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Observation Class ROVs Come of Age

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ABSTRACT

In the 1980's the first of the small commercial observation class remotely operated vehicles (ROVs) appeared on the market. At that time they were called Low-Cost ROVs (LCROVs). To meet the LCROV criteria, their purchase price had to be under $50,000. As is many cases, the concept was ahead of the technology. Today, the technology has moved to a point where observation class ROVs (OCROVs) are not only inexpensive, but reliable and capable. Their tasks range from dam inspections to body recoveries and even treasure hunting. This paper will discuss the developmental history and state-of-the-art of OCROVs, their limitations, capabilities, and which models are presently "leading the pack" operationally.

Keywords

ROV, OCROV, Observation, Survey, Homeland Security.

1 INTRODUCTION

Today, massive remotely operated vehicles (ROVs) probe the ocean depths worldwide. Even the deepest point in the ocean, the Mariana Trench, has seen the footprint of an ROV – Japan's *Kaiko*. But the complex work vehicles that populate the offshore drilling platforms and ships are not the only systems that have come of age through the advancement of technology; the observation class ROVs (OCROVs)—generally portable ROVs that weigh less than 200 lbs (91 kg)—have taken the technological advancements and the miniaturization of electronics and camera systems and applied them to an ever-increasing array of missions. Missions such as body recovery, dam inspections, nuclear inspections, treasure hunting, archeology, fish assessment, ship husbandry and more recently homeland security have become routine for OCROVs. No longer are observation vehicles an expensive addition to a dive company's tool bag; they have become a necessity, keeping divers out of hazardous situations or conditions and allowing the small vehicles to enter underwater locations too confining for a diver.

But advancements in technology can also increase complexity and cost. While many OCROV developers are marketing increasingly complex systems, others are returning to the days of the "flying eyeball." Regardless of a company's design philosophy, OCROVs have come of age. The following sections will discuss the history of OCROVs, the unique missions they are performing, the technology they are incorporating and those who are cornering the market.

2 HISTORY

The first truly commercial ROV, Hydro Products *RCV 225* (Figure 1), was delivered to Stolt-Nielsen Seaway Diving in 1974. In addition, the *RCV 225* (181 lbs (82kg), 1,312 ft (400m) depth capability) was considered the first "flying eyeball" to be used commercially. Not only was it a flying underwater camera, but it also looked somewhat like a giant eyeball. While these small vehicles were much cheaper than the larger ROVs that eventually populated the offshore market, they were far from low-cost.

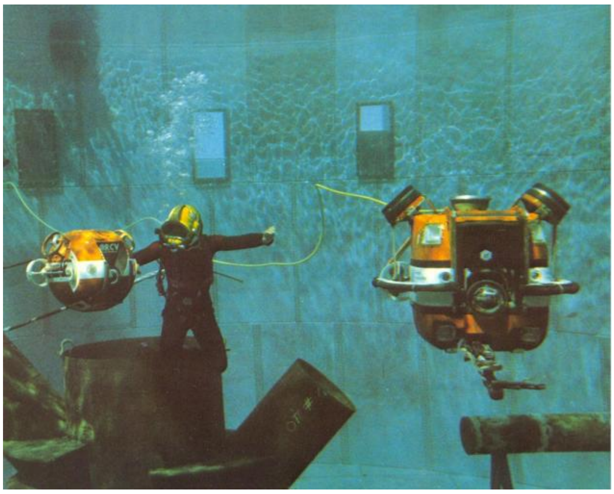

Figure 1. Hydro Products *RCV 225* and *RCV 150*

In the 1980s, the OCROVs were dominated by the small "low-cost" ROVs (LCROV). These were classified by the industry as costing between $10,000 and $50,000 USD (Given 1989). The first LCROV appeared in 1981 when International Submarine Engineering introduced the 109lb (54kg), 1,181 ft (360m) capable *RASCAL*, which sold for about $45,000 USD. Next came the *MiniRover* in 1984 at a breakthrough price of $28,600. This 40lb (20kg), 328 ft (100m) depth capable vehicle became the hot seller at the time. Right behind the *MiniROVER* was the introduction of Deep Ocean Engineering's *PHANTOM* vehicle in 1985, capable of 500 ft (152m) and selling for around $30,000 USD. This was followed shortly thereafter by

Mitsui's *RTV-100* priced under $30,000 USD. By the end of 1990, 27 manufacturers had developed 35 different versions of LCROVs (Wernli 1999).

