Tradeoffs between Umbilical and Battery Power in ROV Performance

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Abstract—**For many existing inspection class ROV designs, a powered umbilical was the obvious choice as a means of providing system power. But advances in battery capability, coupled with the sheer diversity of applications and associated task requirements for which ROVs are now being targeted, has resulted in an interesting tradeoff between the capabilities of umbilical versus battery power. This paper will examine tradeoffs between battery and umbilical power as well practicalities for both custom and off-the-shelf ROV systems.**

Keywords—umbilical, battery, ROV performance, survey

I. Introduction

SeaView Systems has been actively involved in ROV survey and custom tooling projects targeting a broad range of applications including potable water supply systems surveys, infrastructure surveys, submerged repair work as well as oceanographic and other applications for many years. As the diversity of applications and the stringent requirements of specific projects has increased, SeaView Systems has often been faced with weighing tradeoffs between using an existing vehicle design, typically employing a powered umbilical, or developing a custom or semi-custom vehicle targeting a particular application. For many recent applications, the tradeoff also includes consideration of battery versus umbilical power. This paper presents some of the concrete considerations for specific applications and in some cases the resulting ROV that was deemed best fit for the application.

II. Design Considerations in Power Tradeoff

For many interesting application that could benefit from an ROV survey such as water or hydroelectric system surveys, a prime consideration is avoiding or minimizing system shutdown and risks related to plant equipment. Typically for these types of applications, shutdown time comes at a tremendous cost. At the other end of the spectrum are applications such as route surveys, where shutdown and plant considerations are not typically a concern. These and numerous other considerations enter into the decision of what vehicle is best suited to a particular application.

When considering what vehicle or design to employ, and specifically whether to use a powered umbilical or substitute battery power, among the considerations are the following:

- How much power is required for the vehicle?
- What is the penetration distance for the project?
- What are the communications requirements for real-time monitoring and control during the project?
- What special requirements dictate aspects of the vehicle design?

The combination of power required and penetration distance is often the primary one in selecting a power source. Line loss in a powered umbilical means that increasing penetration length dictates increasing power supply in order to overcome line loss. As the power requirement increases, it can become a significant consideration in the logistics of the operation. This is especially true on ship-based operations where an increasing power supply may dictate a larger vessel and rapidly increasing costs, reduced options for vessel, and general increased constraints on the operation.

Against these considerations is the concern that increasing power requirement, when supplied by battery power, produces increased vehicle size that may not be practical within the constraints of many survey environments such as pipelines.

In addition to power considerations, one must consider the communications requirements for the vehicle. For many existing systems, the powered umbilical provides a simple means for the inclusion of a fiber optic link between ROV and control station that provides powerful communications possibilities. But for very long pipeline inspections, where the choice of a powered umbilical brings challenges, an unpowered fiber link might be practical if batteries can provide sufficient power. For other applications, a radio link, while also bringing challenges and limitations, might be a practical possibility.

In addition to these considerations, there are sometimes constraints that are specific to a particular deployment. For example, some sensing applications such as route surveys focusing on unexploded ordnance may dictate a low EM noise requirement that cannot be achieved with a powered umbilical. Depending on conditions, an umbilical may also be a potential hazard or source for mechanical problems. For still other applications, the mechanical considerations around an umbilical, such as surf conditions may weigh in favor of a battery solution.

The sections that follow describe specific applications and how the above tradeoffs went into determining the choice of power supply as eventually deployed.

III. Survey Of Vehicle Designs

The following presents a short review of a number of vehicles as deployed using off-the-shelf or modified designs, or custom designs targeting particular applications, as deployed for various projects by SeaView Systems.

A. *Standard powered-umbilical ROV*

The consideration of cost is often primary and for such cases, the possibility of deploying an off-the-shelf ROV design often wins out if practical considerations allow. While it has been modified by SeaView in many ways including improved electronics for better survey equipment support (using SeaView's SVS-109 fiber optic multiplexer to add HD video and other port support, for example) as well as modified with increased thruster power, the SeaEye Falcon is a representative of the sort of work horse off-the shelf ROV that is the first candidate for many applications.

