2009 MATE International ROV Competition

www.marinetech.org/rov_competition/index.php

ROVs: The Next Generation of Submarine Rescue Vehicles

June 24 – 26, 2009
Massachusetts Maritime Academy
Buzzards Bay, Massachusetts

COMPETITION MISSIONS

COMPETITION OVERVIEW

The ROV competition is divided into two competition classes: **RANGER** and **EXPLORER**. Eligibility requirements for both classes are listed within the 2009 **General Information** document. Please review these requirements carefully.

The MATE Center worked with OceanWorks International and the Deep Submergence Systems Office at Portsmouth Naval Shipyard to create a competition that highlights the history and technological advances being made in submarine rescue systems. The mission scenario focuses on a submarine rescue training exercise where teams pilot their ROVs to inspect the submarine for damage, deliver emergency supplies, and replenish the onboard air supply, among other tasks.

The competition consists of underwater missions, technical reports, engineering presentations, and poster displays with the following scoring breakdown:

- Mission
  - **EXPLORER** – 300 points (max), plus a time bonus
  - **RANGER** – 300 points (max), plus a time bonus
- Engineering & communication – 200 points (max)
  - Technical reports – 80 points (max)
  - Engineering evaluations – 80 points (max)
  - Poster displays – 40 points (max)

Information about the **EXPLORER** and **RANGER** class competition missions, including how to build the mission props, is included in ***this*** document, **Competition Missions**; photos and SolidWorks files of the mission props are located in the document entitled **Mission Prop Photos and SolidWorks Assemblies and Drawings.** The **Engineering & Communication** document contains information about the technical report, engineering evaluation, and poster display.

The MATE Center extends its most sincere thanks and gratitude to Rick Cecchetti of the Deep Submergence System Program Office at Portsmouth Naval Shipyard for his tremendous contribution to the 2009 competition mission scenario and his review of the mission tasks. A great deal of thanks and gratitude also go to Elan Groberman of OceanWorks International for his contributions to the scenario and tasks as well as his introductions to Rick and other resources in the submarine rescue community. The MATE Center and the ROV competition are very fortunate to have had access to Rick and Elan's time and technical expertise and look forward to having them join us at the international competition!

****

History of Submarines and Submarine Rescue: Highlights from centuries of innovation, tragedy, and triumph

Rick Cecchetti, Project Engineer
Deep Submergence System Program Office at Portsmouth Naval Shipyard

Put simply, submarines are designed to go below the surface (dive) and return successfully (surface). They differ from submersibles in that submersibles have limited underwater capability; submarines are designed to stay underwater for extended periods without surfacing to refuel or replenish supplies for the crew on board. Today there are research, tourist, and personal submarines, but the numbers are small. Throughout history submarines have been designed and built primarily for military purposes.

The history of submarines includes some very interesting and innovative engineering solutions. Sheepskin bags for ballast tanks and dropping of ballast stones to surface are two examples. Modern versions of these methods are still in use today.

Until the late 19th century, most submarines were made out of wood. The first submarines made from pieces of metal riveted together were built during the U.S. Civil War era. The first submarines made from a welded metal hull were built in the U.S. during the 1930's.

In addition to hull design and construction, propulsion has advanced considerably from the early days – from man-power to steam, internal combustion, battery, chemical, and nuclear power. Today there are even some non-nuclear submarines that utilize fuel cells or other technologies that allow them to stay submerged for weeks, rather than the hours or days of previous non-nuclear submarines.

As with most pioneering technologies, the history of submarines and submarine rescue systems is filled with "firsts." The following is a short (with the emphasis on short) timeline of submarine milestones, from the first thought that a craft could submerge to the first submarine powered by a nuclear reactor – and from the tragedies to the advances they spurred on in submarine rescue and escape technology and operations.

THE HISTORY OF SUBMARINES

The first idea of submerged watercraft

Englishmen William Bourne is credited with writing down the first ideas concerning displacement of water by ships in 1580. He theorized that by changing its displacement, a ship could go below the surface of the water. No one knows for certain if he ever went further than theory.

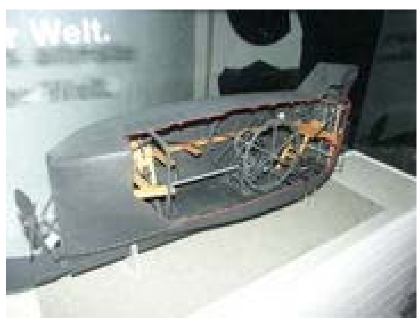
The first submerged attack

The first military submarine was designed and built in Connecticut during the American Revolutionary War. David Bushnell designed the *Turtle*, which was a one-man submarine made of wood and powered by two hand-operated screws. Ballasting was by a foot-operated pump and valves.

The *Turtle* made one attack on a British ship at anchor in New York Harbor. The plan was to attach a timed charge to the hull of the ship and slip away undetected. The attack was unsuccessful because the copper that covered hull of the ship prevented the *Turtle* from attaching the charge. Nevertheless, it can be said that the *Turtle* ushered in the age of submarine warfare.

Turtle replica

The first blockade breaker
In 1850 Prussian army corporal Wilhelm Bauer designed the *Brandtaucher* ("incendiary diver") to break the Danish Navy's blockade of the German port of Kiel. It did succeed in forcing the Danes further out to sea. The crew of the *Brandtaucher* also participated in the first successful submarine escape (see below for details).

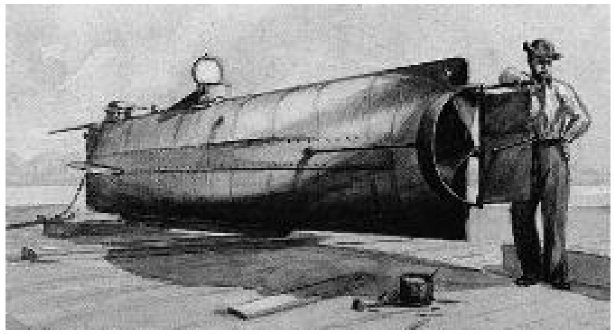


Brandtaucher

The first (somewhat) successful attack
The CSS *Hunley* was built by the confederate army in the hopes of giving them an advantage in the hard-fought U.S. Civil War. The *Hunley* was equipped with two watertight hatches, one forward and one aft, atop two conning towers with small portholes. The *Hunley* was powered by eight men on a hand crank connected to a single propeller.

On February 17th, 1863 the CSS *Hunley* attacked and sank the USS *Housatonic* outside Charleston, South Carolina. This was the first warship ever sunk by a submarine. Shortly after the attack, the *Hunley* was lost with all hands. At the time it was believed the charge she embedded into the *Housatonic* also caused her demise.

In 1995 the *Hunley* was discovered about 1000 yards from the attack. She was raised in 2000. A new report issued in October 2008 indicates that, rather than the explosive's detonation, the loss may have been caused by asphyxiation as the crew ran out of oxygen while fleeing the attack.



CSS *Hunley*

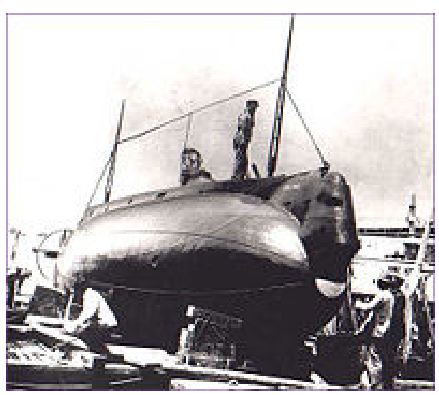
What's in a name? Designation of submarines in the U.S. Navy
Submarines have different designations depending on their purpose. For example, N stands for nuclear power. SS means submersible ship, making SS the designation for a fast-attack diesel submarine. SSN is a fast-attack submarine that uses nuclear power. SSBN is a nuclear submarine that carries ballistic missiles. AGSS is the designation for an auxiliary submarine with diesel power. (Auxiliary refers a submarine that has different missions and may or may not have weapons.) SSG is used as a designator for a diesel-powered, guided missile submarine.   SSGN is a nuclear-powered submarine capable of launching guided missiles.

(Eventually) the first U.S. Navy contract to build a submarine
In 1887 the U.S. Navy advertised a competition for a submarine. Engineer John Holland won the competition, but he was never offered a contract to actually build the ship. The U.S. Navy advertised a contract again in 1888 and again 1893, but still did not purchase a submarine.

In 1895, tired of being given the run-around, John Holland told the U.S. Navy that he was taking offers from foreign navies for his submarine. His "threat" apparently worked and on March 3rd a contract was given for the *Plunger*, which was powered by steam. Congress then authorized him to build two more submarines of the same type.

On April 11, 1900 the *Plunger* was accepted by the U.S. Navy and renamed the USS *Holland*. Some considered it a "novelty" and not a true warship. Despite this sentiment, Holland became known as the "father of the modern submarine."

