

Manned Research Submersibles: State of Technology 2004/2005

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INTRODUCTION

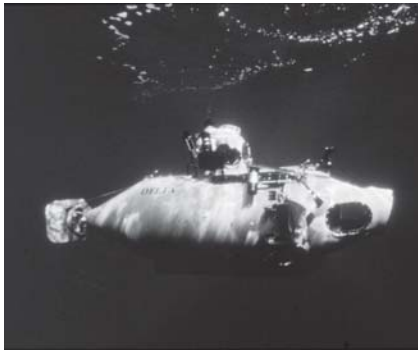
There is no simple way to provide an overview of the state of manned submersibles. The scope of applications is broad, ranging from complex vehicles for deep submergence exploration, to large multi-passenger tourism submersibles and small work submersibles. It is useful to group the industry into three sectors: 1) research, 2) tourism and 3) commercial applications. This overview is the first of three that focuses on the research vehicles in activity today. Many of the submersibles are national assets and their activity gives a good sense of international emphasis in research. However, it also includes submersibles operated by smaller organizations and institutes that each have their specialties.

Research Submersibles Active Today

Research is a well established application for manned submersibles. The vast majority of this use revolves around deep submergence work for national research programs. These are largely government funded programs and the names of the submersibles are well known: ALVIN (USA), NAUTILE (France), SHINKAI (Japan), MIR (Russia). These submersibles have been around for 20 to 40 years and the media exposure given to their fantastic expeditions largely defines the general public's concept of manned submersibles. It is therefore noteworthy to obtain an overview of this sector.

All submersibles and associated organizations are presented in alphabetic order. The table below gives a summary list of the research submersibles covered.

DELTA Oceanographics

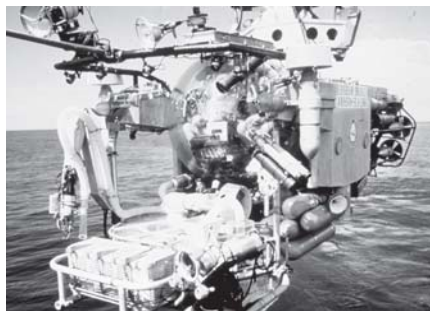


Delta Oceanographics operates the DELTA submersible, a 3 person vehicle rated to 365 meters (1200 feet). Delta is part of the longstanding Nekton family of deep submersibles and operates out of Camarillo, California. Delta started operation in 1987 and has since performed 6,436 dives. In 2004 Delta made 255 dives over 70 days, logging

364 hours underwater. Its mobility allowed it to spend the month of April in Portugal on behalf of the Ocean Technology Foundation. The SEMAPP project was a collaborative effort between U.S. and Portuguese organizations to study the marine environments of the Portuguese continental shelf. In June and July 2004, the submersible moved to Alaska where it dove along the Aleutians for the National Marine Fisheries Service. In August it spent a month diving the National Marine Sanctuaries in California, visiting the Cordell Banks, Monterey Bay and the Channel Islands, to collect base-line sea-life data for the marine reserves. In September it continued work in California for NOAA, the West Coast National Undersea Research Program and a survey with Mineral Management Services to investigate fish assemblages on the offshore oil platforms (www.deltaoceanographics.com).

Organization	Submersible	Depth Rating		Location
Delta Oceanographics	<i>Delta</i>	365 m	1,200 ft	California, USA
Harbor Branch Oceanographic Institution	<i>Johnson-Sea-Link 1</i> <i>Johnson-Sea-Link 2</i>	915 m	3,000 ft	Florida, USA
		915 m	3,000 ft	
Hawaii Undersea Research Lab	<i>Pisces IV</i> <i>Pisces V</i>	1,980 m	6,500 ft	Hawaii, USA
		1,915 m	6,280 ft	
IFREMER Research Lab	<i>Nautile</i>	6,000 m	20,000 ft	FRANCE
Institute for Nautical Archaeology	<i>Carolyn</i>	60 m	200 ft	TURKEY
JAMSTEC	<i>Shinkai 6500</i>	6,500 m	21,325 ft	JAPAN
Max-Planck Institute	<i>Jago</i>	400 m	1,300 ft	GERMANY
PP SHIRSHOV Institute of Oceanology	<i>MIR 1</i> <i>MIR 2</i>	6,000 m	20,000 ft	RUSSIA
		6,000 m	20,000 ft	
Woods Hole	<i>ALVIN</i>	4,500 m	14,765 ft	Mass., USA

