USCG

MSST VideoRay ROV Program

Program Review, Status and Recommendations

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Subject: Review of VideoRay Program and Recommendations

Mr. Nagy:

SeaTrepid and VideoRay have recently completed the delivery and training on the MSST VideoRay ROV and acoustical positioning systems for MSST's 91101, 91102, 91103 and 91104. Attached please find a summary of those operations as well as some recommendations for incorporating the ROV-based inspection/security systems for the USCG.

The report is divided into 3 basic components:

1) Summary of the VideoRay ROV program to-date
2) Recommendations to implement the equipment currently deployed
3) Some specification suggestions as to a USCG ROV-based security system

This report is from the contractor's point of view without access to internal USCG 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 USCG's VideoRay 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 USCG.

In December, 2002, USCG purchased three VideoRay Pro II ROV systems for operational evaluation with its newly established MSST units. The USCG later expanded this ROV technology commitment to include a fourth system as well as acoustical positioning capability for all four systems deployed.

With the expansion of the traditional USCG surface mission to now include 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 security threats. This technology is also adaptable to some of the more traditional roles of the USCG including environmental monitoring, safety/regulatory enforcement and facilities/vessel maintenance chores. Will this ROV technology commitment be sufficient to fulfill the new role of finding security threats and/or some of the more traditional roles?

The VideoRay Pro II systems with integrated acoustical positioning 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 USCG'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.

I. Summary of the VideoRay ROV program to-date

A. Initial Purchase of 3 VideoRay Pro II systems

USCG (through G-OPD) purchased 3 VideoRay systems in late 2002. These systems were distributed to Chesapeake, VA (MSST 91102), Galveston, TX (MSST 91104) and Boston, MA (STA Boston) for a 6-week evaluation period. Factory Initial Training was provide by VideoRay/SeaTrepid for these three locations at Groton, CT on March, 2003. The systems then spent 6-weeks during early to mid-2003 in field for trials. The Galveston and Boston units were then transferred to San Pedro, CA (MSST 91103) and to Seattle, WA (MSST 91101) for an additional 6-week trial period. VideoRay/SeaTrepid Initial Training was provided for those locations in Alameda, CA in May, 2003. The West Coast systems then spent another 6-weeks during mid-2003 in field for trials.

The three VideoRay Pro II systems remaining in the field after the initial training were located at MSST San Pedro, MSST Chesapeake and MSST Seattle.

B. Acoustical Positioning Training and Deployment of fourth VideoRay Pro II System

USCG (through G-OPD) then purchased three VideoRay Acoustical Positioning system enhancements (The "Universal Positioning System") for the systems currently in the field plus another VideoRay Pro II with acoustical positioning system for the Galveston, TX unit (MSST 91104). Delivery/Training dates and POC's for each location were as follows:

San Pedro, CA (MSST 91103) – September 2003 (POC ET2 Smith)
Galveston, TX (MSST 91104) – November 2003 (POC ET1 Pipkins)
Seattle, WA (MSST 91101) – November 2003 (POC ET1 Fairall)
Chesapeake, VA (MSST 91102) – December 2003 (POC BM1 Gibson)

C. Status as of early-December, 2003

Each of the four designated MSST's received initial training on the VideoRay Pro II along with the integrated acoustical positioning systems. 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 the San Pedro Ship Hull LBL acoustical positioning system [which requires a repaired Remote Baseline Station].

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 USCG's underwater mission requirements, 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 USCG surface mission to now include 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 security threats. This technology is also adaptable to some of the more traditional roles of the USCG including environmental monitoring, safety/regulatory enforcement and facilities/vessel maintenance chores.

Underwater ROV/Camera technology runs from pole cameras all the way to fully integrated autonomous robotic vehicles. The VideoRay system deployed with USCG is somewhere in the middle of these extremes as a basic "Flying Eyeball" with basic mechanical intervention and integrated acoustical positioning. Will this 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

MSST Boat Geo-Referenced Positioning

One of the requirements for the initial deployment of the VideoRay system onto the MSST boats was that the system fit aboard the standardized RB-HS boat design without modification. Due to this, some equipment redundancy was necessary in order to obviate the necessity to tap into the RB-HS's electronic or power package. Specifically, the acoustical positioning system needs some data feeds as well as power in order to deploy off of the RB-HS boat with geo-referenced short baseline acoustical positioning.

