US Army

Outland 1000 ROV Program

DRAFT – For Discussion Purposes Only

Program Review, Status and Recommendations

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Subject: Review of Outland 1000 ROV Program and Recommendations

SFC Haney:

SeaTrepid and Outland have recently completed the delivery and training on the TACOM Outland 1000 ROV and sonar systems for [***Clay, I need the command designations***]. Attached please find a summary of those operations as well as some recommendations for incorporating the ROV-based inspection/security systems for the US ARMY.

The report is divided into 3 basic components:

1) Summary of the Outland 1000 ROV program to-date
2) Recommendations to implement the equipment currently deployed
3) Some specification suggestions as to a US ARMY ROV-based security and inspection system

This report is from the contractor's point of view without access to internal US ARMY documentation. The views expressed within this report are those of the author's and SeaTrepid ONLY. This report is produced as part of the service provided by SeaTrepid during training operations.

Sincerely,

Robert D. Christ

attachment

EXECUTIVE SUMMARY

The purpose of this report is to summarize the US ARMY's Outland 1000 Remotely Operated Vehicle (ROV) program to date, make suggestions as to how best to implement the systems already deployed and to make recommendations as to further developmental work concerning this technology/capability within the US ARMY.

Beginning in May 2004, the US ARMY purchased 20 Outland 1000 ROV systems for operational evaluation with its combat diver and deep-sea diving units.

With the expansion of the traditional US ARMY diving mission to now include new responsibilities, matching the proper technology to the mission is essential to achieving mission objectives. It is the understanding of this author that the initial mission of the ROV technology is for commercial-style diving support, EOD functions, Public Safety Diving-like functions and security threats. This technology is also adaptable to some of the more traditional roles of the US ARMY including facilities/vessel maintenance chores. It needs to be evaluated if this ROV technology commitment will be sufficient to fulfill the new role of finding security threats and/or some of the more traditional roles.

The Outland 1000 equipped with sonar system were purchased as commercial off-the-shelf (COTS) systems. The systems currently deployed function to the purpose for which they were initially designed. This design may or may not be optimal for the US ARMY's needs. Further investigation is needed in order to develop Standard Operating Procedures so as to take advantage of the systems currently deployed. Further, the development of a specification listing will be necessary for "Built-to-Order" ROV systems. In the opinion of this author, the short-term development work for the US ARMY's ROV program should focus on the integration, logistics and support for the systems deployed as well as further work on sensor and navigational accessory integration.

I. Summary of the Outland ROV program to-date

A. Initial Purchase of 20 Outland 1000 ROV systems

US ARMY (through TACOM) purchased 20 Outland 1000 systems beginning in May 2004. These systems were distributed as follows (Serial Number/Date Delivered/Delivered to):

112	MAY-04	ARMY, Panama City
113	MAY-04	ARMY, FT. EUSTIS VA
114	MAY-04	ARMY, Hawaii
115	MAY-04	ARMY, Hawaii
116	JULY-04	ARMY, FT. EUSTIS VA
117	JULY-04	ARMY, FT. EUSTIS VA
118	AUG-04	ARMY, FT. EUSTIS VA
119	AUG-04	ARMY, FT. EUSTIS VA
121	OCT-04	ARMY, FT. EUSTIS VA
122	OCT-04	ARMY, FT. EUSTIS VA
123	NOV-04	ARMY, FT. EUSTIS VA
124	NOV-04	ARMY, FT. EUSTIS VA
125	NOV-04	ARMY, FT. EUSTIS VA
126	NOV-04	ARMY, SFG, Ft Lewis, WA
127	DEC-04	ARMY, SFG, Ft. Bragg, NC
128	DEC-04	ARMY, SFG, Ft. Bragg, NC
129	DEC-04	ARMY, SFG, Ft. Campbell KY
130	DEC-04	ARMY, SFG, Ft. Carson, CO
134	MAY-05	ARMY, SFG, Key West
135	MAY-05	ARMY, SFG, Okinawa

Three Factory Initial Training sessions were provided by Outland/SeaTrepid. One session was conducted in Key West in August 2005 and two separate sessions were conducted at Ft. Eustis in October 2005.

B. Status as of early-November, 2005

Each of the designated diving command units received initial training on the Outland 1000 along with the integrated sonar systems [***Clay, please verify this***]. The extent of the training given was limited to basic theory of operation, basic operations and maintenance for the system. As of the date of this report, all systems are reported as fully operational with the exception of SN 118 [which requires a repaired Control Box].