Harbor Branch Oceanographic Institution



Harbor Branch Oceanographic Institution (HBOI) is located in Fort Pierce, Florida. HBOI operates two deep capability submersibles: Johnson-Sea-Link 1 (JSL1) and Johnson-Sea-Link 2 (JSL2), both rated to a maximum depth of 915 meters (3000 feet) with room for one pilot and one observer in the observation sphere and one crewman and another observer in the rear compartment. JSL1 was commissioned in 1971 and JSL2 in 1975. To date, the two submersibles have logged over 7400 dives all around the world.

In 2004 HBOI operated both subs on two research vessel support ships, performing a total of 158 dives. The submersible JSL1 was on board the *RV Seward Johnson* for 28 days, working from Charleston, South Carolina to Key West, Florida, supporting fisheries projects, deepwater coral reef investigations, drug discovery programs and deep water exploration and documentation. Funding came from Harbor Branch Oceanographic Institution (HBOI), Florida Atlantic University (FAU), State of Florida and the National Oceanic and Atmospheric Administration (NOAA) office of Ocean Exploration (OE). JSL1 was transferred to the *RV Seward Johnson 2* in support of filming operations at the wreck site of the *SS Republic* off Savannah, Georgia for National Geographic Television and Odyssey Marine Exploration. It also spent 30 days at the cold seep chemosynthetic sites in the Gulf of Mexico for NOAA's Ocean Exploration office, National Science Foundation (NSF), Minerals Management Service (MMS) and the United States Geological Survey (USGS). Subsequently, JSL1 was 20 days in the Gulf of Maine in support of mid-water zooplankton studies. JSL1 completed 142 dives in support of the Marine Sciences in

2004. The Submersible Johnson-Sea-Link 2 (JSL2) underwent a refit in 2004 that included a redesign of the video and lighting controls, emergency gear storage and communications systems within the acrylic pilot's sphere. JSL2 underwent sea trials and was followed by a 13 day mission off Charleston, South Carolina funded by NOAA/OE investigating the deep water fish populations and coral reef habitat of that area. JSL2 completed 16 dives in 2004.

For 2005 Harbor Branch is continuing to support the same programs as in 2004 with only one support ship. The two submersibles have a total of 117 funded days as of this writing. Operations will be conducted in the Bahamas, the East Coast of the U.S. from the Gulf of Maine to Key West, Florida, and into the Gulf of Mexico. Harbor Branch is a strong proponent of increased budgets for the marine sciences using manned submersibles and has active in-house efforts outlining basic concepts for a deeper sub in the 8000 to 10,000 fsw maximum depth range in the future. (www.hboi.edu)

Hawaii Undersea Research Laboratory



Pisces V

The Hawaii Undersea Research Lab (HURL) is part of the University of Hawaii's School of Ocean & Earth Science & Technology. It operates two submersibles: Pisces IV, rated to 1980 meters (6500 ft) and Pisces V, rated to 1915 meters (6280 ft). Both submersibles offer room for one pilot plus two observers. Both underwent a full overhaul for its ABS class in spring 2005 and installed a new surface tracking system. During the testing of this new equipment in neighboring waters, the crew discovered a World

War II wreck, the Japanese submarine I-401 as well as a U.S. World War I submarine, S-19, scuttled in the 1930's. The I-401 was a major find. This was the largest diesel-electric submarine ever built. It was capable of carrying and launching three aircraft. In 1945 it had a mission to bomb the Panama Canal but surrendered at war's end, before completing the mission. Following the discovery of the I-401, Pisces IV and V headed for a five-month South Pacific expedition. The first group of dives was on Vailulu'u Seamount near Samoa, which recently generated a new cone. This was a monitoring project in conjunction with Scripps Institution of Oceanography. The following groups of dives were undertaken in conjunction with the New Zealand Institute of Geological and Nuclear Sciences.



