ROV *Deep Discoverer*

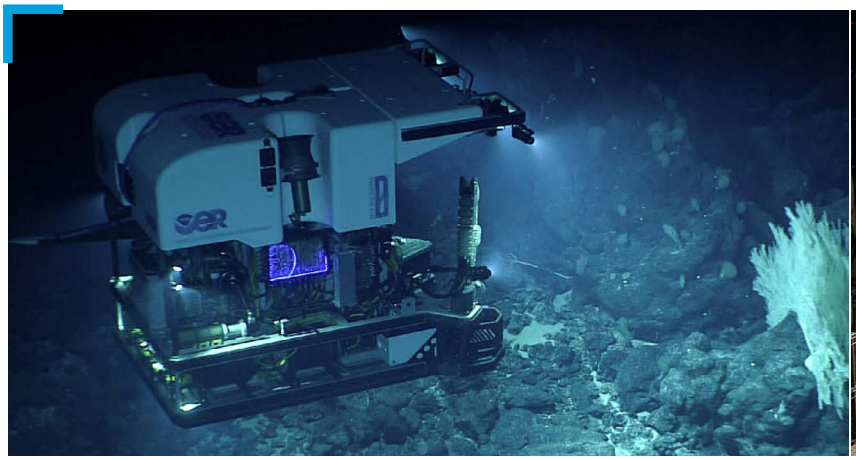
SIZE	**L** 3 m (10 ft.) x **W** 2 m (6.5 ft.) x **H** 2.6 m (8.5 ft.)
WEIGHT	4,082 kg. (9,150 lbs.)
EQUIPMENT	Cameras capable of capturing high definition videos, 20 LED lights, multiple sensors, two manipulator arms to collect samples
DEPTH	Maximum of 6,000 m (19,685 ft.)
SPEED	1 knot under its own power; 3 knots if towed

Features

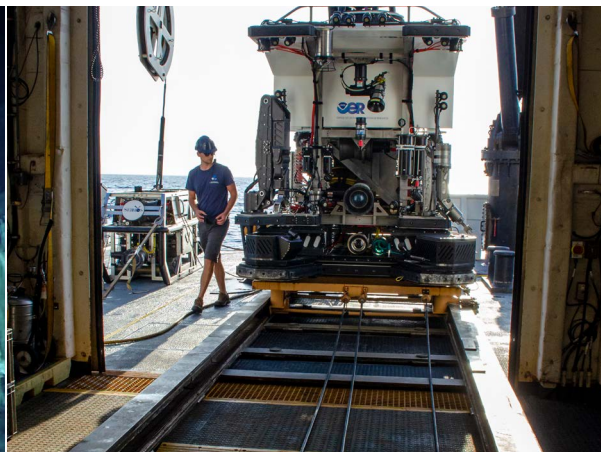
The Remotely Operated Vehicle (ROV), *Deep Discoverer*, also known as "*D2*," is operated from the NOAA Ship *Okeanos Explorer* with its sister ROV vehicle, *Seirios*. *D2* is connected to *Seirios* and to the ship by a long fiber optic cable. *D2* is about the size of a mini-van. It is piloted by engineers in a control room on the ship. Capable of diving to 6,000 m, *D2* provides scientists with access to the deep ocean. In addition to its lights, cameras and manipulator arms, *Deep Discoverer* carries five 1.7-liter containers for water sample collection. A rotary suction sampler has six 4-liter sample jars for collecting more delicate biological samples.

Can Do

Deep Discoverer captures amazing high-definition video. This ROV's primary camera can zoom in on a three-inch long organism from 10 feet away. *D2*'s 20 LED lights illuminate the otherwise dark depths of the ocean. *Deep Discoverer's* dexterous manipulator arms give operators the ability to both biological and geological samples. Using the ROV's sensors, researchers gather additional information on the deep ocean environment such as salinity, water temperature and dissolved oxygen. Live video from *D2* travels from the seafloor to the ship and then via satellite connection to scientists located on shore. They use the real-time video to provide guidance to the pilots on where to go and which samples to collect. The live stream ROV video is also broadcast to the Internet, allowing anyone to join in on *D2*'s adventures.



