Human Body Search and Recovery Using Mini-ROVs

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I. INTRODUCTION

Mini-ROVs (Remotely Operated Vehicles) have been used as rapid response tools for the search and recovery of human bodies in zero visibility, inaccessible and "beyond diver depth" environments for some time now.

In the past several years, the mini-ROV industry has grown from engineering prototypes to commercial off the shelf products. In the process prices have dropped and capabilities have increased. As a result, the aggregate sales of mini-ROVs have soared. The market has become sufficiently large enough to attract the attention of companies who are designing sensors and accessory products specifically for these platforms which require smaller size and weight then previous designs.

With these new technologies readily available, more and more law enforcement agencies are adopting mini-ROVs into their repertoire. The mini-ROV should not be considered a diver replacement tool, it should be considered a diver enhancement tool providing an advanced "eyeball" in the water to assist them with safety, response time and project costs. And for the most part, experienced divers have the shortest learning curve and make the best mini-ROV pilots.

II. MINI-ROV BY DEFINITION

There are three basic categories of ROV's:

A. Observation Class
Small electrically powered vehicles, historically used mostly for inspection.

B. Work Class
Large vehicles, often with hydraulic power, are able to carry big loads of tooling packages, multi-function manipulators, etc. can be used to directly retrieve objects underwater.

C. Special Use Class
Special use ROVs are purpose built for a specific task such as hull inspection or cable burial.

The Observation Class vehicles can be further classified into three divisions:

A. Micro
Micro class ROVs are the smallest in size and weight. Today's Micro Class ROVs can weigh less than 3 kg (6.6 lbs). These ROVs are used as an alternative to a diver, specifically in places where a diver might not be able to physically enter such as a pipeline or small cavity. They essentially are a swimming eyeball with no other sensors on-board; typically limited to operating in still waters with no current.

B. Mini
Mini Class ROVs are one man deployable systems and typically weigh in around 15 kg (33 lbs). In addition to inspection, Mini Class ROVs can be used as sensor delivery platforms and can be outfitted with simple grabbers and other accessories and are able to perform in moderate water currents.

C. Medium
Medium class ROVs typically require more than one person or a hoist to deploy. Greater payload capability enables them to carry larger size sonars and cameras. Ability to work in higher currents is another attribute.

Mini-ROVs can be effectively used in a variety of applications. These applications generally fall into a combination of the following 4 categories:

1. Observation
Scientific Research, Commercial Diving

2. Inspection
Hydrologic, Ship Husbandry/Hull Inspection, Offshore Oil & Gas, Port Security, Crime Scene Investigation, Aquaculture

3. Search / Recovery
Emergency Response, Archeology, Treasure Hunting, EOD

4. Custom Sensor Delivery Platform
Radiation Detectors, Thickness Gauges, High Definition Cameras, Low-Light Cameras, Sonars, Water Quality Sensors, Science Research

As new technology develops, the capabilities of mini-ROVs continue to advance and open doors to new applications.

III. SENSORS & TOOLS

Mini-ROVs are essentially underwater sensor and tool delivery platforms. These additions to the mini-ROV allow a vehicle to be configured for a particular application. We will discuss some of the common sensors and tools used.

A. Video

All mini-ROVs have at least one video camera standard in the front, if not two. The standard forward facing video cameras are usually high resolution, color cameras. A secondary low-light, black & white camera is often provided for use in turbid waters. A tilt mechanism on the forward facing cameras allow the pilot to look in a 180° vertical range. Panning in the horizontal plane is usually achieved by rotating the entire vehicle or moving the mini-ROV laterally. Some vehicles have a rear facing camera for backing up and monitoring the umbilical for snags and entanglements.

Hi-def video cameras are just starting to come down enough in size to fit on/in mini-ROVs. Some have the added bonus of a digital still capability. Hi bandwidth telemetry, such as fiber optics, is required on the mini-ROV to utilize the resolution of these cameras.