II. Recommendations to implement the equipment currently deployed

A. Deployment Concepts

With any new operational system employing a new technology, new methods of operation are required in order to fully take advantage of the enhanced capabilities and inherent limitations. An example of this is the advent of the aircraft. It took the development of new methods, techniques and training upon introduction of this new system in order to branch this technology to weapons delivery, aerial observation and passenger transport. Later came the development of instrument navigation technologies and procedures for all-weather capabilities. During each phase of development, a team tested techniques and worked out the best procedures for deployment from the concept stage through to the user level implementation.

With the expansion of the US ARMY's underwater mission requirements to include underwater robotics, new methods and means must be developed in order to take full advantage of this new technology while limiting the need to "recreate the wheel" through trial and error methodology.

B. Defining Mission Requirements

With the expansion of the traditional US ARMY diving mission to now include further below water responsibilities, matching the proper technology to the mission is essential to achieving mission objectives. It is the understanding of this author that the initial mission of the ROV technology is for commercial-style diving support, EOD functions, Public Safety Diving-like functions and security threats. This technology is also adaptable to some of the more traditional roles of the US ARMY including facilities/fixed structure/vessel maintenance chores.

Underwater ROV/Camera technology runs from pole cameras to fully integrated autonomous robotic vehicles. The Outland system deployed with the US ARMY is somewhere in the middle of these extremes as a basic "Flying Eyeball" with basic mechanical intervention and integrated sonar. It needs to be investigated if this technology will be sufficient to fulfill the new role of finding security threats and/or some of the more traditional roles.

C. Integrating currently deployed ROV systems with current infrastructure

RHIB with Sonar and Geo-Referenced Positioning

To this author's understanding, one of the requirements for the initial deployment of the Outland system onto the US ARMY support platforms was that the system fit aboard the standardized RHIB without modification. Due to this, some equipment is necessary in order to obviate the necessity to tap into the RHIB's electronic or power package. If acoustical positioning system is to be used, some data and power requirements are needed in order to deploy off of the RHIB with geo-referenced acoustical positioning and sonar. Small 3 kW Honda generators have been sourced. However, a laptop computer is needed for each system in order to run the sonar or other sensor packages deployed aboard the ROV submersible.

Short baseline acoustical positioning involves the deployment of a 3-transducer array over the side of the vessel/location of opportunity to derive basic range and bearing location for the submersible from the transducer array. That can either be derived relative to the transducer array or can be derived geo-referenced. The system ordered by US ARMY can be operated in either mode.

Real-time magnetic vessel heading information is needed in order to snap the submersible's relative bearing from the transducer array [mounted at known locations on the boat] to magnetic bearing. A real-time GPS feed is needed in order to geo-reference the transducer array. Once the GPS origin and distance/magnetic bearing are obtained, the submersible location is easily resolved.

High-quality heading and GPS information is available from the hydrographic survey software currently deployed on some US ARMY survey boats. Further, with an easy software update, the geo-referenced position of the submersible can be displayed on the survey display. This would eliminate the need for the separate Outland flux-gate heading sensor [and time-consuming separate calibration of same] as well as the [non-differential] GPS receiver used for a regular COTS acoustic positioning system. The output standards are all NMEA standard - meaning they are a non-proprietary format and portable between different vendor positioning systems.

Currently, a separate AC power source is needed to power the Outland system along with its accessories. There are high-capacity battery systems aboard the standard US ARMY RHIB in case a battery-powered inverter is preferred as a power supply. A 3 kW generator, however, should be sufficient to run the systems as currently configured.

To summarize, a small modification to the standardized design of the RHIB could yield cost, time and space savings in further ROV system implementations.

D. Defining and Writing SOPs for ROV Operational Deployments

In order to fully take advantage of the operational capabilities of this new technology, techniques are required so as to make optimal deployments with minimal time, equipment resources and manpower. A program can be established whereby each foreseen operation be tested in a realistic environment so that operational data may be gathered and SOPs defined.

Some possible steps to implementation of this program are as follows:

1. Establish a list of foreseen mission requirements/operational tasks
2. Define the completion objectives
3. Test conceivable means of achieving these objectives
4. Write and Implement SOPs to the unit level allowing for leeway in the field based upon the situation at hand.
5. Produce training manuals as well as establish a training location for standardization.

