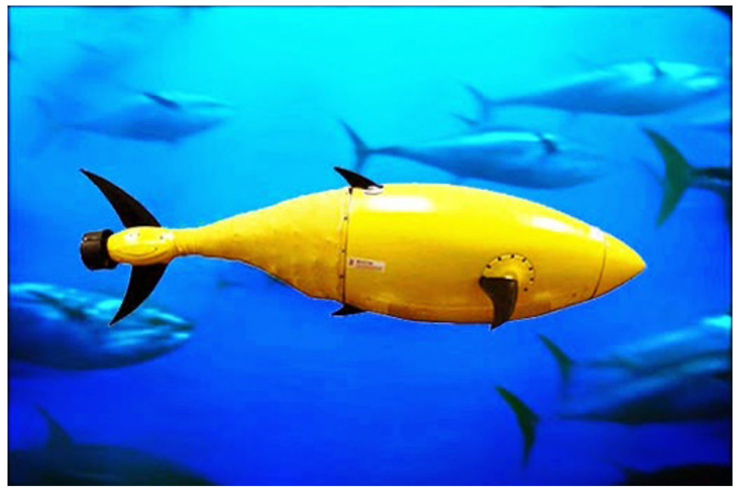
Unmanned Underwater Vehicles

The Next Insurgent Threat

Daniel | Duane



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The Project on International Peace and Security
Institute for the Theory and Practice of International Relations
The College of William and Mary

Please direct inquiries to:
Project on International Peace and Security (PIPS)
Institute for the Theory and Practice of International Relations
The College of William and Mary
427 Scotland Street
Williamsburg, Virginia 23185
tele. 757.221.1441
fax. 757.221.4650
pips@wm.edu

Electronic copies of this report are available at www.wm.edu/pips

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Amy Oakes
Dennis A. Smith
Co-directors

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The Next Insurgent Threat

The U.S. Navy is investing in Unmanned Underwater Vehicle (UUV) technology as a tool for intelligence, warfare, and maintenance and has recognized the emerging counterforce threat posed by peer-competitors fielding UUVs. However, policy analysts have paid insufficient attention to the possible uses of UUVs for countervalue attacks by non-state actors. Declining costs and growing capability will lead to a wider proliferation of UUV technology. This likely trend will provide insurgent and terrorist organizations with access to technology that is difficult to counter and will further increase their ability to disrupt sea and communications-based trade—for example, through the mining of harbors and cutting of undersea communications cables or pipelines.

Introduction: The Rise of UUVs

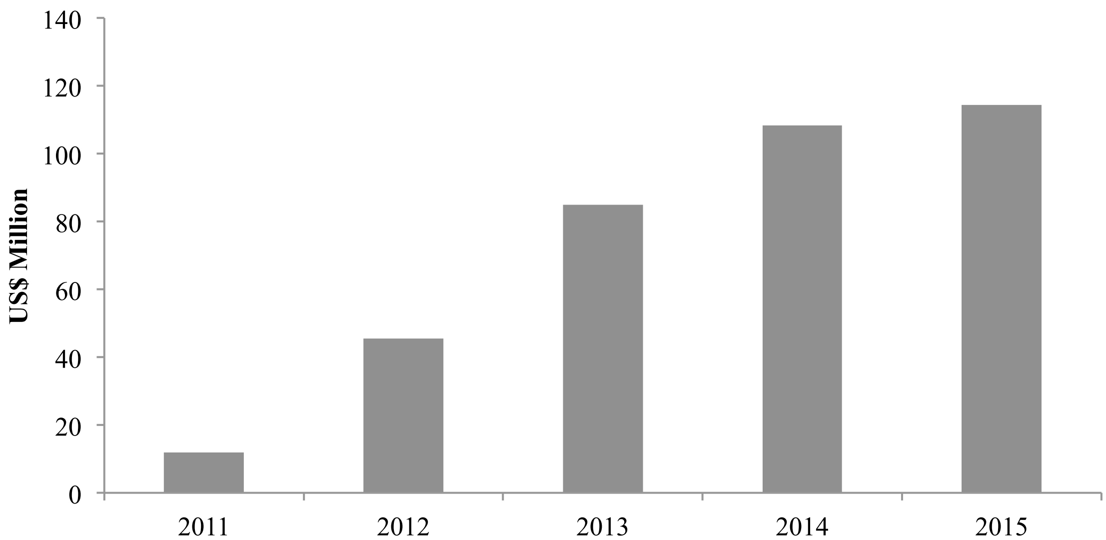
Unmanned Underwater Vehicles (UUVs)—computer-controlled systems operating under the sea—are becoming a key asset in Naval warfare.[1] In 2014, the Pentagon announced plans to double its funding for underwater drones.[2] The Navy's *UUV Master Plan* published in 2003 suggested that in the next 50 years UUVs will be used for surveillance, anti-submarine warfare, and inspection, among other duties.[3]

