
NURP/UCAP

The *Johnson-Sea-Link* on R/V *Seward Johnson*.

Tools for Undersea Research

Understanding the ocean is one of our most important challenges today, thus the development of sensing, sampling, and observing systems to support that mission is essential.

The National Undersea Research Program (NURP) is the nation's scientific research program that specializes in providing access to advanced undersea diving and observation technologies. The tools NURP scientists use to explore beneath the sea range from research submersibles, remotely operated vehicles (ROVs), and autonomous underwater vehicles (AUVs) to underwater laboratories, sea floor observatories, and mixed gas diving.

NURP's undersea technologies are used by researchers to get to the sea floor where they can observe, describe, and ultimately explain the phenomena of the oceans and life within it. The oceans are the most complex, challenging and harsh environments on Earth, and to access them requires technology.

Ocean science and exploration play an important role in the responsible stewardship of the environment of our planet. "What submersibles allow us to understand is the full complexities of the ecosystem," said oceanographer Ian MacDonald of Texas A&M University. "You can't map the sea floor and its associated geology and ecology unless you get down there and observe it. Not seeing the complexity of the ocean is like not seeing the trees in the forest."

The national needs for undersea research and NURP's technological capabilities are characterized in this chapter.

The National Undersea Research Program—In Perspective

One year after the National Oceanic and Atmospheric Administration (NOAA) was created in 1971, the Manned Undersea Science and Technology (MUS&T) office began to provide undersea technology primarily for NOAA investigators. In 1979, the National Research Council (NRC) reviewed MUS&T and endorsed the idea for formation of a National Underwater Laboratory System, which later became The National Undersea Research Program (NURP). Ocean resources and environmental problems vary across regions and different technologies are needed, thus the NRC panel supported the regional laboratory system. The program maintains a small headquarters office based at NOAA's Silver Spring, MD, location, and regional undersea research centers. The host institutions provide permanent facilities and infrastructure, so administrative costs are lower. The close ties NURP regional centers have to the regional science community facilitates identification of priority environmental issues and use of appropriate technologies for research projects.

NURP Technologies

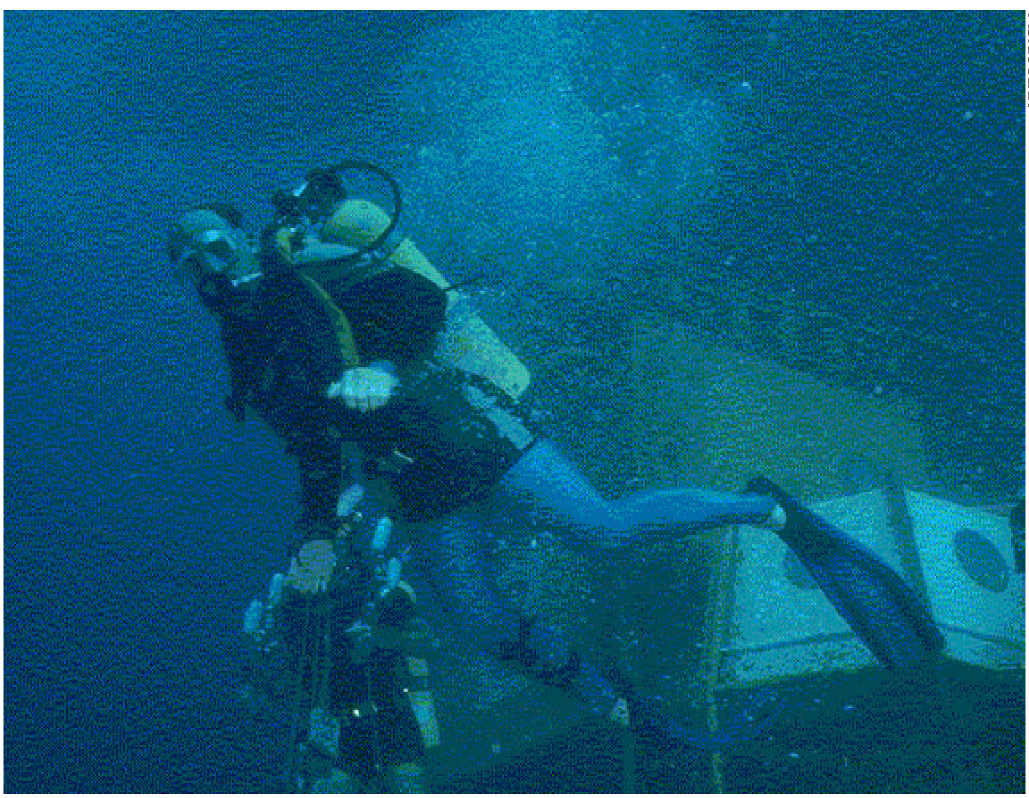
In 1980, the National Research Council (NRC) recognized the need to facilitate access by the nation's science community to undersea procedures and equipment. A more recent NRC report (1996) reinforces the continuing need for development of new, more advanced capabilities.