Lights are an important part of the vehicle's imaging system. A revolution in lighting has been heralded with the advent of high brightness, light emitting diodes. LEDs offer several advantages over other types of lighting for mini-ROVs. Of primary importance is their small size, light weight, and low power draw. Other beneficial features are their ruggedness, size, long life time, lack of hot spots, and ability to operate in air. In addition, LEDs are available with full daylight spectral output and can be dimmed without changing their emitted color.

Mini-ROV LED lights are often contained internally with the vehicle's camera housing. This arrangement generally works well for close to mid range imaging. Backscatter can be minimized, thereby increasing longer range imaging, by mounting the lights away from the camera.

Image of a SeaBotix external 1080 lumen LED light.

Two video comparisons using the LYYN™ video enhancement.

Sometimes high resolution video cameras and high intensity lighting are just not enough to "see" what you are looking for due to turbidity from plankton, algae blooms and/or suspended sediments. This is where using a real-time video enhancement option can really help. LYYN™ Visibility Enhancement

Technology is a video enhancement technology that can be incorporated directly into the control console of the mini-ROV system or used as an external unit to simply run the video from the mini-ROV through before viewing. This enhancement technology is real-time and does not introduce any latency into the mini-ROV system.

B. Scaling Lasers

Many mini-ROVs are equipped with lasers on either side of their cameras. Pairs of lasers put out parallel beams. The video image shows two dots on a target a known distance apart and allows size estimations to be made.

C. Sonars

Sonars use sound waves to "see" underwater. Since they do not rely on the optics, sonars will work just as well in zero visibility rivers as they will in crystal clear tropical oceans. Sonars work by imparting acoustic pulses into the water via one or more transducers. Objects with a density different then the surrounding water will reflect some of this energy back to the sonar where it is detected, processed and displayed.

The lower the frequency of the acoustic pulse, the longer the range and the greater penetration into the object being insonified. Higher frequencies have better the resolution but the shorter ranges. Thus for small object discrimination, high frequency is needed but more time will be required to search a given area. Sonars are not affected by water visibility making them particularly useful in conditions where cameras are limited. Even in the clearest of water, sonars have the potential to image at much longer ranges than video cameras.

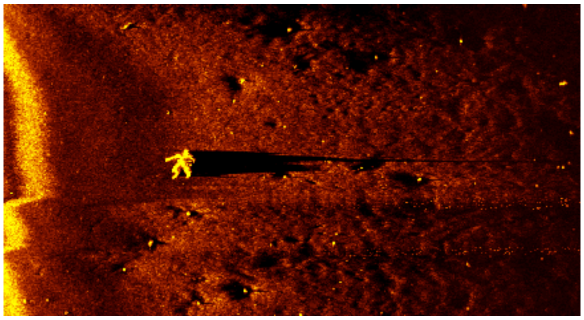
Because the human body has such a high percentage of water in it, it is not a strong acoustic reflector. Air filled organs or SCUBA cylinders, if present, can be seen as bright reflections with low to mid range frequency sonars. Sonars with frequencies above about 900 kHz can image the outline of a body, depending on range, clothing, and other factors.

There are many types of sonar devices. Of primary interest for search operations are imaging sonars which include side scan sonars, scanning sonars and multibeam sonars. These sonars are used on ROVs for obstacle avoidance, object location, and navigation. We will briefly review each type.

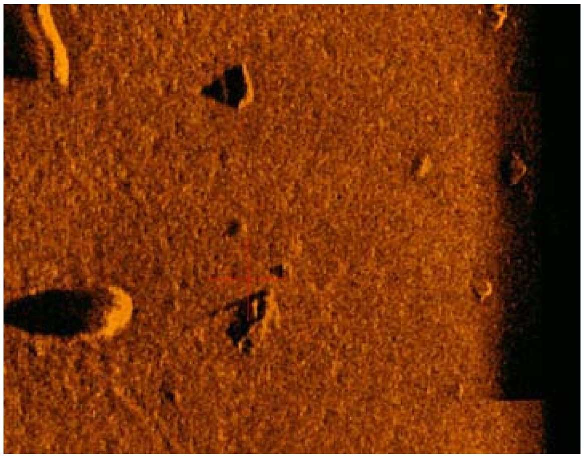
1.) Side scan sonar – Side scan sonars emit fan-shaped acoustic pulses down toward the seafloor across a wide angle perpendicular to the path of the sensor through the water. Slices of seafloor reflection images are stitched together to make mosaics of the bottom. Objects sticking up from the bottom can be seen by their shadows.