As the "undersea battlespace" becomes increasingly important due to advances in surveillance and anti-ship missile technology, elite militaries will invest considerable resources in submarines and UUVs.[4] Moreover, future improvements in acoustic detection systems will increase the risk of manned underwater missions, raising the demand for UUVs as an expendable replacement for submarines.[5] The United States is projected to spend $114.3 million on underwater drones in 2015.

Currently, elite militaries are the primary users of UUVs. However, as the technology becomes less expensive, UUVs will proliferate in the commercial sector, similar to aerial drones.[6] The energy consulting firm Douglas-Westwood predicts the demand for commercial UUVs will triple from 2014 to 2018.[7] UUV commercialization began in 2000 with the release of the following UUV models: *Hugin, Maridan 600, Aqua Explorer 2, Sea Oracle, Explorer,* and *CETUS II.*[8] As the technology develops, UUVs will be used for underwater mapping, oceanographic research, and monitoring oil pipelines.[9] The U.S. Navy's Space and Naval Warfare Systems Command released a report in 2000 predicting that a future billion-dollar UUV market will fuel an "inner space race" between corporations.[10] A report by Douglas-Westwood predicts that global spending on UUVs will increase from $1.2 billion in 2014 to $4.84 billion in 2019, with the BRICS (Brazil, Russia, India, China, and South Africa) experiencing the highest growth rates.[11] Oil companies will likely be the largest customers for commercial UUVs, which they will use to survey drilling sites and pipe routes. A report by C&C Technologies suggests that UUVs could cut the cost of underwater surveys by 59 percent.[12]

To date, policy analysts have primarily considered the potential uses of underwater drones by elite militaries or the commercial sector. While UUVs will have a game-changing effect in both arenas, more attention needs to be paid by the architects of U.S. national security policy to how insurgent and terrorist organizations could use the technology. This paper will explore the future security threat posed by UUVs in the hands of non-state actors. Specifically, it will argue that UUV proliferation will provide insurgents and terrorists with a countervalue weapon that will be difficult to defend against and threaten a variety of targets in the littorals.

Figure 1: Department of Defense Spending on UUVs[13]



Current Capabilities of UUVs

UUVs are a developing technology, but their military advantages are already evident. UUVs are stealthy, deployable, capable of penetrating hard-to-reach targets, and easy to use. These factors make UUVs ideal tools for insurgents and terrorists.

- *Stealth*. UUVs provide insurgents and terrorists with a difficult-to-detect tool for striking maritime targets. UUVs are small, submersible, and quiet, making them hard to detect, compared to aerial drones or submarines.[14] While UUVs could be detected with active sonar, locating a device would be difficult in a noisy region, such as a harbor.[15] In addition, future UUVs could hide from sonar detection systems using destructive interference, acoustic jamming, or acoustic decoys.[16] UUVs also could be modeled after marine life in order to lessen their noise signature and improve stealth. In 2014, Boston Engineering released a UUV disguised as a tuna, the *Bioswimmer*, and another disguised as a shark, the *GhostSwimmer*.[17]

- *Deployability*. Most UUVs are easily transported and deployed, providing insurgents and terrorists a means to attack maritime targets using relatively little equipment. The smallest UUVs weigh 100 pounds and are less than two meters in length. Small UUVs, such as the Remote Environmental Measuring Unit System (REMUS)-100, can be deployed with no special devices or facilities.[18] Large UUVs can be deployed from a crane, either on a shore facility or boat.[19] In the future, UUVs will be deployed from submarines, Unmanned Surface Vehicles, and other UUVs.[20]

