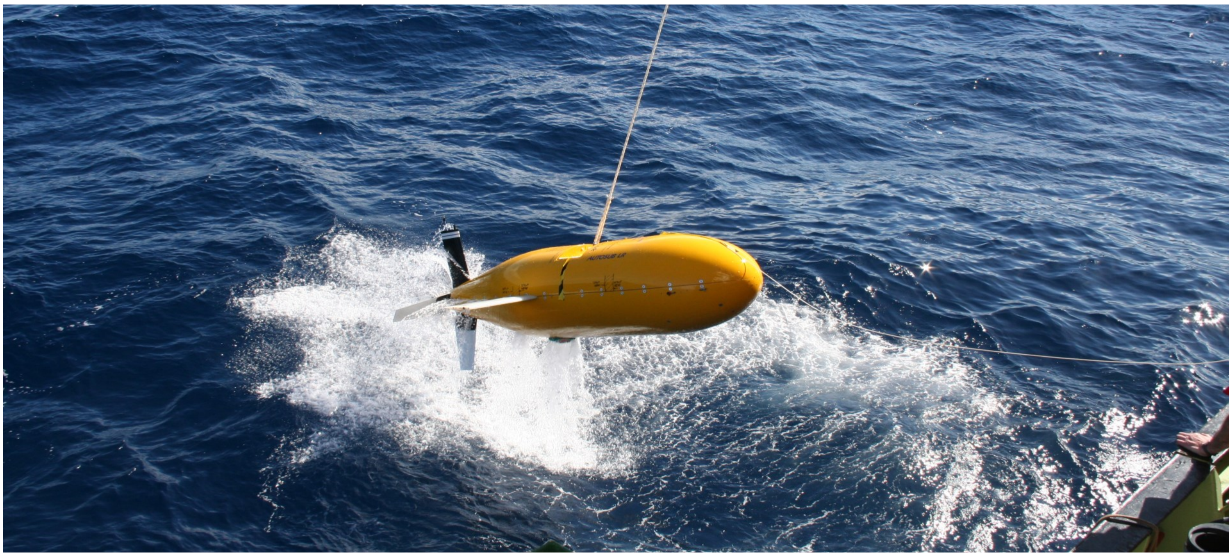
Successful completion of two year project to develop a pressure tolerant Lithium Sulfur battery pack for Marine Autonomous Systems.



Two years ago, a consortium of organisations, part funded by Innovate UK through the Defence Science and Technology Laboratory (DSTL), set out ambitions plans to develop a pressure tolerant battery pack using Lithium Sulfur (Li-S) cells that would revolutionise the way in which Marine Autonomous Systems could be powered at ocean depths.

The consortium, headed by Steatite, brought together the world leading expertise of Li-S manufacturer Oxis Energy, underwater vehicle manufacture MSubs, and the academic prowess and cutting edge test facilities of the National Oceanography Centre (NOC).

The objective of the project was to develop, build and test a Li-S battery pack capable of powering an autonomous underwater vehicle at depths of up to 6,000m. This depth marks the lowest level of the Abyssal plain (continuous ocean floor), with only deep ocean trenches extending beyond this level. Only 2% of the ocean extends deeper than this.

The Deepbots™ UUV

The problem

Autonomous underwater vehicles are increasingly power hungry and need to carry powerful batteries to run lights, propulsion and on board systems.

To protect against crushing water pressure, these batteries are housed in a heavy metal sphere (pressure vessel) which adds considerably to vehicle weight and severely restricts payload capacity.

Removing the need to house batteries in this way would bring a host of benefits in terms of weight reduction, increased endurance and cost savings.

OXIS ENERGY
Next Generation Battery Technology

MSubs Ltd
underwater vehicles & equipment

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

STEATITE
COMPUTING - POWER - COMMUNICATIONS
A Solid State Group Company

The benefits

The immediate benefits of weight saving and increased payload are in themselves enticing, but by utilising Li-S technology instead of conventional Li-ion cells, many other benefits were introduced.

Li-S technology provides superior gravimetric energy density (energy per kg of weight) than other chemistries such as Lithium-ion. This means that underwater vehicles using this technology could have greater speed and endurance. More time in the water equates to a time, and therefore cost reduction, associated with surfacing the vehicle to change the battery packs. Additionally, eliminating the need to open the pressure vessel to access the batteries saves further time.

Li-S cells can also withstand 100% discharge without damage, which means more of the available energy is available for use, and it can be stored for extended periods without need of maintenance. The chemistry is more environmentally friendly, a pertinent issue given the sensitive nature of the environment in which it will operate.

The cells also provide neutral buoyancy which means that much of the buoyancy foam required on a deep dive vehicle can be eliminated, saving additional space. But of particular importance is the fact that Li-S cells are able to tolerate extraordinary punishment, including total puncture, with little effect on operation and minimal safety issues. It is this ability that makes Lithium Sulfur the chemistry of choice for a battery pack that is expected to operate outside of the protection of a pressure vessel.

