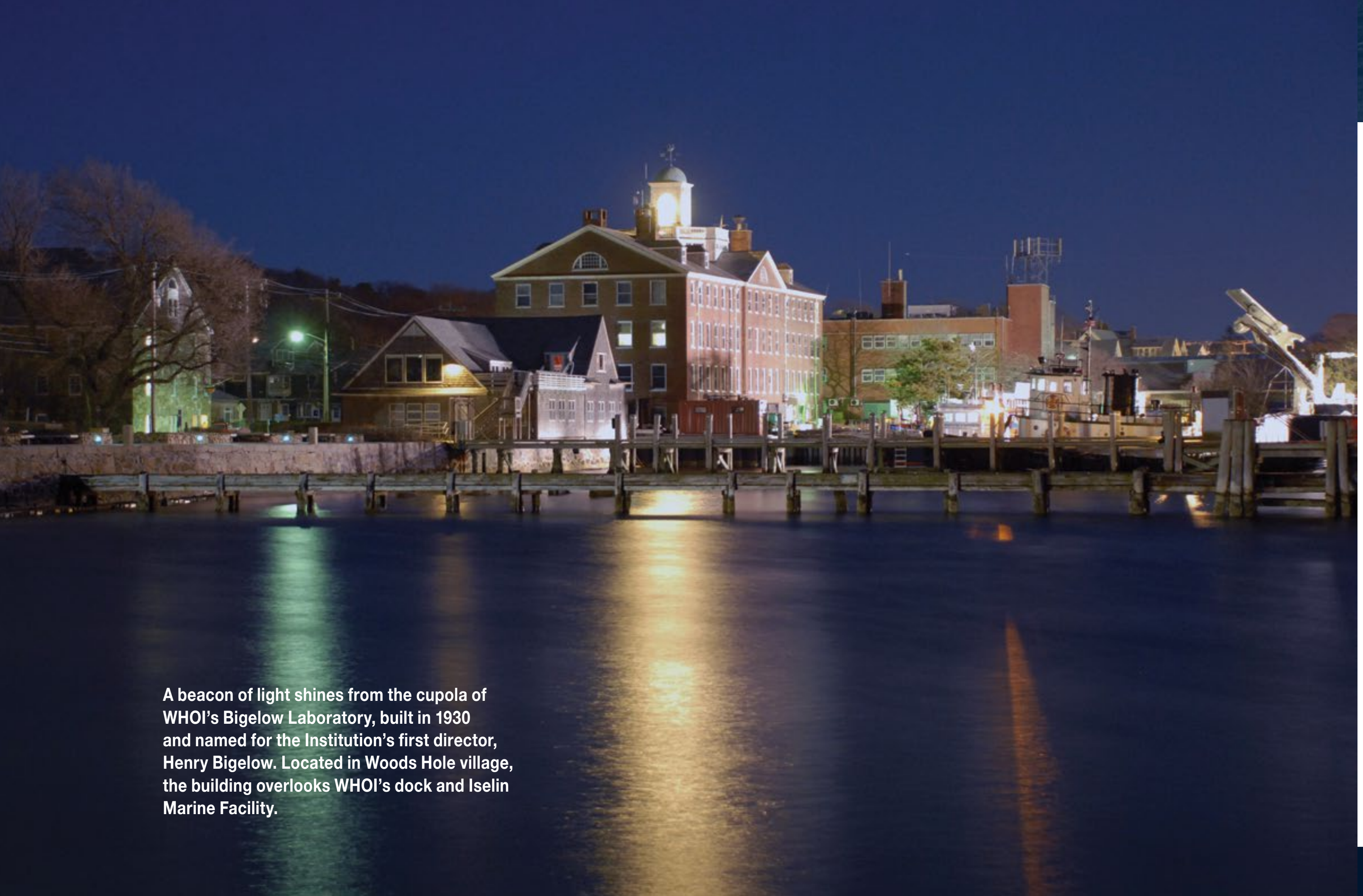
VESSELS & VEHICLES

Woods Hole Oceanographic Institution



A beacon of light shines from the cupola of WHOI's Bigelow Laboratory, built in 1930 and named for the Institution's first director, Henry Bigelow. Located in Woods Hole village, the building overlooks WHOI's dock and Iselin Marine Facility.

James Saenz, WHOI

Woods Hole Oceanographic Institution Vessels & Vehicles

In order to understand the ocean, you have to get in the middle of it. Traditionally, researchers have used ships to photograph the depths, to drop floats and drifters into the currents, and to collect samples of water, rock, and marine life. In recent decades, the observing tools have evolved to include human-occupied submersibles, remote-controlled vehicles, and autonomous robots. Currently, researchers are deploying arrays of instruments connected to shore by seafloor cables—or via satellite from ocean moorings—to deliver continuous, real-time data on ocean processes to a scientist's desktop.

But even as technological advances allow researchers to monitor the seas from shore-based labs, scientists rely on sophisticated ships to get a first-hand look at the environment and to carry their tools and instruments into it. Woods Hole Oceanographic Institution (WHOI) operates a range of vessels and vehicles in support of such efforts.