- *Target Infiltration*. UUVs can stealthily access to areas that would be hard for divers to reach, allowing insurgents and terrorists to approach unnoticed and attack underwater infrastructure. The Navy UUV Master Plan noted that "UUVs can operate in all water depths, in foul weather and seas, under tropical or arctic conditions, and around the clock."[21] While aerial drones and water surface drones may be visually identified or deterred by harsh weather, submerged UUVs are difficult to spot and unaffected by weather.[22]

- *Autonomy and Ease of Use*. Autonomous and easy-to-use UUVs allow insurgents and terrorists to attack fixed maritime targets with little involvement during the operation. Organizations can pre-program autonomous UUVs so that operators need only orient the device and place it in the water. This ease provides users a "fire and forget" capability that gives insurgents and terrorists the ability to flee an area after the device is launched.[23]

Improving Technology

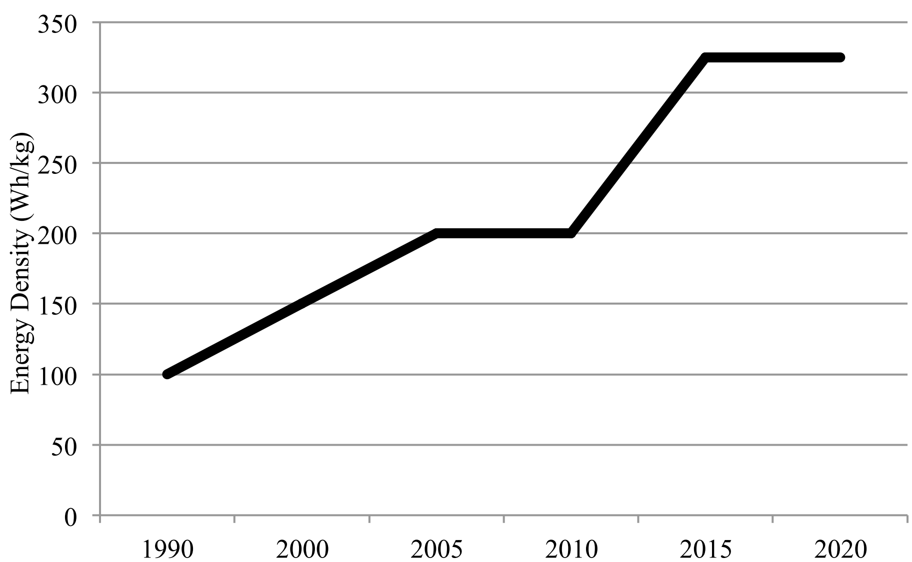
While UUVs offer many advantages, currently there are technical obstacles that prevent their widespread use. UUVs are limited in their endurance, communication, and navigational capabilities. However, future advances in these fields will enable wider commercial and military use.

- *Endurance.* UUVs consume more energy than land and aerial drones, just as swimming across a pool requires more energy than walking. Consequently, the most significant factor limiting UUV use is endurance, which is dependent on the strength of its battery and the efficiency of its propulsion system.[24] In 2012, the former Chief of Naval Operations Gary Roughead announced that half of UUV research funding should focus on improving endurance.[25] In 2013, Mark Kosko, Boeing's program manager for unmanned undersea systems, predicted "game-changing" improvements in UUV endurance by 2015.[26]

  The battery life of UUVs ranges from 5 hours for lightweight UUVs to 30 hours for heavier ones.[27] Large UUVs last longer because they can carry heavy, highpowered batteries. For example, the Large Displacement Unmanned Undersea Vehicle (LDUUV) is equipped with a battery weighing 3.5 tons, allowing it to travel for 28 hours. Within the next two years, these large UUVs are expected to reach endurances of 70 days.[28]

