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ROV Backbone control system for rapid development of Underwater Robotic Systems.

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Abstract: **The need for robotic underwater intervention comes in many forms. The need is generally driven by a specific issue or challenge that requires a solution in a relatively short time period and delivered at the lowest possible cost.**

Though ROV's often act as a good platform from which to deploy job specific tools, certain operational restrictions may prohibit the form of a standard ROV to be applied to a specific application necessitating the development of a project specific vehicle or tool. To begin development of an entire ROV-like system from scratch every project would result in unacceptably long project lead times and cost.

SeaView Systems has demonstrated how a robust, modular underwater robotic control system with multiple functionality may be developed and deployed. By doing so we are able to demonstrate how a high quality of service may be maintained while controlling cost and project lead time.

This paper will first discuss the need for flexibility and rapid development of Remotely Operated Vehicles (ROVs) and ROV-like systems to meet demands of ever changing market demand. It will then discuss a solution developed by Seaview Systems, Inc and give a brief history as to how a "backbone" ROV control system was initially conceived and developed. By providing a block diagram explanation of the system architecture we will show how the system is essentially modular and able to be quickly adapted on a project by project basis. The paper will go on to provide several case studies showing how a single control system may be configured for use in the field, and will finally propose some further applications.
Robotic Underwater Intervention is a term that covers a deceptively wide range of technologies. It covers tasks in the broad categories of underwater construction (equipment placement, touch-down monitoring, tie-ins, dredging and other site preparation tasks), inspection, search and recovery, salvage, benthic surveys, hydrographic surveys, metrology surveys, ordinance disposal, homeland security 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 Automated Underwater Vehicles (AUVs) of one form or another are often the most efficient means of performing the described 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 capability ordinarily requires a very significant expenditure of time and capital. Even when capital is available, lead times for the delivery of a new purpose built ROV is typically in the order of 3 months or more which will often preclude an operator from bidding on any particular project having a requirement for services inside of the order lead time. Compounding the issue is an insufficient certainty of the operator to know just when and if a particular capability will be called upon. In order to be able to provide their clientele with a particular capability, the operator must be prepared to carry the purchase and maintenance costs of plant in the event it is not employed over a given period.

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Being in a relatively small market, a small ROV service company, in order to keep fully employed, must be open to taking on whatever task the market will provide in order to be successful. This “shotgun” approach results in the need for a small organization to have a very wide range of capability with a minimum of overhead. All of this results in significant commercial pressure on the operator to reduce capability or raise costs.

In the attempt to address these issues, a mitigating solution has been demonstrated by SeaView Systems, Inc by developing a 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 compass as well as provide modular control for various actuators such as thruster motors, linear and rotary actuators, and hydraulic servo valves, as well as providing power and telemetry support for various sensors such as sonars (multi-beam and scanning), Doppler velocity logs, bathymetry and oceanographic sensors.
The need for robotic underwater intervention comes in all manner of shapes and sizes and is generally driven by a specific issue or challenge that requires a solution in a relatively short time period. Clients typically have an issue they need resolved in as short a time as possible and at lowest possible cost.

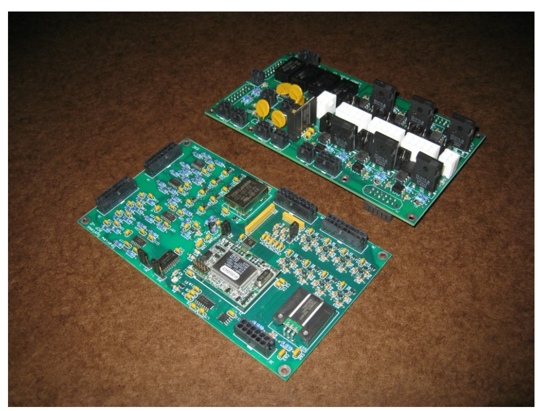
Though ROVs often act as a good platform from which to deploy job specific tools, certain operational restrictions may prohibit the form of a standard ROV from being applied to a specific application, which then necessitates the development of a project specific vehicle or tool. An example of such a restriction is the need to get a capable ROV through a manhole, valve or other restriction. 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.

The first version of the ROV backbone was developed in 2003 when SeaView Systems first entered the long distance tunnel and pipeline investigation market. It was developed as an auxiliary thrust and telemetry package for a SeaBotix LBV150. The SeaBotix provided the bulk of the required control functions while the backbone provided two additional thrusters, auxiliary lights and profiling sonar telemetry.

Initial use of the ROV Backbone was to provide auxiliary thrust to SeaBotix LBV150s along with auxiliary lighting and sonar telemetry.

Since that early beginning, the ROV backbone system has developed into a compact, robust and modular underwater robotic control system with wide functionality that may be customized and deployed in a relatively short amount of time at controlled cost.

The system employs fiber optic telemetry: a single board micro-controller is embedded on both surface and subsea control boards while custom daughterboards provide subsea power control and distribution.



