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Underwater Drone Technology

May 1, 2019

Finding ways to overcome physical limitations so that humans can dive deeper and stay underwater longer has been an ongoing quest. Back in the 15th century, Leonardo Da Vinci drew sketches of a submarine and a robot. Had he thought to combine the two concepts, he would have created a prototype of an unmanned underwater vehicle, or underwater drone. Instead, the world had to wait another five hundred years.

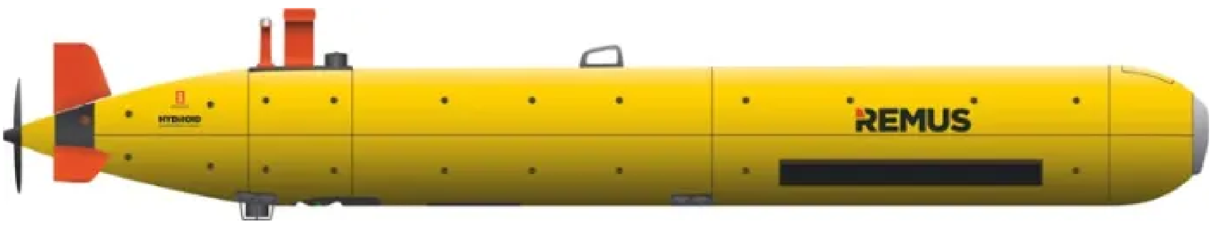
Orca drones for the U.S. Navy (Image courtesy of Boeing)

In the 1950s, in response to sea mines that would go on to destroy or damage more naval ships than all other types of attacks, the U.S. Navy began developing an unmanned underwater vehicle (UUV) that could dive 10,000 feet (rated depth) and function for four straight hours. In the succeeding decades, the Navy developed UUVs that could retrieve lost equipment such as torpedoes or a missing atomic bomb, save submarine crews lost at sea, or locate shipwrecks, including the Titanic. At the beginning of the 21st century, UUVs increasingly became a faster, cheaper, and safer alternative than sending humans and trained animals to defuse sea mines. For example, it takes a team of human divers 21 days to clear sea mines in one square mile, but a UUV such as the Hydroid REMUS can complete the task in only 16 hours.

HOW DO UNMANNED UNDERWATER VEHICLES (UUVS) WORK?

Unmanned underwater vehicles consist of remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs).

REMOTELY OPERATED VEHICLES (ROVS)



REMUS 6000. (Image courtesy of Hydroid).

ROVs were developed first and are controlled by humans from a distance. Their sizes vary.

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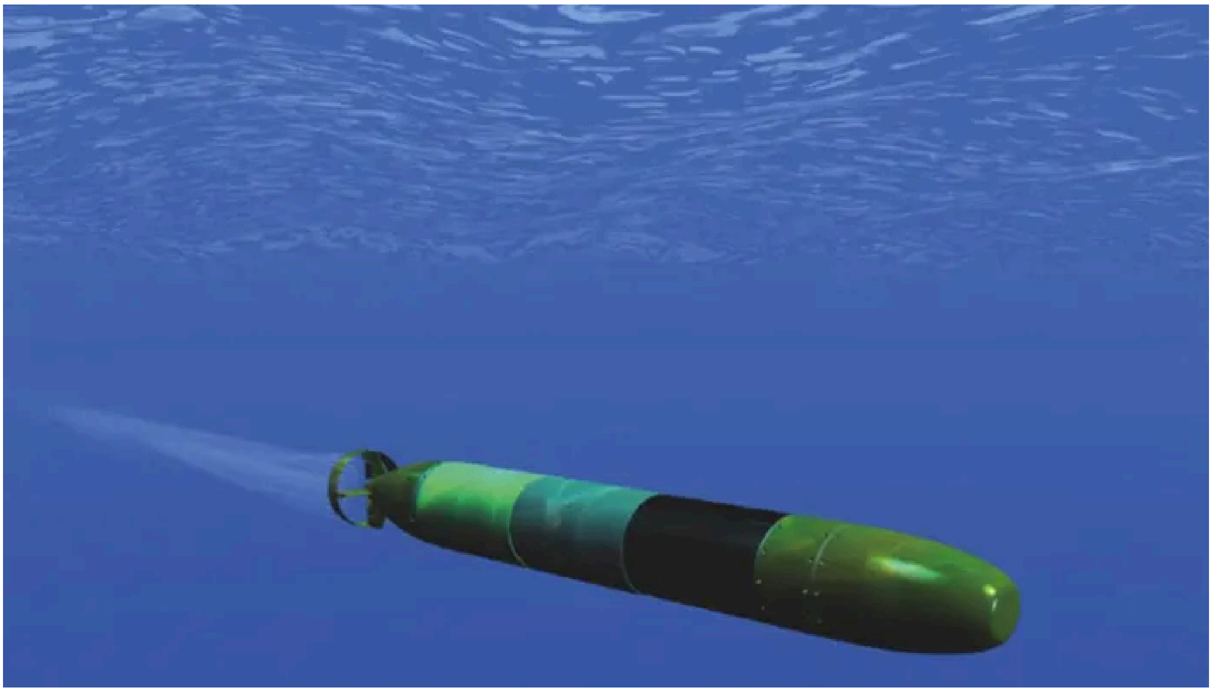
Linked to a host ship by an umbilical tether that houses energy cables and communication cables, ROVs use a tether management system (TMS). The TMS makes it possible to adjust the length of the tether to minimize the underwater effect of cable drag. By employing a flotation pack and a thruster, heavy-duty ROVs can achieve precise motion control even in high-current waters.