E. Data/Intel Availability in Support of ROV Operational Deployments

Making available data based upon Intel could assist in deployment of ROV systems. Currently, large vessels are required to transmit AIS information via VHF as well as to give advance notification of arrival into US Ports. An example of Intel assisting ROV operations would be the procedural pairing of AIS information with a generated/registered ship hull drawing transferred to the operational level for possible physical investigation. Headquarters could update its database of drawings on an ongoing basis sending periodic updates into the field. An extensive ship hull database could be generated from various sources. Once Port Operations is notified of a ship arrival, class of vessel information could be gathered along with drawings of that class for on-site hull inspection while still at sea.

F. Equipment Staging Area

Currently, all equipment is stored in equipment storage areas of the various commands. One recommendation for an easy additional deployment location is to outfit a van with a table, chair and power source so as to easily and quickly drive up to a dock location to drop the system in the water with minimal (<2 minutes) deployment time. This would be in keeping with the rapid-response and multi-role nature of the US ARMY as well as allow for vessel-borne, land-based and RHIB-deployment of the ROV camera systems. In either case, the equipment as well as trained operators should be as close to the "Action" (i.e. ports/waterway/traffic) as is possible.

G. Personnel Profile for Equipment Operators

Anyone with a basic understanding of video gaming is an acceptable operator of ROV equipment. There are, however, certain attributes to a proficient field operator of ROV equipment whom is most capable to getting the mission accomplished.

The largest single industry operator of ROV equipment in the world is the Offshore Oil & Gas Industry. The best possible profile of an ROV "Pilot" is an electronics engineer who is also an aircraft pilot as well as an experienced commercial scuba diver. The reason for the aircraft pilot/scuba diver profile is the ability to think in 3-dimensions along with a divers knowledge of the underwater environment. The reason for the electronics background is the degree of technical knowledge (i.e proficiency in working with applied electronics and industrial computer equipment) needed in the field.

Since the optimal profile for this specific task may not be available in the line duty soldier, a team comprising members with an operations discipline, an electronics discipline and perhaps a diving discipline would be preferable. Just as a proficiency in diving is only gained through experience in-water, so is a proficient ROV pilot trained through stick time with the system on actual field operations. Any soldier can be trained to operate this equipment. The superior operators will be motivated to accomplish the task and be interested in the technology.

The US ARMY is in the midst of coming to grips with this same personnel and training issue with its Unmanned Aerial Vehicle Program. There is a direct correlation with regards to this technology. Many of the successful transition techniques can be borrowed from this program.

H. On-Going Training Program

Let us address training requirements for the Outland ROVs currently deployed:

a. Initial – Either develop an internal ROV training facility to train currently deployed personnel or appoint a contractor to regularly visit specific deployment locations using currently developed or enhanced manufacturer's training materials. Development of a personnel selection criteria, basic training manual/curriculum and establishment of a central training location are required.
b. Recurrent – Establish qualification performance guidelines for proficient ROV operators using a series of establish piloting tasks using the model for UAV pilot training as specified in standard UAV training materials.
c. Differences – At this time, this capability would not be necessary unless a new line of ROV systems were to be deployed with US ARMY. If/when a new system is deployed, currently-qualified ROV pilots would require differences training between ROV platforms.

I. Documentation and Maintenance Program

a. Command Responsibility – A unit or department should be assigned with overall fleet-wide responsibility for maintenance and support of the system. This would simply be an experienced person somewhere within the US ARMY that tracks the usage of ROV systems establishing a spares depot, expertise (a sort of "technical help line" in computer terms) in operations, operations planning and support on a 24-hour basis. Individual unit responsibility and accountability should initially be given to a single individual at each location so as to maintain control over the operations and maintenance of each operational system. From there, integration into the US ARMY maintenance tracking system can be established, mean time between failures (MTBF) on critical components can be computed and further developmental feedback communications can be accomplished.

b. Conformity with Existing Standards – Once experience is gained with the systems, the fleet-wide systems can then be integrated into the US ARMY's vehicle tracking and maintenance systems [or some other equipment-specific tracking program].

c. Maintenance Requirements and Scheduling – Scheduled maintenance and system down time can also be intelligently administered within the already-established procedures. This would lower the need for direct backups in each location by keeping in centralized spares store as well as high-usage backups where needed.

d. Unit/Division/Headquarters Reporting – Centralized reporting will allow for service bulletin and fleet-wide informational distribution for items relating to common usage issues for systems in the field.