Pisces IV

The first two of these New Zealand legs were done jointly with NOAA's Office of Ocean Exploration. These featured volcanological work examining the ecosystems and hydrothermal systems of 12 active volcanoes in the New Zealand EEZ. The third leg involved a joint program between the University of Mississippi and the Institute of Geological and Nuclear Sciences, New Zealand, focusing on collecting biologically active material from Brothers Volcano. The New Zealand EEZ contains large areas where no deep sea exploration has ever taken place.

The second half of the five-month South Pacific mission began on June 6, 2005, with a month-long volcano diving program with the University of Kiel. This will be followed by six weeks of NURP benthic ecosystem work in July and August. (www.soest.hawaii.edu/HURL/)

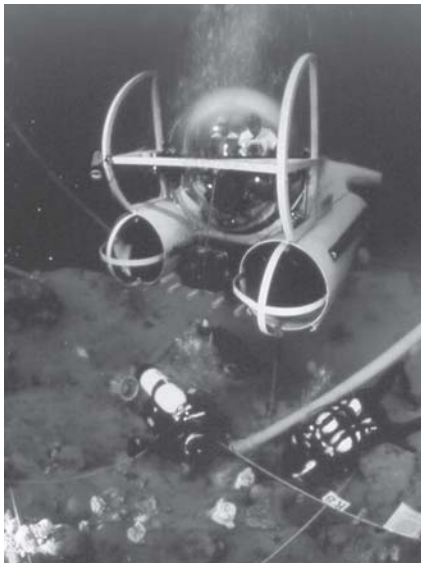
IFREMER



IFREMER, based out of Brest in France, is home of the NAUTILE submersible, France's national deep submergence vehicle. The Nautille is rated to a maximum depth of 6000 m (20,000 ft). Fully overhauled in 2002, it carries a crew of 3 (1 pilot and 2 passengers). The biggest event at IFREMER this year is the commissioning of its new research ship the *Pourquoi pas?*. It was named after the ship of the French Explorer Jean Charcot (1867-1936) who explored the Arctic and Antarctic. The new ship was built in the naval shipyards of St-Nazaire at a cost of \$66M euros, financed 55% by IFREMER and 45% by the Ministry of Defense. Nautille's original support ship, the NADIR, was sold this year and is being overhauled in the US for commercial operation. The *Pourquoi pas?* is fully equipped for ROV deployment, launch and recovery of the NAUTILE and for submarine rescue operations for the military. Home based out of Brest, the ship is designed for sea expeditions of 45 days with a crew of 18-30 plus room for 40 researchers and a complete floating laboratory. Part of the onboard equipment includes a multibeam sonar capable of sounding to 7000 m (23,000 feet) depth. The first civilian expedition is scheduled for this summer, a joint project with JAMSTEC, the Japanese research institute. The expedition named EXOMAR will spend 40 days around

the Azores, collecting bacteria from the very deep and dark zones around hot vents. The first military expedition, named ZMAG, is scheduled for early 2006 in the Caribbean and in Guyana.

Institute for Nautical Archaeology



The Institute for Nautical Archaeology, part of Texas A&M University, operates a 2-person submersible in Bodrum, Turkey. Called "Carolyn", the submersible was built in 1999 by SEAmagine Hydrospace Corp. and started operation in 2000, helping in the excavation of the Tektus Burnu site. Configured with a two-person cabin (pilot plus one observer), the submersible is rated to a maximum depth of 60 m (200 feet). The submersible is operated from the catamaran mothership *Milliwanda*, which is equipped with a lift platform between its pontoons to launch and retrieve the submersible. The submersible is used in two modes of operation. One as an observation platform for the excavation director, who can hover in position and monitor the progress of diver teams that each have 20 minutes of bottom time on the wreck. The second mode is as an exploration vehicle to search for new wrecks. The waters are very clear and the bottom is rocky, which makes it difficult for sonar imaging. The submersible is used as a travel vehicle for the head archaeologists to scour the sea floor for visual indices of possible wrecks. Unusual formations were easily examined by divers for closer inspection. In the first expedi-

tion in 2001, Dr. George Bass was successful in locating 36 wrecks in a six week time frame. Twelve of these were known and re-confirmed, 12 were new wrecks and 12 were possible wrecks. INA worked in underwater archaeology for 40 years in the Aegean Sea and previously had a record of finding 1 new wreck every 2 years. INA trained two new pilots in 2004 and is excavating a first century AD wreck carrying a complete set of stones forming a Roman column. The excavation is near the port of Izmir and will proceed from May to September. Search expeditions for new wrecks are scheduled for the calm months of October and November. (<http://ina.tamu.edu>)