The Falcon and vehicles like it often provide a baseline capability set that, if insufficient, dictates a more tailored solution.

Fig. X. The SeaEye Falcon is a workhorse inspection class ROV that is designed around the de facto standard, a powered umbilical.

B. Chiton pipeline inspection vehicle

The first custom designed vehicle to be examined here is SeaView's Chiton pipeline inspection tool. This vehicle, designed specifically to be able to perform a long distance pipeline penetration through a narrow access point, was restricted in size by the physical constraints of the pipeline access point.

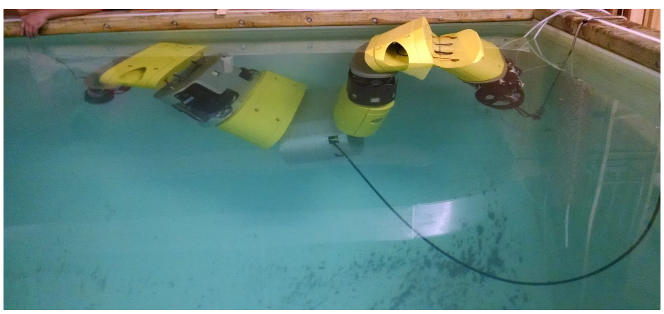

Fig. 2 SeaView's custom-designed Chiton ROV has the capability to articulate when entering a constricted access point, then tighten into a rigid frame ROV. It uses a powered umbilical.

Because the survey which the Chiton vehicle targets is both long in penetration distance and duration and the vehicle is restricted in size, battery powered operation was not a practical possibility.

C. Titan pipeline inspection vehicle

For another potable water system inspection that was performed by SeaView, the physical size restrictions were not nearly as stringent. In particular, the pipeline requiring inspection was 16 feet in diameter. One tunnel inspection, approximately 32,000ft long x 16ft diameter, presented special challenges. The tunnel is only able to be shut down for limited periods of approximately an hour (depending on water demand) and had not been inspected in its entirety for decades. Working from each end using standard umbilical powered ROV's would only provide 62% coverage.

Modifying SeaView's "Raptor" ROV (itself a modified Falcon vehicle) to hold sufficient battery power to allow it to pull 32,000ft of optical fiber was considered as an option but this would have required two passes through the tunnel and was deemed to be too expensive, especially if a vehicle capable of carrying out the survey requirement, full video coverage of the pipeline periphery, could be devised to perform the survey in a single pass.

For this survey, the only way to get single pass coverage was to design a vehicle with arms that could position cameras around the periphery of the large diameter pipeline.

In order to inspect the entire tunnel, SeaView developed a water-propelled, battery powered tool capable of providing full video and profiling sonar coverage of the tunnel. Penetration distance would be accurately measured using a encoder based line counter with a time stamp. Video and sonar data to be post processed with penetration distance to provide accurate position of video and sonar data.

Seaview's Titan is a purpose designed vehicle built to the specifics of the tunnel inspection but with an eye toward using the same design or modifications of it for future long tunnel work. Titan was built around a battery power pack because the length of the tunnel it was designed to inspect would have been challenging to power over umbilical. This motivated several design attributes on the vehicle.

Power budget for the entire penetration was estimated based on expected power loads required to run the cameras, lights, sonar and computers for 18hrs (32000ft @30ft/min) with some margin for safety.The result of the power calculations came to a requirement for 17.6 kWh of battery capacity driving 8ea 10,000 Lumen LED lamps and SD cameras. Other loads included a profiling sonar, digital video recorder and onboard computer. This battery capacity, while making for a very heavy central housing on the vehicle was found to be practical given the size of the passage to be inspected and the possibility to include large battery banks in the center of the neutrally buoyant vehicle.

The core of the concept was that, since the plant could not be shut-down for any extended period, we would use that fact to our advantage and use the water flow to provide the considerable motive force required to haul 32,000ft of rope through the tunnel.