A-size Autonomous Underwater Drone (Image courtesy of Lockheed Martin)

Smaller ROVs are used mainly for observation and inspection in the research, military, or recreational sectors because they can only withstand shallow deployment (around 1,000 feet or 300 meters) and have limited horsepower. On the other hand, the largest and most heavy-duty ROVs are suitable for the oil and gas industry because they can dive as deep as 20,000 feet and perform multiple tasks like lifting, drilling, construction, and pipeline inspection.

AUTONOMOUS UNDERWATER VEHICLES (AUVS)

In recent years military applications have taken the next step and begun using AUVs, which, unlike ROVs, operate independently of human control and do not have to be tethered to a larger vessel.

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the ship to the drone, since VLF or ELF transmitters are too bulky to mount on the drone. Also, VLF and ELF have long wavelengths and thus extremely low bandwidth (1-2 kbps) that restricts the rate of data transfer. Acoustics may therefore be the most suitable communication solution for AUVs, but challenges include signal diffusion, relatively low bandwidth, and power consumption. At 20 kbps, the bandwidth offered by acoustic modems is still insufficient for real-time video, meaning that the human operator on the ship will only see delayed images. The use of high-definition cameras may supplement the collection of information.

Navigation: Signal distortion by water also hampers how well AUVs orient themselves. Therefore, most AUVs use inertial navigation. Inertial navigation supplements dead reckoning calculation of the drone's current position based on the previously determined position and known or estimated speed over time and course with motion sensor (accelerometer) and rotation sensor (gyroscope) data. Also, AUVs use a Doppler velocity meter that acoustically estimates the drone's velocity relative to the sea bottom and ultra-short baseline (USBL) positioning, which works by emitting a regular acoustic signal from a surface reference point, such as a support ship's underwater beacon.

Power: AUVs must run reliably and safely for days, even weeks, without human intervention. Therefore, they need more efficient ways to move around or consume energy. For example, by converting buoyant, vertical motion to horizontal motion with its wings, an underwater glider propels itself forward with little energy. While most AUVs use rechargeable lithium batteries, some of the larger AUVs use aluminum-based semi-fuel cells that are higher-maintenance.

Independence: Researchers are also trying to make AUVs more independent by developing machine intelligence solutions that enable AUVs to navigate complex situations and solve problems by themselves.