III. Some specification suggestions as to a custom-built US ARMY ROV-based security/inspection system

A. Some Possible Characteristics of an Optimal US ARMY ROV System

a. Lightweight and compact for easy single-man portability.
b. Low power consumption operating on either shore power or from small boat 12 vdc source.
c. Powerful thrusters for operating in currents.
d. Robust design to take the punishment of field ops.
e. Good GUI (Graphical User Interface) requiring minimal technical knowledge by operator.
f. Strong situational display within GUI for ease of orientation.
g. As much integration of processing and operational capacity as is possible to reduce setup time.
h. Open architecture to allow for industry standard COTS parts so as to reduce spares cost and ease replacement of components.
i. Minimal maintenance requirements.
j. Long useful life.
k. Modular construction to allow for easy component replacement and technological upgrades/evolution in the future.
l. Ability to plug and play into existing infrastructure at US ARMY.

B. Discussion of design issues

a. Voltage, Power and Tether Length

Most current systems employ one of the following two philosophies with regard to power delivery:

1. Utilize low voltage power, with a larger tether and limited cable length capability. This method is effective for smaller ROVs [such as Outland] that do not require large amounts of power and are not intended for operation below depths of 500 feet.
2. Utilize higher voltage power, with a smaller diameter tether cable and longer length capability. Generally this power deliver method is used on large ROVs or those with a very small tether cable. There is some discussion within the industry that higher voltage power is dangerous or unsafe. However, proper industrial procedures for electrical protection are effective in keeping the system safe.

b. Bollard Pull, Tether Drag and Hydrodynamics

These factors all come into play when calculating vehicle speed and ability to operate in current.

1. Bollard pull is a direct measurement of the ability of the vehicle to pull on a cable. Values provided by manufacturers can vary due to lack of standards for testing - "Actual bollard pull can only be measured in full scale, and is performed during so-called bollard pull trials. Unfortunately the test results are not only dependant on the performance of the [vehicle] itself, but also on test method and set-up, on trial site and on environmental conditions . . ." (Hannu Jukola and Anders Skogman from a paper called Bollard Pull).
2. Hydrodynamics is another aspect of ROV design which must be considered holistically. Although a vehicle shape and size may make it very hydrodynamic (i.e. - LBV or NovaRay), there is often a trade off in stability. Some manufacturers seem to spend considerable effort making their ROVs fly faster, but in most situations it is diving to depth that consumes time. Surprisingly, dive speed is seldom mentioned in vehicle specifications.

It is bollard pull, vehicle hydrodynamics and tether drag together that determine most limitations on vehicle performance. The smaller the tether cable diameter, the better - in all respects (except, of course, power delivery). Stiffer tethers can be difficult to handle, but they typically provide less drag in the water than their more flexible counterparts. Flexible tethers are much nicer for storage and handling, but they tend to get tangled or hang up more often that those which are slightly stiffer.

c. ROVs in currents

The use of ROVs in current is an issue that is constantly debated among users, designers and manufacturers. This is not a topic that can be settled by comparing specifications of one vehicle versus another. One of the most common misconceptions is that maximum speed equates to an ability to deal with current. When operating at depth (vs. at the surface) the greatest influence of current is on the tether cable. It is the ability of the vehicle to pull this cable that allows it to operate in stronger currents. A vehicle with more power, but not necessarily more speed, will be better able to handle the tether cable (example of which would be bollard pull of a tugboat versus that of a speedboat – an ROV is a tugboat!). The most effective way to determine a vehicle's ability to operate in current is to test the vehicle in current. Experience of the operator can have a significant affect on how the vehicle performs in higher current situations. It is this author's belief that there is currently no small ROV that can be considered effective in any current over three knots.

d. Battery-Augmented Power Transmission
In order to keep tether diameters small, some small ROV manufacturers have considered the use of on board batteries to reduce the power being sent down the tether cable. Although theoretically feasible, the current power-to-weight ratio of available batteries makes this impractical. As battery technology improves this method of power delivery becomes much more viable.