In 1898, Holland joined other investors to form the Electric Boat Company. Today Electric Boat in Groton, Connecticut continues their long tradition of building underwater boats for the U.S. Navy with its *Virginia* class submarines.



USS *Holland* (SS-1)

The irony of "ungentlemanly" warfare
At the turn of the century, many within the world's navies considered submarine warfare "ungentlemanly." Prior to submarines, when a merchant ship was attacked during war, it was taken as a prize. The crew was given the chance to stay with the ship if the ship was being towed to shore or to board lifeboats if the ship was sinking. As merchant ships began to shoot at or ram surfaced submarines, submarines were forced to attack unannounced and the "gentlemanly" offers to save the crews ceased.

The first use of submarines in World War
The World Wars saw significant changes in submarine design and operations. For example, hulls went from riveted to welded. But still, most submarines were designed to operate on the surface and submerge only occasionally.

German engineering changed all that. During World War II, the Germans developed a snorkel system that allowed submarines to charge batteries while submerged. This decreased the need for going to the surface as the snorkel provided the air necessary to run the onboard diesel generators to charge the batteries.

After World War II, the U.S. Navy performed reverse engineering on two German U-boats (*Unterseeboot* or "undersea boats") and from there developed a set of goals to improve the U.S. submarine fleet. These modifications came under the moniker of the Greater Underwater Propulsion Program (GUPPY). The GUPPY "mods" came in different variants for existing submarines, but the overall purpose was to improve undersea operations. It included streamlining the hull, increased battery capacity, improving maneuverability, and, in some cases, adding a snorkel to allow underwater charging of the ship's batteries.

The U.S. Navy's "first true submersible" was a tuna
In 1953, the little known submarine USS *Albacore* was commissioned. Under the leadership of Admiral Charles "Swede" Momsen, *Albacore* was conceived to inaugurate a radical change in submarine design. World War II experience had shown that speed, endurance, and maneuverability were key requirements for submarines. *Albacore*'s smooth, rounded hull was designed with underwater speed as the prime requirement. In spite of being underpowered, she quickly set speed records for submarines that would stand for decades.

The *Albacore* was modified many times during her life to try various control surfaces and power plant configurations. Today the *Albacore* is in a museum in Portsmouth, New Hampshire.

USS *Albacore* (SS-569)

The U.S. Navy's first nuclear-powered submarine
In 1954, the U.S. Navy launched a traditional-shaped submarine with an untraditional power plant. The USS *Nautilus* first went to sea on nuclear power in January 1955 and forever changed the way that submarines would operate.

USS *Nautilus* (SSN-571)

In April of 1959 the first submarine to marry a nuclear power plant and a true submarine hull – that is, a hull that was designed specifically for submerged operations – was commissioned. The USS *Skipjack* (SSN-585) was the first of six submarines in its class. Using nuclear power, these submarines could remain submerged for months at a time, ending vulnerability at the surface and increasing the stealth operations of submarine warfare.

THE HISTORY OF SUBMARINE RESCUE

USS Squalus rescue – the first of its kind
In May of 1939, the USS *Squalus* (SS-192) was undergoing the final phases of testing and performing emergency dives when she sank off the coast of New Hampshire in more than 240 feet of water. The aft section of the submarine quickly flooded and 26 men perished. However, in the forward compartment, 33 men survived the initial incident.

At the time the *Squalus* was operating alone, but within a few hours the USS *Sculpin* (SS-191), her sister ship, came to search for her. The crew of the *Sculpin* sighted a red smoke bomb then found the rescue buoy that was attached to *Squalus* floating at the surface. In the buoy there was a telephone, and the *Sculpin* crew talked briefly with the *Squalus* crew before the buoy's cable parted and communications were lost. Desperate to find the disabled submarine, the *Sculpin* dragged a grapple along the seafloor. After hooking onto *Squalus*, the crew of the *Sculpin* attached marker buoy for the rescue team.

USS *Sailfish* (SS192)
(Formerly the USS *Squalus*)

The closest submarine rescue ship, the USS *Falcon* (ASR-2), was docked in New London, Connecticut, with one of her main engines undergoing repair. The *Falcon* was built in 1918 as a minesweeper and later converted to a diving and submarine rescue platform. Her equipment included diver support equipment and a McCann Submarine Rescue Chamber (SRC). Originally designed by Admiral Charles "Swede" Momsen with revisions made under the charge of Lieutenant Commander Allan McCann, the McCann SRC is large steel bell-shaped chamber that can be lowered with cables down to the escape hatch on a sunken submarine.

Upon hearing the news about the *Squalus*, engineers quickly finished the work on the *Falcon*'s engine, and she got underway immediately for the New Hampshire coast. But not before the best and brightest of the diving community at the Navy Dive School in Washington, DC were put onto a plane bound for New Hampshire. Because of foggy conditions in New England, the plane had to land in Rhode Island and the divers were transported by high-speed car, complete with a police escort, to the Portsmouth Naval Shipyard where they met up with the *Falcon*. It was reported that these brave souls were more frightened by the ride than any of the heroic acts they would soon be performing in the *Squalus* rescue.

The man in charge of the rescue operations was the creator of the McCann rescue chamber, Commander "Swede" Momsen, a navy submariner and rescue diver. Since the U.S. Navy acquired its first submarine in 1900, it was the accepted wisdom that no crew would survive when a submarine went down. Momsen refused to believe that. He was the head of a deep-sea experimental diving unit who had spent years inventing or working on a number of devices that might help save trapped submarine crew. In addition to the McCann SRC, he designed the Momsen Lung, an underwater rebreather that would allow a submariner to breathe normally as he made a free ascent to the surface.

After the 14-hour race from New London and with Commander Momsen directing operations, the *Falcon* arrived at the site. A four point mooring was laid to provide a stable position for the rescue operations. The depth of the water was 242 feet, well below the normal operating depth of the divers, but that did not deter Momsen and the dive team. Momsen had been working on an experimental gas mix that would allow divers to work deeper without risk of the bends or other decompression sicknesses. The dive team would be the first to use this mix in a real emergency situation.

The divers attached the McCann SRC downhaul cable. After three successful trips bringing survivors to the surface in the SRC, the downhaul cable jammed and the cable began to unravel. Rather than severing the cable completely, Swede ordered the SRC back to the bottom. Divers attempted to attach a new cable, but with no luck. With time running out, a member of the rescue team on board the *Falcon* was able to attach a clamp below the break in the downhaul cable and the SRC was brought to the surface with the remaining survivors.

In four trips and 39 hours after the *Squalus* began her ill-fated dive, 33 crew members were returned to the surface. The official cause of the *Squalus* sinking was listed as a faulty diesel air supply. While some disagreed with this conclusion, no one would argue with the need to make changes to future submarine designs to ensure that a similar incident would never happen again.

The HMS Thetis (N25) incident – the British face their first submarine tragedy

The HMS *Thetis* sank during sea trials when a torpedo tube was accidently opened, allowing sea water to flood the forward compartments of the ship. The stern remained on the surface and four people escaped successfully, but the remaining 99 men died. This incident happened within a week of the successful rescue of the USS *Squalus*.

The *Thetis* was recovered, refloated, and renamed HMS *Thunderbolt*. However, despite its resurrection, the ship could not escape what seemed to be its inevitable fate. The *Thunderbolt* was lost with all hands during World War II.

HMS *Thunderbolt*
(formerly the HMS *Thetis*)

The Brandtaucher – the first submarine escape
The first submarine escape occurred in Kiel, Germany in 1850. The *Brandtaucher*, a submarine designed by Prussian Corporal Wilhelm Bauer, became stuck in the mud at about 60 feet below the surface. The three-man crew waited six hours for enough water to leak through the damaged hull to equalize the pressure inside the hull with the sea water pressure outside the hull so that they could open the hatch and free-ascend to the surface. All three survived.

The USS Tang – the first successful escape from a modern submarine using specifically-designed escape equipment
On October 24, 1944, while on its fifth and final World War II patrol, the USS *Tang* (SS-306) launched her last torpedo. The torpedo broached, curved to the left, and turned back toward the *Tang*. The submarine fishtailed under emergency power to clear the turning circle of the torpedo, but it struck her abreast the aft torpedo room approximately 20 seconds after it was fired. She sank, stern first, in water 180 feet deep.

She had been on the surface at the time of the torpedo strike and, of the nine men on the bridge, three survived by swimming all night long. Thirteen of the crew on board attempted escape from the forward compartments of the stricken submarine using the Momsen Lung, but only eight successfully reached the surface.

A total of nine *Tang* survivors were picked up by a Japanese destroyer escort. They spent the remainder of the war in Japanese prisoner of war camps.

The USS THRESHER – the first complete and tragic loss of a U.S. nuclear submarine
The USS *Thresher* (SSN-593) was the first in a new class of fast, quiet, deep-diving, nuclear-powered submarines. She was designed for optimum performance of sonar and weapons systems. Her thick hull meant that she could dive to more than 1,000 feet, deeper than any previous submarine.