Typically side scan sonars are towed from a surface vessel although in shallow water they may be fix mounted to the ship. Usually they are moved through the water at speeds of 2-5 knots but some models are available that can be used in excess of 10 knots.

Side scans can be mounted on mini-ROVs but their long transducers and need for a very stable platform make them ill-suited for use on most mini-ROVs. However, mini-ROVs are great at investigating targets identified by side scan sonars and determining what these targets are.



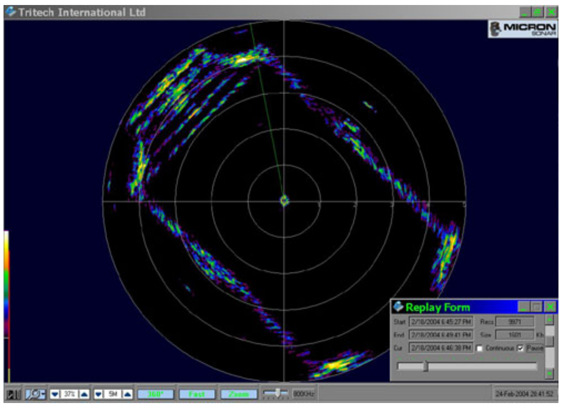
Victim's body imaged using a Marine Sonics Technology Centurion with a 900KH tow-fish in 40 m (131 ft) of water.



Victim's body imaged using a Edgetech 4125-P sidescan sonar in 6 m (20 ft) of water.

2.) Scanning sonar – Scanning sonars have narrow acoustic beams that are mechanically rotated to cover up to 360 degrees. The sweep range can be reduced to scan a smaller sector. Depending on frequency, the range of scanning sonars is 75-305 m (250-1000 ft). Ideally, the sonar should be stationary while it is sweeping to prevent image blur. In practice the mini-ROV needs to sit on the bottom or hover in the water column while a wide sector scan is being made.

Often times a scanning sonar is mounted on a tripod and deployed from a surface ship by its cable. After completing a scan the tripod with sonar is then recovered and moved to another position. Any anomalies are then investigated with an mini-ROV or diver. For uneven underwater terrain it is desirable to have a gimbled mount on the sonar to level it. A compass integrated with the sonar allows the user to know orientation of the image. If one is not available putting an acoustic reflector in the image at a known position can serve the same purpose.

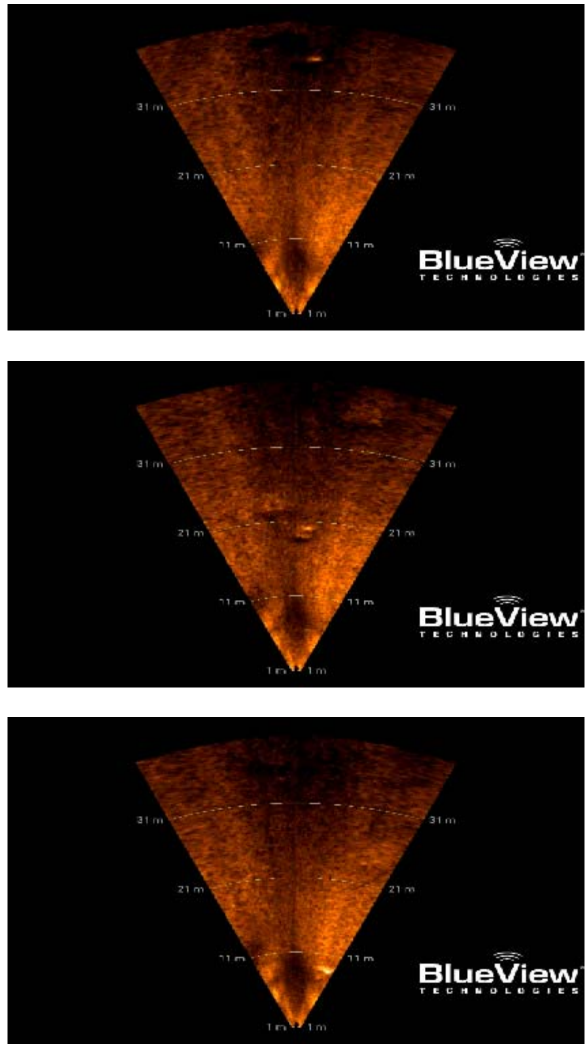


Imaging a swimming pool with a Micron Scanning Sonar.

