MAY 2017 SINGLE ISSUE PRICE $4.50

SEA TECHNOLOGY®

WORLDWIDE INFORMATION LEADER FOR MARINE BUSINESS, SCIENCE & ENGINEERING

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Vehicle Design For the Littoral Zone

SurfROVer Handles Transitional Zone from Shore to Deepwater

By Matthew Cook • Dr. Tim Crandle • Ed Celkis

SurfROVer is the latest in a line of inventive, special-purpose ROVs designed and built by SeaView Systems of Dexter, Michigan. A battery-operated crawler with a low-profile design and wide footprint that creates an extremely stable vehicle, SurfROVer targets the transitional zone between shore and deepwater environments that often cannot be addressed by other vehicles. The challenges of the transition zone include potential active surf conditions, where key aspects of SurfROVer's design make it capable of operating in otherwise impassable conditions. SurfROVer's innovative battery-powered propulsion system makes it ideal for specialized applications such as route surveys and unexploded ordnance (UXO) surveys and for deployment of a cable/pipeline tracker, as well as applications in otherwise impassible surf, such as active surf bathymetry surveys.

(Top) SurfROVer emerges from heavy surf conditions during field trials at the ocean-side shoreline at Duck, North Carolina. In this configuration, targeting relatively shallow water, the mast supports a GPS antenna that allows precise navigation control and location of survey data. (Bottom) The front view of SurfROVer shows a host of survey equipment, including lights, HD and SD cameras, multiple sonar imagers and a current profiler.

Exploiting the Latest Technologies

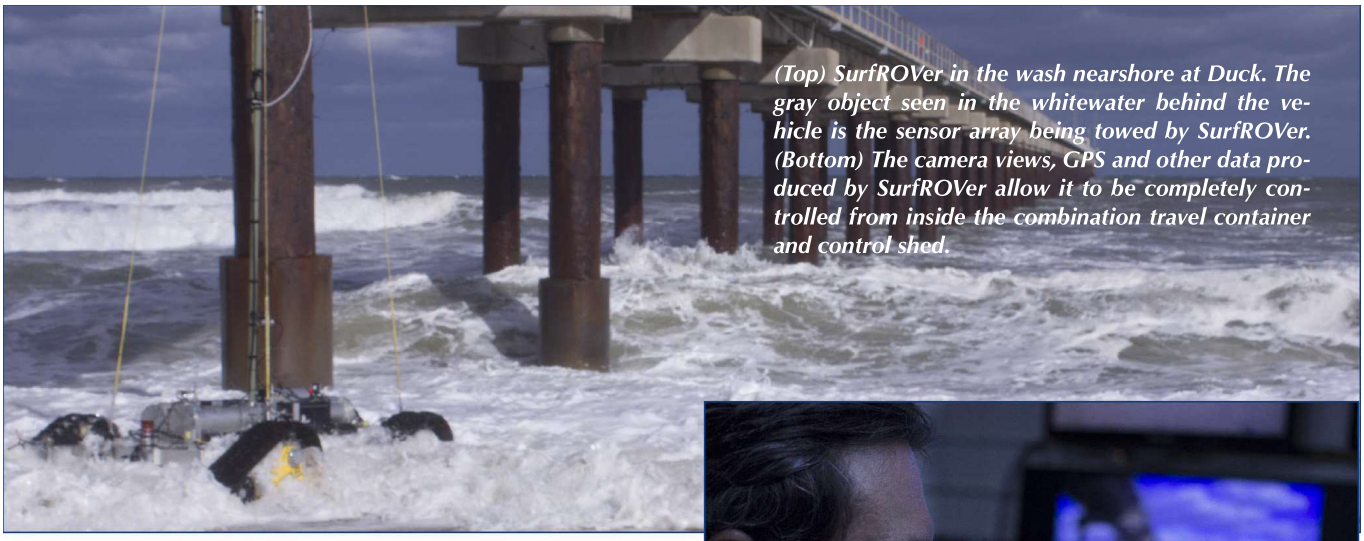
For many underwater applications in deepwater conditions, an ROV can readily be "flown" to perform structural inspections or survey work. But the littoral zone, where surf conditions, insufficient depth and the hazards of shore proximity present special challenges, remains relatively unexplored by standard ROVs.