WHOI is a member of the University-National Oceanographic Laboratory System (UNOLS), a consortium of 62 U.S. academic institutions and national laboratories. Those partners coordinate scientific expeditions aboard 20 federally supported research vessels.

WHOI currently operates two ships for UNOLS, and the Institution also owns and operates a coastal research vessel for work in Northeastern waters. Each of these floating laboratories comes with a range of sonar and bottom-mapping equipment, sampling gear, diving and small-boat launching facilities, and meteorological sensors.

As host institution for the National Deep Submergence Facility, WHOI operates and maintains the nation's deepest-diving human-occupied vehicle (HOV), *Alvin*. For five decades, the submersible has brought scientists to the deep seafloor, allowing them to explore a sunless world of extreme pressures and unique creatures.

The ships and *Alvin* submersible are complemented by remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). ROVs are tethered to a support ship by fiber-optic cable and controlled by pilots on the surface. AUVs are untethered robots that are dispatched on programmed missions. Both types of vehicles can remain submerged much longer than HOVs, making them ideal for surveys and mapping.

The following pages provide a glimpse of the principle vessels and vehicles operated—and sometimes built—by WHOI scientists, engineers, and crew members.

R/V *Atlantis*

The research vessel (R/V) *Atlantis* is owned by the U.S. Navy and operated by WHOI for the oceanographic community. It is one of the most sophisticated research vessels afloat, and it is specifically outfitted for launching and servicing the *Alvin* human-occupied submersible.

Delivered to Woods Hole in April 1997, *Atlantis* was built with six science labs and storage spaces, precision navigation systems, seafloor mapping sonar, and satellite communications. The ship's three winches, three cranes, machine shop, and specialized hangars were specifically designed to support *Alvin* and other vehicles of the National Deep Submergence Facility (page 23).

The ship carries a complement of 36 crew members, science technicians, and deep submergence group members, as well as a scientific party of 24 men and women for as long as 60 days. Because *Atlantis* goes where *Alvin* is needed for exploration, the ship operates in all of the world's oceans and is rarely seen in Woods Hole. In recent years, the ship and sub have spent most of their time exploring underwater volcanoes and hydrothermal vents in the Pacific Ocean.

Atlantis is part of a class of similar Navy-owned research vessels designed and built by Halter Marine of Pascagoula, Mississippi. Similar-class ships include R/V *Thomas G. Thompson*, operated by the University of Washington, and R/V *Roger Revelle*, operated by the Scripps Institution of Oceanography. *Atlantis* is the only vessel designed to support both *Alvin* and general oceanographic research.

Atlantis is the namesake of WHOI's first research vessel, a 142-foot, steel-hulled, ketch-rigged ship that sailed 299 cruises and more than 700,000 miles for ocean science from 1931 to 1966. The Institution's flagship and symbol, it was the first American ship built specifically for research in marine biology, marine geology, and physical oceanography. The space shuttle *Atlantis* was named for the original WHOI research vessel.

Specifications:
Range: 32,000 kilometers (17,280 nautical miles)
Speed: 20.4 kilometers/hour (11.0 knots) cruising
Length: 83.2 meters (273.2 feet)
Beam: 16 meters (52.5 feet)
Draft: 5.8 meters (19 feet)
Laboratory space: 327 sq. meters (3,517 sq. feet)
Gross Tons: 3,200

Chris Linder, WHOI

Delivered to Woods Hole in April 1997, *Atlantis* was built with six science labs and storage spaces, precision navigation systems, seafloor mapping sonar, and satellite communications. The ship's three winches, three cranes, machine shop, and specialized hangars were specifically designed to support *Alvin* and other vehicles of the National Deep Submergence Facility (page 23).

R/V *Neil Armstrong*

The newest member of the WHOI fleet, the R/V *Neil Armstrong* is owned by the U.S. Navy and operated by WHOI for the ocean research community. Named for the American hero whose "small step" provided humanity with a new perspective on our planet, this vessel will carry on its namesake's legacy of exploration and is the first oceanographic research vessel named for a space explorer. The 238-foot R/V *Neil Armstrong* will carry a complement of 20 crew members and 24 scientists for as many as 40 days.

The new ship features a number of enhanced capabilities for scientists working on board. These include acoustic navigation and tracking systems that operate at various depths; a specially designed hull that diverts bubbles from the sonar area; a centralized freshwater cooling system to provide heating, ventilation and air conditioning; and dual-controllable propellers with variable speed motors for increased efficiency. New systems designed to improve the safety of scientific operations and enable the vessel to effectively operate in higher sea states than existing vessels of this size include advanced over-the-side handling systems and state-of-the-art hull mounted bottom mapping and acoustics transducers.

One of two new research vessels in the "Armstrong Class" of ships, the vessel was commissioned by the U.S. Navy and built by Dakota Creek Industries, Inc., shipyard in Anacortes, WA. The *Neil Armstrong* will serve a pressing need for a new general-purpose research vessel based on the U.S. East Coast and will be deployed for a wide variety of oceanographic and ocean engineering missions. The ship is also expected to support new initiatives in ocean observing in high latitudes, as well as new efforts to study North Atlantic ecosystems and their sustainability. Its sister ship, the R/V *Sally Ride,* will be operated by the Scripps Institution of Oceanography and will enter service in late 2015.