On April 10th, 1963 the *Thresher* was conducting sea trials after an overhaul at Portsmouth Naval Shipyard when something went horribly wrong. During a deep dive, what experts believe was a silver-brazed pipe that broke at depth lead to a series of events that automatically shut down the submarine's nuclear reactor. Unable to restart her reactors immediately, the *Thresher*'s crew could not keep her from sinking beyond crush depth. Moments later, the U.S. Navy's underwater listening system picked up a powerful implosion. All 129 lives on board were lost, including the submarine's builder and shipyard personnel.

After an extensive underwater search using the bathyscaphe *Trieste*, the oceanographic ship *Mizar*, and several other ships, *Thresher*'s remains were located on the sea floor, some 8,400 feet below the surface, in six major sections. The twisted wreckage was described as an "automobile junkyard." The tragedy shocked the American public as well as the U.S. Navy, which vowed that the *Thresher* crew members would not die in vain.

USS *Thresher* (SSN-593)

SUBSAFE – the first rigorous submarine safety program in the U.S.
The loss of the *Thresher* is considered a watershed moment in the history of submarine safety standards, escape, and rescue. Two significant changes occurred as a result of the disaster. After a U.S. Navy board of inquiry found that the design and building of modern submarines did not provide adequate safeguards for the hostile operating environment of the deep ocean, a new submarine safety program called SUBSAFE was created and more focus was brought to submarine escape and rescue.

The stated purpose of the SUBSAFE program is to provide "maximum reasonable assurance of watertight integrity and recovery capability." The SUBSAFE program is based on strict quality control for any system that can affect the ability of the submarine to reach the surface. This includes strict control of the procurement of raw materials through the building, installing, and testing of all sea-connected components, ballast control air systems, hydraulics, and control surfaces. The SUBSAFE Program is completely focused on bringing the disabled submarine to the surface.

Once SUBSAFE was in place, the U.S. Navy embarked on a massive redesign and upgrade program for all submarines in service to include SUBSAFE design and construction upgrades. These included major work on high pressure air, hydraulics, and control systems.

Critics say that the SUBSAFE is expensive, but to the families of submariners, it has been worth it. From 1915 through 1963, the U.S. Navy lost 16 submarines to non-combat incidents, about one submarine every three years. Since SUBSAFE began in 1963, only one U.S. submarine has been lost, and that was the USS *Scorpion* (SSN-589), which had not yet had the SUBSAFE alterations installed.

USS *Scorpion* (SSN-589)

DSRVs – the first submersible dedicated to ensuring the safe rescue of the crew
In addition to the SUBSAFE program, the *Thresher* loss convinced the U.S. Navy to develop an alternative to the SRC that could reach the depths where modern submarines could survive. The Deep Submergence Project Office was formed, with the funds and official permissions to issues proposals for new research and new technologies that could keep up – or down, rather – with submarines.

The design and construction of a Deep Submergence Rescue Vehicle (DSRV) was one result. The DSRV is a free swimming, battery-powered submersible that is transported “piggyback” on specially modified submarines of various navies. The DSRV can dive, locate the disabled submarine, and attach itself to the submarine’s escape hatch. After the DSRV is properly attached to the submarine, the submarine’s hatches are opened and the submariners can enter directly into the DSRV. Once the crew is inside, the DSRV detaches itself from the submarine and transfers the crew to the surface support vessel, which can be a ship or specially modified submarine.

The DSRV-1 (*Mystic*) was launched in 1970 and remained in service until October of 2008, when the U.S. Navy’s Submarine Rescue System-Rescue Capable System (SRS-RCS) took over. The cornerstone of the SRC-RCS is the Pressurized Rescue Module System (PRMS), a remotely operated rescue vehicle system that represents the next generation of submarine rescue systems.

And this leads to a discussion of where submarine escape and rescue are today.

DSRV-1 (*Mystic*) on a USN 688 class submarine

Author’s note: *Multiple sources were used in preparing this document. Credit for the information goes to the Internet, resource books, and the collective memories of submariners at the Portsmouth Naval Shipyard.*

Worldwide Submarine Rescue & Escape Today

Rick Cecchetti, Project Engineer
Deep Submergence System Program Office at Portsmouth Naval Shipyard

The innovations, tragedies, and triumphs of the past helped to shape the submarine rescue and escape systems of today. From the “primitive” Momsen Lung to the sophisticated, multi-faceted Submarine Rescue System-Rescue Capable System (SRS-RCS), submarine rescue and escape technology has come a long way, benefitting from the creativity and “smarts” of navy personnel, engineers, and technicians who pushed the envelope of design and engineering in order to save lives.

The actual systems aside, probably the single most important development in submarine rescue and escape of the past 20 years is the coordination between nations through the International Submarine Escape and Rescue Liaison Office (ISMERLO). The U.S Navy, in particular, is in a much better position with ISMERLO because of the increased focus on the whole process – survivability, escape, rescue, and how they all interrelate.

And it is with ISMERLO that the list of submarine rescue and escape assets that exist in the world today begins.

International Submarine Escape and Rescue Liaison Office (ISMERLO)
On August 14th, 2001, Russia announced that one of its newest submarines, the *Kursk*, had sunk in the Barents Sea. Various news agencies reported possible survivors in relatively shallow water.

The world's submarine rescue agencies immediately went into action. Command centers were set up in countries all over the world. Call backs went out to all rescue personnel and preparations were made to load transportable rescue systems onto airplanes.

Sadly, the world eventually learned that no one aboard the *Kursk* remained alive aboard. The international submarine community mourned the loss of its fellow submariners.

But that was not the end. As with previous tragedies, the *Kursk* incident brought about action – this time in the form of ISMERLO. Headquartered in Norfolk, Virginia, the purpose of this office is to provide a place for the gathering and dissemination of submarine escape and rescue information.

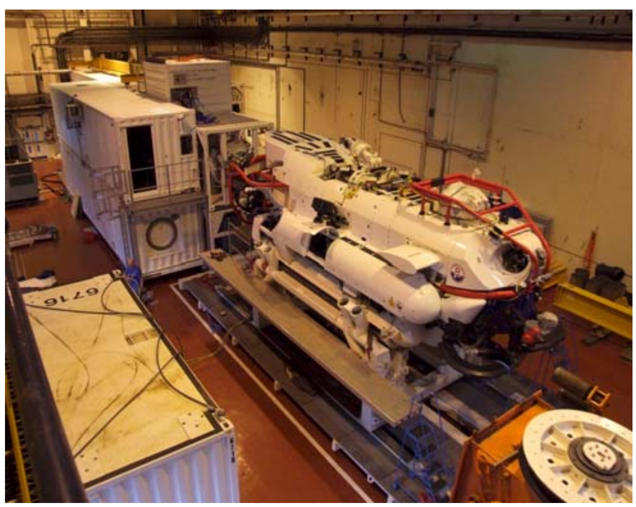
ISMERLO encourages participation from all nations that operate submarines. If an incident does occur, ISMERLO participating nations can access a web-based chat page where they can report on the availability of their equipment and where the status of the rescue is tracked.

Visit www.ismerlo.org for more information about the office and the international submarine rescue and escape assets that follow.

Australian Navy
The *Remora* is the first Remotely Operated Rescue Vehicle (RORV) designed and built by OceanWorks International of North Vancouver, British Columbia, Canada. In service since 1995, the *Remora* can transport up to six rescuees from a disabled submarine.

Australia's *Remora* RORV

NATO Submarine Rescue System (NSRS)
The NATO Submarine Rescue System (NSRS) is a free-swimming, multi-national submarine rescue asset. Put into service in 2006, the NSRS includes Transfer Under Pressure (TUP) capability, which is the ability to maintain the rescuees at the same (elevated) pressure throughout the rescue process. The NSRS is operated by France, Great Britain, and Norway.



NATO NSRS

NATO NSRS being launched

Japanese Marine Self-Defense Force
The Japanese Marine Self-Defense Force (JMSDF) operates two ships dedicated to submarine rescue. Each is equipped with a Deep Submergence Rescue Vehicle (DSRV).

JMSDF DSRV *Angler Fish 2*

The JMSDF also operates an OceanWorks International "hard suit," which is a one atmospheric diving suits used for submarine location and evaluation.

Republic of Korea (ROK)
The Republic of Korea (ROK) has a dedicated submarine rescue ship, *the Chung Hae Jin*, which is equipped with a free-swimming DSRV. The ship is also outfitted with recompression chambers and a deck for helicopters. The DSRV can carry up to 10 passengers at a time.

ROK DSRV LR5K

Peoples Republic of China (PRC)
The Peoples Republic of China (PRC) has three rescue ships with Submarine Rescue Vehicles (SRVs) on each ship. Little is known about these SRVs.

France
As noted above, the French Navy is part of the NATO NSRS team. France also operates an Atmospheric Diving Suit (ADS) and an ROV.