APPLICATIONS

With stronger processing power and a bigger power supply, AUVs can take on more challenging projects, such as locating the sunken Argentine navy submarine ARA San Juan in 2018 and recovering the black boxes from the crashed Air France Flight AF447. AUVs are also poised to stretch the range of applications they take on. Used for ship hull inspection, wreck inspection, nuclear reactor decontamination, exploration,
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	General Dynamics (Bluefin)	Boeing	Lockheed Martin	Teledyne	Saab	Kongsberg	Hydroid
Product example	Bluefin-21	Echo Voyager	Marlin	Gavia	Sabertooth	HUGIN 1000	REMUS 600
Type	AUV	AUV	AUV	AUV	AUV/ROV hybrid		
Weight	1650 lbs.	100,000 lbs.	3,500 lbs.	105 lbs.	1400 lbs.	1400 lbs.	500 to 850 lbs.
Rated Depth	15,000 ft.	11,000 ft.	12,000 ft.	3000 ft.	3600 ft.	9000 ft.	1800 ft.
Power source	Lithium battery, rechargeable	Battery, rechargeable, and marine diesel generator	Battery, rechargeable	Battery, rechargeable	Battery, rechargeable	Battery, rechargeable	Lithium battery, rechargeable
Estimated Endurance	25 hours at 3 knots	3 months; or 280 km	60 hours over 14 days; 100 km	7 hours	8 hours	100 hours at 4 knots	Up to 24 hours
Navigation	Inertial navigation	Inertial Navigation, Doppler Velocity Log, depth sensors	Doppler aided inertial navigation, USBL, terrain navigation	Inertial navigation, Doppler velocity meter, USBL	IMU/Doppler and terrain naviga-tion	Inertial navigation, micro-navigation	Inertial navigation, acoustic doppler, sonar
Application	Research, military	Oil and gas, military	Oil and gas, military	Research, military	Oil and gas, military	Research, oil and gas, military	Research, military

Table 1: Comparison of underwater drones (not all models are included)

The REMUS drones by Hydroid probably have the oldest and most recognizable brand, mainly due to high-profile operations involving REMUS drones such as sea mine detection during Operation Iraqi Freedom. Also, Canada, Japan, and NATO countries are using REMUS AUVs in their military. Of the many types of REMUS drones, REMUS 6000 is the biggest unit.

General Dynamics' Bluefin-21 is most famous for its involvement in the search for the wreckage of the missing Malaysia Airlines Flight 370 in 2014. The U.S. Navy had previously ordered several Bluefin-21 UUVs for its Black Pearl AUV program. Currently, the U.S. Navy is looking to improve the Bluefin-21, especially its two-way communication capability. Meanwhile, General Dynamics is developing the Knifefish, which is based on Bluefin-21 and has improved capabilities in detecting mines and working with Littoral combat ships.

Boeing's Echo Voyager is, by far, the biggest AUV around (hence dubbed "XLUUV"). At close to 100,000 lbs., it has the longest endurance and one of the deepest rated depths. Echo Voyager is also completely autonomous, as it does not have to be launched from, controlled by, or recovered to a support vessel. What's more, Boeing is building the Orca, which is based on Echo Voyager and promises to have more warfare capabilities than just those of mine removal so that it can potentially substitute for the much more expensive Littoral combat ships. Lastly, Boeing has been acquiring AUV start-ups to expand its portfolio.

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mair hat act as train ed Martin is also acquiring AUV start-ups as part of its expansion in the sector.

CHALLENGES AND FUTURE PERSPECTIVE

Manufacturers aim to continually improve the functionality, performance, eco-friendliness and power efficiency of their UUVs. Saab has already launched an AUV/ROV hybrid that can switch between roles during a mission, and there will be more hybrid launches in the future. Also, the sector is turning to biomimicry to improve propulsion and maneuverability, as in the case of Festo's AquaJelly and EvoLogics' BOSS Manta Ray. Moreover, there is concern that the USBL technology disrupts marine life and could interfere, for example, with the acoustic communications whales use when feeding, breeding, and breaching. Lastly, researchers are experimenting with combining different battery and power systems with supercapacitors, extracting energy from seawater, installing underwater power stations to refuel the UUV, and transferring power wirelessly.

Manufacturers are likely responding to the continual commitment from the government. Within the U.S. Department of Defense, the Navy receives the biggest budget to develop unmanned systems. The Navy plans to have its squadron of UUVs by 2020 and ultimately replace trained animals with Kongsberg/Hydroid's REMUS MK 18 Mod 2 Kingfish in sea mine removal operations.