ROV *Deep Discoverer* documents the benthic communities at Paganini Seamount in the central Pacific ocean. *Image courtesy of the NOAA Ocean Exploration, Deep-Sea Symphony: Exploring the Musicians Seamounts. https://oceanexplorer.noaa.gov/technology/subs/deep-discoverer/media/d2-1-hires.jpg*



ROV *Deep Discoverer* being prepared for launch during a dive for the Windows to the Deep 2018 expedition. *Image courtesy of Art Howard, GFOE, Windows to the Deep 2018. https://oceanexplorer.noaa.gov/technology/subs/deep-discoverer/media/d2-2-hires.jpg*

Operated by: NOAA Ocean Exploration

ROV *Little Hercules*

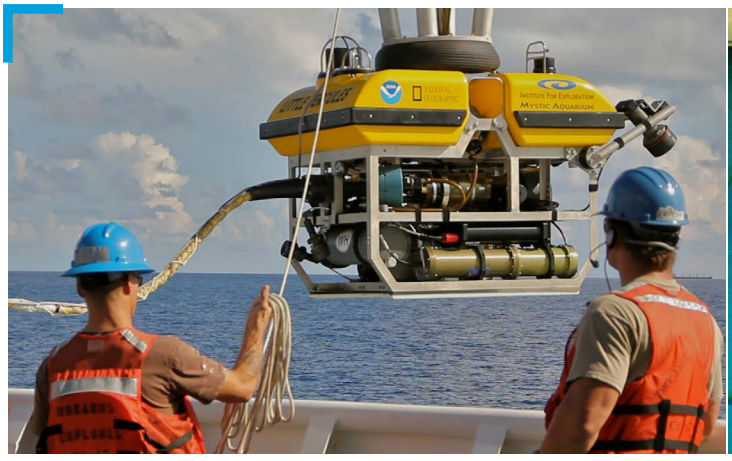
SIZE	**L** 1.4 m (4.6 ft.) x **W** 1 m (3.3 ft.) x **H** 1.2 m (3.9 ft.)
WEIGHT	400 kg. (900 lbs.)
EQUIPMENT	Navigation sensors, altimeter, pressure sensors, Cameras capable of capturing high definition video, two mini sensor cameras, LED lights
DEPTH	Maximum of 6,000 m (19,685 ft.)
SPEED	2 knots

Features

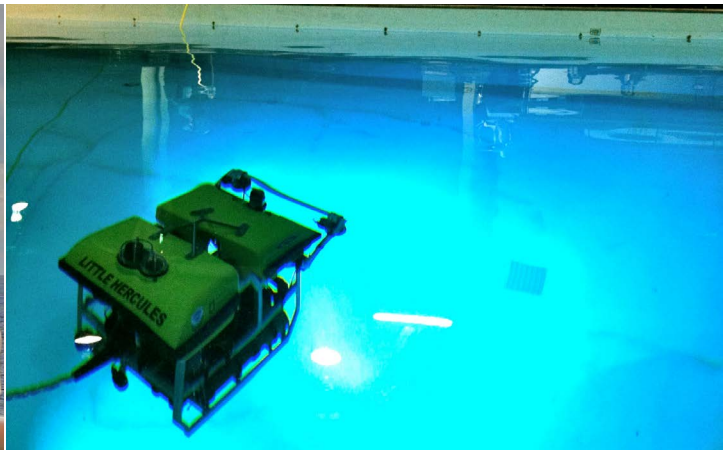
The Remotely Operated Vehicle (ROV) *Little Hercules* is one of four ROVs that dive from the Exploration Vessel (E/V) *Nautilus*. This relatively small ROV (about the size of a refrigerator) is tethered to another ROV, such as the *Atalanta*. The pair work together like diving buddies. *Atalanta* acts as a stabilizer, separating the motion of the ship above from the delicate work of *Little Hercules* below. While *Little Hercules* weighs about as much as two motorcycles, flotation foam – called syntactic foam – makes it neutrally buoyant in water. Four propeller thrusters power the ROV forward, backward, up and down. The altimeter on board measures the ROV's height above the seafloor. Pressure sensors relay its depth in the ocean. *Little Hercules* can be outfitted with additional equipment and tools needed to carry out its research mission.

Can Do

Little Hercules is engineered to dive as deep as 6,000 m. Equipped with an ultra-high-definition camera, it is specifically designed to gather high-quality video images of the seafloor. Its smaller size makes this ROV highly maneuverable. Pilots on E/V *Nautilus* "fly" *Little Hercules* through the ocean with the assistance of its onboard sensors. Navigation transponders communicate with transponders on the ship to give pilots the vehicle location on the seafloor. There is no GPS underwater! *Little Hercules* uses sonar scans to gather data on objects that are out of view from its cameras and lights.