3.) Multibeam sonars - As the name implies, multibeam sonars use transducer arrays to create multiple acoustic beams simultaneously so a sector can be scanned all at one time. Refresh rates are on the order of 10 times per second. Due to their rapid refresh rate, image smearing is not an issue and the mini-ROV can acquire sharp sonar images on the fly. The high data rate produced by all these images require a high bandwidth connection to the surface such as Ethernet.

Lately several small 3D multibeam imaging sonars have been introduced.

D. Grabbers
Most mini-ROV grabbers on the market today are single function manipulators consisting of a fixed arm with the grabbing (or cutting) head at the end. The SeaBotix LBV Grabber (also used on other mini-ROVs) offers the option of five different interchangeable grabber head attachments giving a wide range of versatility.



Three images approaching a drowning victim’s body using a BlueView P450E multibeam sonar wit h a range set to 41 m (135 ft.).

SeaBotix Large Interlocking Jaws with a 11.5 cm (4.5 in) opening (above).

Pictured above are the SeaBotix Grabber Head attachments which include the Inter-Locking Jaws, Cutting Head, 3-Jaw Head, & Parallel Jaws.

E. Acoustic Tracking Systems

Since GPS signals do not penetrate through water, acoustic methods have been devised to allow the operator to know the position of his mini-ROV at all times. This is very helpful for a variety of reasons including navigating search patterns and re-locating underwater objects. All acoustic tracking systems rely on beacons which can be pingers, which emit a sound pulse at a predetermined interval, transponders which emit a pulse in response to a specific acoustic interrogation pulse, or responders whose pulse is triggered via a wire from the surface. The beacon(s) pulse is detected by a hydrophone suspended from the surface and connected to a computer or controller which determines range and bearing.

There are several commons types of underwater positioning systems.

Long Baseline (LBL) - LBL systems utilize three or more acoustic transponders on the seafloor to communicate with a beacon on the mini-ROV. By triangulation with the ship (and its GPS), the position of the transponders can be accurately determined and then used to determine the position of the ROV. LBL is the most accurate type of acoustic tracking system but suffers several drawbacks including the lengthy time to set up and calibrate the system, the cost of the multiple transponders, and the ability to only track the ROV when it is within range of the seafloor transponders.

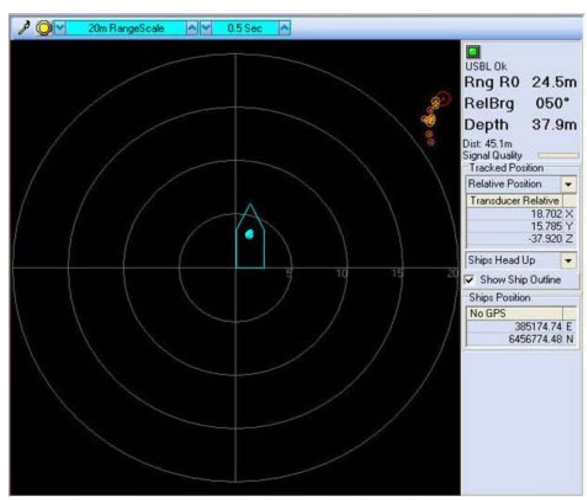
A variant of this approach is inverted LBL which uses transponders on surface buoys (each with GPS receivers) instead of ones on the seafloor.

Short Baseline (SBL) **-** SBL systems consist of one beacon on the ROV and three or more hydrophones hanging over the side of the ship, dock, or other surface structure. SBL systems have the advantage of not needing to deploy and calibrate seafloor transponders. It has accuracies and costs that are intermediate to the other two methods.