6.5in Long x 4in Wide ROV Backbone motherboard (lower left) and Power Control daughterboard module (upper right)

Specific daughter board control tasks include:

- Brushless DC thrusters
- Linear actuators
- Tracks
- Other subsea tooling
- Dimmable LED lights
- Heading, pitch and roll inputs
- Sonar and auxiliary power control
- Leak detection
- Load/current detection
- Subsea supply voltage monitoring
- Pan Tilt Zoom camera control

A surface industrial PC is used for display of subsea sensors and to run more sophisticated control algorithms, histograms, monitoring etc.

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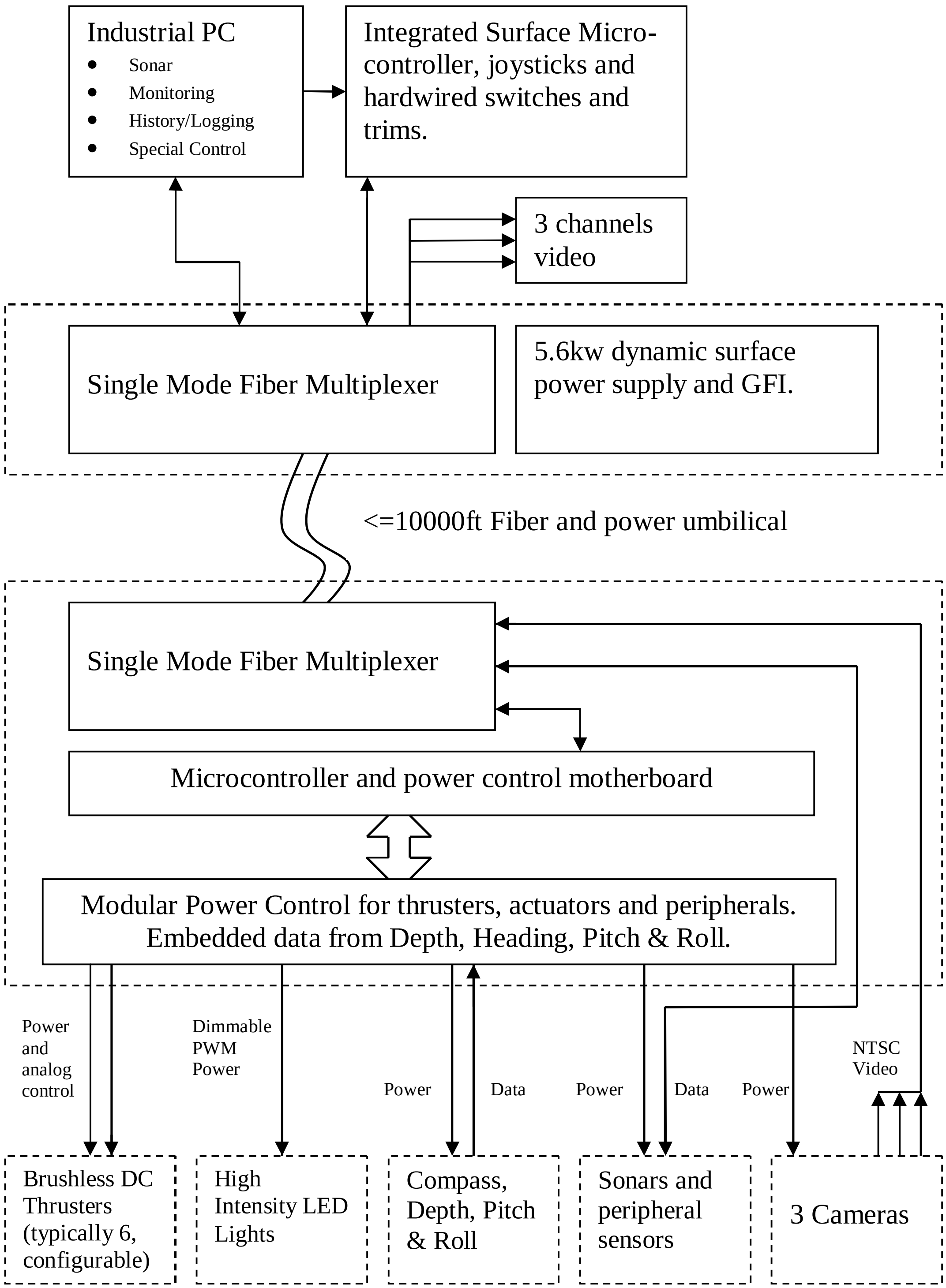
ROV "Backbone" Control System: General Overview Block Diagram.



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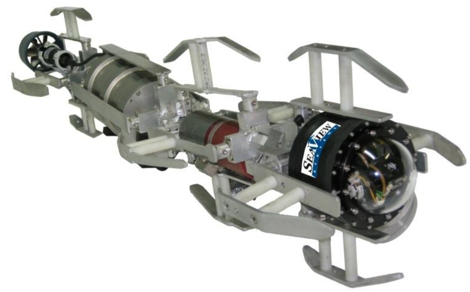
Case Study #1: Long Distance ROV

ROV backbone built into polyethylene frame to create Long Distance ROV capable of penetrating up to 10,000ft through and 18" diameter opening.