The *Okeanos Explorer* crew launches the vehicle during test dives off Hawaii. *Image courtesy of the NOAA Ocean Exploration, INDEX-SATAL 2010. https://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/rov/media/launch_hires.jpg*



Little Hercules ROV at the University of New Hampshire during tank testing. *Image courtesy of the NOAA Ocean Exploration, INDEX-SATAL 2010. https://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/rov/media/test_tank_hires.jpg*

ROV *SuBastian*

SIZE	**L** 2.7 m (9 ft.) x **W** 1.8 m (6 ft.) x **H** 1.8 m (6 ft.)
WEIGHT	3,200 kg. (7,055 lbs.)
EQUIPMENT	Five thrusters, navigation instruments, Cameras capable of capturing high definition video, lights, multiple sensors, two manipulator arms
DEPTH	Maximum of 4,500 m (14,764 ft.)
SPEED	0.5-3 knots

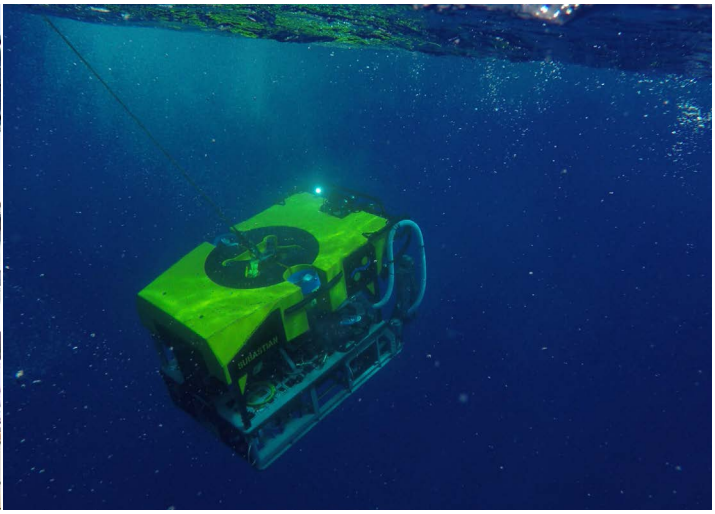
Features

The Remotely Operated Vehicle (ROV) *SuBastian* is approximately the size of a subcompact car. Like other ROVs, *SuBastian* is fitted with syntactic foam, which makes it neutrally buoyant while in the water. Five powerful thrusters work like propellers to move the vehicle sideways, forward, backward, up, and down. *SuBastian* has many different tools for sample collection and measuring water quality. In addition to its built-in sampling tools, *SuBastian* can be customized, so scientists can add new equipment to it as needed.

Can Do

SuBastian can be used in many different kinds of operations due to all its different sampling systems and ability to place and retrieve equipment on the seafloor. Some of *SuBastian's* sampling tools include multiple bioboxes and a multi-chamber suction sampler for collecting delicate samples. *SuBastian* has two incredibly maneuverable arms that can move seven different ways. Ten cameras record images from all angles of the vehicle. The images can then be stitched together to create a larger image of the seafloor, called a photo-mosaic. Scientists use *SuBastian's* ultra-high definition camera to capture and live stream video. The live stream enables both scientists and the public to participate virtually in ROV operations.

ROV *SuBastian* being positioned on deck after a recovery. *Image courtesy of the Schmidt Ocean Institute.* https://schmidtocean.org/wp-content/uploads/SuBastian-SeaTrials-20160720-5255-1.jpg



ROV *SuBastian* returns to R/V *Falkor* after a successful dive during sea trials off the coast of Guam. *Image courtesy of the Schmidt Ocean Institute.* https://schmidtocean.org/wp-content/uploads/Guam-SuBastian-20160808-underwaterRecovery1.jpg

Operated by: Schmidt Ocean Institute

ROV *Nereid Under-Ice*

SIZE	**L** 3.7 m (12 ft.) x **W** 1.8 m (6 ft.) x **H** 1.8 m (6 ft.)
WEIGHT	1,800-2,000 kg. (3,968-4,409 lbs.) depending on configuration
EQUIPMENT	Battery; acoustic, chemical and biological sensors; Cameras capable of capturing high definition video; electro-hydraulic manipulator arm
DEPTH	Maximum of 2,000 m (6,500 ft.)
SPEED	In excess of 1.3 m./sec.