Ultra Short Baseline (USBL) **-** USBL systems are similar to SBL except that instead of using the three surface hydrophones, a single multi-element hydrophone array is used instead. This makes them the quickest tracking system to set up and the least expensive of the three methods, although their accuracy is not as high.

USBL systems have proven to be the most popular acoustic tracking system used on Mini- ROVs and several companies now make USBL systems specifically for this platform.

Tritech Micron Nav USBL Tracking System



Tritech Micron Nav Tracking System software display.

All three of these techniques determine the relative position of the target to the ship. Using the ships

GPS position, the absolute position can be determined. System accuracy can be improved by correcting for the ships heave, pitch & roll movement, by using an external heading sensor, and by measuring the speed of sound at the deployment location.

IV. Searches

Several important factors need to be resolved before starting an underwater search. They include deciding where to start the search, determining the area to be searched, selecting a search pattern, and ultimately marking the target when found.

Generally the search starts at the point the victim was last seen. From there a search area is calculated by estimating drift due to winds, currents, tides, topography and the amount of time estimated to have elapsed since the time last seen. Bottom material and vegetation should also be considered as well as water depth. The human body has a glide ratio of about 1:1 so the fall diameter is two times water depth.

Ideally the search area is matched to the search tools available and vice versa. Side scan sonars are best for covering large areas. Scanning sonars are useful for mid size search areas. Mini-ROVs using video cameras and high resolution sonars are best suited for small search areas and for investigating targets identified with the side scan or scanning sonars.

The search area is often broken up into several smaller ones. Additionally, a determination is often made of primary and secondary search areas.

Systematic searching is vital to success of the operation. A good search technique ensures complete coverage of the area and clearly defines areas already searched and areas remaining to be searched.

Search lane widths are generally 60-80% of the visibility range which allows for lane overlap. Lane width is determined by the camera's field of view and height over the bottom. Auto depth or auto altitude controls on the mini-ROV greatly help when searching so lane widths do not vary.

If there is little or no current then it is easiest to keep track of your orientation by running your search lines on even compass headings, i.e. north, south, east or west. If the current is sufficient to cause the mini-ROV to drift out of its lane then it is best to set up your search lines directly up or down current. Navigation is done using the mini-ROVs compass and monitoring how much umbilical has been paid out. Auto heading controls on the mini-ROV and acoustic tracking systems are great to have when conducting searches.

Following are several common search patterns.

A. Parallel Track
This is the most common method used by mini-ROV operators. At the end of each lane the vehicle comes back at 180 degrees from the previous pass. The back and forth pattern is commonly known as mowing the lawn. If unsuccessful the searchers may run a second set of parallel tracks at right angles to the first set in order to view the bottom from a different angle.

B. *Expanding Square*
A pattern of progressively larger squares (a "square spiral"). The expanding square search pattern is used when the search area is small and the last seen position is known within close limits. This pattern begins at the last seen position and expands outward in concentric squares. If error is expected in locating the last seen position, or if it's expected that the victim drifted, the square pattern may be modified to an expanding rectangle with the longer legs running in the direction of the target's probable movement.

C. *Circle*
Used to cover an area using a central point to make full 360 degree circular sweeps. This is usually done with the pivot point on or near the bottom by using a clump weight. By moving where the weight is attached to the umbilical cable, successive rings can be swept by the mini-ROV. This technique is helpful when there is a current running on the surface that does not extend all the way to the bottom. It is also used when working from a hole cut into ice covered water.

D. Arc Search
In the arc search a pattern of concentric arcs is swept by letting out more umbilical for each pass. It is used when a full circular sweep can't be done due to obstruction by a structure such as a pier or dam wall.

Using the lateral thruster allows the mini-ROV to sweep side-to-side without turning. This can be an effective technique to use in rivers and areas with strong currents. Instead of fighting the current head on, let the vehicle sweep arcs down current from the boat.