The *Neil Armstrong* was launched in early 2014 and will enter service in spring 2015.

Specifications:
Range: 21,298 kilometers (11,500 nautical miles)
Speed: 22.2 kilometers/hour (11.0 knots) cruising
Length: 72.6 meters (238 feet)
Beam: 15.24 meters (50 feet)
Draft: 4.57 meters (15 feet)
Main Laboratory space: 95.0398 sq. meters (1,023 sq. feet)
Gross Tons: 3,204 long tons

Steve Berentson, WHOI

The 238-foot (72.6-meter) vessel, *Neil Armstrong* can stay at sea for up to five weeks. It is equipped with sophisticated navigation and communication systems and can accommodate a wide variety of scientific projects.

R/V *Tioga*

The R/V *Tioga* is an aluminum-hulled coastal research vessel that serves ocean scientists and engineers working in the waters off the Northeastern United States. *Tioga* is owned by Woods Hole Oceanographic Institution.

Launched in 2004, this small, fast research boat was designed and outfitted for oceanographic work close to shore. Speed allows *Tioga* to operate in narrow weather windows, meaning researchers can get out to sea, complete their work, and make it back before approaching foul weather systems arrive.

Tioga can accommodate six people for overnight trips—including the captain and first mate—and up to 10 people for day trips. The boat is equipped with water samplers, a current profiler, and an echo-sounder, used by scientists to conduct seafloor surveys. *Tioga* has two winches, including one with electrical wires to collect real-time data from towed underwater instruments. Buoys can be deployed using the A-frame on the stern, which is similar in size to those on WHOI's large ships.

Since its delivery to Woods Hole in April 2004, *Tioga* has been used to collect water samples during harmful algal blooms ("red tides") and oil spills; to recover autonomous "gliders"; to test and deploy new instruments; to tag right whales with monitoring instruments; and to provide an introduction to ocean sampling techniques for undergraduates and graduate students. The boat has made dozens of trips to WHOI's Martha's Vineyard Coastal Observatory.

Designed in part by Roger Long Marine Architecture of Cape Elizabeth, Maine, *Tioga* was engineered and built by Gladding-Hearn Shipbuilding of Somerset, Massachusetts.

The name *Tioga* comes from an Iroquois word meaning "swift current." It is also a Seneca name meaning "the meeting of two rivers."

Specifications:
Range: 555 kilometers (300 nautical miles)
Speed: 33 kilometers/hour (18 knots) cruising
Length: 18.3 meters (60 feet)
Beam: 5.2 meters (17 feet)
Draft: 1.5 meters (5 feet)
Laboratory space: 18.5 sq. meters (200 sq. feet)
Gross Tons: 53

Tom Kleindinst, WHOI

The nimble and speedy *Tioga* mostly plies the waters around Cape Cod, though it has worked as far south as New Jersey.

Alvin

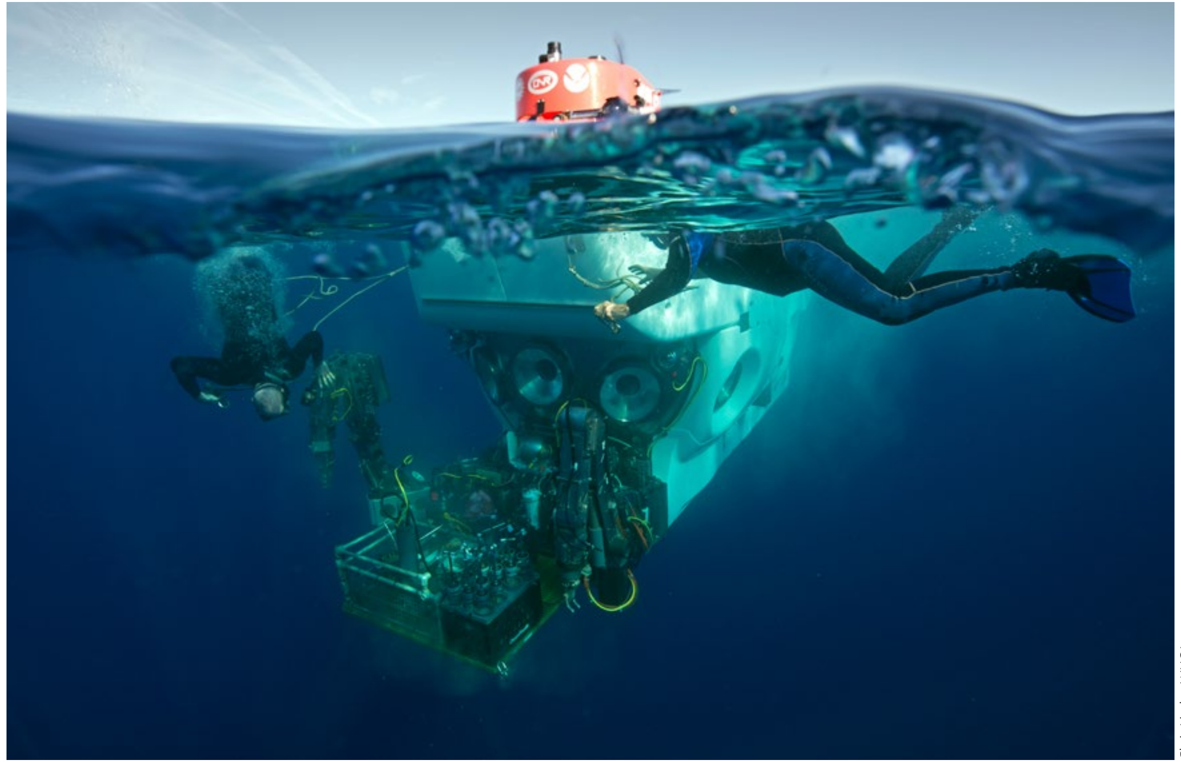
Alvin is the world's longest-operating deep-sea submersible. It was launched in 1964 and has made more than 4,700 dives, along the way participating in some of the most iconic discoveries in the deep ocean. From 2011 and into 2014, *Alvin* underwent a comprehensive overhaul and upgrade largely funded by the National Science Foundation, which greatly expanded its capabilities and eventually will put almost the entire ocean floor within its reach.