Features

The Remotely Operated Vehicle (ROV) *Nereid Under-Ice (NUI)* is built to travel up to 40 kilometers (25 miles) laterally underwater, rather than the few hundred feet of a typical ROV. Operators on board the ship send control signals to *NUI* via a hair-thin optic tether. *NUI* transmits data back to the ship the same way. Other ROVs are powered by their ship via a heavy tether. *Nereid Under-Ice* carries its own battery power on board. This allows the tether to be much smaller and lighter so that *NUI* can maneuver more easily. *NUI* carries acoustic, chemical and biological sensors for investigating the underwater environment. Its electro-hydraulic manipulator arm can perform seven different functions.

Can Do

Scientific exploration of ocean environments that are covered in thick ice may be impractical, dangerous or nearly impossible to do. Even an icebreaker ship may not be able to approach the area closely. *Nereid Under-Ice* enables researchers on board the ship to study these under-ice environments from a safe distance. *NUI* can sample or survey mid-level in the ocean, land on the seafloor, or closely inspect the underside of the ice layer. This ROV can access ice pressure-ridges, melt-pools and crevasses. Its high-definition video equipment allows researchers to visualize mapping and survey data in real time. *NUI*'s manipulator arm can retrieve samples and place instruments. Data gathered by *NUI* help scientists learn about the under-ice plants and animals of the Arctic food web. Mapping the underside of ice can help climate modelers to forecast the future of the Arctic and Antarctic.

Nereid Under-Ice, a hybrid remotely operated vehicle designed and built by researchers in WHOI's Deep Submergence Laboratory. *Illustration by Casey Machado, Woods Hole Oceanographic Institution.* https://www.whoi.edu/multimedia/nereid-under-ice/

A WHOI engineer installs a new shroud over one of the maneuvering thrusters on the *Nereid Under-Ice* remotely operated vehicle. *Photo by Tom Kleindinst, Woods Hole Oceanographic Institution.* https://www.whoi.edu/multimedia/under-the-ice/

Operated by: Woods Hole Oceanographic Institution

AUV *Sentry*

SIZE	**L** 2.9 m (9.7 ft.) x **W** 2.2 m (7.2 ft.) x **H** 1.8 m (5.8 ft.)
WEIGHT	1,250 kg. (2,750 lbs.)
EQUIPMENT	Navigation systems; acoustic navigation/ communication; multiple sensors, sonar mapping system, high resolution digital camera
DEPTH	Maximum of 6,000 m (19,685 ft.)
SPEED	Maximum of 2.3 knots

Features

Sentry is an Autonomous Underwater Vehicle (AUV), which means that it can dive without direct human control or connection to a ship. Its hydrodynamically efficient shape allows fast ascents and descents underwater. *Sentry* is designed for operations that require extreme maneuverability. It can "fly" very close to the seafloor on rough terrain. Sentry's complex navigation system is aided by acoustic navigation. Operators aboard the ship use acoustic communication to monitor the AUV and the status of its many sensors. *Sentry* can carry additional scientific equipment such as a mass spectrometer, 3-D imaging system, and pumped filter samplers to collect plankton.

Can Do

AUV *Sentry* can be used as a stand-alone vehicle or work in tandem with the human-occupied vehicle (HOV) *Alvin*. Common missions for *Sentry* involve surveying the seafloor to map features such as hydrothermal vents. *Sentry* is used to explore deep-sea coral reefs, shipwrecks and oil wells. Its sonar mapping system includes a multibeam echo sounder that can generate finely detailed 3-D models of the seafloor. These high-resolution maps enable scientists to better understand large-scale geological processes. *Sentry* can take digital bottom photos in mid-ocean ridges, deep-sea vents, and cold seeps at ocean margins. Its high-resolution digital camera can take a picture every three seconds. This provides scientists with an immense amount of data about the seafloor.

A variety of communication and tracking devices line the top of *Sentry*, allowing scientists to stay in continuous touch with the AUV. *Photo by Richard Pittenger, Woods Hole Oceanographic Institution.* https://www.whoi.edu/multimedia/a-sentry-in-the-sea/

WHOI engineers prepare to test *Sentry* off of the coastal research vessel *Tioga*. *Photo by Ken Kostel, Woods Hole Oceanographic Institution.* https://www.whoi.edu/multimedia/sentry-in-photos/

Operated by: Woods Hole Oceanographic Institution

AUV *Orpheus*

SIZE	**L** 1.7 m (5.7 ft.) x **W** 1 m (3.3 ft.) x **H** 1.3 m (4.3 ft.)
WEIGHT	250 kg. (551 lbs.)
EQUIPMENT	Four fixed-directional thrusters; visual terrain-relative navigation (four cameras); sensors to detect methane, hydrogen sulfide and helium
DEPTH	Rated for 11,000 m (36,089 ft.) when testing is completed
SPEED	0.5 to 1 m/sec. across the seafloor