As battery and propulsion technology develops, UUV use will become more practical. In recent years, the average gain in battery capacity has been six percent every year.[29] These advances in battery life have improved the endurance of unmanned systems. For example, fuel cells powered by chemical reactions quadrupled the battery life of aerial drones in 2013.[30] UUV endurance will see a similar increase when fuel cell technology is available for underwater vehicles. Since 2011, the Office of Naval Research and the U.S. Navy have put increased funding into the development of fuel cell technology for UUVs.[31]

Figure 2: Improvements in Lithium Battery Capacity[32]



Alternative energy sources could also improve UUV endurance.[33] Researchers at Stanford University have developed a prototype “nanowire battery,” which can hold ten times the charge of existing lithium-ion batteries.[34] While technical issues currently prevent the widespread implementation of nanowire batteries, venture capitalists have raised $30 million to produce nanowire batteries commercially, which could hold 50 percent more energy than other batteries on the market.[35]

In addition, improvements in the efficiency of propulsion will increase the endurance of UUVs. Gliders are a type of UUV that use buoyancy-based propulsion to limit the amount of power needed for movement.[36] Teledyne Benthos developed the Slocum Glider, which uses the thermal energy in its environment to power its engine. The Slocum Glider has a range of 25,000 miles and can be deployed for five years.[37] Falmouth Scientific released a UUV that improves its battery life by harnessing solar power.[38] UUV operators can also compensate for a lack of endurance by deploying the UUV from a submarine, boat, or Unmanned Surface Vehicle.

- *Communication*. While underwater communication currently is limited, improvements in signal processing and acoustic communication will enable operators to better control UUVs when they are submerged. Since radio waves do not propagate under water, UUVs cannot be remotely controlled like aerial drones. As a result, UUVs can connect to human operators at the surface, but they must be largely autonomous when submerged. Improvements in acoustic systems have allowed for some basic control—a human operator can use underwater sound waves to transmit basic commands like "stop" or "come home," but the UUV has to make more complicated decisions by itself.[39]

  A paper from the Center for Strategic and Budgetary Assessments reports that the range and bandwidth of underwater communication systems are increasing "to the point where they can support undersea operations over relevant distances in real time."[40] Recent advances provide increased bandwidth to acoustic communication systems in underwater vehicles with limited power and space.[41] Materials Systems recently developed a Common Acoustic Communication Module for UUVs, which increased the amount of bandwidth by 130 percent.[42] Moreover, UUVs could use lasers and LEDs for short-range, high-bandwidth communication.[43]

- *Navigation*. Compared to aerial drones, navigation is difficult in UUVs. GPS does not work underwater, and cameras have limited visibility when submerged. As a result, the majority of underwater drones rely on inertial navigation, where the UUV estimates its position using internal motion sensors.[44] However, inertial navigation can be unreliable; even the best motion sensors are subject to drift over time, causing the UUV to miscalculate its position. To counter this problem, submerged UUVs periodically surface to confirm their coordinates through GPS.[45] However, surfacing may not feasible for stealth missions that require the UUV to stay submerged for long periods of time.

  Alternatives to inertial navigation allow UUVs to determine more precisely their location. In acoustic navigation, a UUV determines its position relative to a beacon that emits a constant acoustic pulse. While acoustic navigation allows a UUV to determine its position precisely, these systems are costly and logistically difficult.[46] In geophysical navigation, a UUV estimates its position using physical clues such as sea floor features, magnetic fields, and variations in gravity. Geophysical navigation is accurate in some cases, but it requires that the terrain be distinctive enough for the UUV's sonar and optical sensors to extract useful information, and it requires prior knowledge of the terrain.[47]

UUV Targeting: From Counterforce to Countervalue

The policy community primarily has focused on the uses of UUVs in a counterforce context—namely using UUVs to locate and target enemy vessels. However, with increased capabilities and lowered costs, insurgents and terrorist groups will be able to repurpose commercial UUVs to conduct countervalue attacks, in which they target nonmilitary assets in order to inflict economic and political costs. Potential targets of countervalue attacks include marine vehicles, infrastructure, and commercial assets. Advances in **endurance**, **communication**, and **navigation** will further increase the probability of UUV countervalue operations, though target sets will vary with the rate of technological advancement.