e. Gyro and/or Magnetic Compass Steering for Heading Stabilization
Auto-heading is a term commonly used in the industry, but it is misleading. Some very large, very expensive systems incorporate high-end inertial navigation systems that can give them a true auto-heading, but smaller systems tend to employ what is better described as heading stabilization. The ability to perform heading stabilization is affected in a large part by vehicle stability (which is a result of shape and flotation distribution) - a vehicle that is inherently stable will hold heading more effectively. For vehicles that are less stable or more susceptible to current, the addition of a gyro can improve the heading stabilization performance. A gyro by itself suffers from inherent drift rendering it ineffective - it must be used in combination [slaved] with a magnetic compass. The Outland 1000, as delivered to the US ARMY, is equipped with a 'rate gyro' used to stabilize the vehicle in the 'auto heading' mode. This gyro is not slaved to magnetic heading and is subject to drift.

f. Fiber -vs- Copper (bandwidth requirements)
Many smaller ROVs [such as Outland] utilize copper conductors only to transmit power, video and communications. In order to keep tether cables small and increase overall bandwidth, other small ROV companies are now using hybrid fiber optic / copper tether cables to minimize tether size and improve overall performance. Running a standard analog video camera over a copper tether is practical for short lengths, but copper is susceptible to induced video noise and suffers limitations in terms of maximum transmission length. Fiber optic cable, on the other hand, can deal with multiple video signals and communications with minimal concerns about noise or length. As technology improves, it is likely that the vehicles will incorporate other technology, such as digital video and Ethernet, which require much higher bandwidth than is practical on copper conductors. Fiber has sufficient bandwidth to deal with these technologies and more. One drawback to fiber optic cable is the short cycle life of the standard fiber connectors (dirt and damage can render a fiber connector useless much more quickly than a copper connector). Some manufacturers circumvent this problem by terminating the fiber devices within the tether cable structure so that the user serviceable connections are always copper only.

g. Finding the Right Size/Power/Performance Ratio

The balance is dependant on the specific application. In cases where portability is an issue, there will obviously be limitations on power. In most cases, clients that buy a small ROV find themselves wishing for "just a little more power" or "just a little more depth capability". In general, it is a good practice to ask for just a little more than what is thought to be required. The Outland 1000, as delivered to the US ARMY, currently has the highest thrust capacity of vehicles in its category.

C. US ARMY-Specific issues

a. The US ARMY's primary operational area for this technology is ports and close littoral areas. From initial experiences, any more than a 500-foot tether length is excess. The submersible depth rating should be scaled to the tether length.
b. Tether drag is a function of tether diameter. Tether should be as small as is possible while maintaining its neutral buoyancy characteristics.
c. Power transmission through the tether should be at as high a voltage as is possible (for efficiency reasons) while staying within safety constraints.
d. Use of direct current power obviates the need for significant shielding of other conductors within the tether (lowering tether weight and diameter).
e. Fiber optics have a higher bandwidth and future growth potential, but involve a higher current construction cost.
f. As a general rule, the more massive an ROV submersible the more stable is the platform. However, gyro stabilization and software can compensate much of this factor for smaller systems.
g. The optimal size of the system will be the largest which will fit comfortably aboard/on anticipated vessels/platforms of opportunity.
h. The optimal thrust will be at least 25 pounds forward thrust. Also, forward and reverse thrust should be approximately equal so as to allow maneuvering in all directions.
i. Minimum demonstrated speed capability should be 2.5 knots average speed over a 100-foot test range.
j. Sub should demonstrate good high-speed (above 2 knots) handling stability characteristics without significant diving or broaching tendencies.
k. Camera should have the capability to view as much area around the sub as is possible without significantly distorting the image.
l. Lights should illuminate all areas viewed by the camera(s).
m. A dedicated camera should view the tether leading from the sub at all times to as far away from the termination point as is possible.
n. A tether turn counter would be helpful to counter significant tether distortion.
o. The sub design should be as closed a frame as is possible to allow for hydrodynamic streamlining.
p. The separation of the center of buoyancy from the center of gravity should be as wide as possible to gain greater pitch/roll stability.
q. An aspect ratio of .5/1 or greater (width to length) for the sub will allow for greater directional stability at higher speeds. However, this stability issue can be compensated for in software.
r. Propellers preferably would be counter-rotating on same planes to counteract "Torque Turn" tendency.
s. It would be optimal to have lateral thrusting capability, but the cost and efficiency losses could prove prohibitive. This function could be covered by greater camera area coverage.