Alvin is owned by the U.S. Navy and is operated by WHOI through the National Deep Submergence Facility. The sub is named for Allyn Vine, a WHOI engineer and geophysicist who helped pioneer deep submergence research and technology.

Alvin's most famous exploits include locating a lost hydrogen bomb in the Mediterranean Sea in 1966, exploring the first known hydrothermal vent sites in the 1970s, and surveying the wreck of RMS *Titanic* in 1986. In its final series of dives before its recent upgrade, *Alvin* explored deep-sea biological communities in the Gulf of Mexico near the site of the *Deepwater Horizon* blowout and oil spill.

Alvin returned to service in early 2014, having completed the first phase of a major upgrade. *Alvin* now boasts several new improvements including a new titanium personnel sphere, which is significantly larger, with ergonomic improvements, larger and improved viewport visibility, enhanced lighting and camera systems, which are all rated to a depth of 6,500 meters. During a future second phase upgrade, the sub will be powered by a new battery system and will be capable of descending to 6,500 meters depth, putting 98 percent of the seafloor within our reach.

Specifications:
Length: 7 meters (23.1 feet)
Beam: 2.5 meters (8.4 feet)
Height: 3.7 meters (12.1 feet)
Weight: 26.5 tons (53,000 pounds)
***decreasing in Stage 2*
Operating Depth: 4,500 meters (14,764 feet)
increasing to 6,500 m in Stage 2 (21,325 feet)
Dive Duration: 6-10 hours
increasing to 8–12 hrs in Stage 2
Science Basket Payload: 400 lbs.
Personnel Sphere Volume: 171 cubic feet



Chris Linder, WHOI

Built as the world's first deep-ocean submersible, *Alvin* has made more than 4,700 dives and, after the Stage 2 upgrades, will put 98 percent of the seafloor within reach.

Jason/Medea

Jason is a remotely operated vehicle (ROV) designed and built by WHOI's Deep Submergence Laboratory to allow scientists to access 98 percent of the seafloor without leaving the ship. As part of the National Deep Submergence Facility at WHOI, *Jason* is a national asset used by ocean scientists across the country.

Jason is a portable, two-body ROV system. A 7-kilometer fiber-optic tether delivers electrical power and telemetry from the ship through *Medea* to *Jason*, which then returns data and live video imagery. Suspended in the water above *Jason*, *Medea* serves to isolate *Jason* from the movements of the ship, while providing lighting during sea-floor operations.

Jason is equipped with sonar, water samplers, video and still cameras, and lighting gear. *Jason's* manipulators collect samples of rock, sediment, or marine life and can place them in the vehicle's basket or on "elevator" platforms that float heavier loads to the surface.

Pilots and scientists work from a control room on the ship to monitor *Jason's* instruments and video while maneuvering the vehicle. The average *Jason* dive lasts a day, though operators have kept the vehicle down for as long as 8 days.