JAMSTEC, Japan



The Japan Agency for Marine-Earth Science Technology (JAMSTEC) operates today's deepest diving manned submersible, the SHINKAI 6500. Rated to a maximum depth of 6500 m (21,325 feet) the submersible weighs 25.8 tons and has a crew of 2 pilots and 1 researcher. In 2004 the submersible was scheduled for ten expeditions. In particular, in fall of 2004 SHINKAI 6500 spent three weeks diving on volcanic rift features in the Lau Basin, southeast of Fiji, before going to New Zealand. In a joint study between JAMSTEC and New Zealand's GNS (the Institute of Geological and Nuclear Sciences Limited), SHINKAI 6500 performed a series of dives exploring the Brothers caldera volcanoes and seafloor hot springs off the New Zealand coast. This 17 day expedition was part of an ongoing relationship between Japanese and New Zealand science organizations. This is the same area being explored by a joint NOAA expedition with Pisces IV & V. The interesting part of

this expedition was that SHINKAI 6500 had just been retrofitted with pressure compensated lithium-ion batteries during summer 2004, to replace the original silver-zinc batteries. JAMSTEC presented the results of the battery tests and the sea trials of this upgrade at the Underwater Intervention 2005 conference. SHINKAI 6500 had demonstrated a flawless series of 18 successful dives with the new batteries. JAMSTEC was very pleased with the performance of these new batteries as well as the reduction in maintenance gained from this conversion. The expedition to Fiji and New Zealand was part of this field test. The 2005/2006 schedule shows 8 expeditions ranging from biology research in nearby waters to geological research in the Japan Trench, the Kuril Trench and the Northwest Pacific and biological studies in the Indian Ocean. We will hope to hear more field data from the performance of the new batteries at Underwater Intervention 2006.

Max-Planck Institute



The Max Planck Institute, based in Seewiesen Germany, operates the JAGO submersible, a 2-person submersible that can dive to a depth of 400 m (1,300 feet). JAGO has a cruising speed of 1 knot with a seating configuration of 1 pilot and 1 observer and is certified to Germanischer Lloyd. Built at the institute in 1989, JAGO has accumulated a total of 855 dives all around the world. This includes work

in alpine lakes, Comoro Islands, North Sea, Red Sea, Mediterranean, Norway, Iceland, South Africa, Japan (Mariana Ridge), New Zealand, Namibia, Indonesia and the Black Sea. In 2004, the submersible performed 50 dives, for a total dive time log of 185 hours. The joint German-South African venture was part of an agreement on Science and Technology Transfer to study the distribution of coelacanths in the Greater St. Lucia Wetland Park. JAGO performed a series of 16 dives into the submarine canyons off South Africa's Northeast coast. Researchers sighted three new coelacanth specimens, pushing the number of known specimens living in South African waters to 24. The research team has studied coelacanths for 15 years off the Comoro Islands, which are home to the largest known population within the Western Indian Ocean.

For 2005, JAGO will be on a diving expedition off the Lofoten islands, in North Norway, aboard the German Research vessel *Poseidon*. The three week July expedition on deep water corals will involve researchers from University Erlangen and IFM-GEOMAR in Kiel. Immediately afterwards, JAGO is scheduled to be transferred onto the *MV Polarsyssel*, in Tromsø, northern Norway. For most of August, the submersible will take part in a polar historical expedition to the most northern wreck at the North Cape off Spitsbergen. The expedition is led by Dr. Fricke and the team of Max-Planck Institute. In conjunction with this expedition, the submersible will be used to document the wreck of the *Nautilus* (www.amphilsoc.org/library/exhibits/nautilus/intro.htm) from Sept 05 to Sept 11 2005, in the fjord off Bergen. The project will be led by the JAGO team and Dr. Steward Nelson. From January 2006 onwards the JAGO team and the submersible will move to the Leibniz Institute of Marine Sciences IFM-GEOMAR in Kiel (www.ifm-geomar.de). The long-range plan is to operate JAGO from this new facility and eventually to build a new submersible in Kiel, capable of diving to 1000 meters. In the long-range future, IFM-GEOMAR would like to build and operate a 3000 m submersible.