Now the intent of this historical review is not to list everything that has happened since 1974, but to provide perspective on the last 35 years of OCROV development. To address the latter end of this historical review, the development of two vehicles will be addressed: the *VideoRay* and the *Little Benthic Vehicle* (*LBV*). Typical OCROVs are shown in Figure 2 (Christ el al 2007); representative specifications are shown in Table 1.

Figure 2. Typical OCROVs

The *VideoRay* (Figure 3) really broke the size and price barriers when it hit the market in 1999. Under 11 lbs (5kg) and with 1000 ft (305m) depth capability, the diminutive vehicle has become the hottest selling OCROV with over 1,200 being used worldwide. The baseline vehicle sells for under $6,000 USD.

Today's *LBV* (Figure 4), developed by SeaBotix Inc., is very similar to the breakthrough *MiniRover*. The *LBV150BE*, which weighs in under 25lbs (11.3kg) and can dive to 492 ft (150m), sells for under $37,000 USD. Adjusting for inflation of 106% since 1984, the *MiniRover* cost would be closer to $59,000 USD today. Over 650 *LBV* systems have been sold to date.

Figure 3. VideoRay OCROV

Figure 4. Little Benthic Vehicle (LBV150SE-5)

Few things get smaller, increase in capability and get cheaper over time. iPods, cell phones, and OCROVs are a few examples of such items. The remainder of this paper will address just how capable the OCROVs have become.

Table 1. Representative OCROV Specifications

NAME	COMPANY	WT. (KG) IN AIR	DEPTH (M)	BUILT
Little Benthic Vehicle (LBV)	SeaBotix, Inc., US	10-15	150-1500	650+
Outland 1000	Outland Technology Inc., US	17.7	152	93+
300F ROV	Seamor Marine, Canada	16	300	40+
RTV Series	Mitsui, Japan	42	150	310+
VideoRay Series	VideoRay LLC, US	4-4.85	0-305	1250+

3 OPERATIONAL TASKS

From the simple beginnings of the technology as a mobile self-propelled underwater camera to today's sensor and light tooling delivery capabilities, the OCROV has developed into a versatile tool for many tasks previously available only through diver deployment.

3.1 Survey

With the porting of small acoustic beacons to the smaller OCROV vehicles as well as the integration of the latest in ring laser gyro technologies for high-precision navigation, the OCROV is capable of delivering a variety of sensor packages to remote and hazardous locations with positive pairing of the sensor data with location. With the increased efficiencies of electric thrusters, the OCROV vehicle is capable of delivering packages capable of tracking buried pipelines (Figure 5a), acoustically imaging pipelines proud of the bottom (Figure 5b), visually surveying bottom contour and acoustically mapping the bathymetry of a closed area with a high-degree of positional accuracy. The OCROV's use in survey is now limited only to the pilot's skill and imagination.