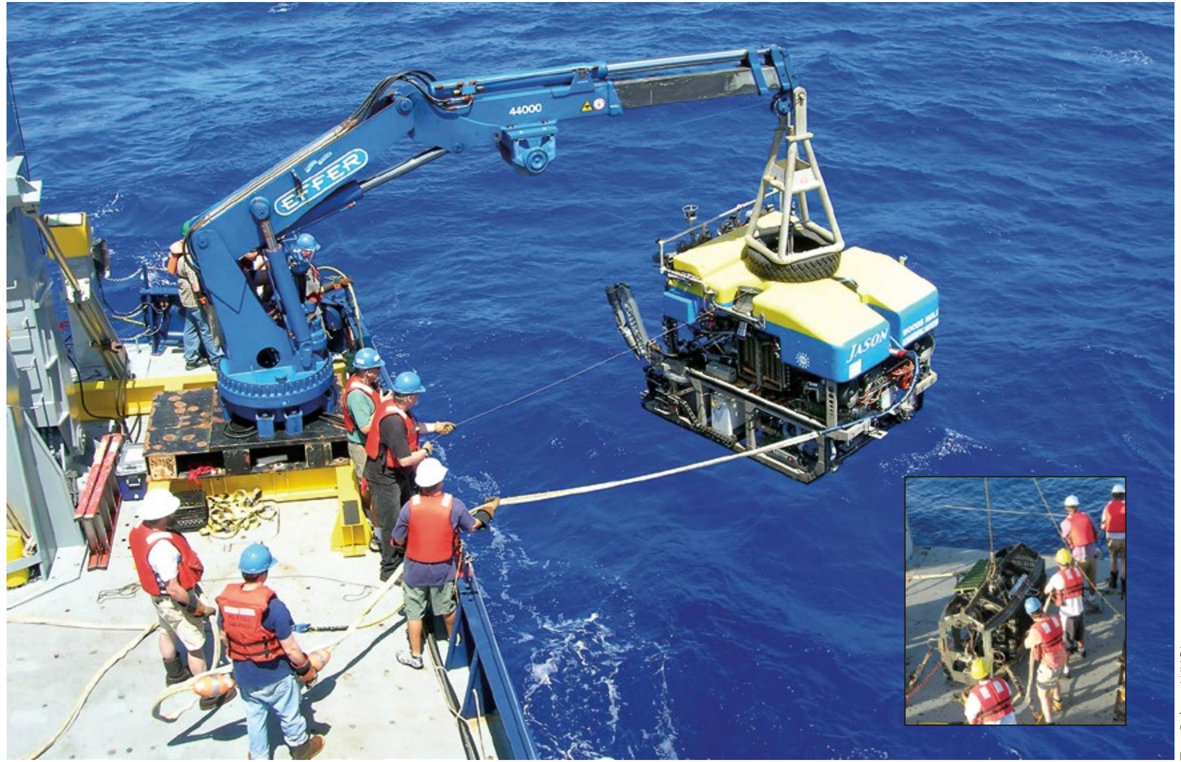
Jason was first launched in 1988, and the system has been used for hundreds of dives in oceans around the world. In 2002, with funding from the National Science Foundation, the Office of Naval Research, The W.M. Keck Foundation, and WHOI, a sturdier, more advanced, second generation *Jason* was developed.

A prototype version named *Jason Jr.* was used to survey the wreck of RMS *Titanic* in 1986, and the fully developed *Jason* visited a 1,600-year-old Roman trading ship in 1989. Since its early achievements, *Jason* has extensively explored the deep ocean, encountering an active volcanic eruption on the sea floor in 2009, and enabling many biological, chemical, and geological discoveries.

Jason and *Medea* are named for the adventurous ocean explorer of Greek mythology and for his wife.

Specifications:

Depth Capability: 6,500 m (21,325 ft)
Dimensions: 3.4 m (134") long, 2.4 m (96") high, 2.2 m (88") wide
Weight: 4,128 kg (10,000 lbs.) in air (approx.) -
Tether: 70 m long, 20 mm (0.8") diameter, neutrally buoyant
Maximum Vehicle Speed: 1.5 knots forward, 0.5 knot lateral, 1.0 knot vertical
Propulsion: Six brushless DC electric thrusters, 250 lbs. of thrust



Tom Bolmer, WHOI

The remotely operated vehicle *Jason* is lowered in the Pacific Ocean in 2006 to explore an erupting underwater volcano near the Mariana Islands. Sensors left near the site indicated that the volcano, called Northwest Rota-1, still showed signs of activity. The deep-sea explorer returned to the site in April 2009, where scientists found that the volcano was still erupting. *Medea* (inset) is *Jason*'s partner vehicle. *Medea* serves a tether management role that decouples *Jason* from surface motion.