Drawing upon extensive experience with both off-the-shelf ROVs and custom vehicle designs, as well as the latest advances in battery chemistry and the company's own custom control electronics capabilities, SeaView Systems decided to rethink the possibilities for a vehicle that could operate in energetic surf and traverse directly from shore up to depths of 100 m.

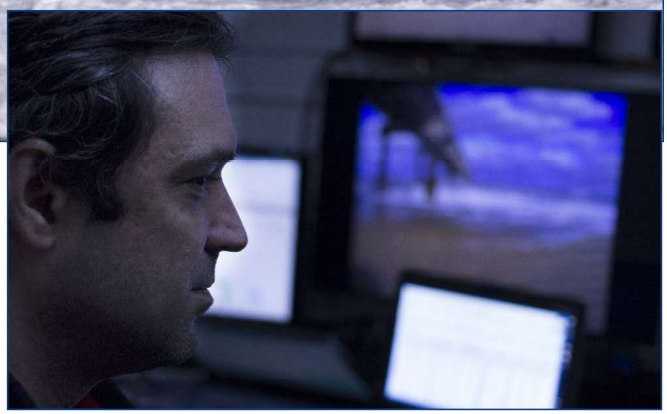
Some key design considerations that would make for the most versatile vehicle included: wide and low vehicle profile for maximum stability; low center of gravity with high mass for operation in energetic surf; wide track drivers for good traction with low-psi footprint; high-powered drive motor system for versatile payload or towing capacity; robust mechanical design capable of withstanding the rigors of high surf; high maneuverability, point-turning capability; ease of deployment and transport; and use of as many off-the-shelf components as practical to maintain low cost.

One of the first design considerations was the propulsion for the vehicle. After careful consideration, SeaView decided on an electric motor-driven hydraulic system that provides a high level of torque to each of the four tracks. In order to keep overall system cost down, SeaView used a combination of custom-machined components and standard off-the-shelf parts that were readily available for more mundane terrestrial applications. The tracks, for example, were mass produced for use on truck setups.

The first application for SurfROVer was pulling an extremely sensitive sled-mounted electromagnetic UXO detection system developed by White River Technologies. The requirements of the electromagnetic survey equipment dictated that the vehicle have a very low electromagnetic noise floor.



(Top) SurfROVer in the wash nearshore at Duck. The gray object seen in the whitewater behind the vehicle is the sensor array being towed by SurfROVer. (Bottom) The camera views, GPS and other data produced by SurfROVer allow it to be completely controlled from inside the combination travel container and control shed.



This requirement meant that power could not be provided via the standard powered umbilical as the movement of the powered umbilical in the surf would cause too much interference with the UXO sensing equipment.

Instead, SeaView elected to power SurfROVer with twin battery banks. These battery packs consist of 1,344 total individual cells built into banks of 40 cells each, with 14 banks per battery for a total mass of batteries in bottle of 65 kg. Each bank of cells is individually assembled with a controller board that allows system diagnostics to be fed back to the control station of the system and allows for intelligent charging that efficiently and quickly tops off the batteries after use in the field. By using high-capacity lithium chemistry batteries in sizable banks with a sophisticated battery management system, SeaView was able to design SurfROVer with capacity to charge fully in a few hours and operate for as long as a complete workday on a single charge.

The mass of the battery bottles also ends up being a large fraction of the overall vehicle mass and contributes to the overall stability of the platform. By mounting these bottles near the axle height of the vehicle, low on the frame, they contribute to the low overall center of mass for the vehicle.