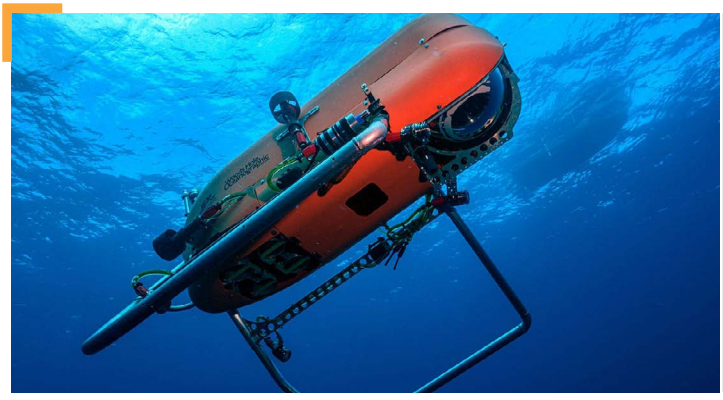
Features

The *Autonomous Underwater Vehicle (AUV) Orpheus* is about the size of a large outdoor barbecue grill and its orange "shell" is a protective plastic skin. The vehicle's smooth shape reduces drag, which increases its energy and its small AUV's compact shape makes it nimble and maneuverable. *Orpheus* has thick syntactic foam flotation covering its body.

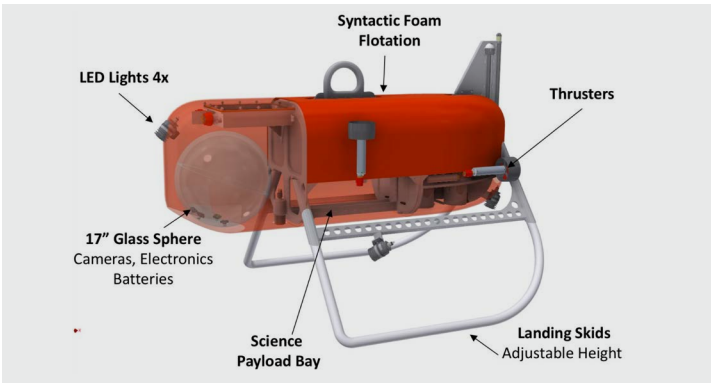
Like other underwater robots, *Orpheus* is designed to withstand extreme pressure and electronics are safely housed in a compression-resistant glass sphere. Rubber tubing in the wiring outside the sphere is filled with mineral oil to resist pressure. These are used to get the connections out to all the thrusters, lights and sensors. Even small research vessels can launch *Orpheus*, due to its light weight (relative to other submersible vehicles).

Can Do

Orpheus will act as an ocean-floor detective to investigate deep trench ecosystems. Designed to work independently, it will eventually be networked with a fleet of other underwater drones to explore the vast area of the hadal zone. At depths of 6,000-11,000 m, the "hadal zone" is the most remote and least understood ocean habitat on Earth. *Orpheus* will use image-recognition technology to identify objects and animals in this dark, murky environment and can maneuver around obstacles and land on the seafloor to collect samples. Software will allow this AUV to build three-dimensional terrain maps of the seafloor by stitching together images of features it sees. Scientists will use these data to learn about novel adaptations that have evolved to sustain life under extreme pressure. *Orpheus* is outfitted with sensors to detect methane, hydrogen sulfide, and helium, all promising ingredients for life. Developed in collaboration with NASA's Jet Propulsion Laboratory, *Orpheus* will set the stage for future exploration of other ocean worlds, such as the ice-covered liquid ocean on Jupiter's moon Europa.



Orpheus begins its descent into Veatch Canyon on the continental shelf off of the U.S. Northeast in September 2019. *Photo by Evan Kovacs, Marine Imaging Technologies, LLC / Courtesy of Woods Hole Oceanographic Institution.* https://www.whoi.edu/multimedia/orpheus-explores-the-oceans-greatest-depths/



A labeled diagram of *Orpheus*. *Photo by Taylor Heyl, Woods Hole Oceanographic Institution.* https://hadex.whoi.edu/wp-content/uploads/sites/124/2018/11/N801583.jpg

Operated by: Woods Hole Oceanographic Institution