NURP serves the science community by making undersea technologies, which NURP either owns or leases, available for scientific research.

Advanced Scientific Diving

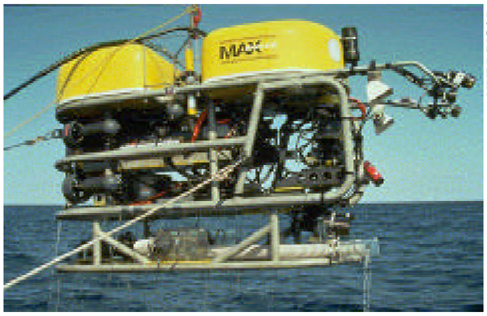
In shallow water, the most effective way to study the seas is to place humans directly underwater. Although strides have been made to make deeper diving possible, there are still severe restrictions on the depth and length of time divers can spend underwater. Research on undersea ecosystems often requires diving to depths beyond 40 m (131ft)—work that can't be done with conventional scuba diving equipment.

Using oxygen enriched air (nitrox), divers are able to extend their bottom time. NURP provides scientists with both nitrox equipment



NURP/UNCW

Dr. Stephen Wing departs *Aquarius* for a reef dive to examine how internal waves affect reefs.



NURP/UCAP

The ROV *Kraken*.

A deployment of the *Odyssey* AUV in Antarctica.

and personnel to carry out their missions. In 1997, the program helped scientists conduct more than 2,000 nitrox dives with a flawless safety record.

Divers working from surface vessels are limited by factors such as weather, gas supply, and decompression sickness. The ability to live and work beneath the waves is provided through saturation diving and the *Aquarius* undersea laboratory, the only undersea habitat in the world devoted to science. The habitat, owned and operated by NURP, is located in 20m (65 ft) of water at the base of a coral reef within the Florida Keys National Marine Sanctuary—an ideal site for studying the health of sensitive coastal ecosystems. The habitat accommodates four scientists and two technicians for missions averaging ten days. The *Aquarius* program successfully completed 21 missions over a 32-month period between 1993 and 1996. It was recently upgraded with modern communication systems to enhance continued operations for the next five years. Achievements include description of the damaging effects of ultraviolet light on coral reefs; improved understanding of coral feeding biology; fossil studies to better understand present-day changes to coral reefs; and water quality studies to evaluate pollution sources and impacts.

Robotic Vehicles

NURP operates undersea robots or remotely operated vehicles (ROVs) that can be deployed from ships of opportunity. Access to a variety of ROVs is provided—some leased, some owned by the program. NURP's ROVs have worked from the tropics to the poles.

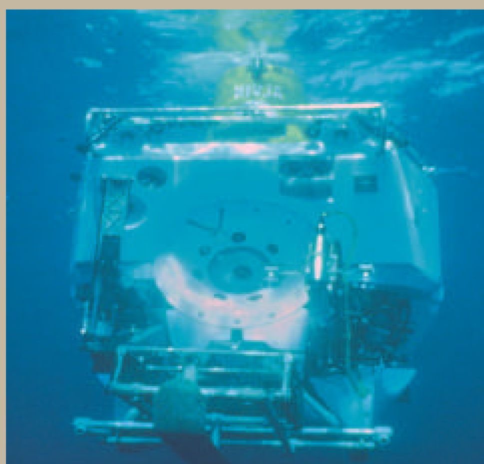
Autonomous Underwater Vehicles (AUVs) are the most recent development in underwater technology. Independent of the surface, battery powered and controlled by computers using various levels of artificial intelligence, these vehicles are programmed to carry out various underwater survey tasks. NURP and Sea Grant funded the initial development of the Odyssey series of AUVs at the Massachusetts Institute of Technology (MIT) Sea Grant College Program's Autonomous Underwater Vehicles Laboratory led by James G. Bellingham.