India
India has one submarine rescue support ship, the *Ins Nireekshak*. The *Nireekshak* carries two DSRVs that are each capable of rescuing 12 men at depths of up to 300 meters and a submarine rescue chamber capable of transporting 10 submariners. Two recompression chambers are also installed on board the *Nireekshak*.

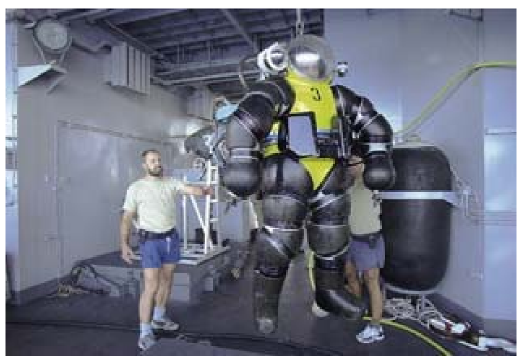
Italy
The Italian Navy has three different vehicles in its submarine rescue arsenal. The first is a free-swimming SRV (SRV 300). The SRV 300 is designed for operations in up to 300 meters of water. It can carry up to 12 passengers and operate with internal pressures up to 6 atmospheres. The SRV 300 is not air transportable but is carried by a dedicated support ship, the *Anteo*.

Anteo with the SRV 300

The second Italian vehicle is a variant of the McCann Submarine Rescue Chamber (SRC).

McCann SRC on the Italian Navy *Anteo*

The third Italian vehicle is an OceanWorks International ADS capable of operations in up to 330 meters.



Italian ADS

Russian Federation
The Russian Federation's PRIZ class of DSRVs consists of four vehicles built from 1986 to 1991 and operated from rescue ships designed to carry up to two DSRVs at a time. Each DSRV can carry up to 20 passengers, including its crew of four.

In August of 2005, the Russian DSRV AS-28 was entangled off the coast of Kamchatka. The incident resulted in a worldwide submarine rescue effort with many countries offering assistance. A British rescue team with a ROV assisted in cutting the DSRV free from entangling lines. All personnel were safely returned to the surface.

Russian Federation’s DSRV AS-32

The Russian Navy’s assets also include eight OceanWorks International hard suits that are each capable of operating in up to 1,200 feet.

Russian ADS

Singapore
The Singaporean Navy maintains a support ship, the M/V *Kendrick*, an ROV, and Emergency Life Support System (ELSS) pods. ELSS pods contain medical supplies, food, candles, and other supplies. The ROV delivers the pods to the crew of the disabled submarine through the escape hatch.

Spain
The Spanish Navy has a submarine rescue ship, the *Neptuno*, which is a converted oilfield tug.

Sweden
The Swedish submarine rescue ship is the HSwMS *Belos*. The *Belos* is a converted oil field support ship that carries the SRV *Urf*. In addition, the *Belos* carries an ROV, an ADS, and diver support equipment. The *Belos* is also equipped with decompression facilities and is capable of transferring the rescuees under pressure (TUP) from a variety of rescue vehicles.

The free-swimming *Urf* can transfer an entire Swedish submarine crew of 35 at one time.

Swedish *Urf*

Turkey
Turkey operates a submarine rescue ship, the TNS *Akin*, which carries a McCann SRC. The *Akin* was purchased from the U.S. Navy in 1973.

The Turkish Navy also operates QUANTUM hard suits and is a member of the NSRS rescue team.

United Kingdom
Great Britain has had one of the most comprehensive submarine escape and rescue programs for years. The United Kingdom Submarine Rescue System (UKSRS) consists of a Submersible Craft for Ocean Repair, Position, Inspection and Observation (Scorpio) 45 ROV, the LR5 manned rescue submersible, and a TUP system, among other assets.

Great Britain is also part of the NSRS team.

United States
The Submarine Rescue & Diving Recompression System (SRDRS) replaced the U.S. Navy's DSRV in October of 2008. To date, only the first two (of three) subsystems of the SRDRS have been delivered.

The first subsystem is the Advanced Underwater Work System (AUWS) that consists of an ADS system (ADS2000) and locating equipment. The AUWS was certified for use in 2006. The U.S. Navy's ADS2000 consists of four hard suits and three Launch and Recovery Systems (LARS). The suits can be used with or without the LARS. The suits are designed for operations in up to 2,000 feet, with the intention that two suits are used at any given time.

U.S. Navy's ADS2000

The second subsystem is the Submarine Rescue System-Rescue Capable System (SRS-RCS), which became certified as rescue ready in October of 2008. The SRS-RCS consists of an OceanWorks International RORV called the Pressurized Rescue Module (PRM) and a LARS. The PRM and LARS come with all the necessary support equipment, including electrical generators and air compressors, for 24-hour-a-day operations.

All the U.S. Navy systems are air transportable. They are housed at the North Island Naval Air Station in San Diego, California.

U.S. Navy's PRM

The final subsystem of SRDRS is the Transfer Under Pressure (TUP) capability, which is still in acquisition. The SRDRS includes two 32-man recompression chambers and the necessary deck connecting systems to allow rescuees to be transferred from the rescue vehicle to the recompression chambers under the pressure in which they were rescued at depth.

USN Submarine Rescue Chamber

The U.S. Navy also operates an SRC that is an improved design of the McCann SRC. The SRC is positively buoyant and winches itself onto the disabled submarine using a cable that has been connected to the center of the escape hatch. The SRC is limited to an operating depth of 850 feet.

Author's note: *Multiple sources were used in preparing this document. Credit for the information goes to the Internet, resource books, and the collective memories of submariners at the Portsmouth Naval Shipyard.*

****

ROVs: The Next Generation of Submarine Rescue Systems

In October of 2008 the U.S. Navy certified its Submarine Rescue System-Rescue Capable System (SRS-RCS) as "rescue ready." The commissioning of the SRS-RCS, designed and built by OceanWorks International, ushered in a new era – an era in which ROVs are now the cornerstone of the most advanced submarine rescue systems in the world. It also further demonstrated the versatility of ROV technology and how this technology continues to benefit industry, government, science, academia, and the military since first being introduced more than 50 years ago.

While still tethered to and controlled by operators at the surface, remotely operated rescue vehicles (RORVs) differ from typical ROVs in that they are designed to carry people. Using what was once a diving bell, combining it with a work class ROV package, and adding an articulated submarine mating skirt, OceanWorks International essentially created a "manned ROV." Two rescue personnel travel on board the vehicle to the disabled submarine. Once there, these personnel are responsible for docking the vehicle to the disabled submarine and transferring the crew to safety.

The RORV and auxiliary equipment that OceanWorks designed and built for the U.S. Navy is called the Pressurized Rescue Module System (PRMS). While the PRMS is not the first RORV system engineered by OceanWorks, it is the first designed & built from the ground up for submarine rescue. It is also the first to be fully "air transportable" to a vessel of opportunity – that is, a vessel in the vicinity of the disabled submarine that is capable of hosting the rescue operation.

Unique features of the PRMS include:

● The Pressurized Rescue Module (PRM). At 24 feet long and 8 feet wide, this "diving bell" has the largest rescue capacity of any system in existence today. In addition to the rescue personnel, the PRM has seats for up to 16 submariners.

● Ballast system. Sixteen individual water bags, each weighing the equivalent of one person, "ride" in the empty seats as the PRM descends. The bags are drained into the disabled submarine to compensate for the buoyancy changes as the submariners are transferred into the PRM.

● Articulated transfer skirt. This skirt allows the PRM to mate to the disabled submarine deck at angles up to 45 degrees. In addition, since skirt swivels to match the angle of the disabled submarine's escape hatch, the vehicle can stay level during the rescue.

● Ability to mate to topside decompression chambers. Once back on board the support ship, the vehicle mates to a transfer lock that enables the rescued submariners to transfer under pressure (TUP) into a decompression chamber. Here they can be monitored closely as they are slowly brought back to atmospheric pressure.

The U.S. Navy will name its PRMS the *Falcon* after the USS *Falcon*, the ship that was used as surface support during the USS *Squalus* rescue and salvage operations in 1939. The *Falcon* improves the U.S. Navy's submarine escape and rescue capabilities by eliminating the need for specially modified submarines or support ships to transport the rescue vehicle to the site of the disabled submarine. The *Falcon* is the second of three components of the Navy's Submarine Rescue Diving Recompression System (SRDRS), which includes other assets such as atmospheric diving suits, side scan sonar, and decompression chambers.

For nine months, OceanWorks personnel worked with the U.S. Navy to train its personnel to safely and successful operate the *Falcon*. Part of this training involved several rescue training exercises designed to demonstrate the vehicle's features as well as the potential for future RORV technology development.

And a submarine rescue training exercise using RORV technology is where your mission begins.

References
OceanWorks Submarine Rescue Systems
www.oceanworks.com/submarineRescueSystems.php

Pressurized Rescue Module System
www.oceanworks.com/cms/pdfs/OW2002_Pressurized%20Rescue%20Module.pdf

Sea Trials on the New US Navy Submarine Rescue System
www.oceanworks.com/cms/pdfs/SeaTrials_USNavySubRescueSystem.pdf

Lifting Lives from Down Under
www.oceanworks.com/cms/pdfs/052004_Navy%20Times.pdf

See www.oceanworks.com/videos.php for videos of the PRM and other OceanWorks submarine rescue assets.