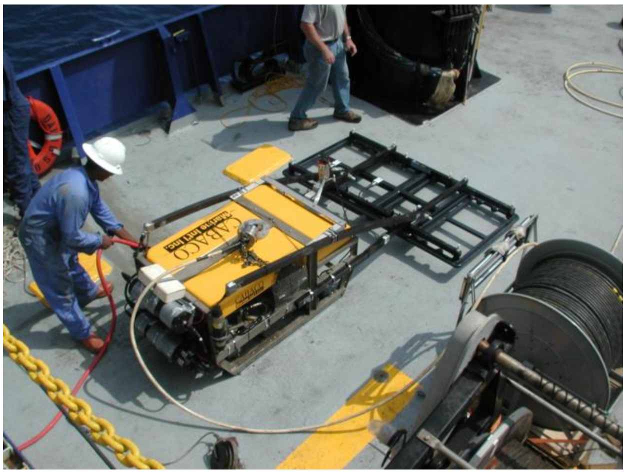

Figure 5a. OCROV with Pipe Tracker

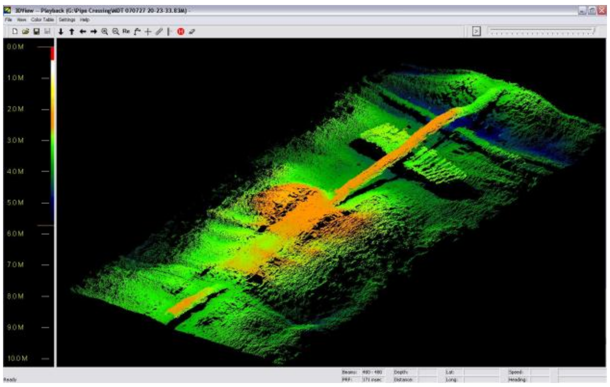

Figure 5b. Imagenex Dual-head Multibeam Pipeline Survey

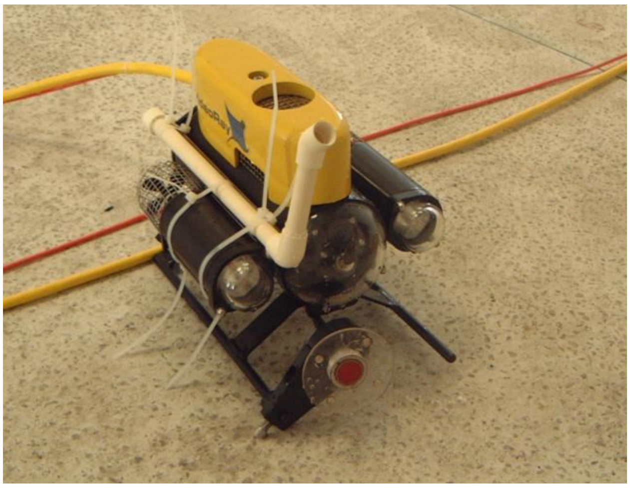

Figure 6. Micro-OCROV with Ultra-sonic Metal Thickness Gauge Attached

3.2 Inspection

With the maturity of the technology, sensor manufacturers who have previously developed sensor packages for diver deployment have adapted these same sensors for OCROV deployment. Some of the more prevalent inspection sensor technologies are acoustic Ultrasonic Metal Thickness Transducers (Figure 6), 2D/3D single/multibeam as well as acoustic lens imaging sonar, sub-bottom profiling sonar, etc.), magnetic (Magnetic Particle Detection, pipe tracking, etc.), radiation (flooded member detection, radiation sensors, etc.) and varying degrees of high-resolution and high-definition multi-wavelength cameras.

3.3 Intervention

The primary requirement for basic intervention is a simple means of locomotion. The OCROV has the basic necessities to perform locomotion and thus intervention. Various means of light-intervention are simply a matter of adapting varying electrical motor/drive-train mechanisms to a tool. Common means of locomotion are the rotary and/or linear actuators available in Commercial Off-The-Shelf (COTS) fashion. Once the actuator is gained, the simple mechanism can be attached to the frame then mated with tooling. Examples of intervention mechanisms are the single or multi-function manipulator (Figure 7), grinder (mounted to rotary actuator), brush (mounted to rotary actuator), cutters (mounted to linear actuator) (Figure 8), saw (mounted to rotary actuator), sample collection probe (Figure 9), hydraulic wire cutter (Figure10) and multibeam sonar (Figure 11).

3.4 Sensor Delivery and Fusion

High bandwidth sensors (e.g., High-Definition Cameras, 3D multibeam imaging acoustics, etc.) are now portable through the tether of the OCROV due to the miniaturization of Ethernet-based components. Fiber optic multiplexers and Ethernet extenders allow both light-wave as well as copper-based high-bandwidth data transmission for sensor throughput. As an example, with the advent of ultra-high accuracy navigational sensors (now small enough to fit aboard the OCROV), the high-bandwidth 3D multibeam imaging sonar data can be fused with positional data to form 3D mosaic point cloud rendering of subsea structures.

Figure 7. OCROV with Single Function Manipulator

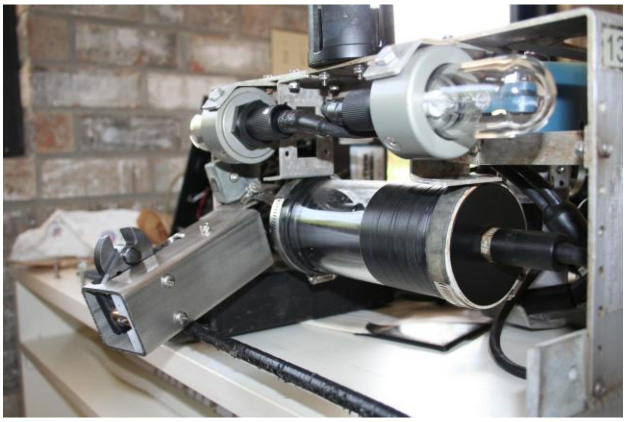

Figure 8. OCROV with Wire Cutter Fashioned to And Powered by Manipulator Whip

Figure 9. OCROV with Sample Collection Tube, HID Lighting and Mechanically Scanning Sonar

Figure 10. OCROV with Hydraulic Wire Cutter

Figure 11. OCROV with Multibeam Sonar

4 RECENT ADVANCEMENTS / ACCOMPLISHMENTS

The technology is racing forward on many fronts limited only by the imagination of the field personnel to its application. Further, OCROVs are being used in combination with larger "Mother" vehicles to make difficult structure penetrations in deep, high-current or very remote locations.