PP SHIRSHOV Institute of Oceanology

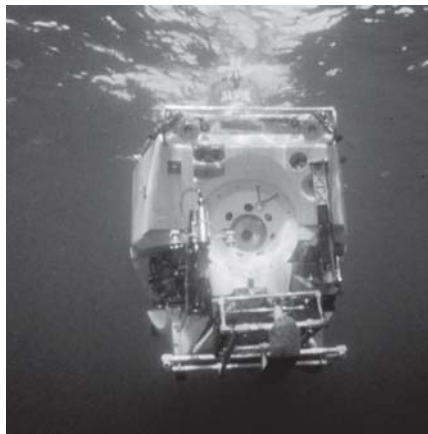


In December 1987 the two deep manned submersibles MIR-1 and MIR-2 were completed and tested by the PP Shirshov Institute of Oceanology of the Russian Academy of Sciences (www.sio.rssi.ru). From early 1988 these two submersibles traveled on scientific expeditions aboard *R/V Akademik Mstislav Keldysh*. Since then the two MIR submersibles have been around the world, diving different areas of the Pacific, Indian, Atlantic and Polar oceans. The submersibles are rated to a maximum depth of 6000 m (20,000 feet) and are both configured to carry a pilot plus two observers. Unique features of the MIR submersibles include the iron-nickel batteries which provide each submersible with 100 kWh of power, almost twice that of other 6000 meters rated submersibles. This high power capacity provides the ability to undertake long underwater work schedules (15 to 20 hours total). It also allows the submersible to power up to eight 1200 W HMI lights, a great feature for underwater filming. The MIRs have an underwater speed of 5 knots and their seawater ballast systems equip the vessels with broad buoyancy control for its vertical maneuvering. The pilot can control its vertical speed from a few centimeters all the way to 35-40 meters per minute. The same seawater system is used for trim control, thereby avoiding the use of mercury.

In spring of 2004, both submersibles underwent their 5 year overhaul and their pressure hulls were hydrostatically tested for renewed certification by Germanischer Lloyd. The MIR subs have accumulated over 400 deep dives, with 40 to the *Titanic*. They are scheduled for four touring expeditions in

2005, following a similar schedule to 2004. The submersibles will dive the *Bismarck* wreck in June, followed by two separate expeditions to the *Titanic* in July and early August.

Woods Hole Oceanographic Institution



WHOI operates the U.S. Navy-owned Deep Submergence Vehicle (DSV) ALVIN as a national oceanographic facility. Rated to a maximum depth of 4,500 meters (14,765 feet), a typical dive takes two scientists and a pilot down for a period of 8 hours. WHOI also operates three research vessels: the *Knorr*, the *Oceanus* and the new *Atlantis*, which supports the ALVIN. ALVIN is operated through the National Science Foundation (NSF) and keeps a busy schedule, considering it is over 40 years old. From its inaugural dive on June 26, 1964 in Woods Hole harbor, ALVIN began 2005 with its 4075th dive. The average depth of all these dives is approximately 2,000 meters (6,500 feet) and it has logged a total of over 28,000 hours of bottom time. To date, ALVIN has carried more than 12,000 persons, averaging 6.9 hours per dive. By far the majority of its dives have been for Biology (1455 dives) and Geology (1435 dives). The remaining missions include Chemistry (474), Engineering (280), Search & Survey (235), and Training/Certification (195). A great online resource with detailed operations logs for ALVIN can be found at WHOI's Web site: www.whoi.edu/marops/vehicles/alvin/alvin_dive_charts.html.