Sentry

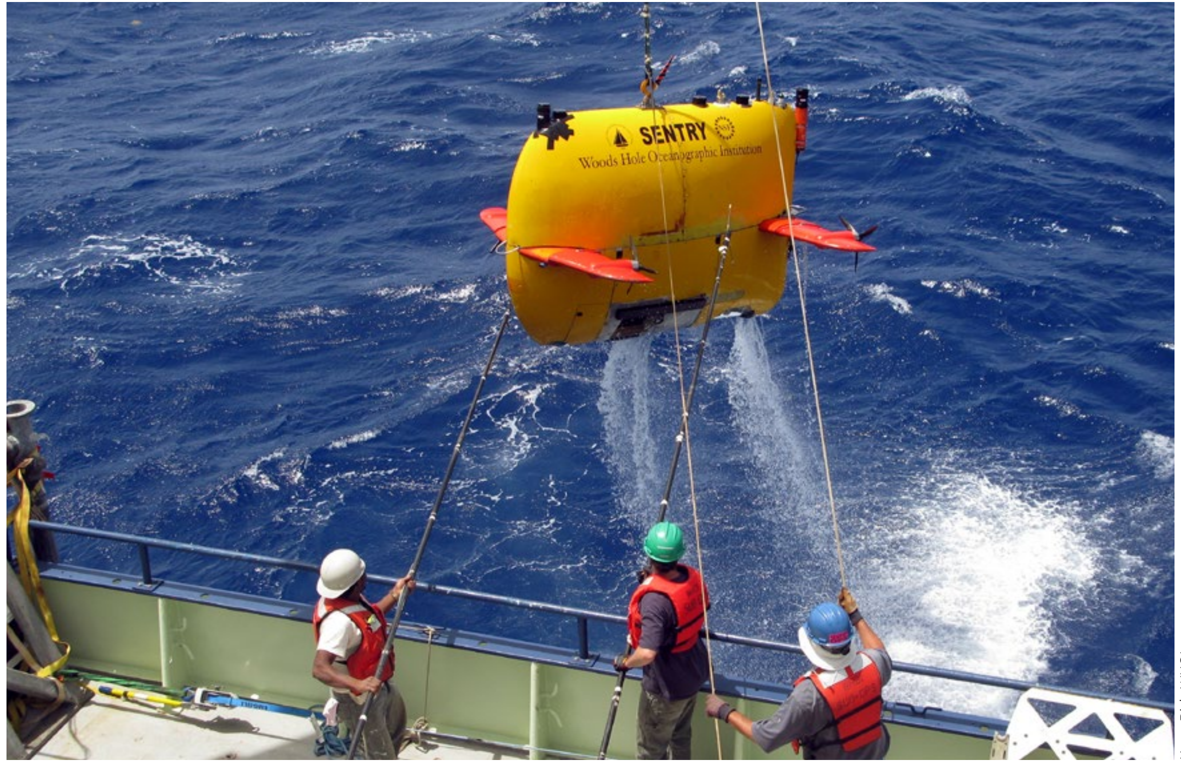
The autonomous underwater vehicle (AUV) *Sentry* was designed and built at WHOI with funding from the National Science Foundation. *Sentry* can operate to 6,000 meters (19,685 feet) depth, with a design that emphasizes extreme maneuverability, close bottom following, large and innovative payloads, and rapid transit to and from the seafloor. As part of the National Deep Submergence Facility, *Sentry* is a national asset used by ocean scientists across the country.

Sentry can be mobilized readily for use as a stand-alone vehicle on a wide range of research vessels but can also be used very effectively in tandem with *Alvin* and an ROV such as the NDSF's *Jason* or a variety of other cabled or tethered assets to improve the efficiency of deep submergence investigations. *Sentry* produces bathymetric, sidescan, chemical, and magnetic maps of the seafloor and is capable of taking high-quality, digital, color photographs in a variety of deep-sea terrains including along mid-ocean ridges and at ocean margins and in complex settings such as hydrothermal vent and cold seep ecosystems.

The acoustic communications in *Sentry's* navigation system can give the vehicle's operators information on the vehicle's state and sensor status, as well as allow them to re-task the vehicle in mid-mission.

Sentry is increasingly being utilized for a much wider range of oceanographic applications. In addition to its standard sensors, *Sentry* has carried numerous custom sensors and recently began taking pumped filter samples. The *Sentry* operations team is always on the look out for new collaborations to develop new missions and applications for the vehicle.

Specifications:
Depth Capability: 6,000 meters (19,685 feet)
Dimensions: Length: 2.9 meters (9.7 feet)
Width (with fins extended): 2.2 meters (7.2 feet)
Height 1.8 meters (5.8 feet)
Weight: 1,250 kilograms (2,750 pounds) without extra science gear
Operating Range: 50-70 kilometers, (38-54 mile) depending on speed, terrain and payload
Operating Speed: 0–1.2 m/s (0–2.3 knots)
Propulsion: Four brushless DC electric thrusters on pivoting wings
Endurance: 18-40 hours depending on mission type
Turnaround time: 16 hours



Henry Dick, WHOI

Sentry is a state-of-the-art, free-swimming underwater robot that can operate independently, without tethers or other connections to a research ship. The autonomous underwater vehicle, or AUV, is pre-programmed with guidance for deep-water surveying, but it can also make its own decisions about navigation on the mountainous volcanic terrain of the seafloor.

Nereid Under-Ice (NUI)

The newest robot in the WHOI fleet is *Nereid* Under Ice (NUI), a remotely operated vehicle that provides scientific access to under-ice and ice-margin environments. The new vehicle enables exploration and detailed examination of biological and physical ice-margin and under-ice environments through the use of high-definition video and a range of acoustic, chemical, and biological sensors tailored to suit the needs of an individual expedition.

Developed by engineers in WHOI's Deep Submergence Laboratory and their colleagues at Johns Hopkins University and the University of New Hampshire, the robotic underwater vehicle provides scientists studying polar regions with a real-time capability to operate a remotely-controlled inspection and survey vehicle under ice, unconstrained by the motions of a support vessel.

In July 2014, NUI successfully completed its first under-ice field expedition from aboard the Alfred Wegener Institute's ice-breaker *Polarstern*. In addition to conducting engineering trials and collecting video imagery beneath the ice, the vehicle was equipped with various biological sensors for studying near-ice primary productivity.