****

OVERVIEW

The scenario that your team now faces is this: to design and build an ROV capable of successfully completing a submarine rescue training exercise. The exercise includes the following four tasks:

Task #1: Survey and inspect the submarine for damage (25 points max)
Task #2: Pod posting (100 points max)
Task #3: Ventilation (100 points max)
Task #4: RORV (remotely operated rescue vehicle) mating (75 points max)

The future of submarine rescue systems depends on your team's technical abilities, ingenuity, and hard work. Nations – and people's lives – are counting on you.

GOOD LUCK!

****

EXPLORER and **RANGER** class teams will compete in ONE mission that consists of the four distinct mission tasks listed above. Both **EXPLORER** and **RANGER** class teams will get **TWO** attempts to complete this single mission. The higher of the two scores will be added to the engineering and communication score to determine the total overall score for the competition.

The time allotted to complete the mission tasks (i.e., the mission performance period) is 15 minutes, plus 5 minutes to set up your system and 5 minutes to demobilize your equipment and exit the control shack. Your team will receive a time bonus for successfully completing the missions and returning your ROV to the surface and touching the side of the pool by the control shack before the mission performance period ends**. YOU MUST COMPLETE TASK #1 FIRST, BEFORE ATTEMPTING THE OTHER MISSION TASKS; HOWEVER, ONCE TASK #1 IS COMPLETED, YOU CAN COMPLETE TASKS #2, 3, AND 4 IN ANY ORDER.** Your ROV does not need to return to the surface between mission tasks.

TIME BONUS

Teams will receive 1 point for every minute and 0.01 point for every second under 15 minutes remaining. Your mission performance period ends when your ROV has successfully completed ALL FOUR OF THE MISSION TASKS, returned to the surface side of the pool under its own power, and a team member at the launch station has physically touched the vehicle. Time bonus points will be awarded accordingly.

****

Task #1: Survey and inspect the submarine for damage.

In a real-world submarine rescue training exercise or in an actual disabled submarine situation, rescue crews would first inspect the submarine for damage and report the location and extent of that damage before any rescue or repair tasks were attempted. Therefore your team MUST complete this survey and inspection before moving on to attempt the remaining mission tasks.

A modern submarine
(courtesy of OceanWorks International)

Task #1 involves conducting a visual survey and inspection of the submarine to find and identify 5 points of damage. In this rescue exercise, the points of damage will be simulated by the capital letters A, B, C, D, and E. Using your ROV's camera(s), your task is to pilot your vehicle around the perimeter of the submarine and locate each point of damage on your video monitor(s).

This mission task involves:

- **Descending to the submarine.**
- **Piloting your ROV around the complete perimeter of the submarine.**
- **Locating a damage point on your video monitor(s).**

Scoring – up to 25 points

- Descending to the submarine – 5 points
- Piloting your ROV around the complete perimeter of the submarine – 10 points
- Locating ONE damage point on your video monitor(s) – 2 points for each damage point located (up to 10 points total)

Once you have located a damage point on your video monitor(s), you must state "damage point A (or B, C, D, E)" and show that damage point on your video monitor to a mission official. Once you receive confirmation from the official that he/she sees the damage point on your video monitor(s), you will receive your points and can continue with the mission task. You can locate the damage points in any order. At some point during this task, your ROV must travel completely around the perimeter of the submarine.

MISSION PROP SPECIFICATIONS
The submarine is simulated by black, blue, and/or gray milk crates. The deck of the submarine is level.

The body of the submarine is seven milk crates set in a straight line and held together with cable ties (zip ties). Each individual milk crate is approximately 32 cm in length, 32 cm in width, and 27 cm tall. All together, the length of the submarine is approximately 2.3 meters.

The conning tower extends from the center milk crate of the submarine body. The conning tower is an additional two milk crates high, making the total height of the conning tower (from the base to the top) approximately 87 cm. The top milk crate of the conning tower is set on its side (32 cm length).

A periscope rises vertically 30 cm above the top of the conning tower. The periscope is made of ½-inch PVC pipe with a ½-inch 90^{o} elbow on top. Dive weights are used to hold the submarine to the bottom of the pool.

Capital letters A, B, C, D, and E simulate the damage points. Each letter is reflective silver, boldface font on a black background. Each letter is 3.8 cm (1 ½ in) in height and 2.1 cm in width. The letters were purchased from Home Depot, part # 840-880.

Each letter is mounted onto the submarine using Velcro. A piece of Velcro "hooks" is attached to the backside of each letter. Corresponding pieces of Velcro "loops" are attached to various locations on the submarine. Dive support staff will vary the location of each letter between mission runs and between each team's individual mission attempts. In other words, each letter will change its location throughout the competition to avoid providing teams that "go last" with an advantage over teams that "go first."

****

Task #2: Pod posting.
Ensuring the safety of the crew is the top priority of any submarine rescue operation, be it a training exercise or real-life emergency situation. Rescuing the crew from the submarine is the ultimate goal; however, if a rescue vehicle is not immediately available or it has been determined that the submarine can be brought to the surface in time, the task turns to providing the crew with emergency life support supplies.

These supplies include medical supplies, oxygen candles, food, and CO_2 absorbent, among other items, that are delivered via Emergency Life Support System (ELSS) transfer pods. Once at the site of the disabled submarine, the pods are transferred into the escape tower by a Deep Submergence Rescue Vehicle (DSRV), Atmospheric Diving Suit (ADS), or RORV where the crew inside can then access them.

The ELSS transfer pods are deployed and delivered to the seafloor via a carousel assembly. The carousel is deployed using a launch and recovery system that consists of crane winch and lift line that attaches to the top of the assembly. The carousel assembly and launch and recovery system are "fly-away," meaning that they can be flown to the closest port then sailed to the vessel hosting the rescue operation.

ELSS pods and carousel assembly
(courtesy of OceanWorks International)

The carousel assembly can be launched in “live boat mode” where the vessel is underway and/or experiencing rough seas. The carousel is slowly lowered to the seafloor using a powered winch. Once the carousel has reached the seafloor, an acoustic coded signal sent from the vessel releases a motorized shackle on the carousel. This then frees the lift line and allows the line to be pulled to the surface to remove any potential entanglement problems. This also allows the crew to prepare the next carousel for deployment.

ELSS pod carousel launch
(courtesy of OceanWorks International)

With the pods on the bottom and the lift line securely out of the way, the rescue vehicle can begin delivering the emergency supplies.

Task #2 involves opening the hatch of the submarine's escape tower, inserting up to 5 ELSS transfer pods into the escape tower, and closing the hatch. In this rescue exercise, the ELSS carousel assembly has already been deployed and is resting (weighted) on the seafloor near the submarine.

This mission task involves:

- **Turning the hand wheel to unlock the hatch.**
- **Opening the hatch.**
- **Removing an ELSS transfer pod from the carousel assembly.**
- **Inserting the pod into the escape tower.**
- **Closing the hatch.**
- **Turning the hand wheel to lock the hatch.**

Scoring – up to 100 points

- Turning the hand wheel of the hatch from the "close" to the "open" position – 10 points*
- Opening the hatch so that it remains open and with access to the escape tower – 15 points
- Removing an ELSS transfer pod from the carousel assembly so that it is no longer in contact with the assembly – 5 points for each pod removed (up to 25 points total)*
- Inserting the pod into the escape tower so that the pod is completely inserted (i.e., no part of the pod is emerging from the tower) – 5 points for each pod inserted (up to 25 points total)*
- Closing the hatch so that it remains closed and with no access to the escape tower – 10 points
- Turning the hand wheel of the hatch from the "open" to the "close" position – 15 points*

***RANGER and EXPLORER mission tasks differ in the following ways:**
RANGER teams must turn the wheel 180^{o}.
EXPLORER teams must turn the wheel approximately 360^{o}.

Each RANGER team ELSS transfer pod weighs up to 1 N in water.
Each EXPLORER team ELSS transfer pod weighs up to 2 N in water.

Your team can remove more than one pod at a time from the carousel; similarly, your team can insert more than one pod at one time into the escape tower. Your team is not required to remove the pods from the carousel assembly using the handle located at the top of the pod. However, your team cannot lift the carousel assembly, transport it to the escape tower, and "dump" the pods into the escape tower. Your team cannot intentionally move the carousel assembly in any way.

MISSION PROP SPECIFICATIONS

The ELSS pod is constructed from a 20 cm length of 3-inch diameter ABS pipe. The top of the pod is a 3-inch PVC end cap; the bottom of the pod is a flat, 3-inch knockout end. The lift mechanism for the pod is a 1-3/8 inch by 3-11/16 inch long style U-bolt attached to the top end cap. The U-bolt rises 6 cm above the top of the end cap.