All in all, ALVIN performed 115 dives in 2004. It started its expedition year in San Diego. Aboard the *RV Atlantis* it explored the

East Pacific Ridge for most of February, performing 18 dives to a maximum depth of 4370 m (14,334 ft). Reaching Costa Rica by the end of February, ALVIN performed the next two expeditions recovering samplers and collecting fluid samples at hydrothermal vents. ALVIN performed a total of 17 dives at average depths of 2,500 m (8,200 feet) and as deep as 4,370 m (14,347 feet). In April, ALVIN performed a ridge-integrated study with a focus on biology and chemistry integration of the East Pacific Rise. ALVIN again performed a series of 17 dives to an average depth of 2,500 m (8,200 feet). From there, ALVIN headed for Seattle and during the month of May performed a series of dives off Vancouver Island deploying a prototype moored-buoy seafloor observatory. It continued to explore the Juan de Fuca Ridge, testing equipment and recovering incubators. ALVIN then headed north to the Gulf of Alaska where it performed a total of 19 dives in August surveying volcanic seamounts and collecting volcanic rock. ALVIN surveyed all five seamounts down to a maximum depth of 3,260 m (10,692 feet). In September, the *Atlantis* headed out from Astoria and took ALVIN for two dives on the Gorda Ridge collecting marine macrofauna at hydrothermal vents at a maximum depth of 2,658 m (8,718 feet). ALVIN returned to San Diego in November where it performed engineering dives in the San Clemente Basin. It continued on to the East Pacific Rise performing 28 dives over two months at an average depth of 2,500 m (8,200

feet) collecting incubators, fauna, hydrothermal fluids and testing chemical instruments.

In 2005, ALVIN spent the month of January in transit to the South Pacific, to the Easter Islands and Tahiti. The submersible spent more than three months on a series of 39 dives in the South Pacific before transiting to Costa Rica by May. There the *RV Atlantis* launched ALVIN for a series of dives along the Galapagos Rift. As of early July, the *Atlantis* reached Seattle where it plans to dive the ALVIN until the end of September and return through the Panama Canal to be in Woods Hole by mid-October.

New ALVIN Replacement HOV



Due to the aging of ALVIN, NSF and NOAA funded the National Deep Submergence Facility (NDSF) to undertake the development and construction of a replacement for ALVIN. The construction and features of the new submersible were reviewed to generate specifications for the submersible and its sub-systems in sufficient detail for construction. Science input to this process was implemented through a special advisory committee formed in collaboration with the Deep Sub-

ALVIN DIVE LOG FOR 2004 – 2005

mergence Science Committee (DeSSC) so that science requirements were factored into the design. A separate RHOC (Replacement HOV Oversight Committee) was also created to bring many views from various industries to oversee the production contract. This includes views from NSF, WHOI, the U.S. Navy, research institutes, universities and industry. The specifications have been defined and a request for proposal (RFP) was issued to SouthWest Research Institute to undertake the construction of the main pressure hull.

The planned capabilities and features of the Replacement HOV will include:

- Increased depth capability
- Increased bottom time
- Increased energy capacity
- Improved fields of view
- Increased access to the seafloor
- Improved interior ergonomics
- Increased interior electronics and science payload
- Reduced physical and chemical disturbances to science study areas
- Improved operational and maintenance features
- Improved battery access
- Less complicated and more robust sphere design

Conclusion

Research submersibles and the institutions that operate them remain the most prominent and visible sector of manned submersibles to the general public. The work tends to be at the forefront of science and propels the imagination of everyone of what really lies in our oceans. The community and educational outreach of these major institutions make a great effort to catch the interest of the younger generations. All levels of institutions vesting their future interest in the ocean through manned submersible exploration positively help give a sense of access and subsequent stewardship of this space we call the oceans. It further fosters the hope that despite our tremendous resource management challenges at hand, our modern civilization can change the course of history and change the way we see and use the oceans; like humans changed the use of agricultural land 10,000 years ago. It starts with human access and exploration. It is driven by discovery and nurtured by education.

Just as research submersibles remain at the forefront of technology, millions of guests have traveled on tourism submersibles and have had access to see things they would never have dreamt about. The next sector of manned submersible use is Tourism, which is a powerful tool to educate the public on the very basics of ocean eco-systems. The forthcoming second part of this review will discuss the submersibles and operations around the world fostering ocean awareness to the general public.