Meanwhile, navies in the UK, France, Russia, Japan, and China continue to use UUVs or develop related technologies to stay competitive. For example, China is working to incorporate artificial intelligence into drones, and Russia is developing nuclear-powered drones. Whether for the purposes of exploration, research, rescue, military or defense, one thing is clear – advanced technologies used in underwater drones will continue to develop.

This article was written by John W. Koon, Contributing Editor, Aerospace & Defense Technology.

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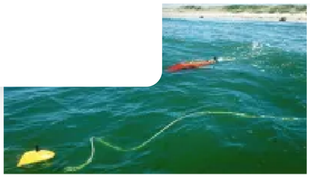

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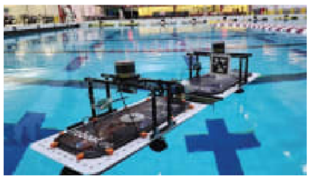

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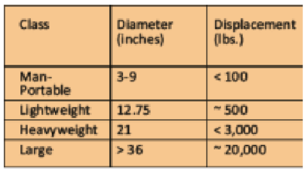
UUV Developments for Defense and Commercial Applications



Class	Diameter (inches)	Displacement (lbs.)
Man-Portable	3-9	< 100
Lightweight	12.75	~ 500
Heavyweight	21	< 3,000
Large	> 36	~ 20,000

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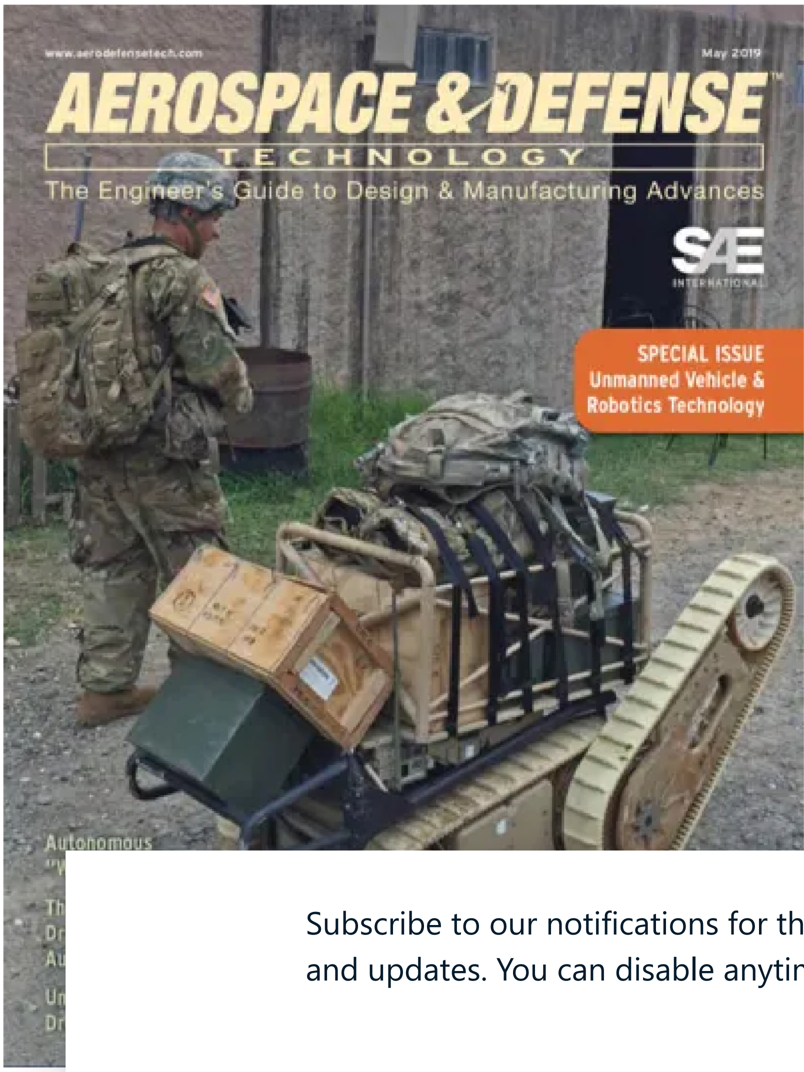

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