Managing Risk in AUV Development and Deployment

AUVs Present Technical and Operational Risks Users and Developers Should Understand

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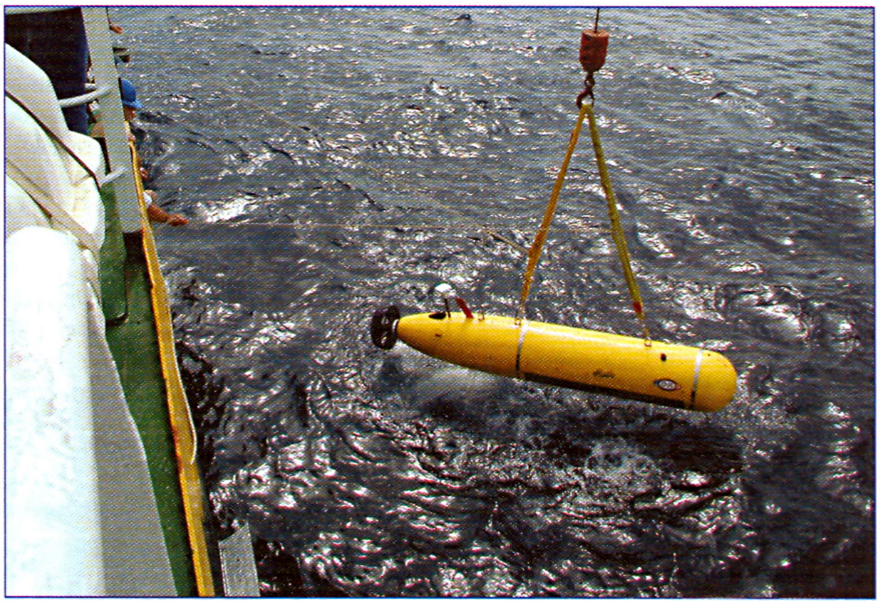
Autonomous underwater vehicles (AUVs) have been a subject of research and development, particularly in defense circles, for decades. As Moore's Law marched on, yielding ever more powerful computers, and software became more capable, AUVs became viable tools for many missions. Naval interest turned from the blue water challenges of the Cold War to the complexity of the littorals, driving investment in AUVs for missions such as mine countermeasures. This major defense investment yielded collateral benefits for industry and science.



(Top) AUVs are relatively easy to launch from most vessels.

(Bottom) Small boats can aid AUV recovery but are not viable in all conditions.

In the early 1990s, science began to consider AUVs as a potential tool for economical access to the ocean. As the vehicles matured, they yielded new data and began to take hold with oceanographers. As the '90s closed, spin-offs of academic labs began to commercialize small, relatively inexpensive AUVs. Simultaneously, the economics of deep-ocean survey, especially for offshore oil interests, drove commercial operators to adopt AUVs in business-critical applications.

While AUVs have proven their capabilities, they are only slowly entering service in nonmilitary applications. Even the offshore industry, eager to realize the cost savings AUVs offer, has not seen a flood of vehicles and operators enter the market. The scientific community has also seen AUVs enter service relatively slowly. This is in contrast to the U.S. Navy, which has advanced AUVs into the fleet. The Navy does have a different budget outlook from the science community, but it is not unlimited. The offshore oil community has significant resources but still moves relatively slowly toward AUVs. A possible explanation for this trend is the element of risk in AUV development and deployment.

Technical and Operational Risks

Risk is a complex subject, with much quantitative and qualitative research

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available to support formal risk analysis. In the case of AUVs, the most basic partition of risk is into technical and operational concerns. While the economic risks of lost revenue are another reality, they are beyond the scope of this article.

Undersea systems face many challenges. Corrosive seawater and pressure at depth are familiar to the ocean engineer. Robotic systems in any environment present challenges for electromechanical systems, software and control.

The mature remotely operated vehicle (ROV) industry has provided many solutions to bringing robots under the sea. Once engineers "cut the cord" and make an undersea vehicle independent of surface power and control, they add to the complexity of the system and increase its technical risk and the potential for vehicle loss.

Control systems, including software and hardware, provide the "brains" for AUVs. Due to the ongoing developments in these core components for other fields (such as aerospace), AUV control systems are rarely a source of major risk. Most apparent failures of a control system are a result of operator error. In the author's experience with AUV control failures in multiple field operations, post-mission analysis usually found the error to be a typographical, sign, geographic datum or other operator error. As relatively "dumb" systems, AUVs faithfully execute their instructions, no matter how bad those instructions may be. Other users of AUVs share this experience.

A system critical to all AUVs is energy storage. Some vehicles use fuel cells or primary batteries, but most use rechargeable batteries, often using cells originally intended for consumer electronics. While consumer lithium-ion batteries have experienced quality concerns and recalls, they are the basis for many commercially available AUVs. Some vehicles use cells contained in pressure vessels, while others are pursuing pressure-tolerant systems. These approaches have different challenges and benefits, especially in their use of vehicle volume. However, they both rely on a combination of cell manufacturing techniques and battery-control electronics to minimize risk. Any energy storage system presents technical risks, but the increasing procurement of AUVs by the Navy is driving safety and reliability testing that continues to improve this key subsystem.

AUVs have matured into largely reliable tools. Ongoing military investment and commercial applications are developing a history of the technology that will allow for a more significant statistical analysis of the technical risks. Currently, the best evaluation may come from the insurance industry. There are a limited number of underwriters that cover AUV loss, but the leaders in the field indicate that technical risks are not the dominant factor in their underwriting. They consider operational risks to be the major concern.