A significant percentage of the work that SeaView Systems performs is long distance tunnel and pipeline investigations. When size permits we will use our Falcon DR ROV due to its ability to carry more illumination and sensors, however some projects have restricted access through small manholes but still require a long distance penetration with full video and sonar coverage. To accommodate this requirement we built our ROV backbone into an ROV frame. The frame is octagonal in cross section to allow it to pass through a manhole of as little as 18" in diameter. The vehicle is full featured with 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 8000'. The cost of the frame itself represents about 2% of the overall cost of the vehicle and was developed in about 3-4 weeks.

Case Study #2: SeaView Serpent



ROV backbone built into articulated aluminum skid frame for video inspection and sonar modeling of pipelines as small as 9" diameter.

The Serpent frame was developed for inspecting very small diameter pipelines. The ROV backbone is mounted in a series of 4 articulated units each unit connected to the next with a universal joint. The front unit holds a Pan, Tilt, Zoom camera, the next a profiling sonar, then the electronics bottle, and finally two or three thrusters. This vehicle is not flown like an ROV but rather runs along skids and acts more like a shuttle. It is appropriate for the investigation of relatively clean, water filled pipelines of diameters as small as 9". The frame represents less then 1% of the overall cost of the vehicle and was developed in about 3 weeks.

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Case Study#3: Smart Grapple

ROV backbone installed into Smart Grapple frame. Grapple may be "flown" over object to be picked and using internal cameras, be orientated over target prior to clamping jaws shut. Grapple frame rated to lift up to 1600lbs in single pick when appropriate jaws are fitted.

SeaView Systems developed the Smart Grapple on contract to JF White Contracting of Boston, MA. JF White are a joint venture company in the building of an Ultraviolet treatment plant which treats the Delaware Aqueduct, part of the main supply of potable water feeding New York City. Part of this project involved the cleaning out of some 1400lbs of debris from the bottom of a 400ft deep shaft in order to access a leaking valve in the bottom of the shaft.

The ROV backbone was integrated into a tool to provide a suspended grapple that could be navigated about the bottom of the shaft, orientated to large objects, and 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, 4 thrusters, an electrical linear actuator to drive the jaws, dimmable LED lighting and a compass/depth sensor.

In a period of 6 nights each of about 6 hours of access we used a combination of the Smart Grapple and a Seaeye Falcon DR ROV to remove 1400lbs of debris.

The Smart Grapple frame represents around 20% of the overall system cost and was developed in about 5 weeks.

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Case Study #4: SeaView "Raptor" modification to Saab Seaeye Falcon DR

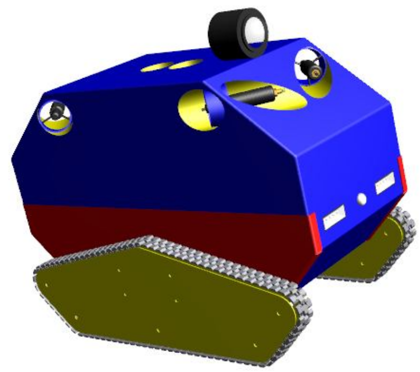
Concept drawing of SeaView "Raptor" modification to Saab Seaeye Falcon DR. 6 additional thrusters are fitted to basic Falcon DR frame to provide a minimum of 63% more forward thrust and 110% more vertical thrust.

Though in its basic state the Saab Seaeye Falcon DR represents one of the most powerful and capable ROVs on the market, on some projects we find that we need a larger vehicle to both carry excess payload and work in excessive currents. In order to supplement the thrust of the Falcon DR we have integrated the ROV backbone system into the Falcon DR to develop extra thrust. In its current configuration we are using relatively small Model 300 Tecnadyne thrusters giving an overall increase in forward thrust of 70lbs force, which represents a 63% increase in total thrust. The ROV backbone is capable of supporting significantly larger thrusters capable of more than doubling the standard Falcon DR's thrust, with an increase in surface area of around 30%.

Future applications:

Free flying tracked vehicle: Among our future plans for the ROV backbone is a concept to build the backbone into a tracked vehicle fitted with soft buoyancy and thrusters. 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 rock falls and areas which are to soft to provide traction.

The existing control system will lend itself to a simple integration which will provide us with a highly sophisticated and high powered tracked vehicle capable of free flying that can be built using a minimum of external resources.



Concept drawing of tracked vehicle fitted with thrusters and soft buoyancy. Vehicle will be capable of "flying" over flooded rock piles and cave-ins in situations found in mine remediation.

Concrete mattress installation frame: Another 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 sonar, and then 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 of dive spread.

Automated Underwater Vehicle:
Coupled with a sophisticated control computer residing on the vehicle and power/thrust efficient thrusters, the ROV backbone could be deployed in an AUV mode using battery power.

In conclusion, this paper demonstrates how when supported with the necessary technical skill sets needed to design and develop daughterboards and supporting software on an "as needed" basis, an investment in a basic control system, surface power supply and a range of umbilical cables presents a cost effective and flexible method for providing a wide range of capabilities to clients in a rapid turn around time, at controlled cost.