t. The sub should have a "tool pack" allowing the plug in of multiple items from serially fed sensors to mechanical manipulation devices to extra camera equipment.
u. A digital still camera capability is desirable. Under current technological development, dual digital video/still capabilities are becoming available.
v. Imaging sonar is an absolute necessity as is some sort of acoustical positioning system.
w. Any positioning system should plug into existing US ARMY navigation equipment seamlessly. Also, an ROV positioning system should display on industry standard geo-referenced vector-based electronic charts as well as accept charts or inputs from other hydrographic or sonar survey equipment (including swimmer detection sonar) for positive identification of anomalies.

D. ROV technology today

a. All of the base technologies are available today. It is just a matter of integration.
b. The small ROV industry is populated with small players with minimal funding due to absence of any volume customer base.
c. The technology is rapidly changing following the trend towards smaller less expensive systems operated with fewer applied resources. However, the functionality of the smaller systems is rapidly gaining on their larger and more expensive ROV brothers.
d. Battery-Augmented Power Transmission versus direct power transmission has been debated in the industry for some time. The benefit of a battery pack allows for higher instantaneous power delivery to the sub over a long tether length through smaller (lower diameter/drag) conductors. But the added weight of a battery pack aboard the submersible requires greater floatation [hence drag] in order to accept the higher payload.
e. Gyro and/or Magnetic Compass Steering for Heading Stabilization is a rapidly evolving control enhancement which will be required for ease of use on any US ARMY small ROV system.
f. Fiber –vs- Copper (bandwidth requirements) – discussed in a previous section. Fiber is a rapidly evolving field with real costs falling rapidly.
g. Finding the Right Size/Power/Performance Ratio is a matter of matching the trade-offs of technology today with the mission requirements.

E. Positioning Technology today (capabilities/limitations)

a. Why Positioning in General and Acoustics in Particular? For a basic text on Acoustic Positioning, please refer to "Underwater Acoustic Positioning Systems" by P.H. Milne (Gulf Pub. Co. c1983. ill. 294). Due to the inherently low visibility within the operating areas of the US ARMY, some sort of positioning system is essential. RF penetrates only a few wavelengths through water; therefore, underwater acoustics is necessary.
b. SBL [short baseline] – This is the technology currently deployed on the USCG MSST boats. The advantages are easy deployment of the hydrophone array as well as inexpensive components. The down side of this technology is propagated inaccuracies from inexact locations of the transducers due to boat swing and movement during operations.
c. USBL [ultrashort baseline] – This technology places the transducers on a single receiver unit. The advantages of this technology are ease of deployment and

calibration as well as only one transducer head to consider. The down side of this technology is its expense, its limited cone of reception and its intolerance of inaccurate head orientation.

d. LBL [long baseline] – This technology places individual battery operated transponders widely spaced intervals (up to 14 km.). This is survey grade technology; however, it is expensive, time consuming to place and recover the transponder array and requires specialized skills and training to operate.

F. ROV-Mounted Imaging Sonar Technology today (capabilities/limitations)

a. Mechanically scanning sonar – there are several manufacturers of small inexpensive imaging sonar systems on the market today. Some are fixed frequency and some are tunable. The function of an ROV system is the final identification of items of interest after a search by other means. In order to image small objects, high-frequency sonar (above 500 kHz) is needed for producing enough detail of the target to eliminate non-significant targets. This frequency has a maximum useful range of approximately 200 feet. The advantage of this technology is its light-weight inexpensive deployment. Its disadvantage is the tendency to "smear" the image unless the submersible is extremely stable or resting on bottom.

b. Multi-beam and Multi-beam focused array sonar – (please reference a white paper entitled "Object Identification with acoustic Lenses" by Edward Belcher et al located at: http://www.apl.washington.edu/programs/DIDSON/Media/object_ident.pdf) Successful results in zero visibility water conditions have been obtained with use of Multi-beam and focused array sonar. The capability enhancement produced by these type sonar systems is the high-refresh rate (5 to 27 frames per second) with extremely high-resolution imaging. The limitations for small ROV systems are their narrow aperture (generally well less than 90º) and their relatively high power consumption (20 to 30 watts for a DIDSON – a definite issue for smaller systems with limited power budgets). In order for this tool to be effective, it may be teamed with a mechanically scanning sonar (as specified in a. above). Another limitation for smaller ROV systems is their lack of directional stability possibly smearing the sonar image generated during sonar operations. The Outland 1000 as delivered to the US ARMY allows for RS-485 connectivity through the tether cable. Modification would be required in order to accommodate the Ethernet (or higher bandwidth) communications protocol required to relay the data to the surface collection unit.