NURP continues to support AUV development. Designing a low-cost, multi-task AUV that wouldn't destroy a science budget if lost in the ocean was a top priority of investigators at the Long-term Ecosystem Observatory (LEO-15) off the coast of New Jersey. REMUS (Remote Environmental Monitoring Units) designed by WHOI engineer Chris von Alt with funding from NURP met this criteria. The torpedo-shaped tetherless submersible responds to an acoustic beacon emitted between nodes to follow a survey pattern. Plans are for each REMUS to be equipped with different kinds of sensors like video cameras, side scan sonars, current meters, and chemical sensors to measure conditions and parameters such as dissolved oxygen. REMUS will dock at a subsea transfer station to recharge its batteries and transfer its data through a fiber-optic cable to the shore.

Submersibles

Research submersibles carry humans directly to the midwater realms or the sea floor in many parts of the ocean. NURP routinely sponsors research that uses a wide variety of submersibles. With its fish bowl acrylic sphere, two scientists comfortably make observations at 920 m (3,000 ft) while inside the *Johnson-Sea-Link* (JSL) submersible. *JSL* is owned and operated by the Harbor Branch Oceanographic Institution (HBOI) and leased regularly to NURP scientists. For example, it enabled NURP scientists to study a variety of deep-sea communities in the newly developed continental shelf oil fields of the Gulf of Mexico.

Cooperative agreements between the Navy and other government agencies made Navy submersibles available for science and helped prolong their use, but cutbacks in federal spending have decreased the number of submersibles available for deep ocean exploration. Unfortunately, the *Turtle* was decommissioned in 1997, and the *Sea Cliff* was decommissioned the following year. This will leave the *Alvin* as the only U.S.-owned