The solution

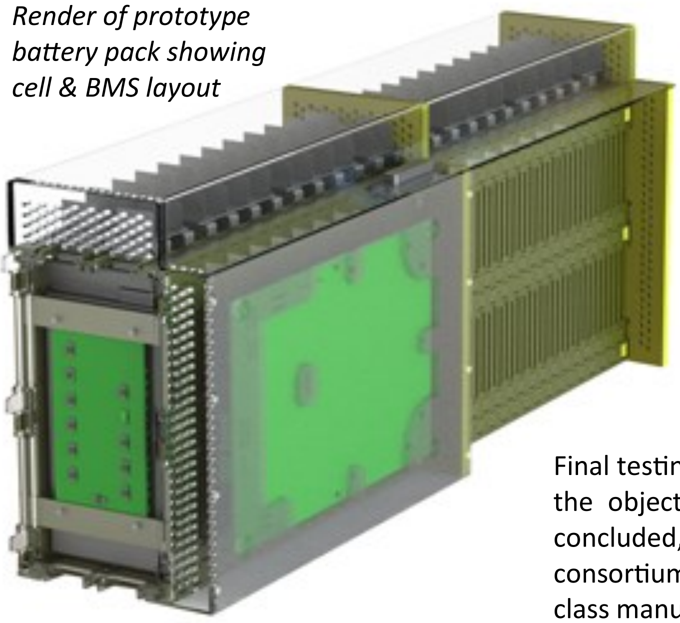
The consortium needed to find a way to produce a battery pack that could operate effectively at depths of up to 6,000m. Water pressure increases by 1 atmosphere for every 10 meters of depth, and at 6,000m, the pressure is 600 times greater than mean atmospheric pressure at sea level. Low temperature is also an issue, with average temperatures at this depth hovering around 4°C. This is a truly punishing environment and the consortium faced a number of technical challenges as a result.

The solution laid with a combination of Oxis Energy's Li-S cells and Steatite's all new, multi-chemistry Battery Management System (BMS).

Initial research & development, and subsequent testing at the NOC's world class laboratories, soon showed consistent performance of the cells and the Battery Management System.

As expected, the cells exhibited great tolerance to pressure. This tolerance is achieved in part by encasing the cells in oil, thereby providing uniform pressure transfer from the surrounding water. This rigorous testing demonstrated the viability of a finished battery pack early in the programme.

Render of prototype battery pack showing cell & BMS layout



At the start of the project's second year, the first full scale prototype battery pack was under construction. The 24v 600w pack consisted of 24 cells in a 12S2P arrangement, with the BMS located to the side of the pack.

Testing continued, and by the summer of 2017, 8 prototype battery packs had been constructed and were ready for integration into a UUV for open water testing by consortium member MSubs Ltd.

Final testing proved successful and having completed all of the objectives set our 2 years earlier, the project was concluded, cementing the world leading status of the consortium members and Steatite's capabilities as a world class manufacturer of custom built battery packs.

Findings

- The cells and BMS can withstand the pressure of 664 atmospheres (equivalent to a water depth of 6,640m) at a temperature of 4°C, with being compromised on integrity.
- The cells (rated at 300Wh/kg in standard conditions) achieved 289Wh/kg at 450 atmospheres of pressure and 4°C.
- The gravimetric energy density of the complete optimised battery is 184Wh/kg.

The next steps

The design of the prototype battery pack has been refined into an optimised design, which is both smaller and lighter than the original. This is in effect a 'building block', and it can be fully customised depending upon application requirements.

Although designed for marine and oceanographic applications, the implementation potential of the technology is far reaching, covering areas such as energy storage, unmanned and autonomous systems.

Further optimisation of the battery pack design along with increases in cell energy density will enable us to achieve robust energy systems with improvement in gravimetric energy density for underwater applications, over the most capable Li-ion alternative, by a factor of between 2 and 3.

This incredible achievement is testament to the hard work and extraordinary expertise of the consortium members and the foresight of the UK government for providing funding for such projects through Innovate UK and the DSTL.

The technical know how achieved through this project will enable the next generation of energy dense, safer and more environmentally friendly battery power systems.

MAS_CASE_STUDY_V2017-11-Rev1.pdf

STEATITE CREASEFIELD (CREWKERNE)
17 NORTHERN WAY
CROPMEAD INDUSTRIAL ESTATE
CREWKERNE
TA18 7HJ

STEATITE LIMITED (HEADQUARTERS)
RAVENSBANK BUSINESS PARK
ACANTHUS ROAD
REDDITCH
WORCESTERSHIRE
B98 9EX

WWW.STEATITE.COM
A SOLID STATE GROUP COMPANY
Telephone: **+44 (0)1527 512400**
Fax: **+44 (0)1527 512419**
Email: **sales@steatite.co.uk**