A custom designed swing arm system was developed that would open into the moving water to capture motive force and also to distribute arm-mounted cameras around the periphery of the pipeline.

Aline counter that was keyed to an encoder with timestamp enabled accurate penetration distance to be logged with each video record and sonar information.

The design consisted of a large pressure housing able to carry sufficient batteries to run lights, cameras, sonar and computers for sufficient time to perform the inspection at optimum survey speed of 30-45ft/min. The pressure cylinder would support booms that would open up much like an umbrella, positioning each camera to view a strip of tunnel circumference that would overlap with adjacent cameras on either side.

Ultimately, we selected lithium ion cells as the best available option that would offer the power we required at a manageable size and cost, when coupled with a custom battery bank design and sophisticated battery management system (BMS). See Fig 1.

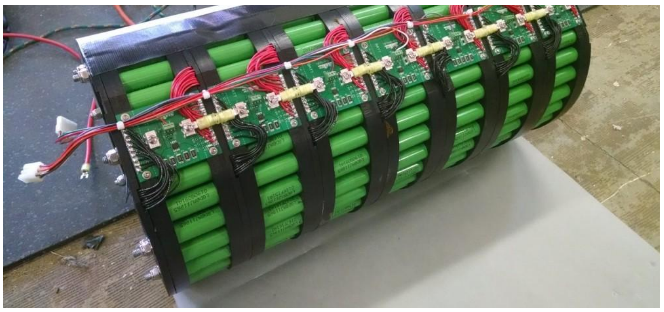

Fig. 1. A set of battery banks showing the electronics used for the battery management system.

Hinged booms at the forward end of the pressure housing were set up to open and close as the shuttle was run back and forth much like an umbrella opening and closing. The system was configured so that the booms would be closed tightly against the pressure housing during deployment with the pumps off but, once in the tunnel with the pumps activated, a series of drogues fitted out in front of the tool, would provide the necessary force to deploy the booms.

Buoyancy was fitted to bring the system to a neutrally buoyant state and provide a means to mount the profiling sonar.

Titan was also fitted with a haulback line and a distance counter that could register the position of any features seen on the tunnel video or recorded on profiling sonar. This was achieved by running the haul-back line through a line counter fitted with an electronic encoder at the vessel immediately as the haul-back line left the winch.

To monitor and ensure correct operation as Titan was initially deployed, the vehicle was fitted with a 1000ft long fiber that was set up so that a sharp tug on the fiber would pull it away from Titan. The fiber enabled verification of functioning of the cameras, lights, DVRs (digital video recorders) and sonar computer and that all clocks were synchronized with our line distance counter computer

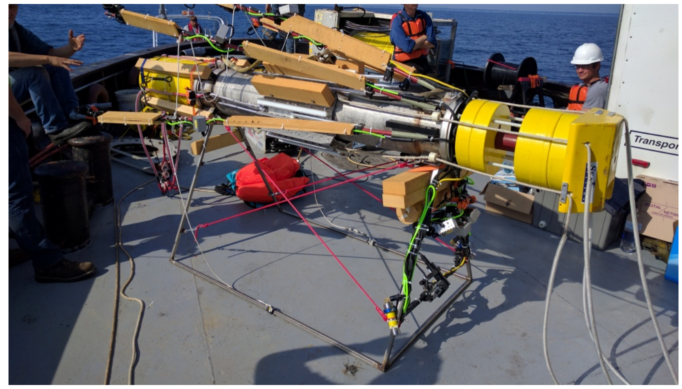

Fig. 3. Titan being prepared for deployment.

This initial stage also enabled verification of excellent visibility in the low turbidity water and a survey speed of around 30ft/min, which would achieve good survey coverage well within the battery life of the system. Once we came to the end of the 1000ft test fiber, this was manually pulled away and the survey proceeded without the benefit of real time monitoring.