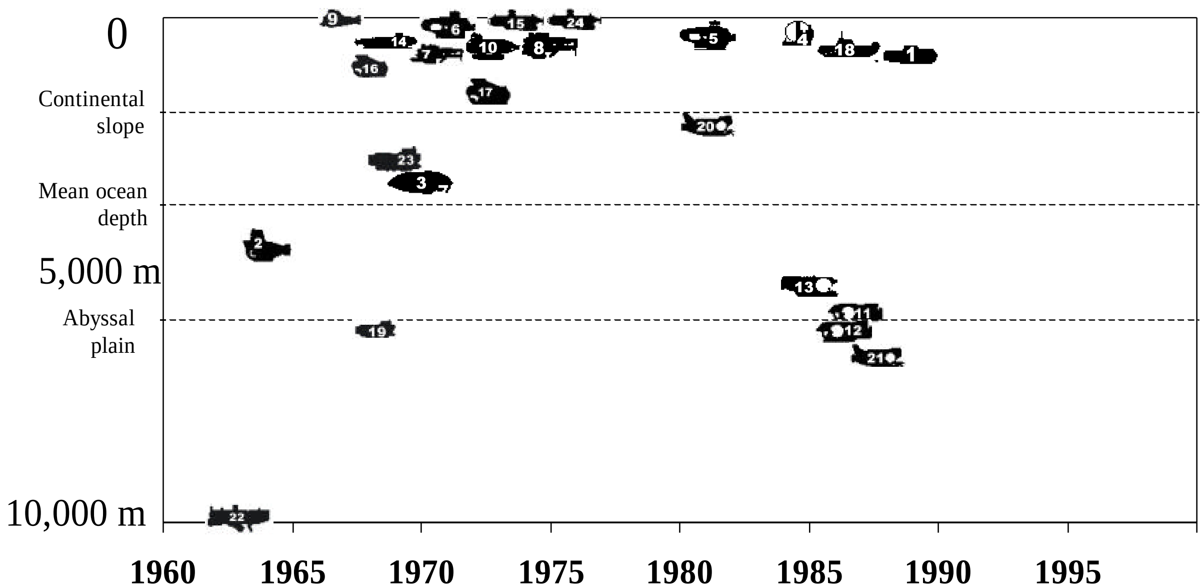


RON CATANACH

The Alvin is used by scientists in the deep sea

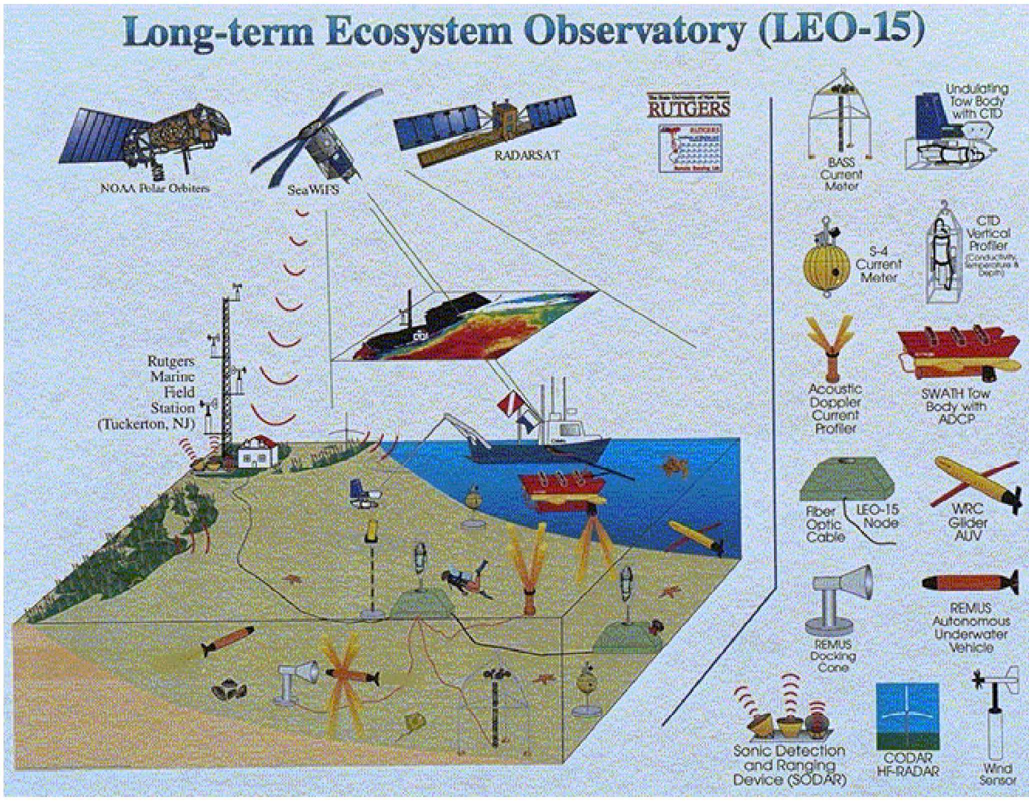
The blockbuster movie, *Titanic*, begins with footage of the celebrated wreck taken from the most renowned research submersible, *Alvin*. In 1956, engineer Allyn Vine of Woods Hole Oceanographic Institution (WHOI) attended a symposium in Washington, where it was resolved to develop a national program for manned undersea vehicles. The science community first obtained the *Trieste* bathyscaphe, but it was quite large and not very maneuverable—a better craft was needed for science. In 1964, Litton Systems delivered the DSV *Alvin* (named after Vine and the popular chipmunk) to Woods Hole. Following shallow tethered dives near Woods Hole, the first free dive took place on August 4 to a depth of 10 m (32 ft).

Research Submersibles



1 = 3gst9 · 2 = Alvin · 3 = Cyana · 4 = Deep Rover · 5 = Delta · 6 = Gamma · 7 = JSL I · 8 = JSL II · 9 = Makali'i · 10 = Mermaid II · 11 = MIR I · 12 = MIR II · 13 = Nautile · 14 = NR-1 · 15 = PC-15, L1 · 16 = Pisces II · 17 = Pisces V · 18 = Saga · 19 = Sea Cliff · 20 = Shinkai2000 · 21 = Shinkai6500 · 22 = Trieste I · 23 = Turtle · 24 = Clelia

Source: National Research Council, *Undersea Vehicles and National Needs*, 1996; NOAA's *The Ocean System - Use and Protection*, 1989.



NURP/MAB

Schematic of the Long-term Ecosystem Observatory off the Coast of New Jersey.

DSV used by scientists capable of reaching 4,500 m (14,760 ft). *Alvin*, built in 1964, has spent more than 21,500 hours submerged on almost 3,200 dives to an average depth of more than 2,000 m (6,400 ft). NURP has been a contributing partner with the Navy and the National Science Foundation in support of *Alvin's* research activities since the 1970s.

