Undersea defense applications demand robust battery technology

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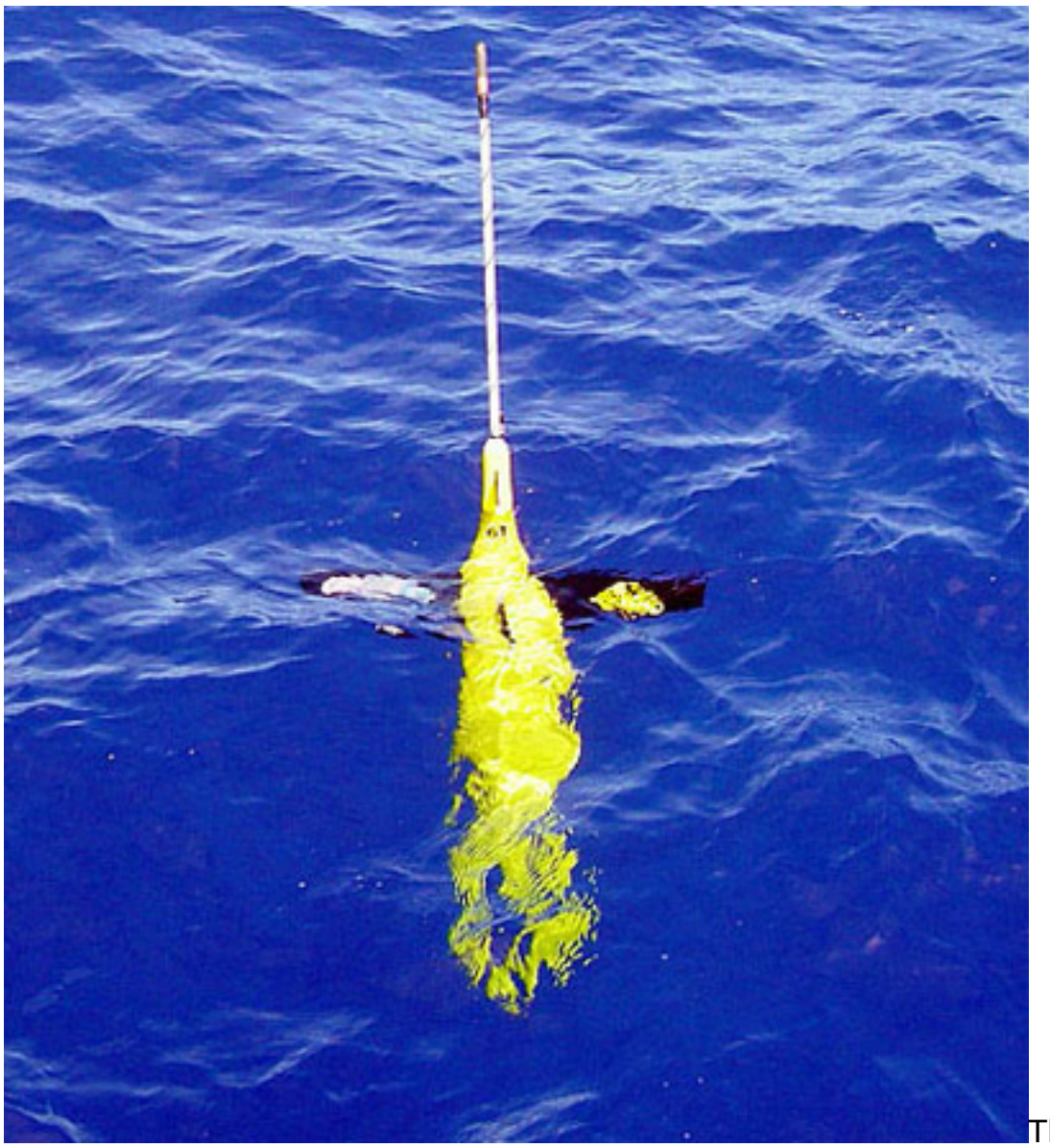
Optimized power, energy and performance are critical in demanding oceanic conditions

Unmanned underwater vehicles (UUV) and sonobuoys continue to occupy a critical role in undersea warfare, and the design of such technologies – especially with regard to their power systems – is acutely important due to their growing indispensability to a variety of tactical defense operations. A range of key marine defense missions are being vastly enriched by using UUV technology; these include: intelligence, reconnaissance, surveillance, communications, mine detection, military oceanography, navigation and anti-submarine warfare. Air-launched or hand-launched from aircraft and ships conducting enemy surveillance, sonobuoys operate as expendable sonar systems that are capable of precisely ascertaining a submarine's location and then tracking its speed and course of travel.