All operators of marine equipment recognize the difficulties of working at sea. The dynamics of the ocean surface and vagaries of weather challenge even the best marine operators. AUVs bring some benefits and some major challenges to the oceangoing professional.

The most challenging phases of operating any undersea system are launch and recovery. By virtue of having no tether, AUVs are usually quite easy to launch. However, lifting a large mass over the deck and into the water is never trivial, and dropping a vehicle on the deck is not unheard of. Once in the water, an AUV must still clear the hull, and especially the propellers, of the support vessel. A failure to coordinate the movements of the AUV and the vessel can result in a collision, which in at least one incident known to the author caused an AUV to meet an untimely end in the ship's propellers. Despite these dramatic possibilities, most AUV launches are incident free.

Upon recovery, AUVs present more challenges than their ROV brethren. By virtue of being tethered to the ship, ROV recovery strategies are usually straightforward and make use of motion compensators and other mechanical aids. AUVs, in contrast, must first be tied to the ship in some fashion. Methods used for human-occupied submersibles frequently rely upon divers to attach lines to the vehicle. Such an approach is not likely to be cost effective for operators who hope to use AUVs extensively, nor is it likely to lead to low insurance premiums. Instead, many AUVs release a light line and buoy, which can then be recovered via a grapnel. Once secured, the AUV can be brought on deck by ramps or articulated cranes. While launch and recovery should never be taken lightly, experience has shown that AUVs can be reliably launched and recovered. Many techniques have been evaluated and presented, and AUV operators should carefully evaluate the options.

Working at sea presents regulatory concerns. With varying jurisdictions and a complex web of laws and enforcement agencies, any seagoing operation is wise to review its legal status before sailing. Yet, legal and regulatory aspects of AUV operations are poorly defined. By simultaneously being free of the support ship yet "under command," the status of an AUV as a vessel is unclear. Once underway, is an AUV a vessel "not under command" due to its inability to implement the maritime rules of the road? Or is it the responsibility of the support vessel's commanding officer to post a "watch" for the AUV?

The legal situation is unclear. Some analysis was conducted in the United Kingdom in 2000 and is being updated. Additional opinions have been offered in the United States, but the overall situation is unresolved. It would appear there is some legal risk, albeit difficult to quantify, for AUV operators. Technical standards organizations have recently convened subcommittees on rules and regulations. These efforts will improve the situation, but they remain incomplete.

In the face of this uncertainty, operators must develop their own approach to managing liability. AUV owners and operators must await further legal developments and, in the meantime, should exercise an abundance of caution in their operations.

Managing Risk

Based on case studies presented elsewhere and extensive communications with leading AUV developers and operators, some recommendations may be made for those adopting AUVs in field applications.

Managing technical risk requires a careful evaluation of the user's situation, budget and anticipated needs. Individual users needing only one or two AUVs may choose to procure a largely standard AUV with only minimum modifications to support user needs, effectively mitigating much of the technical risk. Vendors have developed quality control processes and robust engineering solutions. The major AUV vendors have collectively delivered many systems to a variety of customers. This history is a compelling reason for individual customers to procure the closest matching commercial product.

Agencies or customers with specialized needs, demand for large numbers of vehicles or both might consider a spiral development approach. Pilot programs that drive technical evolution are initially expensive but yield valuable lessons. If possible, procurement of a variety of commercial products can be helpful. If the customer effectively coordinates their actions and exchanges technical information, investing in two or more AUV types during the pilot phase will result in significantly greater institutional knowledge. Once this knowledge base can be directed toward the broader goals of the organization, it can then use broader acquisition efforts to benefit from an economy of scale in ordering multiple AUVs of a similar design. Customers, notably the Navy, have benefited from this approach.

Managing operational risk requires a careful analysis of the AUV user's goals and objectives. In some cases, the goal of acquiring unique data drives the operational risk management approach. Some AUV science programs have chosen to fund the construction of multiple AUVs in preparation for the potential loss of a vehicle in a high-risk environment, such as under ice.

A novice user is encouraged to employ a capable marine operations team and integrate it with the AUV construction effort. Judicious use of the vendor's technical support is usually a wise investment. Planning for this and the costs of funding the operational team's training and engineering trials must be accounted for in initial planning. Simply budgeting for the purchase cost of an AUV is inviting operational challenges, with a worst-case scenario being loss of the vehicle.

All AUV users face the burden of building capable teams to deploy their AUVs. With the majority of this experience currently resident in the staff of AUV vendors, it will take time to expand the pool of operators. Given the scrutiny underwriters apply to the qualifications of the AUV operators and the vessels AUVs are deployed from, it would be prudent for the entire community to collaborate in the development of capable AUV operators.

Sharing experience with technical and operational challenges will allow the AUV community to rapidly evolve and expand the use of this tool in a variety of applications. Professional societies play a key role in sponsoring conferences. While these have often focused on the technical issues of AUVs, they should move to cover the operational side as well. There is an effort underway in the United Kingdom to develop a "code of practice" for AUV operations, and ASTM International is developing technical standards for unmanned maritime vehicles. Further development and adoption of technical standards and operational practices will advance the field significantly. Experienced AUV users and developers and major customers are encouraged to engage in such activities.

Through open communication and a commitment to the evolution of the entire AUV community, more users will be able to effectively deploy AUVs. This will drive further development by the vendors and, ideally, a positive feedback cycle will develop. While deploying undersea equipment will always be risky, an effective user community will be able to manage the risks of developing and deploying AUVs.

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References

For a complete list of references and an expanded version of this article, contact Justin Manley at manleyj@battelle.org. ■

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