4.1 Thruster Advancements

Some of the more interesting developments on the OCROV thruster front are the magnetic coupling of propellers to the gearing mechanism (thus reducing the risk of thruster damage through foreign object ingestion), the varying of the propeller structure for higher hydrodynamic efficiency and switching of the commutator to the outside of the propeller ring (thus reducing the incidence of propeller-tip vortices). Also, the recent advancements in the area of brushless DC motors have allowed a radical increase in thruster life as well as a great reduction in electrical noise to the video signal and boards aboard the vehicle.

4.2 Economics of Scale

With the proliferation of small systems on the market, component manufacturers independent of the vehicle manufacturers have advanced the art and science of ROVs as well as lowered the overall cost of the vehicles through mass production. The advent of competition coupled with the common acceptance of this technology has brought the overall real price of this technology down by drawing the old-style "One-Off" low volume manufacturing methods away and replacing them with high-volume serial manufacturing techniques.

4.3 User Education

The ROV has gained worldwide acceptance as a mature technology. College-level down to middle-school level programs have adapted the OCROV as an entry-level introduction to their robotics programs. In particular, the Marine Technology Society has sponsored some interesting initiatives aimed at promoting the use of ROV technology in varying applications. In the USA, the Marine Advanced Technology Education (MATE) Center sponsors yearly ROV competitions aimed directly at the young aspiring robotics and oceanography professionals.

4.4 Sensor Bandwidth Enhancements

The two main drivers of sensor bandwidth enhancements for the OCROV are the miniaturization of the fiber optic multiplexer and the radical performance enhancements of the Ethernet extender technology. From the simple 100 foot (30 meter) limitation of just a few years ago, the newest Ethernet extenders have throughput capabilities of high-bandwidth sensors well past 3,300 feet (1,000 meters).

4.5 Standards

In the past, the sensor manufacturers have been burdened by a lack of standards between vehicle manufacturers. The problem causing this lack of any standard was the lack of a strong customer base to push the vehicle and sensor manufacturers together. In the subsea marketplace, the only cohesive customer capable of driving a standard is the military. In 2005, the US Navy sponsored a civilian standard, held by ASTM International, to drive an interface standard for one of their autonomous vehicle programs. That standard has since grown to spread industry-wide. Further, the military continues to adapt further civilian standards (such as the National Marine Electronics Association standard 0183 for serial data string sentences) helping greatly with the worldwide acceptance of small vehicle to sensor protocols.

4.6 Broader Technological Acceptance

Industry trade groups as well as governmental regulatory bodies are recognizing the OCROV as a viable technology by promulgating guidelines and regulations regarding the use/application of OCROVs for compliance purposes. In the minerals extraction industry, the OCROV (as a sensor delivery platform) is now accepted as a primary data-gathering instrument for legal compliance purposes. It is similarly recognized by the hydroelectric, ship husbandry, homeland security, sewerage and waterworks industries.

4.7 Increasing Risks and Cost of Alternatives (Divers)

Traditionally, divers have been the only sensor and tooling delivery platform for underwater projects (i.e., divers did 100% of the subsea work). With the advent of robotic solutions to placing humans in harm's way, OCROVs have steadily taken over the mundane tasks previously borne by divers due to the substantial decrease in risk and cost and the increased loiter time available to the OCROV. As the percentage change between diver-performed and robotic-performed tasks shifts, be prepared to see more robots in all aspects of human existence – particularly in subsea work.

5 SURVEY OF CURRENT ROV MANUFACTURERS

A comprehensive survey of the OCROV industry is not the intent of this paper. Such information is easily found in publications such as *ROVs of the World*. However, a quick review of such references indicates that there are well over 30 various OCROVs being built worldwide (which is probably a low estimate). The total number sold totals well over 3,000 vehicles. Table 1 provides a sample of OCROV specifications.