- *Marine vehicles.*

  Commercial shipping is vulnerable to attacks by UUVs. The stealth and small size of UUVs would allow them to launch surprise attacks on oil tankers and other shipping vessels. However, current limitations in endurance and speed would complicate attempts to attack moving targets for long periods of time.

  Necessary capabilities: **Endurance**, **communication**, and **navigation** would all be necessary for attacks on marine vessels. In order to attack a moving marine vessel, a human operator would need real-time feedback and communication with the UUV. In addition, a UUV would need advanced situational awareness and a long battery life to identify and track its target over time.

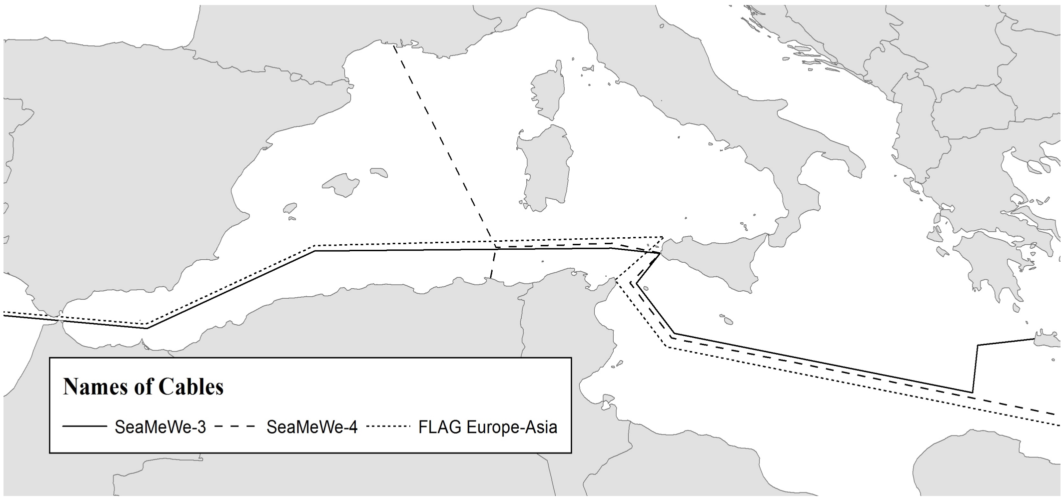
- *Communication networks and Pipelines.*

  Underwater communication networks are vulnerable to attacks by UUVs. Approximately 200 underwater cables link Internet networks worldwide, and an article by *Wired* notes that these cables are "poorly armored, rarely patrolled and only occasionally monitored."[48] As Figure 3 shows, only three underwater cables connect Europe to the Middle East, and they all pass through the same area, making them vulnerable to a single attack. In 2013, three divers were arrested in Egypt for attempting to cut an undersea cable near Alexandria, disrupting Internet and communication speed.[49] The CEO of SEACOM Mark Simpson stated that such sabotage attempts are unusual because undersea cables carry thousands of volts of electricity, posing a severe risk to would-be saboteurs. However, terrorists could use UUVs to disrupt undersea cables without compromising their safety.

  In addition, terrorists could use explosive-equipped UUVs to attack underwater oil pipelines. Terrorist groups have already targeted aboveground oil pipelines, and UUV technology would allow them to access underwater pipelines, which are more vulnerable.[50]

  Necessary capabilities: **Communication** and **navigation** capabilities would be necessary for attacks against underwater networks. A UUV would need advanced spatial awareness to locate an underwater cable, and it would likely need communication with a human operator to precisely place an explosive on an underwater cable or pipeline.

Figure 3: Underwater Communication Networks Vulnerable to Attack[51]



- *Infrastructure.*

Bridges and harbors are vulnerable to UUV attacks, which could result in significant economic losses. A report by the Virginia Institute of Marine Science noted that a single UUV equipped with explosives could slow or stop traffic in the harbor, leading to "attendant economic losses that could stretch for indefinite periods of time."[52] Stephen Carmel, Senior Vice President of Maritime Services for Maersk, argued that the global supply chain is increasingly vulnerable to asymmetric threats, such as cyberattacks and terrorist attacks. In 2002, Booz Allen Hamilton ran a war game simulation in which dirty bombs are smuggled in cargo containers, shutting down major ports for 12 days and resulting in $58 billion in damages to the U.S. economy.[53] Asymmetric actors could use an explosive-equipped UUV to threaten a harbor, disrupting the global supply chain and leading to billions of dollars in damages. This scenario is discussed at greater length below.