In the Pacific Ocean where deep coral reefs and fishery habitats remain largely unexplored, NURP's 69 m (223 ft) support vessel *Ka'imikai-O-Kanaloa (K-O-K)* used with the submersible *Pisces V* carries out deep ocean scientific research. The *Pisces V* is a three-person submersible with a depth capability of 2,000 m (6,600 ft). Two years ago, NURP researchers used the *K-O-K and Pisces V* to reach the submarine volcano Loihi off the big island of Hawaii. Loihi erupted sparking the strongest seaquake ever recorded in the region. *Pisces V* was able to reach the collapsed lava dome 1,000 m (3,200 ft) below the sea surface within a few weeks after its eruption.

NURP/HURL

***Pisces V* on the *K-O-K*.**

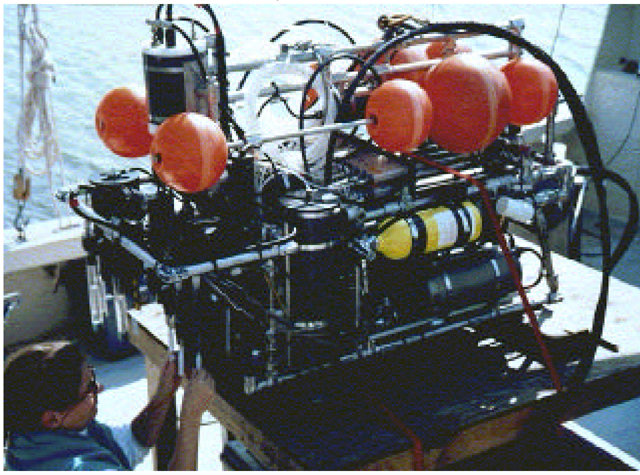
Seafloor Observatories

An innovative approach is being demonstrated by Rutgers University and the Woods Hole Oceanographic Institution (WHOI) at the LEO-15 Observatory at a 15-m (50 ft) depth on the inner continental shelf of New Jersey. We miss most events in the ocean because we don't have sensors in the ocean environment to continuously record what happens there. It took ten years of collaboration between Fred Grassle, director of the Institute for Marine Coastal Sciences at Rutgers University, and WHOI engineer Chris von Alt to realize this goal. LEO-15 is now the focus of a broad spectrum of research sponsored by NURP. Since its inception, more than 50 projects at LEO-15 have been supported with funding from the National Science Foundation, NURP, and the National Ocean Partnership Program.

"Nobody would run a laboratory now without Internet and electrical connections," Grassle said. "And now we have them at the bottom of the ocean." LEO-15 provides this kind of connection with more than a dozen different kinds of sensors at LEO-15 providing real-time information.

Plans for a Hawaii Undersea Geo-Observatory (HUGO) are underway with a fiber optic cable running to the submarine volcano Loihi where underwater seismic instruments are in place to record its eruptions. The submersible *Pisces V* will be available for servicing its instruments.

CLARE REIMERS



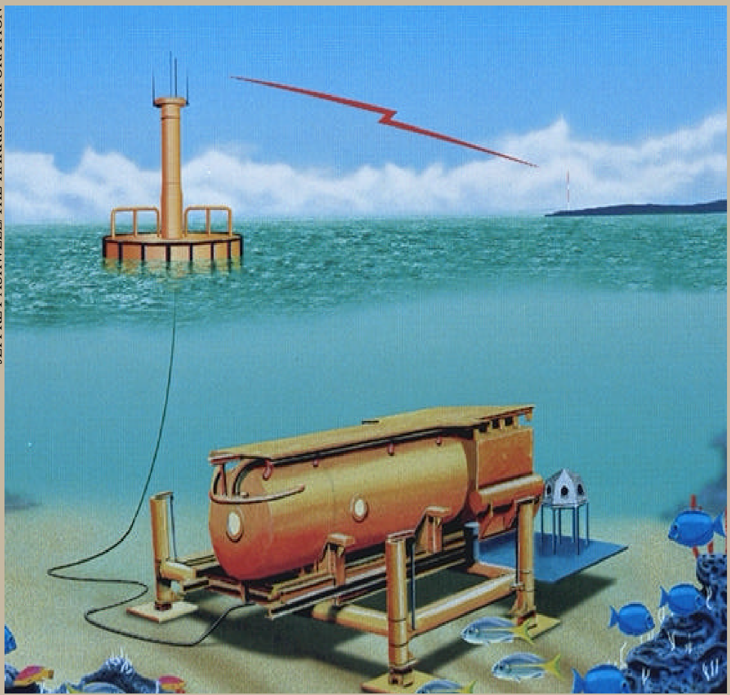
Benthic Shuttle System (BESS).