E. Star Search
A star pattern is used in conjunction with a scanning sonar. With the support boat anchored, the mini-

ROV is run in straight lines to the limit of the umbilical whiling scanning 360 degrees with the sonar. Runs are made every 45 degrees heading out from the starting point to make a start pattern. When the pattern is finished move the boat in the direction of one of the runs by a distance of one half of the umbilical length and run another star pattern. The pattern is repeated as necessary to cover the search area.

V. Target Marking

Once the victim is found, the area should be considered a crime scene until proven otherwise. This may mean bringing in crime scene investigators. Although crime scene investigation is beyond the scope of this paper, it should be noted that ROVs are an excellent tool to help in this effort. Water temperature, depth, body position, and the surrounding area can all be documented by the mini-ROV's sensors and cameras.

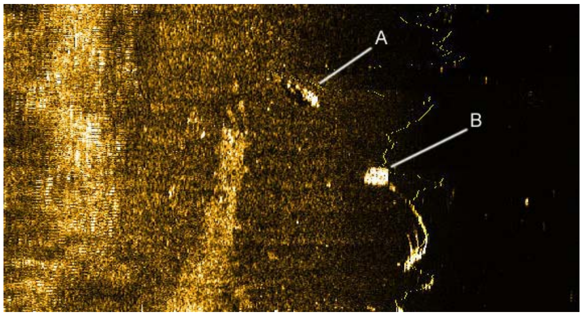
For a variety of reasons it can be important to mark the site. Several methods are used to mark a target underwater so it can be re-acquired.

A. Buoys

A mini-ROV with grabber can deploy a small buoy with line and weight. The buoy is dropped in a manner that allows it to float up to the surface where it can be seen. If desirable, a larger buoy can be added or replace the small buoy. The size of the weight is determined by currents, bottom type and buoy flotation. Generally it is best to anchor the buoy or marker close to the victim but far enough away so they will not interact in any way. If it is feared that the body may drift away then the buoy can be attached to the victim's clothing or body.

B. Acoustic

Active acoustic markers are pingers that broadcast their position to tracking systems and/or ships depth finders tuned to the same frequency. One has to keep in mind the battery life and beam pattern of the pinger to ensure it can be found again.
Passive acoustic markers reflect signals from the ROVs sonar or perhaps the ships sonar. Anything that is a good acoustic reflector can be used but it helps if they have a distinctive shape to differentiate their return from other objects. Examples are ship radar reflectors, subsea buoys, crab/lobster traps, metal wire dog cages, etc.



Klein 3000 Sidescan sonar image. (A) Victim's body (B) An acoustic marker dropped to mark the location .
Image Courtesy: Victoria Police Underwater Security Team

C. Fix with Tracking System

A position fix from the mini-ROV's acoustic tracking system is an ideal marker as no hardware needs to be deployed.

D. Stay on Station

Another alternative to consider is to keep the mini-ROV parked next to the body.

VI. Recovery Techniques

A. Diver Descent Line

This is a very common technique, especially if there is concern over a crime scene. Once the body is located and confirmed by the mini-ROV, using the grabber, lock on to a secure piece of clothing and halt all thrusting. This way disturbance to the body and surrounding area is kept to a minimum. The divers simply follow the umbilical down to the mini-ROV and arrive directly onsite. This also allows the divers a longer bottom time as they do not have to spend time and air searching for the body on their own.

B. Grab and Go

The average adult human body weighs 3-7 kg (7-16 lbs) underwater. This exceeds the payload capability of most mini-ROVs. However, most mini-ROV umbilicals have a strength member that is rated to much more than this. For example the SeaBotix mini-ROV umbilical has a Kevlar strength member that is rated to 315 kg (700 lbs) break strength and 45 kg (100 lbs) working load. By using the mini-ROV's grabber to hold on, the victim can be retrieved by reeling in the umbilical. Divers may want to meet the ROV at shallow depth to secure the victim or bag his body.

When using this technique its best to grab onto a strong, secure item of clothing, belt, belt loop, etc. It is best if grabbing on to the body directly can be avoided.

An example of locking a grabber onto a victim's belt loop (above).