The vehicle's development was funded by the National Science Foundation and WHOI.

Specifications:

Depth: 2,000 meters (6,561 feet)

Weight on land: 1,800-2,000 kilograms (4,409 lbs.) depending on configuration.

Range: 40 km @ 1 m/sec plus 20 km reserve (preliminary). Maximum speed in excess of 1.3 m/s.

Batteries: 18 kWhr lithium-ion

Thrusters: 8 total, configured such that any one and most combinations of two can be damaged without rendering the vehicle unable to return to a support vessel

Lights: LED lighting (8 DSPL Sphere, dimmable),

Sonar: Blueview P900 imaging sonar for obstacle avoidance

Chris German, WHOI

Nereid Under Ice prior to recovery from the edge of pack ice in the Fram Strait during August 2014 sea trials.

SeaBED-class AUVs

Developed and built by engineers in WHOI's Deep Submergence Laboratory, SeaBED-class autonomous underwater vehicles (AUVs) can hover over seafloor targets like a helicopter or "fly" slowly in shallow to deep water depths. The original SeaBED vehicle can descend to depths of 2,000 meters (6,500 feet), enabling it to explore the continental shelves in most of the world's oceans. WHOI also built two other vehicles, *Puma* and *Jaguar*, which share the same characteristics but are rated to operate to 6,000 meters (19, 685 feet). In addition, clones of these vehicles have been built at WHOI for other institutions including the Australian Center for Field Robotics, the National Sun-Yat-Sen University in Taiwan, the Northwest Fisheries Science Center, the Pacific Islands Fisheries Science Center, the University of Puerto Rico, and the University of Southern Mississippi.

SeaBED is particularly well suited to collecting sonar maps and photographs of the seafloor, even in rugged terrain. The AUV has been designed specifically to further the development of underwater color imaging, photo mosaicking, and three-dimensional image reconstruction. SeaBED also includes sensors for measuring currents and water properties.

These vehicles have been involved in missions designed to look for hydrothermal venting under the Arctic ice cap, conduct deep water archaeology in the Mediterranean, look at coral reefs in Bermuda, Puerto Rico, and Hawaii, and for fisheries-related work across the U.S. West Coast, and the Caribbean. In recent years, there has been an increased focus on using these vehicles for under ice missions in the Arctic and the Antarctic.

SeaBED Specifications:

Operating depth: 6,561 feet (2,000 meters)
Dimensions: 2 meters long (6 feet), 1.5 meters tall (4 feet)
Weight: 300 kilograms (661 pounds)
Average speed: .3-.5 meters/second
Powered by: two kilowatt-hours of lithium-ion batteries
Primary sensing: stereo camera and multi-beam

Puma and Jaguar Specifications:

Operating depth: 5,000 meters (16,404 feet)
Dimensions: 2 meters long (6 feet), 1.5 meters tall (4 feet)
Weight: 400 kilograms (881 pounds)
Average speed: .3-.5 meters/second
Powered by: six kilowatt-hours of lithium-ion batteries
Primary sensing: stereo camera and multi-beam

Chris Linder, WHOI

Chris Linder, WHOI

Hanumant Singh, WHOI

Jaguar (left) is an autonomous underwater vehicle built for use under the Arctic ice. *Puma* (top)—an under-ice autonomous underwater vehicle—has sonars and sensors to search wide areas and detect temperature, chemical, or turbidity signals from hydrothermal vent plumes. SeaBED (bottom) is an autonomous underwater vehicle that can fly slowly or hover over the seafloor to depths of 6,561 feet (2,000 meters), making it particularly suited to collect highly detailed sonar and optical images of the seafloor.

REMUS

Invented by engineers in the WHOI Oceanographic Systems Lab, Remote Environmental Monitoring Units, or REMUS autonomous underwater vehicles (AUVs) were initially conceived for coastal monitoring, but are now used as platforms for a wide variety of sensors and instruments. There are now four REMUS AUV designs with different maximum depth limits – 100, 600, 3,000, and 6,000 meters. Due to their high accuracy navigation systems, the REMUS vehicles are particularly well suited for surveying and mapping tasks using side scan and multibeam sonar, sensors, and cameras. The vehicle power is provided by lithium-ion batteries. Electric motors drive a propeller to push the AUV through the water and fins to control steering and diving. Onboard instruments are capable of real-time processing, and the AUV may change its planned track to more closely survey areas of special interest. Over 300 REMUS AUVs have been built.

During Operation Iraqi Freedom in 2003, the U.S. Navy used REMUS vehicles to detect mines in the Persian Gulf harbor of Um Qasr. Another REMUS—known as the Tunnel Inspection Vehicle (TIV)—was developed to survey 45 miles of a New York City aqueduct for leaks. In 2010, two REMUS 6000 AUVs surveyed the wreck of the *Titanic* and the surrounding debris field for signs of deterioration and of undersea life. In 2011, WHOI used three REMUS 6000 AUVs to find and identify the wreckage of Air France Flight 447 more than two miles beneath the surface of the Atlantic Ocean. In 2013, the team took a specially equipped REMUS "SharkCam" to Guadalupe Island off Mexico and captured unprecedented footage of great white sharks in the wild.