The ELSS pod for RANGER class teams weighs 1 N when submerged in water. The ELSS pod for EXPLORER class teams weighs 2 N when submerged in water.

The carousel is constructed from ½-inch PVC pipe. It consists of 6 individual square openings arranged 3 by 2. Each opening is a 9.5 cm x 9.5 cm. This allows the body of the pod (the 3-inch ABS pipe) to sit within the carousel, with the top of the pod (the 3-inch end cap) above the carousel. The carousel is approximately 20 cm in height. Dive weights are used to secure the carousel to the bottom. The carousel is within 3 meters of the submarine. **Note:** Although there are 6 openings in the carousel, there are only 5 ELSS pods.

The escape tower consists of a milk crate (see the **MISSION PROP SPECIFICATIONS** of task #1 above for further details about the submarine), PVC framework, a hatch, and a hand wheel that controls the locking mechanism for the hatch.

To open the hatch, teams must turn the hand wheel until the hatch's locking mechanism is disengaged. For RANGER class, this means turning the hand wheel approximately 180^o; for the EXPLORER class, this means turning the hand wheel approximately 360^o.

The hatch is a 5-gallon bucket lid. The lid is attached to a ½-inch PVC frame by a 2 ½-inch brass hinge. The PVC frame is in turn attached to the submarine (see below for further details). A 6-inch long by 5/16-inch bolt penetrates the center of the bucket lid; this bolt connects the lid to the hand wheel and locking mechanism. The hand wheel is on "top" of the bucket lid, while the locking mechanism is on the "bottom" of the bucket lid.

The hand wheel is constructed from ½-inch PVC and is shaped like an octagon. The outer portion of the wheel is constructed from a series of PVC tees and 45^o elbows. The first PVC tee is attached to a 45^o elbow, which is attached to another 45^o elbow, which is attached to another PVC tee, which is attached to 45^o elbow, which is attached to another 45^o elbow, which is attached to another PVC tee. This pattern continues until an octagon of PVC tees and elbows is created. Note that there are no gaps where the ½-inch pipe between the tees and elbows is visible. All open ends of the tees face inward. Each of these inward facing ends is connected to a PVC cross at the center of the hand wheel. The 6-inch long by 5/16-inch bolt that penetrates the center of the bucket lid also penetrates this PVC cross. The hand wheel ranges from 24.5 cm to 28 cm in diameter. At its center, the hand wheel extends 5 cm above the hatch; at its outer wheel, the hand wheel extends 3 cm above the hatch. The hand wheel takes less than 1 Newton of force to rotate.

The locking mechanism consists of a ½-inch PVC connector with a 17 cm length of ½ inch PVC pipe on one side of the connector. This pipe runs beneath the hatch's octagonal PVC frame and prevents the hatch from being opened until it is turned to the proper orientation.

The PVC frame raises the hatch 7 cm above the submarine deck and also serves to keep the hatch from opening until the proper orientation is reached with the hand wheel. The frame is joined to the milk crate by cable ties that hold a PVC connector vertically to each corner of the milk crate. Each connector is attached to a 90^o elbow facing inward. Each of these elbows is connected to a PVC tee within the frame.

To assist teams in determining when the locking mechanism is open, a section of the hand wheel and a section of the hatch are colored black. The PVC tee above the locking mechanism is painted black and a wedge section of the bucket lid corresponding to the open section of the framework is also painted black. When the black PVC tee matches the black section on the bucket lid, the hatch will open. **Note:** Teams will not need a color camera to determine the status of the locking mechanism; a black and white camera is sufficient.

The hatch, hand wheel, and locking mechanism take less than 2 N of force to lift.

PROP CONSTRUCTION NOTES

Hand wheel

The first PVC tee is attached to a 45^o elbow, which is attached to another 45^o elbow, which is attached to another PVC tee, which is attached to 45^o elbow, which is attached to another 45^o elbow, which is attached to another PVC tee. This pattern continues until an octagon of PVC tees and elbows is created. Note that the octagon is constructed so that the ½-inch pipe between the tees and elbows is NOT visible. All open ends of the tees face inward. Each of these inward facing ends is connected to a single PVC cross at the center of the hand wheel.

Drill a 5/16-inch hole directly through the center of the PVC cross. Insert a 6-inch, 5/16 – 18 bolt completely through the hole in the PVC cross. Use a 1 ¼-inch washer and a 5/16-inch lock nut to hold the hand wheel in place at the top of the 6-inch bolt.

Drill a 5/16-inch hole in the exact center of the 5-gallon bucket lid and insert the 6-inch bolt through the hole. Place a 1 ¼-inch washer and a 5-16-inch lock nut on each side of the bucket lid to hold the lid in place. The bucket lid should be approximately 8 cm from the top of the 6 inch bolt. **Note:** The lock nuts and washers need to be loose enough so that the 6-inch bolt and hand wheel spin freely, but tight enough so that the hand wheel does not "rock" loosely above the bucket lid.

Drill a 5/16-inch hole completely through the center of a ½-inch PVC connector. Insert the 5/16-inch bolt through this hole. Use a 5/16-inch lock nut on each side of this PVC connector to hold it in place. The connector should be approximately 1.2 cm from the bottom end of the 6-inch bolt. Insert a 17 cm length of ½-inch PVC pipe into one side of the connector.

The hand wheel and locking mechanism need to turn together with the 6-inch bolt, so make sure that the lock nuts are tight. A slightly smaller hole than 5/16 may be needed in order to get a tight connection. The bucket lid should NOT turn with the 6-inch bolt.

The hand wheel needs to be properly weighted and buoyed so that opening that hatch takes less than 2 N of force. Use small amounts of flotation inside the ½-inch PVC pipe that comprises the hand wheel to achieve this buoyancy. It is also important for the locking mechanism to maintain its orientation when the hatch is opened. Attach sufficient weight to the short end of the locking mechanism (the section of the ½-inch PVC connector without the 17 cm length of pipe). Alternatively, add a small amount of weight inside the ½-inch PVC pipe of the hand wheel on the side opposite the long end of the locking mechanism. When the hatch is open, the weight and buoyancy distribution within the hand wheel should maintain a "straight up" orientation for the locking mechanism (the 17 cm length of PVC pipe should extend straight up).

The 5-gallon bucket lid is connected to the frame that is attached to the milk crate that is part of the body of the submarine. The lid is connected to the frame with a 2 ½-inch hinge (purchased from Home Depot, part # 613-576). Screw one half of the hinge into the PVC frame on the side farthest from the frame opening and screw the other half of the hinge into the side of the bucket lid.

Paint a section of the bucket lid black and one of the PVC tees in the hand wheel black to assist in determining if the hatch is unlocked. Paint the PVC tee directly above the locking mechanism PVC pipe black. On the 5-gallon bucket lid, use black paint or a black permanent marker to color a wedge section above the opening on the PVC frame. The RANGER class wedge is approximately 60 degrees of circumference. The EXPLORER class wedge is approximately 45 degrees of circumference.

RANGER frame

Connect the first leg of the frame that holds the hatch to the milk crate to a PVC tee angled horizontally. From one side of this first PVC tee, connect a 45^o elbow, then another 45^o elbow, then another tee with the side arm facing downwards. Attach two connectors, pointing downwards, to this PVC tee. The other end of the PVC tee should attach to the second PVC tee forming the second leg of the frame. Connect a

45^o elbow to the other end of this PVC tee, then a connector, then another 45^o elbow, which fits into the PVC tee that makes the third leg of frame. Connect a 45^o elbow to the other end of this third PVC tee, then a connector, then another 45^o elbow. This should attach to the fourth leg of the frame. This leaves a gap of approximately 90^o open. Teams need to turn the hand wheel until the locking PVC pipe reaches this opening, allowing the hatch to open.

EXPLORER frame

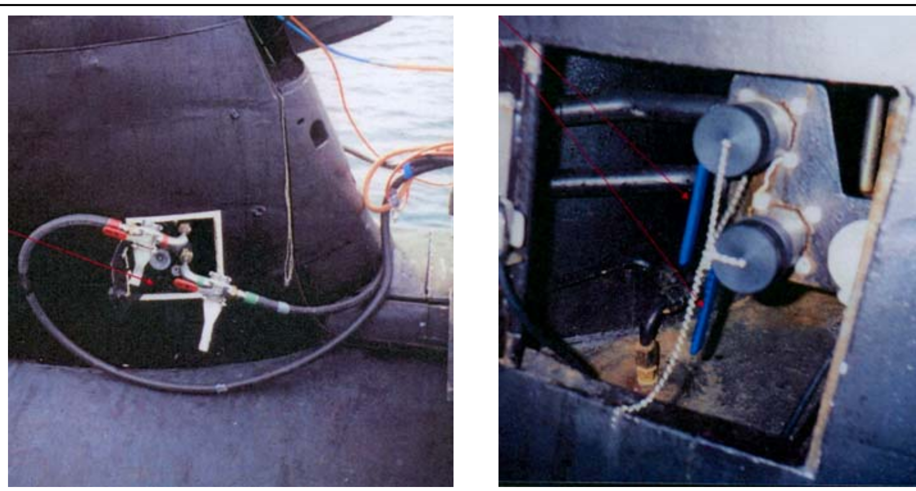
Connect the first leg of the frame that holds the hatch to the milk crate to a PVC tee angled horizontally. From one side of this first PVC tee, connect a 45^o elbow, then a PVC connector, then another 45^o elbow, which fits into the second PVC tee. The other end of the PVC tee connects to a 45^o elbow, then a connector, then another 45^o elbow, which fits into the third PVC tee. The other end of the third PVC tee connects to a 45^o elbow, then a connector, then another 45^o elbow, which fits into the fourth PVC tee. The other end of the fourth PVC tee connects to a 90^o elbow that is pointing downwards. Add two connectors to this elbow, pointing downwards. This leaves a gap of 40^o to 50^o open. Teams need to turn the hand wheel until the locking PVC pipe reaches this opening, allowing the hatch to open.

