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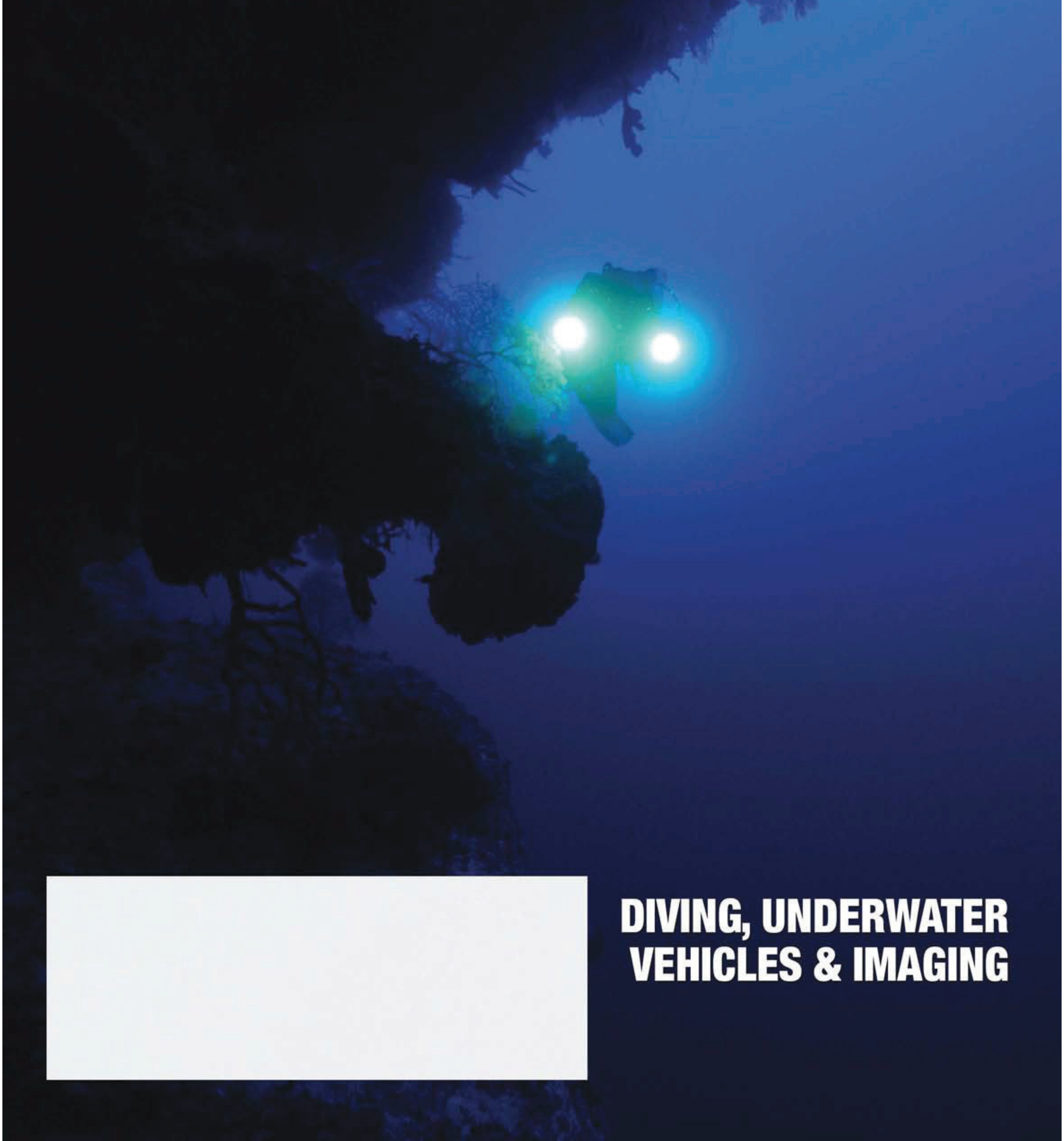

DIVING, UNDERWATER VEHICLES & IMAGING

ROV Backbone For Rapid Development Of Underwater Robotic Systems

Modular ROV Control System Allows Operators to Take on Multiple Projects with Minimal Asset Redundancy and Costs

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Robotic underwater intervention covers a deceptively wide range of technologies, including underwater construction, inspection, search and recovery, salvage, benthic surveys, hydrographic surveys, metrology surveys, ordnance disposal, homeland security, underwater mining and inland infrastructure maintenance. For practical, engineering and commercial reasons, no single underwater vehicle can be employed to perform all of these tasks.

ROVs and AUVs are often the most efficient means of performing these tasks, but from a commercial point of view, unless steady work is assured for each system (not often the case for a small operator), carrying the overhead of a dedicated vehicle to cover each of the broad categories becomes cost-prohibitive. Supporting a wide range of capabilities ordinarily requires a significant expenditure of time and capital. Even when capital is available, lead times for the delivery of new purpose-built ROVs are typically three months or more. This will often preclude an operator from bidding on any project that requires services inside of the order lead time.