Efficiently, safely and reliably supplying power to undersea defense technologies is vital in determining their overall performance and mission proficiency. Moreover, as these devices are being engineered to go faster and farther, for longer periods of time, it is crucial that battery technology evolves to accommodate increasing performance demands. Design challenges presented by such demands are compounded by the ever-present considerations that must be given to costs and safety as well as the limited space that can be dedicated to the storage of a power source within these devices. For these reasons, it is imperative that batteries for undersea applications be fully optimized. Accordingly, this requisite optimization has resulted in a natural progression in favor of the use of lithium-based batteries.

Lithium is the lightest metal element and has a high electrochemical potential, giving lithium-ion (Li-ion) batteries a high specific energy and enabling them to function at higher voltages. This maximizes the power-to-weight ratio of each cell – packing more power potential into the limited battery compartments of UUV and sonobuoys. Li-ion batteries are also low maintenance, with an extended shelf-life and a low self-discharge rate, and they can be repeatedly recharged, which reduces their life cycle cost relative to other technologies.



Three types of lithium batteries – traditional Li-ion, Li-ion based on lithiated iron phosphate (LiFePO4) and lithium-sulfur dioxide (Li-SO2) – are currently being incorporated in the design of UUV and sonobuoys, offering significant benefits over alternatives such as lead-acid, nickel-based, and silver zinc batteries, thus driving an increasing demand for li-ion batteries within the industrial market. While operationally superior, the varying attributes of the three aforementioned lithium electrochemistries give rise to distinguishing advantages and disadvantages, which, in turn, determine their most appropriate applications. Here, each of the three will be examined, providing insight into their features and functionality.

Li-ion batteries are one of highest energy density rechargeable systems and are field-proven in military defense applications. They are lighter and more compact while boasting a lower self-discharge rate and considerably more run time than other rechargeables. Further, their lengthy cycle life enables them to effectively deliver power for extended mission durations; this is especially true of cells using lithium-nickel-cobalt-aluminum dioxide (NCA) chemistry. Among their limited drawbacks, as with all rechargeables, li-ion batteries are more expensive than primary systems. Li-ion batteries are best-suited for surveillance and security operations conducted by UUV and owing to their ultra-high energy density, the

technology is, at present, being explored for incorporation into total ship systems for use as back-up power within each autonomous subsection of a given vessel. This design would enable each division of a ship to operate in tandem to make up a total grid or independently (as would be required in the event that a section of a ship is hit in an enemy attack).

Li-SO2 batteries can deliver high power over a wide temperature range, and in fact, is the only primary technology that can deliver high power at extreme temperatures, ranging from -20°C to +55°C. These lightweight batteries are a cost-effective option with high pulse-power capability and have an extended shelf-life of 6-8 years. Disadvantages of Li-SO2 include their susceptibility to passivation which is a resistive layer formed on the lithium surface that suppresses instantaneous voltage response. Look for a battery vendor with extensive experience working with OEM suppliers to design in effective depassivation protocols to overcome this issue and to successfully integrate Li-SO2 batteries for use in many long shelf-life high power applications. Given this combination of traits, one of the most appropriate applications for Li-SO2 is for use in sonobuoys. Because they operate at shallower depths where it is more difficult to distinguish man-made noises from the oceanic background, Sonobuoys must be capable of emitting high-powered sonar signals or “pings” in order to accurately identify mechanically generated sound waves from submarines and ships. Further, sonobuoys are used only once, therefore a primary battery is the most practical option for use in such a device.

LiFePO4 batteries are rechargeable, high-energy cells designed for applications with long run times and low abuse tolerance. They are field-proven, cost-effective and have superior low temperature performance. While LiFePO4 batteries possess a lower voltage, they are very safe because they are incapable of overcharging and are therefore not prone to thermal runaway (a destructive positive feedback process in which overcharging increases temperature which, in turn, accelerates the release of energy, leading to further increases temperature).

When designing for undersea defense applications, a qualified battery system manufacturer is key to the design process and should be consulted from the beginning to control costs and maintain safety, while engineering for optimized power, energy and performance in demanding oceanic conditions. Above all, proven design integrity and construction are essential in the manufacture of power sources for such applications to ensure their reliability.

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