



# Underwater Remotely Operated Vehicles (ROV)

## Drive & Dive Motion Solutions

## Deep sea exploration - where motion matters

**Elmo's motion solutions are ideal for the ever advancing world of underwater remotely operated vehicles. Beyond the physical advantage, Elmo addresses the need for high speed underwater thrusting with ultra-high voltage drives, thruster start up against water currents with advanced servo algorithms, and mandatory robustness for deep water pressures and shocks.**

### Background

A Remotely Operated Vehicle (ROV) is an unmanned underwater robot that is connected to an operator via a series of cables. Underwater robotic technology has been adapted for a wide range of applications, from servicing deep water oil rigs, to environmental and scientific expedition. Equipped with different sensors, cameras, and robotic manipulators, ROVs are used to monitor, repair, weld, take samples and much more. These highly dynamics vehicles have proven themselves to be reliable, powerful and relatively simple to command, and are the ideal solution for areas unreachable by humans (sometimes several kilometers below sea level). ROVs are exposed to extended subsea temperature (sometimes operated in the arctic), and extreme underwater pressures.

Another type of underwater robot is the AUV (autonomous underwater vehicle). AUVs are most commonly used for survey and mapping missions, and typically do not have an umbilical cord like the ROV. AUVs are too equipped with thursters.



### Mechanical Construction & Limitation

ROV's are self-propelled with a varying number of multi-directional thrusters used to propel, maneuver, and stabilize them in water. While some ROVs also simply used for taking photos or monitoring, others also use robotics manipulators (typically 1, 2 or 3 per ROV depending on their intended use) for a variety of applications. Most typically these manipulators are used for interacting with its environment with tasks such gripping, sample taking, closing/opening of valves, cutting, cleaning, clearing, screwing, welding, etc. As with most marine applications, the space inside a vessel is generally limited. Since space is limited, each of the components onboard the ROV must be as compact as possible

### Power

With extremely high speed thrusters, needing to maintain stability against high water currents, ROVs demand lots of power. A connecting umbilical cord, sometimes 4-6km longs, transmits power, commands, and other data to and from the ROV. The cable core is built up by combining copper conductors for power and signaling, and fiber optic elements for communication. The often very long umbilical cord connecting the ROV to the ship can be several kilometers long, and is prone to significant voltage drops. A big challenge for the industry, as ROVs dive deeper and deeper is to increase power transmissions (while reducing weight). To reduce the strain on the cables and the ROV, typically a Tethering Management System (TMS) is installed between the boat on surface and the ROV itself. The TMS is only a few tens or hundreds of meters away from the ROV, while there could be a few kilometers of heavy

cords behind it to the boat. This reduces stress from the ROV significantly, and is a common industry apparatus on the intermediate TMS station, is also where a step-down transformer reduces and rectifies the high AC voltage from surface, to a lower and useable DC voltage needed by the ROV.

#### **Industry Trend: ROVs Going Electric**

Although traditionally hydraulic, there's an industry wide trend for replacing hydraulic pumps of the manipulators and thrusters for electromechanical and electrical components. Regulations dictate that any leak that occur in the hydraulic mechanisms of the robot need to be reported and assessed for environmental purposes. The fines payed as a result of these leaks are extremely heavy and thus increase the cost of operation and insurance of these robots in the hydrocarbon exploitation and exploration fields. This combined with the low efficiency of hydraulic systems, is the driving force behind the need for a change in the ROV technology to one that is more efficient and environmentally friendly.

(industry standard hydraulic robotic manipulator – [Schilling Robotics](#))

“**Electric robotic systems will perform all tasks in the underwater domain, including those now undertaken by hydraulic systems... ROVs and AUVs in their present form will cease to exist and are replaced by transformative e-robotics that can roam, hover, reside and perform all underwater tasks... This will bring further significant savings...savings that are already here today as electric technologies bring **considerable through-life cost economies...Electric is also more effective... as an all-electric robotic system is up to 50% more efficient, and typically has double the power density of an electro-hydraulic system.****”

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**“Global Remotely Operated Vehicle Market Is Expected to Reach \$5.15 Billion by 2025” ([SBWire](#))**

## D(r)ive into the deep end



### High Speed/Power Thrusting

Elmo's wide range of drives can provide ROVs with ultra-high currents and voltages to accommodate for any thruster speed or acceleration. Thrusters of a few Watts or several Kilowatts are no problem



### Compact & Light ROV

Further contributing to the miniaturization of ROVs, Elmo drives are compact yet packed with power. Extreme power density is crucial for overall footprint and weight reduction



### Thruster start-up against water currents

Advanced servo algorithms such as *Hot Plugging* allow ROV thrusters to begin rotating regardless of any existing thruster motion due to water current



### Handle the Pressure – ultimate deep sea robustness

Elmo drives are designed to operate under extreme environmental conditions, whether in extended temperatures (-40 to 70°C), high pressures, shocks or vibrations



### Umbilical Power Supply – No problem

Whether high voltage or stepped down from TMS, AC supply, or already rectified DC, Elmo drives can handle any supply with a versatile family of drives for any scenario



### Ideal solution for the all-electric ROV

With extreme power density and unmatched efficiency, Elmo is the ideal partner for the all-electric ROV, whether to precisely control the manipulators, or smoothly rotate thrusters



**High Voltage Gold and SimplIQ** drives are often used in ROV applications around the world. Typically, no advanced positioning is used, but rather precise speed control is essential. Hot Plugging, is available with the Gold (and also with SimplIQ to some extent).