Necessary capabilities: Moderate **navigation** capabilities would be necessary for attacks on infrastructure. A UUV could navigate to its target using a combination of GPS and internal motion sensors. Bridges and harbors are large enough that the precision of a human operator would not be necessary for an attack. Since infrastructure targets are immobile, attackers could choose a deployment location close to the target, reducing the need for a long battery life.

As Figure 4 shows, uniform improvements in UUV endurance, communication, and navigation will not be necessary for asymmetric attacks to be feasible. For instance, future improvements in endurance and communication would not be required for attacks on infrastructure.

Figure 4: Technological Advances Necessary for Potential UUV Targets

		REQUIRED IMPROVEMENTS		
		Endurance	*Communication*	*Navigation*
TARGETS	*Marine vehicles*	✓	✓	✓
	Cables and Pipelines		✓	✓
	Infrastructure			✓

A Countervalue Scenario: Harbor Attack

The potential of UUVs in the hands of insurgent and terrorist organizations to pose a credible threat to commercial maritime targets will rapidly grow as technology advances. To illustrate this potential, we examine a countervalue scenario that will be well within the technological capabilities of UUVs in the next five years.

By the year 2020, an organization, such as Hezbollah, could acquire a medium-sized UUV for $50,000 and equip it with a limpet mine—a small, portable mine that explodes after a set time.[54] Limpet mines can be smaller than one cubic foot, and they carry approximately 5 kg of explosive material, such as C-4, which is enough to damage or sink a marine vessel.[55] These mines are designed to be partially buoyant and would not weigh down the UUV.[56] Since limpet mines are small and easily deployed, they are popular among insurgents and terrorists. For example, the eco-terrorist group Sea Shepard used limpet mines to sink ten whaling ships in 2009.[57]

Equipped with a UUV and limpet mine, an insurgent or terrorist organization could extort concessions from a government by threatening commercial shipping in a major harbor. The mere presence of a mine in the harbor—regardless of whether it is effectively delivered on the hull of a ship—likely would increase shipping insurance rates and cause ship owners to halt shipping in and out of the harbor while authorities search for the

UUV. This type of attack is similar to Hamas's attacks on Ben Gurion Airport in 2014, where the threat of rockets landing near the airport caused airlines to cancel flights.[58]

The UUV could be deployed from a cargo ship or fishing vessel at a safe distance from a coastline. In order to maximize stealth, the device could stay submerged and rely on its electric motors to approach and penetrate the harbor silently, guided by internal motion sensors to estimate position on a preplanned course. The noisy acoustic environment around the harbor, combined with the UUV's silent electric drive, would make passive acoustic detection of the device extremely difficult. Once the estimated UUV transit time into the harbor elapsed, the insurgent or terrorist organization could publicly announce the deployment of the UUV into the harbor and issue its demands to the government. If the government cooperates with the group's demands, then the preprogrammed location of the device would be provided. Otherwise, the government would be confronted with the prospect of conducting an intensive search of the harbor and surrounding waters, disrupting valuable commercial trade for days.

This scenario illustrates the potential danger posed by UUV proliferation. Even if UUV endurance, communication, and navigation technologies do not see uniform or significant advances, non-state actors could use them to inflict economic damage using countervalue strategies.

Conclusion

Unmanned Underwater Vehicles will open up an asymmetric battlefield, potentially causing millions in damages. While policy analysts have focused on the counterforce potential of UUVs, they have failed to consider the possibility of terrorists and non-state actors using UUVs to attack previously inaccessible underwater targets. As UUV technology advances and proliferates, asymmetric actors will be able to repurpose underwater drones to attack marine vehicles, underwater pipelines, communication networks, and infrastructure. It is important for the policy community to be fully aware of and prepare for the future threats posed by UUVs before their proliferation becomes widespread.

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