A key consideration for future Titan deployments will be to run with the haul-back line only or to enhance the service by equipping the Titan system with an optical fiber umbilical with a suitable integral strength member. The use of the ruggedized umbilical will allow real-time viewing and recording of all 8 channels of video and the profiling sonar data while still allowing Titan to penetrate distances that could not be accomplished via powered umbilical.

D. *SurfROVer littoral zone crawler*

Another specialized application that was addressed by SeaView using a custom vehicle design is survey work in the surf zone. This relatively untapped area presents special challenges for vehicle stability and mechanical integrity in demanding surf conditions. One of the main application areas for littoral survey is UneXploded Ordnance (UXO) survey. A key consideration for electromagnetic survey operations for route surveys such as UXO survey is the vehicle characteristics as far as electromagnetic noise. One source of noise is the powered umbilical.

In addition to the EM noise advantage of eliminating the powered umbilical, eliminating the umbilical more generally improves the mechanical reliability of the vehicle.

SeaView's SurfROVer vehicle was designed to provide a low EM noise workhorse capable of surveying the difficult to reach littoral zone and capable of conveying a range of survey equipment.

SurfROVer is designed around a 4 track system that gives it great traction with a low PSI footprint. If needed, extra ballst can be mounted on the bottom of the vehicle to increase its stability. The vehicle generally benefits from a low profile that is built around the relatively massive battery packs that are mounted on the deck of the vehicle.

SurfROVer has proven to be very stable in active surf conditions.

Fig. X. SeaView's SurfROVer is a battery-powered vehicle targeting the littoral zone that is capable of operating from shore and into active surf.

SurfROVer is designed around a 4 track system that gives it great

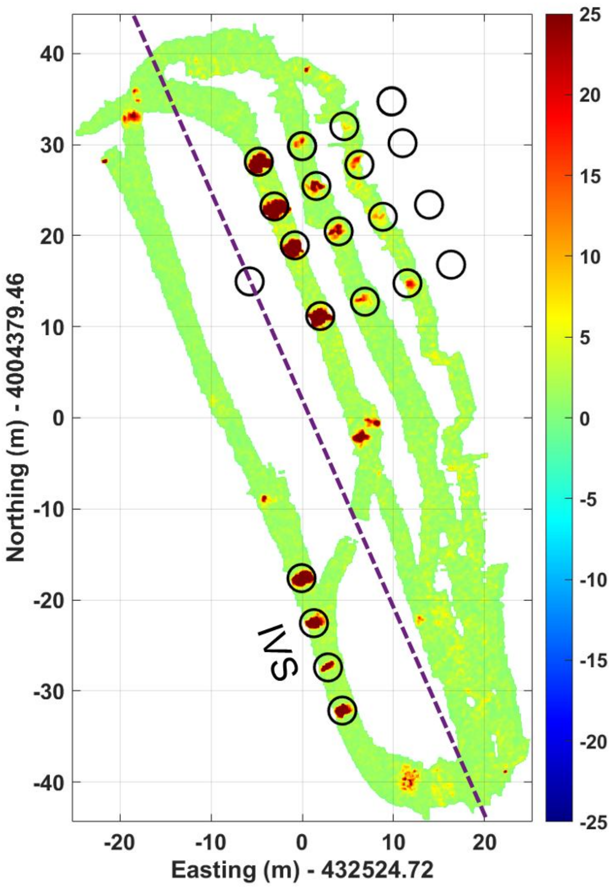

Fig. X. SeaView's SurfROVer towing White River Technologies' EM sensor array in the surf at the Army Corps of Engineers facility at Duck North Carolina.

Fig. X. This track log shows the record of a UXO test mission to survey ordnance targets placed in the array seen in the center of the track image.

IV. CONCLUSIONS

This paper has presented some example vehicles with their target applications that served as a basis for examining the tradeoff between battery and umbilical power. Advances in battery capabilities have made thee considerations increasingly relevant for many special purpose ROV applications and the trend toward battery power is expected to continue. SeaView anticipates the reuse of many of the components and design elments presented in the vehicle descriptions here for future extensions to existing or full custom ROV designs.