****

Task #3: Ventilation.

Replenishing the submarine's air supply is another step taken to ensure the safety of the crew on board while waiting for either a rescue vehicle or for the submarine to be repaired and/or brought to the surface. The process of removing the "bad" air from the submarine and replacing it with "good" air is called ventilation.

To ventilate, a rescue vehicle transports an airline from the surface host vessel to the submarine where it then opens a hatch on the submarine's conning tower to reveal the inlet and outlet valve connections. Once the airline is inserted, the vehicle opens the valve and signals to personnel on board the host vessel to start the flow of air to the bottom.



Inlet valve connections

(courtesy of www.sorbetroyal2002.celex.net/)

Task #3 involves opening a hatch on the side of the submarine's conning tower, inserting an airline, opening the valve to permit airflow, closing the valve to stop airflow, removing the airline, closing the hatch, and returning the airline to the surface.

In a real-world submarine rescue training exercise or in an actual disabled submarine situation, the task would also include opening the valve on an outlet valve connection to allow the “bad” air to escape and removing protective covers in order to access the valve connections. However, in this rescue exercise, you need only focus on the inlet valve connection and do not need to remove a cover to access the connection.

This mission task involves:
- **Transporting the airline to the submarine.**
- **Opening the hatch.**
- **Inserting the airline into the inlet valve connection.**
- **Opening the valve to allow the flow of air.**
- **Closing the valve to stop the flow of air.**
- **Removing the airline from the inlet valve connection.**
- **Closing the hatch.**
- **Returning the airline to the surface.**

Scoring – up to 100 points
- Transporting the airline from the surface to the submarine so that its insertion point does not dangle from the line – 10 points
- Opening the hatch so that it remains open and with access to the inlet valve connection – 15 points
- Inserting the airline into the connection so that it remains in the connection once it is released from the ROV – 10 points
- Turning the valve from the “close” to the “open” position to simulate the flow of air – 15 points*
- After 10 seconds and once the mission control official announces “time,” turning the valve from the “open” to the “close” position to simulate stopping the flow of air – 15 points
- Removing the airline from the connection so that it is completely separated from the connection – 10 points
- Closing the hatch so that it remains closed and with no access to the inlet valve connection – 15 points
- Returning the airline to the surface so that its insertion point does not dangle freely from the line – 10 points

***RANGER and EXPLORER mission tasks differ in the following ways:**
RANGER teams must insert the airline into a 2-inch connection.
EXPLORER teams must insert the airline into a 1 ½-inch connection.

Penalty points
- Airline insertion point dangling from the line – 5 points

Once your ROV reaches the submarine and opens the hatch, you must complete this task in order.

The hatch is located aft of the conning tower (the hatch is oriented vertically). Competition officials will supply the airline; however, it is your team’s responsibility to incorporate this airline into your vehicle so that it can be transported to the submarine. The end of the airline, where it inserts into the valve connection, is “delicate;” it can neither dangle freely by its line as you transport it to the submarine nor dangle freely by its line as you return it to the surface. If it does, your time will receive penalty points. The line is long enough to reach from the surface to the bottom.

Once your ROV inserts the airline into the connection and opens the valve to permit the flow of air, you must notify a mission control official. At that time, the official will, using a stopwatch, verbally count off 10 seconds. At the end of 10 seconds, the official will announce “time.” Only then can your team close the valve to stop the flow of air and remove the airline.

MISSION PROP SPECIFICATIONS

The hatch is constructed of ½- inch PVC and plastic mesh and is essentially a “doorway” to the open side of the uppermost milk crate that makes up the conning tower. Note that the open side milk crate is facing aft. The hatch is 30 cm tall and 30 cm wide. It is hinged on the left side. A handle to open the hatch is located on the right side. The handle is 16 cm in length and extends 9.2 cm from the hatch. The inner dimensions of the handle (i.e., the open space within the PVC) are 10.5 cm wide by 6.5 cm tall. ¾-inch plastic mesh covers the PVC framework. It takes less than 1 N of force to open the hatch.

The RANGER class inlet valve connection is constructed of 2-inch PVC. The EXPLORER class inlet valve connection is constructed of 1 ½-inch PVC. Both the RANGER and the EXPLORER class inlet valve connections are oriented at an upward angle of 45^o and are located on the right side of the milk crate. The inlet valve is approximately 18 – 20 cm deep.

The airline is simulated by a length of 1/8-inch diamond braid polypropylene rope. The rope is long enough to reach the submarine. The point at which the airline is inserted into the inlet valve connection is called the “insertion point.” The insertion point is constructed of a ½-inch insert tee and a 14 cm long plastic yellow garden hose nozzle. The insert tee is designed to assist in transporting the airline hose from the surface to the submarine. The nozzle is 3.4 cm in diameter at the point at which is connects to the insert tee, then tapers to a diameter of 2 cm at the point at which it is inserted into the inlet valve connection. The entire insertion point is 30 cm long. To ensure a successful connection, teams should plan to insert the entire length of the yellow garden hose nozzle (14 cm) into the inlet valve connection. The insert probe will weigh less than 1 Newton in water.

The valve is constructed of ½-inch PVC and is located on the outside, right-hand side wall of the milk crate. The valve handle is 12.5 cm long and extends 2.5 cm from the side of the milk crate. The “CLOSE” and “OPEN” positions are labeled on the wall of the milk crate. To open the valve and start the flow of air, teams must turn the valve 180^o clockwise from the CLOSE to the OPEN position. The valve must remain in the open position for 10 seconds until a mission control official announces “time.” Teams must then turn the valve 180^o counterclockwise from the OPEN to the CLOSE position. Small bolts are in place to keep the valve from turning beyond the OPEN and CLOSE positions. It t less than 1 N of force to turn the valve.

PROP CONSTRUCTION NOTES

Hatch

Attach a PVC connector to each end of a 15 cm length of ½-inch PVC pipe. Use cable ties to secure the connectors to the front of the milk crate. This serves as the anchor on which to attach the hinges.

Next, attach a PVC connector to each end of a 15 cm length of ½-inch PVC pipe. Attach a 90^o elbow to each connector then insert a 24.5 cm length of PVC pipe into each elbow. From there, attach a 90^o elbow to the end of each length of pipe so that the ends of the elbows face each other. Next, insert a PVC tee into each elbow and connect these tees with a 10 cm length of pipe. This creates the 30 cm by 30 cm framework for the hatch. Cover the framework with ¾-inch mesh (check a local hardware or garden store for the mesh).

Next, insert a 6.2 cm length of PVC pipe into the end of each PVC tee. Attach a 90^o elbow to each length of pipe and connect the elbows with a 10 cm length of pipe. This creates the handle of the hatch.

Use a pair of 1 ½-inch hinges (purchased at Home Depot, part # 613-541) to secure the hatch to the milk crate. Make sure to mount the hinges onto the PVC connectors.

Inlet valve connection
RANGER
Insert an 11 cm length of 2-inch PVC pipe into a 2-inch PVC 45^o elbow. Attach a 2-inch PVC connector to the other end of the elbow. Using cable ties, secure the 2-inch PVC connector to the bottom, right-hand side of the milk crate. The 11 cm length of 2-inch PVC pipe will be oriented at a 45^o angle. Use additional cable ties to secure the inlet valve to the right side wall of the milk crate

EXPLORER
Insert a 16.5 cm length of 1 ½-inch PVC pipe into a 1 ½-inch PVC 45^o elbow. Attach a 1 ½-inch PVC connector to the other end of the elbow. Using cable ties, secure the 1 ½-inch PVC connector to the bottom, right-hand side of the milk crate. The 16.5 cm length of 1 ½-inch PVC pipe will be oriented at a 45^o angle. Use additional cable ties to secure the inlet valve to the right side wall of the milk crate.