Battery operation had another benefit when it came to ease of deployment and transport. By fitting SurfROVer with a setup console that could be used when mobilizing the vehicle from within its transport container, the vehicle can be wirelessly controlled with a wireless hand controller. By activating the setup console, the operator need only turn on power to SurfROVer and control it with the wireless hand controller. This possibility proved to be very useful in deploying the vehicle from the transport container, which doubles as a control booth. Rather than needing to position the transport container at the deployment location, the container can be positioned as needed based on practicalities at the work site. And SurfROVer can be "driven" to the deployment location by a single operator with a wireless hand controller walking with the vehicle. Because of the ability of SurfROVer to traverse reasonably rugged terrain, having this capability makes it very easy to deploy in otherwise restrictive environments, which might involve crossing beach or other obstacles.

Made of lightweight aluminum, SurfROVer measures only 2.6 by 2 by 0.8 m yet delivers a pull force of 500 kgf, enabling it to easily pull survey sleds. Its size and weight make it easily transported by flatbed trailer/pickup truck.

Vehicle operation via a fiber-only umbilical eliminates the magnetic interference created by a powered umbilical. This approach necessitates use of either an onboard power source such as batteries or a nonelectrical power technique such as hydraulic drive.

Building on Previous Developments

Previous ROV vehicle development at SeaView has resulted in a set of tools, utilities and skills that factored heavily in the design and implementation of SurfROVer. Among the existing capabilities that come into play are: battery management systems; ganged battery and pressure bottle assembly; system controls using SeaView's ROV bus control system; and system control multiplexer using SeaView's SVS-109 multiplexer.

In particular, the ROV bus system, devised by SeaView with the intent of making common control elements such as light controllers, motor power controllers and system communications operate using standard hardware elements, proved to be highly beneficial for the development of the overall system.

SeaView was able to take advantage of its own SVS-109 fiber-optic multiplexer board to manage video and sonar data feeds via the fiber link. The SVS-109 has been proven and already widely used on many custom ROVs or as an upgrade to vehicles such as the Saab Seaeye Falcon to enhance the bandwidth and number of ports available on the ROV. On SurfROVer, the SVS-109 provides enough bandwidth for video, lights and motor control and enables SeaView to manage the full suite of survey equipment through a single mux board.

Design Tradeoff: Battery vs. Umbilical Power

One of the key considerations in the initial specification for SurfROVer was locomotion. While many ROVs

are powered via high voltage umbilical, this approach has severe limitations for working in active surf conditions. A powered umbilical might be workable for low-energy surf but would be problematic in energetic surf. In addition, the powered umbilical would impose limitations for shoreline proximity. As part of an ongoing push to enable more applications with battery power, SeaView developed a custom power system for SurfROVer that could be reused in a variety of applications. In order to provide the best control, lowest environmental footprint and ease of deployment, SeaView selected an electric motor-driven hydraulic locomotion system and developed a combined battery and bottle system for the SurfROVer that could be used singly or in ganged operation for other vehicles.

GENERAL	
Max Operating Depth	300 msw
Overall Dimensions (LxWxH)	2.6 m x 2 m x 0.8 m
Weight (in air)	680+ kg, depending on configuration
Weight (submerged)	Neg. buoyant: ~600 kg, depending on config.
Ground Pressure	0.52 psi/3.5 kilopascals
Pull Force	500 kgf
Battery Life	8-12 hr.
Speed (Submerged)	~1.5 m/s
Propulsion	Electrohydraulic
Turning Radius	On-the-spot (without tow array)
OPERATING CONDITIONS	
Current Conditions	3-kt. current regardless of incident angle
Bottom Type Environments	Range of soil types (sands, muds) up to 80 kPa
Wave Action/Sea States	Up to 2 m plunging waves; Sea State 3
Traverse Capability/ Obstructions	Traverse capability for obstructions 0-20 cm above flat seafloor; barriers, troughs, macro-ripples, shell reefs; etc.
PAYLOAD CAPABILITY	
Payload Allocation	150 kg+
Payload Volume/Hotel Space	~100 liters
Payload Power	AC/DC voltages available
Platform Data	PTZ camera, 2xSD cameras, direction, velocity, roll/pitch/yaw, pressure depth, health status
Positioning	Desired RTK-DGPS; augment with IMU and USBL (tbd)
Payload Data Interface	10/100 Ethernet, RS232, RS485, TTL. Analog I/P. Digital I/O, Quadrature Encoder. Gbit Ethernet (optional)
TOPSIDE INTERFACE	
PC Interface	Windows control/display
Data Interface	Ethernet via tethered modem (e.g., FO-Ethernet modem)

SeaView Systems' SurfROVer specifications.