While some of the earliest OCROV manufacturers are still pumping out the latest versions of their vehicles (e.g. Deep Ocean Engineering's *Phantom* vehicles), the lion's share of the market is controlled by two of the newer companies that have to be considered the leaders of the pack: SeaBotix and VideoRay.

SeaBotix, with the *LBV*, is going beyond the typical OCROV applications. Recent *LBV* missions have included the recovery of an aircraft black box for the Australian Transport and Safety Bureau and the location and recovery of an AUV that had become trapped under a rock outcropping.

But one of the most unique applications of the *LBV* is its ability to reconfigure into a bottom crawler (Figure 12).

The US Army TACOM has awarded a contract to SeaBotix for 27 LBV150SE-5. The contract vehicles will have the crawler capability along with Tritech Micro Scanning sonar, 3-jaw grabber (Figure 13) with cutting head attachment, LYYN video enhancement and digital video recording capabilities.

Figure 12. LBV150SE-5 Bottom Crawler Configuration

Figure 13. SeaBotix 3-Jaw Gripper

When the technological barriers were falling in the early days of LCROVs, it was joked that once they broke the $5,000 barrier they would appear with the batteries and candy at the checkout stand of the local marine supply store as "An ROV for every yacht." If inflation is taken into consideration, *VideoRay* has broken that barrier. Small, portable (Figure 3), versatile and reliable, *VideoRay* OCROVs are cornering the market that meets their operational capabilities.

Another innovative aspect of the VideoRay experience is their training. On line and classroom training is available, but one of the more unique aspects of their training is the annual VideoRay International Partner Symposium (VIPS), a three-day training conference that highlights the latest trends in micro-ROV operations and technology.

Being the largest selling OCROV manufacturer doesn't necessarily limit the innovation and unique missions by the others. For example, a Fisher *SeaLion* ROV and Diver Mag 1 hand-held magnetometer were employed to investigate and document a 10,000 gallon per minute water leak from a high altitude reservoir in Utah. The unusual approach to this mission was that it was done when the reservoir was frozen over. This would provide clearer water for the documentation. After transporting the ROV by snowmobile, a hole was cut through the 18-inch thick ice and the operation begun (Figure 14). Several locations where the reservoir was leaking were detected and documented, preventing the shut down of a power plant at an estimated loss of $80 million USD per month.

Figure 14. *SeaLion* Inspecting Ice-covered Reservoir

There is a saying amongst the ROV operators, "A good operator will make even bad equipment perform." The meaning of that saying is that an experienced, trained and qualified crew can overcome equipment shortcomings and/or complexities to accomplish the work task. But if excessive time is expended troubleshooting and integrating an overly complex vehicle system, field time is wasted in what would otherwise have been a simple eyeball inspection.

One company that is taking this trend seriously is Submersible Systems Inc. They feel that an OCROV should be akin to the earlier flying eyeballs since that is their primary mission. Incorporating complex subsystems and sensors into the ROV increases the complexity of the vehicle. To counter this trend, they are developing the *TRV* (Figure 15). This concept provides a stable, modular-component vehicle that provides its users with the highest quality video in a simple and reliable system.

Figure 15. Submersible Systems' *TRV*

6 SUMMARY AND CONCLUSIONS

Clearly, today's OCROVs are increasing dramatically in the technology that they are incorporating and the eclectic array of missions they are successfully performing. But increased complexity may also reduce reliability; reduced reliability means that more highly trained technicians and operators may be required on-site to repair the advanced vehicles and subsystems. As those in today's ROV market understand, there is a dramatic shortage of trained and experienced ROV operators. This fact will encourage OCROV manufacturers to produce systems with increased efficiency that can be easily maintained.

While the worldwide population of Work Class ROVs has remained relatively flat over the past 10 years, the population of OCROVs has literally exploded. With this massive increase in small vehicle population comes a substantial incentive for sensor manufacturers to produce advanced sensor packages for these smaller vehicles. Such incentives will also increase the reliability of the sensors and encourage OCROV manufacturers to ensure a "plug and play" capability exists for incorporating the advanced subsystems.

The future tasks for OCROVs will continue to expand. With concerns over the environment, pollution, deteriorating infrastructures, homeland security, and the necessity to reduce operating costs for associated inspections and work tasks, the future is bright for OCROVs. Leading OCROV manufacturers are projecting that their total number of vehicle sales will double within the next two to three years. Such projections prove that OCROV have come of age.

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Submersible Systems, Inc. (Patterson, Louisiana, USA)

VideoRay LLC (Phoenixville, Pennsylvania, USA)

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