Compounding the issue is an insufficient certainty of the operator to know if and when a particular capability will be called upon. To provide clients with a particular capability, operators must be prepared to carry the purchase and maintenance costs of specialized equipment in the event it is not employed over a given period.

Though ROVs often act as a good platform from which to deploy job-specific tools, certain operational restrictions may prohibit a standard ROV from being deployed in a specific application, necessitating the development of a project-specific vehicle or tool. One example of such a restriction is the need to get a capable ROV through a manhole or valve. By nature of its physical geometry, a vehicle able to perform this task will not be very capable in open water. To begin development of an entire ROV-like system from scratch for every project would result in unacceptably long project development lead times and cost.

In attempt to address these issues, SeaView Systems Inc. in 2003 began work on generic underwater robotic control system to provide an "ROV backbone" capability for the rapid development of vehicles and tooling on a job-by-job basis. The system is able to support basic components such as cameras, lights and compasses; provide modular control for various actuators such as thruster motors, linear and rotary actuators, and hydraulic servo valves; and provide power and telemetry support for sensors such as sonars (multibeam and scanning), DVLs, bathymetry and oceanographic sensors.

The flexibility of the ROV backbone system allows SeaView to rapidly and cost-effectively adapt to many different applications that fall under the broad industry category of underwater technology solutions. By using the existing back-

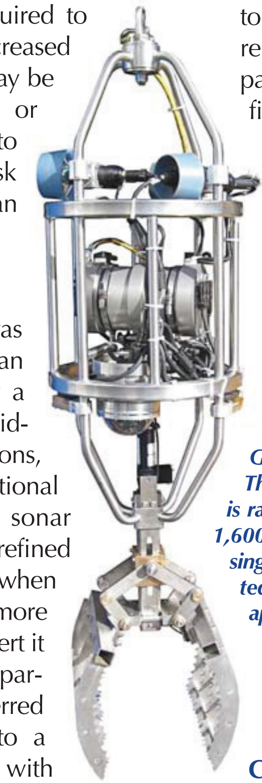
An ROV backbone built into a polyethylene frame to create a long-distance ROV capable of traveling a distance of up to 10,000 feet through an 18-inch-diameter opening.

bone, the systems development effort required to bring a service to market is significantly decreased as job-specific tools, sensors, lights, etc., may be acquired (fabricated, purchased, rented or taken from in-house stock) and integrated into the system. This is a relatively simple task compared with designing and building an entire system from scratch.

ROV Backbone Development

The first version of the ROV backbone was developed over four months in 2003 as an auxiliary thrust and telemetry package for a small observation-class ROV. The ROV provided the bulk of the required control functions, while the backbone provided two additional thrusters, auxiliary lights and profiling sonar telemetry. The concept continued to be refined over multiple small iterations until 2006, when projects came along that required both a more capable ROV system and the ability to convert it for other applications. This need made it apparent that the ROV backbone was the preferred approach, and the system developed into a modular underwater robotic control system with customizable functionality. The observation-class ROV was removed from the system, and the ROV backbone was built to work as a stand-alone system.

The ROV backbone provides the basic hardware to support most any underwater technology sensor. Rather then having to build up an entire system from scratch, the task becomes a relatively simple matter of integration, which is dealt with as part of the job-specific mobilization. The system employs a fiber-optic multiplexer to transmit video and serial telemetry data. A single-board microcontroller is embedded on both surface and subsea control boards while custom daughterboards provide subsea power control and distribution as required. Specific daughterboard control tasks include driving brushless DC thrusters, linear actuators, crawler tracks, dimmable lighting, heading pitch and roll, sonar, auxiliary power, pan, tilt and zoom control, and other subsea tooling.



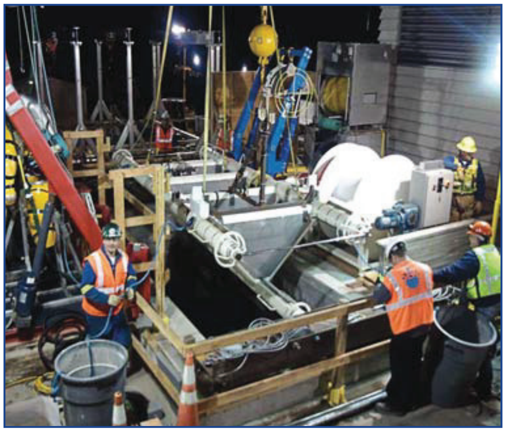
An ROV backbone installed into a Smart Grapple frame. The grapple frame is rated to lift up to 1,600 pounds in a single lift when fitted with the appropriate jaws.

The system is controlled using two microcontrollers: one in a topside hand controller and one in a subsea control bottle. The two units communicate via an RS-232 serial link. The microcontrollers run on internal software written in Dynamic C. The GUI of the topside industrial PC, which displays subsea sensors and runs more sophisticated control algorithms, histograms and monitoring, runs on NI LabWindows/CVI.