A boat recovery using a carabineer to hook on a recovery line in 115 kg (375 ft.) of water. The same technique could easily be used on a drowning victim's belt loop or on a diver's buoyancy compensator.

C. Retrieval Lines
When working at deeper depths or in strong currents, you may not want to risk reeling in the body in case the grabber loses its grip. In these circumstances it may be better to use a retrieval line which consists of a latching hook or carabineer tied to a line that either extends to a surface buoy, boat or the shore. The latching hook is grasped in the jaws of the grabber with the latching mechanism in the open position, then the mini-ROV navigates to the target and attaches the hook to a secure location that is strong enough to withstand the strain of recovery.

It's often easier to work with a very light weight line, called a messenger line, that can be threaded through the target and brought to the surface. A heavier retrieval line is tied to the messenger line and used to retrieve the victim.

D. Lassos
If a secure attachment point is not available, there are several techniques that can be used to lasso the victim. The mini-ROV pilot may attempt to wrap the retrieval line around the target, and then latch the hook back onto its own line. Another method is to build a deployment frame or spar to help place a rope lasso in a desirable position. Unless you want your lasso to float, its best to avoid polypropylene line. Typically 6.4 mm (0.25 in) Nylon rope is all that is needed as it has a working load of around 50 kg (165 lbs).

E. Spider
If all else fails, as a last resort, one can use the mini-ROV to wrap its umbilical around the victim and tie it in a knot as best as possible. Then the body can be hauled to the surface by the umbilical. The reason this is not recommended is that it the umbilical could be damaged during this process, particularly if it contains fiber optic conductors.

VII. Examples

1. La Jolla Shores: Inexperienced Divers
In October, 2008 a 40 year old father and his 19 year old son went for a recreational dive together at La Jolla Shores near San Diego, CA. At their planned target depth of 45 m (150ft) deep the father ran out of air. The two men attempted to execute an emergency accent sharing the 19 year old son's air. At roughly 12 m (40 ft.), the son ran out of air and he became separated from his father. That was the last time the son saw his father. At 9 a.m. San Diego Lifeguards noticed a distressed diver off of the La Jolla Shores Lifeguard Station. Lifeguards paddled out to the son and pulled him to shore.

Twelve public safety divers from the San Diego Lifeguards immediately began a sweep of the area including two divers who descended to 45 m (150 ft) to search. This initial search turned up nothing and another four public safety divers were sent in to search.

Meanwhile, the U.S. Coast Guard and San Diego Lake Ranger Divers arrived onsite to assist in the search. Reportedly, the U.S. Coast Guard attempted to deploy a micro-ROV they had aboard their vessel and was unable to reach the sea floor. The micro-ROV was unmanageable due to the drag on the umbilical from the currents in the water column.

On the other hand, the San Diego Lake Ranger Divers arrived onsite with their SeaBotix LBV mini-ROV and were able to reach the sea floor quickly to begin their assistance in the search. Unfortunately, the San Diego Lake Ranger Divers min-ROV pilot became seasick. Luckily, as with most mini-ROVs, the SeaBotix LBV is a quick learn to become an effective ROV pilot. The pilot quickly handed over the controls of the mini-ROV to San Diego Lifeguard Rich Strobsky and proceeded to instruct him on flying the transect lines while he closely monitored the video screen in 4-6 (15-20 ft) water visibility. After less than 40 minutes of running transect lines, the father's body was located at 47 m (154 ft) deep.

After a quick discussion, it was decided not to attempt to pull the father's body to the surface using the grabber and umbilical of the mini-ROV since they had public safety divers onsite ready to enter the water. Two public safety divers descended following the umbilical of the mini-ROV and successfully brought the father to the surface. Another, deciding factor not to pull the father's body up with the umbilical was the strong currents in the water column. The chance of the grabber losing grip on the father's body was too much of a risk because if the grabber did lose grip half way up from the bottom, the father's body would have floated for an undeterminable distance.