With the trend of ROVs going fully electric, manipulators will begin requiring multi-axis control with full kinematic support, and much more precise operation than required for thrusters.

**Extreme temperatures?** Keep in mind that ROV manufactures often place drives against surfaces cooled by surrounding water.

**Extreme underwater pressure?** Sure, drives may go down several kilometers below surface where pressure could reach 600bar or more, but in such cases they are placed in pressurized vessels and not actually exposed to such pressure.

## 6000 meters below sea level – case study

The European based ROV manufacturer Sub Water Dynamics (SWD) is determined to go all electric with their fleet of models, sold worldwide. Their underwater crafts are used for a variety of professional applications, from servicing deep sea oil rigs to performing important marine life research. With 800 vehicles in operations worldwide, SWD is not just a leader in its field but also a recognized innovator of underwater technologies.



SWD was looking for drive technologies to power their thrusters. While some of their models require 5kW for their thrusters, others such as their heavyweight model (1.5 ton) draw nearly 50kW just for thrusting. However, it wasn't just power SWD was going after. Elmo came into the picture in order to deal with various control related issues, size constraints, and the extended underwater environment.

Elmo's [Trombone](#) servo drive was selected to drive each of the ROV thrusters, propelling the vehicles at 1100-1200 RPM. The Trombone's compact form and high voltage capability made it an ideal candidate for the task. Each Thruster is welded to a small pressurized tube (with thick walls), in which the drive is meant to go. The Trombone was the only drive powerful enough capable of fitting into this pressurized tube. Since completely sealed off with no airing, the Trombone's high efficiency (>98%) was also an essential factor ensuring minimal heat is generated within the enclosed tube.



"Technology breakthroughs are already bringing savings, with reductions in vehicle size, weight, cable diameters, winch size and other elements, leading to more compact systems that make considerable economies for operators... the unprecedented ratio of thrust to volume and speed through water provides the payload, power and control stability needed to carry the range of tooling and sensors usually associated with much larger systems", noted SWD Director of Sales.

One of the major challenges faced by SWD and all other ROV manufacturers, is the on and off switching of thruster rotation, especially when water forces are also a factor. SWD's largest ROV navigates through the water efficiently using 11 different thrusters offering a full 6-axis control. To move in a certain direction, not all thrusters need to be operating simultaneously. An issue arises when a thruster which was just "off" is commanded to turn on, however it is already rotating due to the water currents. The ability to turn a motor on-the-fly while it is already rotating is not straightforward. When the motor drive is typically enables, it is set with an initial 0V command. However since the motor is already rotating with some back-EMF (could be high or low depending on speed), the voltage drop between the zero command and potentially high back EMF may be dangerous. A resulting current spike may be harmful to the drive electronics, and could ultimately

lead to complete failure of the thruster. Elmo’s advanced Hot Plugging motion algorithm protects the system by pre determining the existing back-EMF, and compensating the initial voltage command eliminating the potential for harmful current spikes.

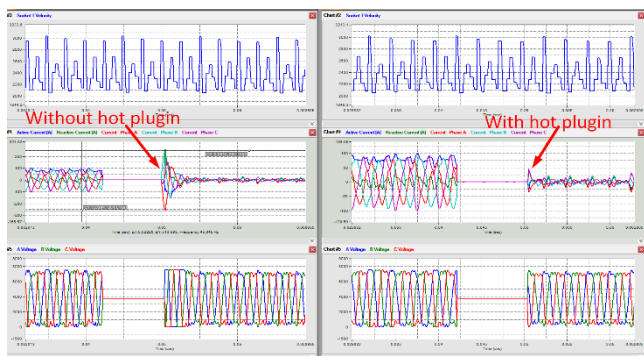


Figure 1: high current spike without Hot Plugging (left), avoidance of dangerous current spike with use of Hot Plugging (right)

Another reason for using the Trombone is its high voltage capacity. Since the ROV is operating in a distance of up to 6km from its power source, on the ship above, sending power down the umbilical cord is a complex operation. Aboard the ship is a power generator, of which output is then further stepped up to an astonishing 3000V 3-phase at 800Hz, which goes down couple of kilometers to the Tethering Management System (TMS). The stepping up is necessary due to the immense voltage-drop expected down the umbilical cord. At the TMS station, and only a few hundred meters away from the ROV itself, the voltage is rectified and stepped down. A DC bus of 500-800V is then available for the ROV, 6km away from the ship. The Trombone is a high voltage drive, capable of supplying up to 800VDC to any motor.



As the industry is moving away from the hydraulic systems, and as international regulations on oil leaks are tightening (with a high price tag), SWD realized that going electric on the robotic manipulators would be inevitable. After utilizing industry standard hydraulic manipulators for years, the SWD engineers decided to develop their own electric robotic manipulators. The 7-axis robotic arms (2 for each ROV) will have an extended reach of 2meters, and will be tasked with assembling and disassembling of components, opening and closing vales, etc. The company is now in design stages, and has selected Elmo’s ultra-small servo drive – the Gold Twitter. The Gold Twitter is the world’s smallest most powerful servo drive, and is the ideal drive to be mounted right within the joints of the manipulators.



Elmo’s off the shelf products answered all the needs required by SWD demanding application, from handling the harsh environment, to facing the challenges of operating against unknown water currents. To top it all, Elmo’s highly compact and highly advanced servo drives provide the mandatory reliability crucial for the remote operations of ROV.