Survey and Sensor Systems—A Few Examples

New automated systems enhance the performance of existing platforms and vehicles, thereby reducing the need for new undersea vessels. An ROV-deployed Benthic Shuttle System (BESS), a flexible instrument package designed by NURP-funded researcher J. Val Klump, his colleagues at the University of Wisconsin, and David Lovalvo, president of Eastern Oceanics, has proved essential for studying the interactions of sediments and their overlying waters in the Great Lakes and in the Mid-Atlantic Ocean. Prior to BESS, no descriptions of dissolved chemicals had been attempted in water depths beyond the easy reach of SCUBA in the Great Lakes, primarily because no technology existed.

Instruments called microprofilers, which probe into sediment to take fine scale chemical measurements, have also been refined by NURP-funded researchers to make strides in our understanding of chemical interactions at the sediment-water interface. Chemical oceanographers Clare Reimers of Rutgers University and George Luther of the University of Delaware are using this innovative sampling technique in the New York Bight to successfully measure carbon cycling in the ocean important for understanding global climate change.

JEFFREY ASHWELL/THE HARRIS CORPORATION



The *Aquarius 2000*

The recent development of *Aquarius 2000* is an example of a NURP partnership with industry and academia. The *Aquarius* underwater laboratory has been redesigned to include an autonomous data/telemetry buoy that was developed in cooperation with the Harris Corporation and Harbor Branch Oceanographic Institution. The buoy will supply all of the life support and communications capabilities previously provided by a barge manned by up to four technicians. In addition, the new buoy will provide real-time data and video links from the sea floor laboratory back to the shore-based support laboratory and eventually to the world via the World Wide Web.

NURP Partnerships

During the past four years, the Navy's manned submersibles, *Turtle* and *Sea Cliff*, were made available to the science community through NURP. Use of the *NR-1* was also coordinated by NURP. The Navy's *NR-1*, with a depth capability of 724 m (2,375 ft), is the world's only nuclear powered research submarine. For wide area surveys and longer cruises, the *NR-1*, which can stay submerged for up to 30 days or more, has proven useful. For example, NURP-funded oceanographer Mary Scranton of the State University of New York at Stony Brook used the *NR-1* to study methane gas seeps in the Mid-Atlantic Bight. Scranton wanted to determine the contribution of this greenhouse gas to the atmosphere. Using this submarine's side-scan sonar to visualize pockmarks or chimneys that identify seeps along the continental shelf, she was then able to collect methane samples from the water column for her experiment.

A recent survey of the Massachusetts Bay for radioactive waste containers illustrates another collaborative partnership through NURP. In this case, NURP provided its ROV, the *Phantom S2*, which was fitted with a gamma spectrophotometer developed by the Department of Energy for detection of radioactivity underwater. The Environmental Protection Agency provided the funding for the ship and submersible, the Harbor Branch Oceanographic Institution (HBOI) donated the transit costs to get its ship and submersible to the Massachusetts Bay area, and the Raytheon Corporation donated its Fluorescence Imaging Laser Line Scan system (FILLS).

Japan, a recognized global leader in the undersea technology arena, is another NURP partner. Through the U.S.-Japan Cooperative Program in Natural Resources (UJNR), U.S. scientists can gain access to Japan's undersea assets. UJNR provides a forum for collaboration between U.S. scientists and their overseas colleagues. Through UJNR, NURP has supported numerous U.S. scientists participating on research cruises on the Japanese submersibles *Shinkai 2500* and the *Shinkai 6500*. UJNR's Diving Physiology and Technology Panel is chaired by NURP. NURP recently sponsored two Japanese physiologists who studied hyperbaric physiology at the University of Wisconsin.

NURP recently partnered with the Institute for Exploration (IFE) and the Jason Foundation to take advantage of a broad-based private educational outreach program. This year, the first phase of the agreement with NURP will involve IFE preparing to transfer advanced capabilities developed through Navy research for the Jason ROV to the *Kraken*, NURP's North Atlantic and Great Lakes Center's ROV. With sophisticated robotics, control, imaging, and mapping technologies, the improved *Kraken* will beome a state-of-the-art ROV used by NURP and IFE for undersea exploration and research.

The Shinkai 6500.