Special Requirements for UXO

For some applications, such as mapping unexploded ordnance, sensitive electromagnetic sensors are required. The copper power supply line, even when shielded, can present an insurmountable source of noise that propagates into the sensor's field of view and perturbs the sensitive electromagnetic readings.

Using a ruggedized fiber-only umbilical line for communications and battery banks for system power brought a key advantage for some survey applications, including UXO surveys that were the focus of the first work with SurfROVer.

The two specially engineered lithium-ion battery pods deliver up to 12 hr. of battery life and require no surface power supply (e.g., generator or shore power). All communications (video, lights, operating controls, etc.) are run over optical fiber. SurfROVer's caterpillar tracks are electrohydraulically driven.

Field Trial Results

A series of field trials were performed in November 2016 in order to test the performance of SurfROVer in various conditions. These included both freshwater and saltwater environments, as well as one near-freshwater estuarial setting on Albemarle Sound, on the inland side of the Outer Banks, North Carolina.

The immediate goal of these tests was to verify the performance of SurfROVer as a tow engine for EM sensors developed by White River Technologies of Lebanon, New Hampshire. For the EM sensing application, precise GPS information for both SurfROVer and the towed EM sensor array was a key data requirement. (The sensor array was towed via a trailing sled that kept the EM sensor at the needed distance from the onboard electronics.)

Initial field trials of SurfROVer were conducted at a Great Lakes location and at the Army Corps of Engineers Field Research Facility at Duck, North Carolina. These trials included three test zones: the beach, an active surf littoral zone and a freshwater estuary test site on the inland side of the lake.

This included GPS positioning, which necessitated a GPS mast that would be above the water surface for all parts of the track, along with a survey GPS base station, so testing in this case was limited to depths of less than 15 ft.

The testing resulted in some insights that will be reflected in design improvements, but the stability of the platform was found to be quite good, even when towing the relatively long arm required for the EM sensors.

Directions for Future Development

Building on the basic framework of the SurfROVer's initial design, SeaView sees a range of possible variations, including a smaller vehicle that would offer less towing force but would be even easier to transport and deploy. In addition, the battery banks as designed offer the possibility of either longer running time by adding more battery bottles, or lower mass by running a single bottle, at the expense of shorter run time. SeaView even envisions the possibility of a fully autonomous vehicle capable of performing extended survey work based on a preprogrammed track plan. At that point, the video game controller used to drive the SurfROVer could be replaced by mission planning software, and the operator could focus on data being produced by the survey. **ST**

Matthew Cook is the president of SeaView Systems, Inc., which he founded in 1998. He has led SeaView through more than 100 successful projects and established the company as a global leader and innovator developing custom vehicles and underwater technology for long-distance tunnel inspections, underwater infrastructure investigations and other marine applications.

Dr. Tim Crandle is the director of research and development at SeaView Systems. He received his Ph.D. in electrical engineering in 1986 from the University of Michigan, specializing in semiconductors. Crandle has held technical, managerial and business development positions in semiconductors and wireless communications.

Ed Celkis is the systems development manager at SeaView Systems. He began working with electronic control and measurement systems at the University of Michigan Marine Hydrodynamics Laboratory in 1998 with force, pressure, acceleration and orientation sensors, as well as microcontrollers and motion control systems. At SeaView, his responsibilities include the development of electronics, software and mechanical devices for the support of underwater technologies.