c. Gyro-stabilized "flashlight" sonar system – this is a new technology under development whereby the imaging sonar is fixed to the submersible (a close analogy would be a flashlight beam) whereby the submersible is rotated to illuminate the target area with a gyro used for painting the image onto a display based upon return and orientation. This technology looks promising and requires further investigation, but certainly is in its infancy.

G. Graphical User Interface today

a. The objective of GUI is the graphical depiction of multiple information sources with as little interpretation time as is possible. Most modern ROVs do not utilize a GUI as part of their control system. Although some systems now include an option for PC control, standard control systems typically utilize a variety of joysticks, switches, push buttons, etc. In the future, with the increase in capabilities and improvements in the performance of tablet PCs and PDAs, ROV control will undergo an evolution. An entire ROV control system could be built into a customizable GUI on a Windows® or Unix based tablet PC. With the inclusion of digital video, recording and viewing can be included on the same platform without the need for additional hardware. With the extra processing power available on a tablet PC (vs. an embedded micro-controller), it is feasible that some operational procedures could be automated and automatic mission logging can be provided all in the same integrated package.

b. Further enhancements of GUI with any US ARMY ROV system would increase its usability and utility significantly. The development of this may require funding from US ARMY.

H. Interesting ROV Technologies in the Wings

a. 360º cameras – currently available to land-based systems on a COTS basis.
b. Control technology – porting of control technologies from other industries would certainly speed the development cycle of ROV control technologies. These include heads-up displays, touch control and closed-loop feedback systems. The objective of control technology is to provide as much sensory feedback to the ROV pilot as is possible in order to figuratively place the pilot's head inside of the submersible for operations. The ability to closely achieve this objective will determine the submersible's utility to the US ARMY.

I. Discussion on Design Standards

a. Manufacturer Non-Specific Standards – This is perhaps the greatest limitation on ROV development worldwide. Almost every manufacturer has its own set of standards for power delivery, communications, video transmission, etc. Until the ROV community can come together and create a set of universal standards, this will continue to be a problem. Different companies have proposed their own protocols as industry standards, but until something is published and mandated by a recognized association (i.e. – MILSPEC, ADC or MTS), the industry is likely to proceed as it has for the last 30 years. The other major shortcoming has to do with a lack of testing and specification standards. As mentioned above, the bollard pull is commonly used to represent vehicle pull capability and power. Until all manufacturers utilize the same methodology it is not easy to compare specifications between vehicles accurately. The same can be said for other quoted specifications like depth and speed. Ideally, an independent organization could be set up to establish the standards or, ideally, perform the testing themselves.
b. Moving Towards an Open Architecture – The possibility of developing a US ARMY-specific or MILSPEC user interface then having other vendors simply design to this format would allow for industry standards to evolve. Consequently, this would speed the developmental process while lowering the barriers to entry of new players and reduce the cost to the US ARMY [and other US Government organizations] of this capability. Currently, sonar and positioning companies are using roughly the same power requirements and protocols - standardizing and publicizing an open architecture would allow numerous companies to provide add-ons and options for a variety of ROVs. As of the date of this report, RADM Landay (PEO LMW for USN) has sponsored an initiative through a civilian standards organization (ASTM International at http://www.astm.org "Committee

F41 on Unmanned Undersea Vehicle (UUV) Systems") focused upon generating standards for underwater systems. The author of this report is an active member of this committee. The only cohesive customer base powerful enough to drive the development of these standards is the DoD. These standards should be seriously considered with any further developmental work with regards to US ARMY ROV systems.