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 USCG 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 RayMarine SeaTalk software currently standard on the RB-HS boats. Further, with an easy software update, the geo-referenced position of the submersible can be displayed on the RayMarine LCD display mounted next to the helm. This would eliminate the need for the separate VideoRay flux-gate heading sensor [and time-consuming separate calibration of same] as well as the [non-differential] GPS receiver included with the USCG purchase. The outputs 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 VideoRay system along with its accessories. There are 3 separate high-capacity battery systems aboard the MSST RB-HS boats. By either integrating a 12 vdc to 110 vac inverter or specifying a pure 12 vdc powered VideoRay system, the bulky space-consuming generator can be eliminated from the boat. There is currently excess breaker capacity from the onboard 12-volt bus.

During the deployment training at the MSST's it was noted that an approximate 1.5 hour setup time was required in order to temporarily rig the MSST boat for VideoRay Geo-Referenced SBL acoustical positioning.

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

Ship Hull Vessel-Referenced Acoustical Positioning

Vessel-Referenced long baseline acoustical positioning involves deployment of a 4-transponder (battery operated) array over the side of a vessel of interest at measured locations along the hull attached to the lifelines of the vessel. The VideoRay is then operated independent of the transponders with acoustical communication for accurate triangulation to locations on the vessel. A side and top view drawing of the vessel is necessary in digital format (.bmp) in order to navigate the VideoRay submersible along and to that scaled drawing.

This system performed as designed at all MSST locations. By far the largest challenge faced during the deployment of this system has been obtaining drawings for the vessel under examination. Once the drawings were located, a learning curve to register these drawings was noted at each location. However, the drawings were easily loaded and activated once registered.

To summarize, in order to fully make use of the Ship Hull inspection system a centralized location/depository for ship drawings database will need to be established. If this procedure is not established, this system, capability and project may languish.

D. Defining and Writing SOP's 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 SOP's 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 SOP's to the unit level allowing for leeway in the field based upon the situation at hand.

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 MSST's. 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 MSST units as well as allow for vessel-borne, land-based and RB-HS-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

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 seaman, a team comprising members with an operations discipline, an electronics discipline and perhaps a law enforcement discipline would be preferable.

H. On-Going Training Program

Let us address training requirements for the VideoRay ROV's 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.
b. Recurrent – Establish qualification performance guidelines for proficient ROV operators using a series of establish piloting tasks using the model for pilot training as specified in standard aviation 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 USCG. 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 USCG 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 USCG 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 USCG's vessel

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 USCG ROV-based security system

A. Some Possible Characteristics of an Optimal USCG ROV System

a. Lightweight and compact for easy 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 cut down on setup time.
h. Open architecture to allow for industry standard COTS parts so as to cut down on 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 USCG.

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 VideoRay] 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. ROV's 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). 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. Realistically, 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.

f. Fiber -vs- Copper (bandwidth requirements)
Many smaller ROVs [such as VideoRay] 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 plenty of 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. A thrust to weight ratio of 1:1 can be found in many of the larger vehicles, but in small ROVs it is impractical - anything close to a .5/1 ratio should be sufficient in small ROVs (less than 30 Kg) for most applications.

C. USCG-Specific issues

a. The USCG's primary operational area for this technology is ports and close littoral areas. From initial experiences, any more than a 300 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 between .5/1 and 1/1 bollard pull to submersible weight ratio.
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.
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 USCG 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 at 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 USCG 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 USCG, 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 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 worry about. 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. Gyro-stabilized “flashlight” sonar system – this is a most interesting 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.

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 USCG ROV system would increase its usability and utility significantly. The development of this may require funding from USCG.

H. Interesting ROV Technologies in the Wings

a. 360 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 USCG.

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 USCG-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 USCG [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.

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 tools. To use the ROV system for any search function other than small limited and defined areas is 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. 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.
c. 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.
d. 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 USCG 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 USCG appears to need 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 USCG/DHS is made, cost savings, economies of scale and usability enhancement are possible. Competitive vehicle manufacturing economies, deployment procedures development and technology innovation are surely soon to follow allowing better force protection, homeland defense and security for America's ports and harbors.

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 (USCG)
SBL	Short Baseline [acoustic positioning]
LBL	Long Baseline [acoustic positioning]
USBL	Ultra-Short Baseline [acoustic positioning]
RB-HS	Response Boat – Homeland Security
USCG	United States Coast Guard
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