2. Nevada County: Rock Jumper

The Nevada County Sheriff's Office was called by Yuba County Sheriff's Office for an agency assist on August 6th, 2008. They had a 28 year old male subject missing in about 27 m (90 ft) of water. Yuba County Marine Patrol Sgt. and dive team leader Bill Siler opted to delay any dive operations until other options had been attempted. He requested the assistance of Nevada County Sheriff's Office and their mini-ROV.

Sgt. Jeff Pettitt and Deputy Phil Easley from Nevada County Sheriff's Office responded to the point last seen and deployed their mini-ROV (SeaBotix LBV200L) at approximately 9:30 AM. At approximately 11:30 AM, with the mini-ROV sitting on the bottom of the lake using their Tritech Micron Scanning Sonar, they picked up a sonar target on the port side of the mini-ROV out about 7m (25 ft) They turned the mini-ROV towards the target and began closing the distance. Approaching the target, they could see the 28 year old victim lying flat on his stomach on the bottom of the lake. The mini-ROV pilot, Sgt. Jeff Pettitt, was able to grab the victim's swimming trunks with their 3-Jaw Grabber and hold on.

At this point, Yuba County divers Sgt. Siler and Deputy Willie Kardatzke entered the water and descended down the ROV's umbilical to the victim. The two public safety divers went into the 5.5°C (42°) water at 11:48 AM and they successfully brought the victim to the surface at 11:56 AM. The total time of personel under the water was 8 minutes.

In response to the ease of this search and recovery operation, Sgt. Jeff Pettitt said, "I have been on dives with divers in the water for periods of about 5 days so this was an amazing improvement to officer safety."

Sgt. Siler said, "I was very appreciative of the assistance of NCSO Sgt. Pettit and Dep. Easley. I was so impressed with the Seabotix LBV200L that I have since purchased one to supplement Yuba County's water search operations."

3. Donner Lake: Ice Skater

A man was ice-skating on Donner Lake near Truckee, CA in January, 2007 when he struck his head during a fall, broke through the ice and drowned in approximately 56 m (185 ft) of water. Truckee Police Department has jurisdiction at Donner Lake, but the depth ruled out the use of any public safety dive units.

The Incident Commander, Sgt. Tim Hargrove, put in a call to a long time colleague, John Shaw of Advanced marine Services who has a SeaBotix LBV mini-ROV which is capable of depths to 150 m (500 ft).

They knew where the victim fell through the ice and had marked it with a buoy the day before. So they put their mini-ROV aboard a Truckee Fire air boat which was the only viable transportation over the frozen lake. The buoy where the man was last seen was about 180 m (600 ft) offshore.

Once the mini-ROV was deployed into the icy water, John was able to follow the buoy line down to the bottom of the lake at 57 m (187 ft) The victim was located within minutes several feet from the anchor using only the video camera and lighting that the mini-ROV was equipped with.

The victim was lying supine with his arms up in a text book position. The crew inspected the situation and knew they were going to have to get creative if they were going to retrieve the victim that day.

SeaBotix LBV with make-shift frame to hold lasso to retrieve drowning victim. Photo Courtesy: Truckee Police Department

The mini-ROV they were working with was not equipped with any sort of grabber. So the team decided they would attach a small frame to the front of the bumper frame of the mini-ROV that would hold a rope with a slip-knot. The idea was to maneuver the slip-knot over one of the victim's arms and constrict it tight to pull the victim to the surface. After a practice run using just the frame, they were able to successfully constrict the rope tightly around the victim's arm and pull him to the surface. The total time to complete the recovery was less than 4 hours.

Video capture of the victim's position at 56 m (183 ft) deep. Video courtesy: Truckee Police Department

This video capture shows the rope constricted around the victim's arm as the body was getting pulled to the surface. Video courtesy: Truckee Police Department

Video capture of the marking buoy before decending and following the line to the bottom of the lake. Video courtesy: Truckee Police Department

VIII. Conclusions

In summary, Mini-ROVs have evolved into highly functional underwater vehicles. Equipped with accessory options, they can be valuable tools in the search and recovery of bodies.

Acknowledgments

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Morton, Shane (Tex)
Victoria Police, Water Police Squad, Underwater Security Team

MacDonald, Ian
Buccaneer Ltd.

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