Case Studies and Applications

The ROV backbone has been utilized in scenarios involving underwater pipeline inspection and cleaning. These are outlined in the following case studies and applications.

Long-Distance ROV. To accommodate tight access points often found in ROV inspections of pipelines and tunnels,



A truss, fitted with optical sighting system, is lowered into shaft where, once positioned, it will be locked in place with an atmospheric diving suit.

SeaView built the ROV backbone into a dedicated ROV frame for Kenosha Water Utility (Kenosha, Wisconsin) in October 2003. The frame has an octagonal cross section that allows it to pass through a manhole as little as 18 inches in diameter.

The vehicle features a pan-tilt-zoom camera, two fixed cameras, compass and depth sensor, dimmable LED lighting and profiling/imaging sonars. This vehicle has performed pipeline inspections in excess of 8,000 feet. The cost of the frame itself represented about 2 percent of the overall cost of the vehicle and was developed in about three to four weeks.

Since its initial deployment, this long-distance ROV has been used on approximately 20 pipeline and tunnel inspection projects.

Smart Grapple. In the spring of 2010, SeaView developed the Smart Grapple, a "flying" debris removal tool suspended from the surface and powered with thrusters, on contract to JF White Contracting Co. (Framingham, Massachusetts). JF White is part of a joint-venture company tasked with building an ultraviolet treatment plant for the main supply of potable water for New York City, New York.

Using the Smart Grapple and a Saab Seaeye (Hampshire, England) Falcon DR ROV, operators cleaned out about 1,400 pounds of debris from the bottom of a 400-foot-deep shaft in order to access a valve sump in the bottom of the shaft. This was completed over six nights with about six hours of access each night.

The ROV backbone was integrated into a tool to provide a suspended grapple that could be navigated about the bottom of the shaft, be orientated with large objects and be able to clamp onto the objects with several hundred pounds of force and lift the objects to surface. The grapple is fitted with a pan-tilt-zoom camera, a small tooling camera in the base of the jaws, four thrusters, an electrical linear actuator to drive the jaws, dimmable LED lighting and a compass/depth sensor. Five different jaw sets were built for removing gross debris, fine debris, plywood sheet and bronze grating.

The Smart Grapple frame, which was the component fabricated specifically for this project, represented around 20 percent of the overall system cost and was developed in about five weeks.

Truss Guidance System. SeaView designed this system last spring on contract to JF White for monitoring the position and attitude of a large truss that was to be installed across a 190-foot-diameter concrete shaft in 400 feet of water. The purpose of the truss was to provide a stable platform from which to stage a large blanking plate being installed into the side of the shaft wall.

The ROV backbone was mounted on the truss prior to installation. Through the use of a camera and optical sighting system and monitoring of heading, pitch and roll, the truss was positioned in place with the aid of a Saab Seaeye Falcon DR ROV fitted with SeaView's Hydrolek five-function manipulator. Once in place, the truss was locked in place by a pilot operating an atmospheric diving Newt Suit.

SeaView Serpent. An articulated shuttle designed for inspecting small-diameter pipelines, the Serpent carries a pan-tilt-zoom camera and two fixed cameras. The system is powered with three thruster motors and uses a profiling sonar to perform measurements of sediment depth within the pipeline under investigation. This vehicle was built on and off during a six-month period in 2006 on speculation of performing a series of pipeline inspections in an oil refinery, but the project never came to fruition. The Serpent is available as a service along with a crew of technicians to perform inspections.

Future Applications

Among SeaView's future plans for the ROV backbone is a concept to build the backbone into a free-flying tracked vehicle fitted with soft buoyancy and thrusters. Fitted with soft buoyancy, this vehicle will be particularly useful in mine remediation projects where the vehicle must be able to view both the crown and invert of a tunnel while traveling over rockfalls and areas that are too soft to provide traction. It will be capable of "flying" over flooded rock piles and cave-in situations found in mine remediation.

The existing ROV backbone control system will lend itself to a simple integration, providing SeaView with a sophisticated and high-powered tracked vehicle that is capable of free flying and that can be built using a minimum of external resources.

Another future application is to build the ROV backbone onto a concrete mattress laying frame. All the requisite components are available on the existing backbone to provide the means to orientate a concrete mattress frame, locate it using USBL acoustic positioning and multibeam imaging sonar, lower the mattresses in place and disengage the frame from the mattresses. The advantage of essentially installing an ROV into a mattress frame is that the frame can be accurately positioned without the added complication and cost of having a supporting ROV or dive spread.

These examples demonstrate how an ROV backbone concept presents a cost-effective and flexible method for providing a wide range of capabilities to clients in a rapid turnaround time, at controlled cost. ■

Matthew Cook, president of SeaView Systems Inc., was originally trained as an electronic weapons systems technician in the Royal Australian Navy. In 1993, he started working with ROVs offshore and in 1998 founded SeaView Systems.