J. Muli-Role Capabilities

a. Security – In practically all instances, an ROV is a final identification tool that identifies items of interest located by other means. The final disposition of the item of interest can be done with the ROV system or by other downstream tool(s). To use the ROV system for any search function other than small limited and defined areas is (in this author's opinion) a waste of valuable time and manpower resources in the field. The ROV system should be able to quickly search out areas and locate either geo/relative referenced points or imaged obstructions and proceed to same in an expeditious manner. Once the search area is cleared, a high-degree of certainty that the area has been eliminated as a target area is required.
b. Deep-Sea Diving and Public-Safety Diving Support – In the oil & gas industry, the ROV has served to reduce risks to divers by allowing for better surface control of the underwater operation. The ROV serves as a safety diver in many operations allowing for reduced underwater man-power and surface monitoring of the job task. Similar increases in control/lowering of risks/reduction in costs may be obtained by US ARMY diving commands. Further, the high-risk labor-intensive "bounce diving" operations spent during attempted identification of underwater targets can be more effectively conducted with ROV equipment.
c. Environmental Monitoring – The ability to transmit water quality, element analysis and other environmental parameters from the submersible to the surface is essential. The submersible then functions as a delivery platform for a variety of instruments to determine the conditions of the area in question.
d. Vessel Maintenance and Safety – Vessel hull condition, running gear status as well as other in-water factors for vessels and port infrastructure are critical to safe port operations. The ROV system should have the capability to crawl into tight places as well as function in a variety of conditions.
e. Anticipated Future Needs – The ROV system should have the capability to field underwater tasks in as broad a spectrum as is anticipated to accommodate future needs.

K. Specific Recommendations for a US ARMY built-to-order ROV System

a. ROV System Size – The size of the ROV system should fit aboard vessels from the smallest response boat to the largest of ocean-going vessels. The system should be compact so as to be single man-portable without use of heavy-lift equipment. From these factors, a submersible size/weight factor of between 10 and 40 pounds fitting in a standard 1620 Pelican (or compatible) case is reasonable.
b. Support Equipment – The move to open architecture allows for laptop computer-based control systems running from any personal computer. The controls for the various stations could be configured with only movement of the essential [and expensive] equipment (submersible/tether/power supply) between deployment

locations. Standardization can then allow for easy switching and matching between deployment locations and platforms. Surveillance vans as well as fast response boats and other platforms of opportunity can then be easily and quickly set up and used.

c. Developmental Time, Cost and Amortization – The built-to-order system could be fielded to proto-type stage certainly within 6 months of the contract award. From a general review of the current marketplace, a development cost to production prototype stage for less than $450,000 is certainly possible if specs are kept simple and specific. With a production run of 100 units, the amortization of $4,500/system could be absorbed within the costing of these systems keeping the primary vehicle to under $30,000 per system.

d. Operational Life Expectancy – Underwater systems undergo excessive abuse due to its operating environment and the union of salt water and electronics. However, with proper maintenance and vehicle simplicity the system should last for years and thousands of hours operation use before it is retired. A good benchmark should be a 2,500-hour operational life or 5 years [whichever comes first].

SUMMARY AND CONCLUSION

With the new mission requirements being adapted, the US ARMY appears to need (and currently possesses) an ROV capability. Currently, the small ROV industry has very few [if any] standards to which it complies. If the decision to custom-build a system for US ARMY is made, cost savings, economies of scale and usability enhancement are possible. The US ARMY has focused its ROV program around the Outland 1000 ROV system. This platform is a strong and capable ROV base system into which to build future capability enhancements. The short-term future development of this program should focus around enhancements to the sensors and navigation accessories as well as furthering the Integration, Logistics and Support facilities for field deployment of this capability.

Table of Acronyms

ROV	Remotely Operated Vehicle
COTS	Commercial Off The Shelf
MSST	Maritime Safety and Security Team
G-OPD	Director of Operations Policy Defense Operations (US ARMY)
SBL	Short Baseline [acoustic positioning]
LBL	Long Baseline [acoustic positioning]
USBL	Ultra-Short Baseline [acoustic positioning]
RB-HS	Response Boat – Homeland Security
US ARMY	United States Army Diving Command
POC	Point of Contact
LCD	Liquid Crystal Display
GPS	Global Positioning System
NMEA	National Marine Electronics Association
SOP	Standard Operating Procedure
MTBF	Mean Time Between Failures
AIS	Automatic Identification System
GUI	Graphical User Interface
MILSPEC	Military Specification
ADC	Association of Diving Contractors

MTS	Marine Technology Society
DHS	Department of Homeland Security
RADM	Rear Admiral
USN	US Navy
PEO	Program Executive Officer
LMW	Littoral and Mine Warfare