Airline and insertion point
Connect a 16 m length of 1/8-inch diamond braid polypropylene rope to a ½-inch insert tee, threaded (purchased at Ace Hardware, part # 42003) by drilling a hole in the top of the insert tee and threading the rope through the tee. Tie a small knot in the rope to hold it in the tee.

Next, thread a ½-inch PVC male adapter into the tee. From there, insert a 9 cm length of PVC pipe into the male adapter. Attach a ¾-inch MHT – ½-inch slip PVC fitting (purchased at Home Depot, part # 685-822) to the length of pipe. Attach a 14 cm long plastic yellow garden hose nozzle (purchased at Ace Hardware, part # 76947) to the other end of the slip fitting, completing the airline and insertion point. **Note:** The ¾-inch MHT – ½-inch slip PVC fitting is simply an attachment to allow a hose to connect to PVC pipe.

Valve
With the milk crate is in its proper alignment (i.e., oriented as it would be for the mission), choose a hole on the right side wall of the milk crate that is approximately 10 cm from the top and 9 cm from the back of the milk crate. **Note:** Teams should be able to use a "natural" hole of the milk crate but, if necessary, teams can drill or cut their own hole. Milk crate designs do differ, but teams should be able find or create a hole in this approximate location.

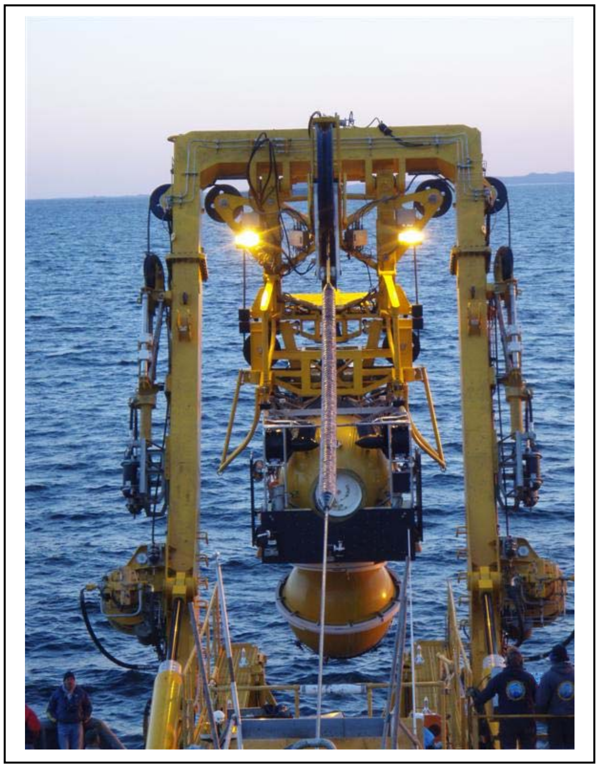
Insert a 37 cm length of PVC pipe through this hole and through the left wall of the milk crate. Attach an ½-inch end cap to the pipe exiting the left wall of the milk crate and attach a 90^o PVC elbow to the end of the pipe exiting the right wall of the milk crate. Use small screws to hold these end pieces in place. Insert a 12 cm length of ½-inch PVC pipe into the 90^o elbow to serve as the handle.

Use a pair of 3-inch 8/32 bolts to keep the handle from passing the "OPEN" and "CLOSE" marks on the wall of the milk crate. With the handle in the CLOSE position, insert a 3-inch bolt just under the handle near the fulcrum. This will keep the handle from dropping below the horizontal CLOSE position. Teams may need to use cable ties, washers and lock nuts, or another method to hold the bolt in place in the side of the milk crate.

Turn the handle to the OPEN position, 180^o clockwise, and insert a 3-inch bolt just below the handle to keep it from passing the OPEN position. Use 1-inch tall letters to label the wall of the milk crate OPEN and CLOSE.

****

Task #4: RORV (remotely operated rescue vehicle) mating.
Once again, the ultimate goal of any submarine rescue training exercise or actual disabled submarine situation is to save the lives of the crew on board. Once the rescue vehicle arrives on the scene and it has been determined that the submarine cannot be repaired and/or freed from the bottom in time to save the crew, the rescue operation begins in earnest. The rescue vehicle is immediately launched and quickly makes it way to the seafloor.



PRM launch during training exercises
(courtesy of OceanWorks International)

Once positioned over the deck of the submarine, the personnel operating the rescue vehicle use sonar altimeters to determine the distance and angle of the submarine deck and, in the case of OceanWorks International's PRM, adjust the articulated skirt angle to match. The personnel then dock the skirt onto the escape hatch.

From there, rescue personnel use pumps to pull water out of the skirt, creating a tight seal. Using the external water pressure to hold the vehicle in place, the pressure inside the skirt is then equalized to the pressure inside the vehicle. Once the hatches are opened, the crew members are transferred from the submarine to the PRM. The rescue personnel then reseal the hatches, flood the transfer skirt, and undock the vehicle from the submarine.

At the surface, the PRM is brought on board the host vessel and the mating process begins again – although this time the skirt is mated with a decompression chamber. Once transferred from the vehicle to the chamber, the crew is gradually brought back to normal atmospheric pressure under the watchful eyes of doctors who monitor them for signs of the bends or other decompression sicknesses.

If there are additional crew members on board, the PRM then repeats the process until the entire crew of the submarine is safely at the surface.

Submariners "rescued" inside the PRM during training exercises
(courtesy of www.boldmonarch08.info/)

Prior to the competition, task #4 involves building and incorporating a transfer skirt into the rescue vehicle. At the competition, task #4 involves mating the transfer skirt to the escape hatch, holding position, then undocking from the hatch. In this rescue exercise, your team is responsible for building and incorporating the transfer skirt into your ROV. **The dimensions of the transfer skirt are assigned by the competition; your team MUST build and incorporate a skirt that falls within the assigned dimensions. Note that the skirt does NOT need to articulate; the deck of the submarine will be level.**

This mission task involves:

- **Building and incorporating a transfer skirt into the ROV.**
- **Mating the transfer skirt to the escape hatch and holding position.**
- **Undocking the transfer skirt from escape hatch.**

Scoring – up to 75 points

- Building and incorporating a transfer skirt that falls within the assigned dimensions into your ROV – 15 points*
- Mating the transfer skirt to the escape hatch so that the transfer skirt completely surrounds the hatch and covers the red band and holding your ROV in that position for 20 seconds until a mission control official announces "time" – 50 points*
- Undocking the transfer skirt from the escape hatch so that your ROV is completely separated from the escape hatch – 10 points

***RANGER and EXPLORER mission tasks differ in the following ways:**
The diameter of the RANGER class escape hatch is 9 cm.
The diameter of the EXPLORER class escape hatch is 10.6 cm.

Your team must build and incorporate a transfer skirt with the following dimensions:

- **The diameter of the internal opening of the transfer skirt (i.e., the part that fits around the escape hatch) may be no more than 11.5 cm.**
- **The transfer skirt must be at least 3 cm "deep" (i.e., it must fit over the escape hatch approximately 3 cm).**

The top 1.7 cm of the escape hatch will be a red-colored band. Your transfer skirt must completely surround the escape hatch and completely cover the red band for the entire 20 seconds.

Once your transfer skirt is mated so that it completely surrounds the escape hatch and covers the red-colored band, you must notify a mission control official and hold your ROV in that position for 20 seconds. The mission control official will work with the dive support staff and/or an underwater camera positioned at the site to confirm that your ROV's skirt completely surrounds the hatch and that it completely covers the red-colored band. Once the mission control official announces "time," you can undock your vehicle from the escape hatch.

If your vehicle separates from the escape hatch so that any portion of the red-colored band is visible at any time during the 20 seconds, you must reposition your ROV and the mission control official will start the 20-second clock again. There is no limit to the number of times that the 20-second clock can be restarted.

MISSION PROP SPECIFICATIONS

The RANGER class escape hatch is constructed from a 3 cm length of 3-inch ABS pipe. It does not extend higher than 3 cm above the deck of the submarine. Note that a 3-inch ABS pipe has an external diameter of 9 cm.

The EXPLORER class escape hatch is constructed from 3 cm length of 3-inch PVC end cap. It does not extend higher than 3 cm above the deck of the submarine. Note that 3-inch PVC end caps have an external diameter of 10.6 cm.

PROP CONSTRUCTION NOTES

To create the **RANGER class escape hatch**, cut a 3 cm length of 3 inch ABS pipe. Wrap a length of red colored electrical tape (1.7 cm in width) around the top of the pipe. Wrap this length of tape around the pipe twice. Drill four holes around the perimeter of the bottom of the ABS pipe (the black section) and use cable ties to attach it to the milk crate.

To create the **EXPLORER class escape hatch**, cut a 3 cm length off the open end of a 3-inch PVC end cap. Paint the length of end cap black. Wrap a length of red colored electrical tape (1.7 cm in width) around the top of the pipe. Wrap this length of tape around the pipe twice. Drill four holes around the perimeter of the bottom of the ABS pipe (the black section) and use cable ties to attach it to the milk crate.

- -