Specifications:

REMUS 100
Diameter: 19 cm (7.5 in.)
Weight: 37 kg (80 lbs.)
Max depth: 100 m (328 feet)

REMUS 600
Diameter: 32.4 cm (12.75 in.)
Weight: 240 kg (530 lbs.)
Max depth: 600 m (1,968.5 feet)

REMUS 3000
Diameter: 14 cm (146 in.)
Weight: 335 kg (740 lbs.)
Max depth: 3000 meters (9,842 feet)

REMUS 6000
Diameter: 71 cm (28 in)
Weight: 862 kg (1900 lbs.)
Max depth: 6000 meters (19,685 feet)

Tom Kleindinst, WHOI

A sample of the REMUS AUVs. Seen here are the R-100, Tunnel Inspection Vehicle, R-600, R-3000, and the R-6000.

Gliders

Autonomous underwater gliders are robotic vehicles that move through the sea in a sawtoothed pattern to measure currents, water properties, and biology. Rather than using a propeller for propulsion, a glider actively changes its buoyancy by moving oil or water into or out of external bladders to change its volume and move up and down in the water. This buoyancy-driven vertical motion is translated into forward motion by the glider's wings, just like a glider flying in air. The glider surfaces periodically to use antennas in its wings or tail to obtain its GPS location, to transmit data, and receive new commands from researchers via satellite. Deployments can last weeks to months, allowing gliders to survey thousands of kilometers at a time.

The small relative cost and the ability to operate multiple vehicles with minimal personnel and infrastructure enables small fleets of gliders to study and map the dynamic features of subsurface coastal waters around the clock and around the calendar.

WHOI research teams have helped develop two types of gliders—*Spray* and *Slocum*. Over the past decade, WHOI researchers have deployed these gliders in a variety of locations including the Gulf Stream, the Gulf of Mexico, California's Monterey Canyon, and the Galápagos Islands. A *Spray* glider was used in the summer of 2010 to track the location and dynamics of the Loop Current in the Gulf of Mexico after the *Deepwater Horizon* oil spill. *Slocum* gliders are being used in coastal and high-latitude locations as part of the National Science Foundation-funded Ocean Observatories Initiative, a networked infrastructure of science-driven sensor systems.

Robert Todd, WHOI

Paul Fucile, WHOI

Spray and *Slocum* gliders are autonomous underwater vehicles that can carry a variety of sensors and can run pre-programmed missions as long as six months in duration.

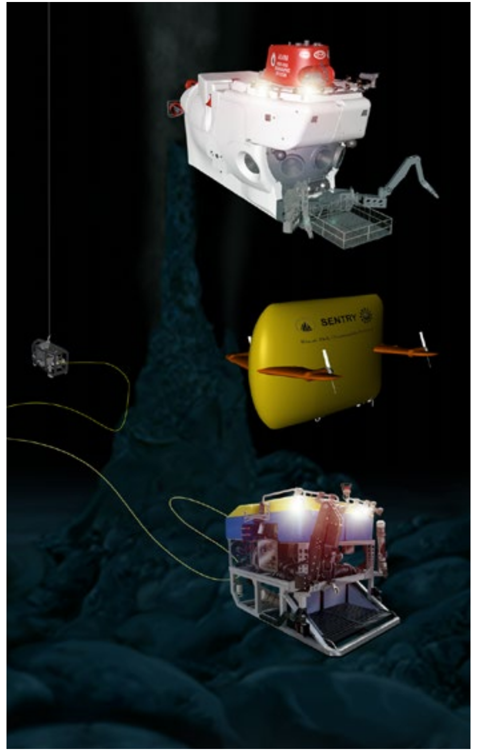
National Deep Submergence Facility

Since 1974, WHOI has operated deep-sea exploration vehicles for the benefit of the entire U.S. oceanographic community. The National Deep Submergence Facility (NDSF), hosted at WHOI, is a federally-funded center that operates, maintains, and coordinates the use of three vital deep ocean vehicles:

- The human occupied submersible *Alvin* (page 10)
- The remotely operated vehicle system *Jason/Medea* (page 12)
- Autonomous underwater vehicle *Sentry* (page 14).

More than half of our planet is covered by water that is at least two miles deep. The unique vehicles of the NDSF carry humans and a virtual "human presence" beneath those deep waters and down to the largely unexplored seafloor. Whether diving 4,500 meters (14,700 feet) or remaining submerged for several days, each vehicle offers unique tools to explore the mysteries beneath the ocean's surface.

The NDSF is sponsored by the National Science Foundation, the Office of Naval Research, and the National Oceanic and Atmospheric Administration. The facility is managed by WHOI and overseen by the University-National Oceanographic Laboratory System (UNOLS), an organization of 62 academic institutions and national laboratories involved in marine research.



Tim Silva, WHOI

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WHOI conducts research around the world in oceanography and ocean engineering and is the largest private, nonprofit marine research and higher education organization in the U.S.

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